CMP ARLES
Constructions Métalliques
et Préfabrication d'Arles

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Dossier CMP Arles : 783

Page/*Sheet*

Client / *Customer* : AIR LIQUIDE AGS GmbH ***Engineered System N° :***

Appareil : *1 X 1800MT LOX STORAGE TANK*
Item

QUALITY CONTROL DOSSIER

PREFABRICATION PARTS

1		12/09/05	DUPRESSOIR	[signature]	14/09/05	HULIN	[signature]	14/09/05	LEBOUCQ	[signature]	
EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC. *STATUS*
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*						

Classement CMP Arles : 783-QCD01
CMP Arles document N°

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OBJET DES MODIFICATIONS
Subject of modifications

INDICE DE L'EDITION *Edition N°*	OBJET DE LA MODIFICATION *Subject of the modification*
1	Première diffusion / *First issue*

CHAPTER 1

CALCULATION NOTES

Earthquake calculation note : 783-NC01
Mechanical calculation note : 783-NC02
Thermal losses calculation note : 783-NC03

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Dossier CMP Arles : 783		Page/*Sheet* 0.1
Client / *Customer* : MESSER	*Engineered System N°* :	

1 RESERVOIR DE STOCKAGE LOX 1800MT

1 x 1800MT LOX STORAGE TANK

NOTE DE CALCUL SISMIQUE ET CHARGES GENIE CIVIL

EARTHQUAKE CALCULATION NOTE WITH LOADING FOR CIVIL ENGINEERING

1		28/07/04	HULIN	[signature]	28/07/04	CABRELLI	[signature]	28/07/04	LEBOUCQ	[signature]		
EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC *STATUS*	
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*			APPROBATEUR *APPROVED BY*				

Projet : *bject* ASU KOSICE	Classement CMP Arles : 783-NC01 *CMP Arles document N°*

Appareil / Item : 1 x 1800 MT LOX

Client : MESSER

Page	DESIGNATION *Desription*	INDICE DE REVISION *Revision number* 0	A	B	C	D	E	F	G	H
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0.2	Fiche d'état de révision / List of current revisions	1								
1	objets des modifications / Subject of modification	1								
2	Geometry	1								
3	Load on storage tank supporting slab	1								
4	Load on storage tank supporting slab	1								
5	Calculation of separate loads	1								
6	Data for civil Engineering	1								
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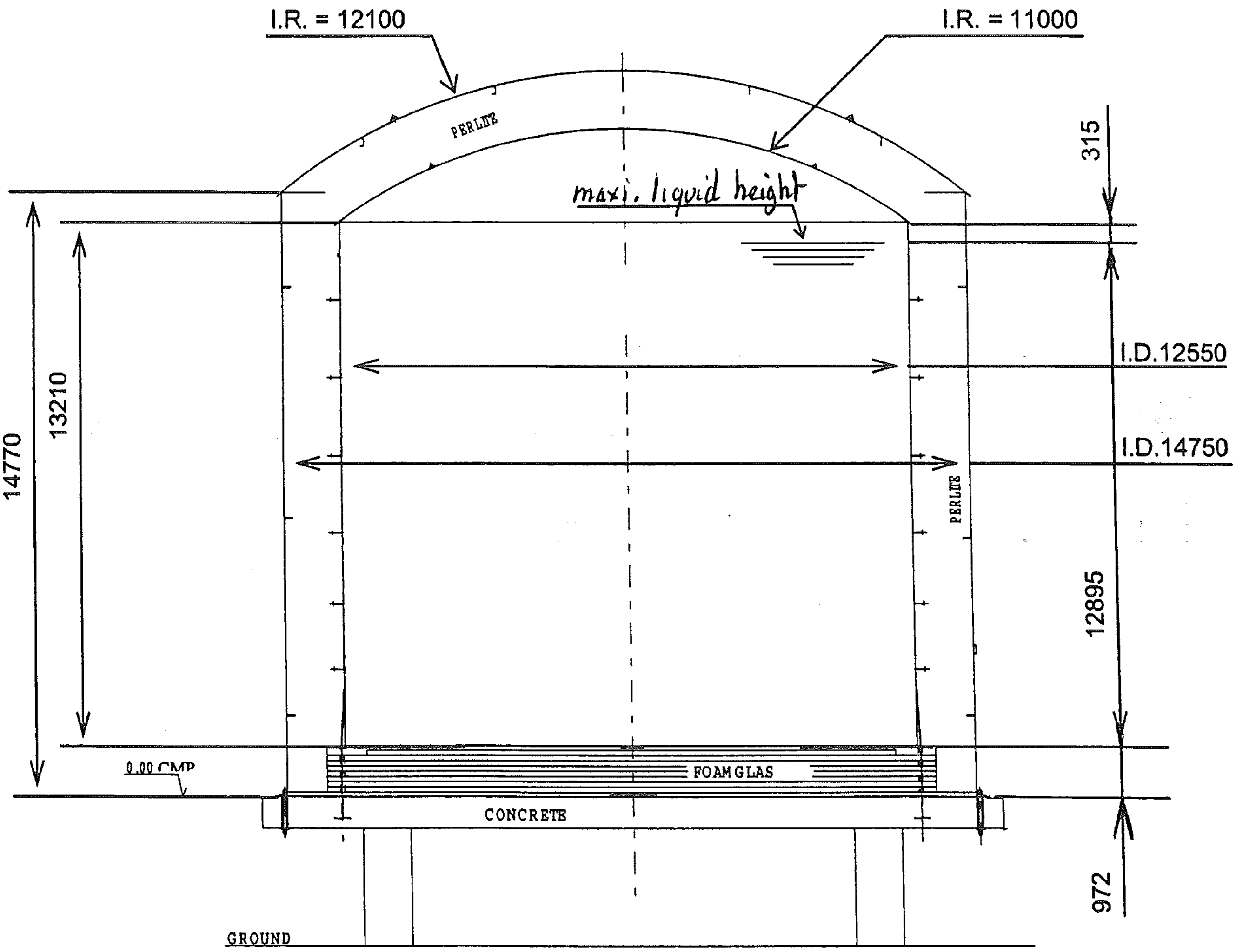
OBJET DES MODIFICATIONS :

(subject of modifications)

INDICE DE L'EDITION Edition n°	OBJET DE LA MODIFICATION (subject of modifications)
1	Premiere diffusion / First issue

GEOMETRIE DE L'APPAREIL :

Geometry of equipment (sketch)



LOADS ON STORAGE TANK SUPPORTING SLAB

1°) UNITS: Forces are expressed in metric tons
1 t = 1 metric ton force = Weight of a mass of 1000 Kg — 1 t = 9810 N
1 N = 1 Newton — 1 Mpa = 1,02E-02 t/m²

2°) DATA: **External casing (id)** Dt = 14750 mm

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	2110	mm	6.00	mm
↑	V2 =	2110	mm	6.00	mm
	V3 =	2110	mm	6.00	mm
	V4 =	2110	mm	6.00	mm
	V5 =	2110	mm	6.00	mm
	V6 =	2110	mm	6.00	mm
	V7 =	2110	mm	6.00	mm
	V8 =	0	mm	0.00	mm
	V9 =	0	mm	0.00	mm
	V10 =	0	mm	0.00	mm
↓	V11 =	0	mm	0.00	mm
Top	V12 =	0	mm	0.00	mm

Height for wind calculation Hv
18082 mm

Shell stiffeners		Width		Thk		Qte
	V1 =	150	mm	20.00	mm	3
	V2 =	0	mm	0.00	mm	0

Roof (Inner radius)	DRe =	12100	mm	7.00	mm
Central part of the roof	dR =	3950	mm	10.00	mm
Roof beams (UPN 140)	D1 =	5000	mm		
	D2 =	10480	mm		
	D3 =	0	mm		
Flat bottom (Y/N) Y	DBe =	15050	mm	5.00	mm
Anchoring ring N	Le =	0	mm	0.00	mm
Stairs	Ms =	2550	Kg		
Top equipements.	Me =	1500	Kg		

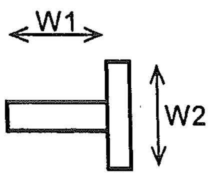
Inner vessel (id) Di = 12550 mm
Service liquid height Hl = 12895 mm

Mini yield strength
fty = 206.50 N/mm²

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	1995	mm	8.00	mm
↑	V2 =	1995	mm	7.00	mm
	V3 =	1995	mm	6.00	mm
	V4 =	1995	mm	6.00	mm
	V5 =	1995	mm	6.00	mm
	V6 =	1995	mm	6.00	mm
	V7 =	1240	mm	6.00	mm
	V8 =	0	mm	0.00	mm
	V9 =	0	mm	0.00	mm
	V10 =	0	mm	0.00	mm
↓	V11 =	0	mm	0.00	mm
Top	V12 =	0	mm	0.00	mm

Shell stiffeners	W1	Thk W1		W2	Thk W2		Qty
type A	180.0	6.0	mm	100.0	8.0	mm	6
type B	0.0	0.0	mm	0.0	0.0	mm	0



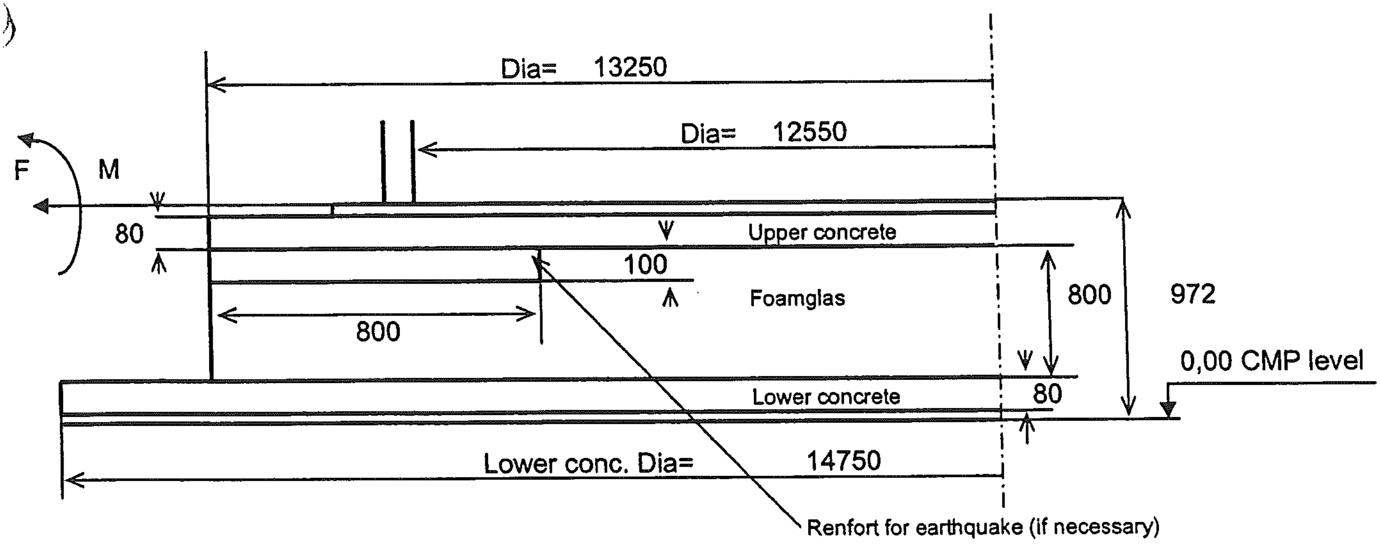
Roof (Inner radius)		DRi =	11000	mm	6.00	mm
Compression ring	Dia= 12600 mm		400.0	mm	15.00	mm
Bottom		DBi =	11320	mm	5.00	mm
Bottom annular ring		Li =	730	mm	7.00	mm
Accessories Piping		M3 =	1000	Kg		

2°) DATA: (Cont.)

Quantity, width and thikness of straps		n =	40	Wia =	100	Tha=	10	mm
Mini yeld strength		Fby=	206.50	N/mm²				
Dia of the bottom insulation		Dbi	=	13250	mm			
Width and thikness of upper concrete renfort for earthquake (if any)		Wuc	=	800	mm	Thc=	100	mm
Densities	Steel	ds	=	8000	Kg/m³			
	Perlite	dp	=	56	Kg/m³			
	Liquid	dl	=	1140.0	Kg/m³		Thk.	
	Upper concrete	dcs	=	2500	Kg/m³	cs=	80	mm
	Lower concrete	dci	=	2500	Kg/m³	ci=	80	mm
Foamglas								
	Density / thk	df	=	130	Kg/m³	cf=	800	mm
	Minimum compressive strength	Mcs	=	0.69	Mpa			
	Safety factor in sismic load	Sf	=	2.00				
Pressure	Design	Dp	=	0.0200	Mpa			
	Test	Tp	=	0.0250	Mpa			
Wind velocity		ws	=	162	Km/h			
Shape factor		Sc	=	0.80				
Load of snow		sl	=	140	Kg/m²			

Seismic conditions : API 620 Appendix L with seismic zone: 2B, Importance factor I=1 and a soil S3

BOTTOM ISOLATION



3°) CALCULATION OF SEPARATE LOADS.

P1= Uplift force acting on the roof of the vessel under design condition
P1= (Di^2 x pi / 4) x Dp
P1= 12550^2 x pi/4 x 0.02
P1= 2474043 N **P1 = 253 t**

P2= Uplift force acting on the roof of the vessel under test condition
P2= (Di^2 x pi / 4) x Tp
P2= 125502 x pi/4 x 0.03
P2= 3092554 N **P2 = 316 t**

P3= Weight of inner vessel exept bottom

Shell		26.90 t
Shell stiffeners		3.63 t
roof		6.65 t
Compression ring		1.90 t
Piping		1.00 t
Total P3	=	**40 t**

P4= Weight of inner vessel bottom

Flat bottom		4.03 t
Annular ring bottom		1.53 t
Total P4	=	**6 t**

P5= Weight of external casing exept bottom

Shell		32.87 t
Shell stiffeners		3.37 t
roof		11.19 t
Roof beams		0.78 t
Stairs + Top equipments		4.05 t
Total P5	=	**53 t**

P6= Weight of external flat bottom vessel (if any) **Total P6 = 7.12 t**

P7= Weight of perlite on the roof of the inner vessel
Volum of perlite 165 m˘ **P7 = 10 t**

P8= Weight of components in the annular space between inner vessel and external casing

1	Volum of perlite	712 m˘	=	39.87 t
2	Volum of lower concrete	3 m˘	=	6.60
		P8	=	**46 t**

P9= Weight of bottom insulation

Volum of upper concrete	11.03 m˘	=	27.58 t
Volum of lower concrete	13.67 m˘	=	34.17 t
Volum of sismic renfort	3.13 m˘	=	7.82 t
Volum of foamglas	110.31 m˘	=	14.34 t
	Total P9	=	**84 t**

P10= Weight of liquid in working conditions
Volum of liquid 1595 m˘ **P10 = 1819 t**

P11= Weight of water during the test
Volum of liquid 1595 m˘ **P11 = 1596 t**

4°) DATA FOR CIVIL ENGINEERING

To be read with the Civil Engeneering drawing.

A = P3 + P7 - P1 B = P3 - P2 C = P4 + P6 + P9

4.1 °) FULL OF LIQUID WITHOUT GAZ PRESSURE:

F1	=	53.0	t	=	P5
F2	=	46.5	t	=	P8
F3	=	50.1	t	=	P3 + P7
F4	=	1915.7	t	=	C + P10
F5	=	0.0	t	=	0

4.2 °) FULL OF LIQUID WITH GAZ PRESSURE:

F1	=	53.0	t	=	P5
F2	=	46.5	t	=	P8
F3	=	0.0	t	=	If A<0: F3=0. If A>0: F3=A
F4	=	2168.7	t	=	C + P10 + P1
F5	=	202.9	t	=	If A<0: F5=A. If A>0: F5=0

4.3 °) HYDROPNEUMATIC TEST:

F1	=	53.0	t	=	P5
F2	=	6.6	t	=	P8 + weight of perlite
F3	=	0.0	t	=	If B<0: F3=0. If B>0: F3=B
F4	=	2008.7	t	=	C + P11 + P2
F5	=	275.9	t	=	If B<0: F5=B. If B>0: F5=0

4.4 °) LOADS DUE TO THE SNOW:

To be added to loads 4.1 , 4.2 & 4.3 cases

F1 = 25.0 t

4.5 °) LOADS DUE TO THE WIND:

To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	27.0	t
MOMENT at 0.00 CMP	=	244.1	tm

4.6 °) LOADS DUE TO EARTHQUAKE:

To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	233	t
MOMENT at 0.00 CMP	=	1539.9	tm

F5 = 9.80 t per strap x 40 = 391.8 t

5 °) MASSES AND HEIGHT OF CENTROIDS

5.1) Mass and height of centroids for inner vessel components

Shell and stiffeners of inner tank	m2	=	30.53 t
Height of centroid of the shell	H2	=	6299 mm
Roof of the inner vessel	m3	=	8.55 t
Height of centroid of the roof	H3	=	14200 mm
Flat bottom of the inner tank	m4	=	5.56 t

5.2) Mass and height of centroids for outer casing components at the level of the bottom of outer casing.

Shell and stiffeners of outer casing	m5	=	36.24 t
Height of centroid of the shell	H5	=	7387.5 mm
Roof and roof beams	m6	=	11.97 t
Height of centroid of the roof	H6	=	16029 mm
Perlite on the roof of the vessel	m7	=	10.00 t
Centroid of the perlite in th roof	H7	=	16029 mm
Perlite in the annular space	m8	=	39.87 t
Centroid of the perlite in this space	H8	=	7623 mm
Bottom of the casing	P6	=	7.12 t
Stairs	m10	=	2.55 t
Centroid fo the stairs	H10	=	7388 mm
Accessories on the casing top	m11	=	1.50 t
Centroid of the accessories	H11	=	17283 mm

5.3) Mass and height of centroids of supporting slab

Weight of concrete	m12	=	34.17 t
Height of centroid concrete	H12	=	40 mm
Weight of bottom insulation + upper concrete	m13	=	49.74 t
Height of centroid of bottom insulation	H13	=	779 mm
Distance between top level of slab and 0.00 CMP	H14	=	960 mm

NOTE : Some factors in formulas acc. to API 620 have been changed in order to obtain correct results in métric units.

A) SEISMIC ZONE : = 2B

V=	Max. volume of tank contents	=	1595.1	m^3		
G=	Density of tank contents	=	1140	Kg/m^3		
Z=	Seismic zone factor from Table L-2	=	0.2	-		
I=	Importance factor	=	1.00	-		
p=	Internal design pressure	=	0.0200	Mpa		
Xs=	Height from the bottom of the tank shell to the center of gravity of the shell	=	6.2578	m		
Wr+s=	Mass of tank shell and roof including attachements	=	40084	Kg		
Ht=	Total height of tank shell	=	13.210	m		
D=	Internal diameter of tank	=	12.550	m		
H=	Maximum design product height	=	12.895	m		
S=	Site coefficient from Table L-3	=	1.5	for	**S3**	Type
g=		=	9.81	M/s^2		
Fby=	Minimum spécified yeld strength of shell and bottom plate	=	206.50	N/mm^2		
tb=	Thickness of bottom plate under the shell	=	7.00	mm		
t=	Thickness of bottom shell course	=	8.00	mm		
n=	Number of anchorages	=	40			
Sa=	Section of anchorages	=	1000.00	mm^2		
Da=	Diameter of anchorcircle	=	12.700	m		
X=	Width of the bottom annular plate (inside)	=	0.665	m		

B) FACTORS :(According to API 620 curves)

D/H=	12.55 / 12.9 =		**0.97**	
Wt=	1595.14 x 1140 =		**1818300**	Kg
FIGURE L-2	W1 / Wt	=	**0.82**	
	W2 / Wt	=	**0.24**	
W1=	Wt x 0.82	=	**1491675**	Kg
W2=	Wt x 0.24	=	**437104**	Kg
FIGURE L-3	X1 / H	=	**0.41**	
	X2 / H	=	**0.73**	
X1=	12.90 x 0.41	=	**5.27**	m
X2=	12.90 x 0.73	=	**9.44**	m
FIGURE L-4	k = 0.6			
T=	k x $D^{1/2}$	=	**3.85**	
C1=		=	**0.60**	
C2=	0,75x S/T if T<4,5 or 3,375x S/T^2	=	**0.2922**	

C) **AT THE BOTTOM OF THE TANK**

MOMENT

M= Z x I x (C1 x Wr + s x Xs + C1 x W1 x X1 + C2 x W2 x X2) x g
M= 0.2 x 1 x [(0.6 x 40083.86 x 6.26) + (0.6 x 1491674.91 x 5.27)
+ (0.29 x 437104.09 x 9.44)] x 9.81

M= 11919172 Nm

SHEAR FORCE

F= Z x I x (C1 x Wr + s + C1 x W1 + W2 x C2) x g
F= 0.2 x 1 x (0.6 x 40083.86 + 0.6 x 1491674.91 + 437104.09 x 0.29) x 9.81

F= 2053780 N

D) **WEIGHT OF THE TANK CONTENTS RESISTING SHELL OVERTURNING**

WL= 23.84 x tb x (Fby x G x H)$^{1/2}$
WL= 23.84 x 7 x (206.5 x 1140 x 12.9)^(1/2)

WL= **290755 N/m**

WL< 1,25 x G x H x D x 9,81
WL< 1.25 x 1140 x 12.9 x 12.55 x 9.81
WL< **2262293 N/m** THEN OK

tb<= MAX(53,35,t) 7.0 <= 8.0 THEN OK

X > 2,79.10^{-03} x WL / (G x H)
X= 0.67 > 0.00279 x 290755.15 / (1140 x 12.9)
X= 0.67 > **0.0552** m THEN OK

E) SHELL COMPRESSION

Max. longitudinal compression force at the bottom of the shell:

$b = Wr + s \times g / (PI \times D) + (1,273 \times M / D^2)$

$b = 40083.8641985722 \times 9.81 / (PI \times 12.55) + (1.273 \times 11919172.23 / 12.55^2)$

b= **106309** **N/m**

Compression stress:

$b \times 10^3 / t$ = 106309.09 x 1000 / 8

F= **13288637** **N/m² = 13.29 Mpa**

According to API 620 appendix L chap L-5-3 F should be less than Fa and in any case less than Fa = Fby / 2.

Value of Fa depends of the ratio of $R = 157,08746 \times G \times H \times D^2 / t^2$ in métric units.

R = 5682.97

If R <= 6894.76 — $Fa = 33,094834 \times t / D + 7,4931208 \times (G \times H)^{1/2}$

Fa= **49.83** **Mpa**

If R > 6894.76 — $Fa = 82,737084 \times t / D$

Fa = **0.00** **Mpa**

Then Fa = **49.83** **Mpa >13.29 Mpa** THEN OK

Fa =< 0,5xFby =< **0.5 x 206.5 = 103.25 Mpa** THEN OK

F) ANCHORAGE:

UPLIFT DUE INTERNAL PRESSURE WHITHOUT INNER TANK DEAD WEIGHT

P= p x PI / 4 x D² x 10^6 - (Wr + s)x 9,81
P= 0.02 x PI/4 x 12.55² x 1000000 - (40083.86) x 9.81

P= **2080821** N

UPLIFT DUE TO EARTHQUAKE

E= 1,273 x M / D²
E= 1.273 x 11919172.23 / 12.55²

E= **96336** N/m

UPLIFT FORCE PER ANCHORAGE

Due to internal pressure

Ap= P / n
Ap= 2080820.78 / 40

Ap= **52021** N

Stress due to internal pressure

Ap/Sa= 52020.52 / 1000
Ap/Sa= **52.02** **N/mm²**

Due to earthquake

Ae= (E x PI x Da) / n
Ae= (96335.65 x 3.14 x 12.7) / 40

Ae= **96091** N

Stress due to earthquake

Ae/Sa= 96090.54 / 1000
Ae/Sa= **96.09** **N/mm²**

ACTUAL STRESS

Ae/sa+Ap/sa= 96.09 + 52.02 **N/mm²**
Ae/sa+Ap/sa= **148.11** **N/mm²**

ALLOWABLE TENSIL STRESS (90% yield strength)

Fby = **185.85** **N/mm²** **THEN OK**

NOTE :
The straps calculation with
1.5 x (gas pressure of 200mbar +
seismic loading) is not considered.

G) ADDITIONAL CONSIDERATION

HEIGHT OF SLOSHING WAVE:

d= 1,124 x Z x I x C2 :
d= 1.124 x 0.2 x 1 x 0.29 x 3.85^2 x tanh (4.77 x (12.9 / 12.55)^(1/2)

[d= 0.3048 m] => 0.3048 (Minimum supplementary height of inner shell)

ACTUAL SUPPLEMENTARY HEIGHT:

Ha= Ht-H
Ha= 13.21 - 12.9
[Ha= 0.315] > 0.305 THEN OK

STRESSES IN CONCRETE RING AND FOAMGLAS

In the concrete ring

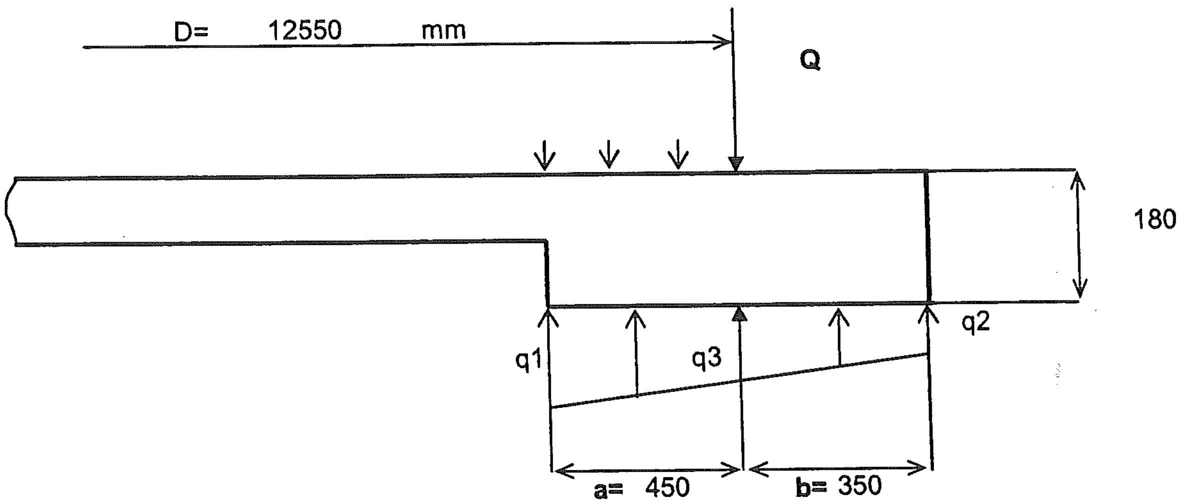
Load per unit of length

$Q = (Wr + S) \times g / Pi \times D + 4 \times M / pi \times D^2$

Q = 106327 N

$p = G \times g \times H$

p = 144210 N/m²



$C1 = q1 + q2$

$= (2 / (a + b)) \times (Q + a \times p)$

C1 = 428054 N/m²

$C2 = q1 + 2 \times q2$

$= (6 \times a / (a + b)^2) \times (Q + a \times p/2)$

C2 = 585455 N/m²

$q2 = C2 - C1$

q2 = 157401 N/m²

$q1 = C1 - q2$

q1 = 270654 N/m²

$q3 = (q1 \times b + q2 \times a) / (a + b)$

q3 = 206949 N/m²

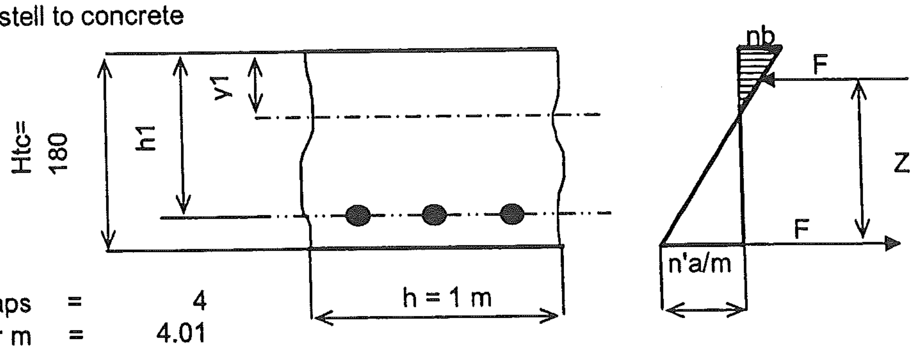
Flexural moment in the concrete ring per unit of length

$Mf = b^2 / 6 \times (2 \times q2 + q3)$

Mf = 10652 N.m/m

STRESSES IN CONCRETE AND RENFORCING BARS

dcs = Upper concrete density = 2500 Kg/m^3
n'a = Tensil stress in iron bars
nf = Compression stress in concrete
m = Ratio of young's moduli of stell to concrete
m = **15**



Quantity of bars between two straps	=	4	
Quantity of bars per m	=	4.01	
Dia of bars	=	16	mm
h1	=	150	mm
Section of bar	=	201.06	**mm²**
Total section of tensile stressed bars on the length 1 m w'	=	**806.30**	**mm²**

Compression force on concrete = tensile force in the bars = F

Mo = h1 / 2 x m x w'
Mo = 6.20

Nu = 1 / 2 x ((1 + 4 x Mo)$^{1/2}$) -1)
Nu = 2.040

y1 = h1 / (1 + Nu)
y1 = 0.049 m

Z = h1 - y1 / 3
Z = 0.134 m

F = M f / Z
F = 79762 N/m

n'a = F / w'
n'a = 98.92 N/mm²

nb = 2 x F / y1
nb = 3.23 N/mm²

Allowable stresses

n'a	**98.92**	**=<**	**172**	**N/mm²**	**Then OK**
nb	**3.23**	**=<**	**7.50**	**N/mm²**	**Then OK**

Compression in the foamglas under the concrete ring

P = (max of q1 and q2) + dcs x g x Htc

P = 275068 N/m^2

P = 0.27507 N/mm^2

Proper weight of the foamglas layers

P'=foamglas thk x g x ro'"

P'= 700 X 9.81 X 0.13

P'= 0.0009 MPa

Total stress at the base of Faomglas

St= P+P'

St= 0.2760 **MPa**

Allowable compressive strength:	**0.69**	**MPa**
Safety factor:	**2.00**	

Calculated safety factor = 2.50 Then OK

8°) SHEAR FORCE AND MOMENT AT 0,00 CMP DUE TO THE EARTHQUAKE

8.1) Outer casing:

Maximum horizontal shear force at 0,00 CMP.

Fe= (36.24 + 11.97 + 10 + 39.87 + 7.12 + 2.55 + ')x 0.12 x 9810

Fe= 128600 N

Maximum moment at 0,00 CMP.

Me= [(36.24 x 7.39) + (11.97 x 16.03) + (10 x 16.03) + (39.87 x 7.62) + (2.55 x 7.39) + (1.5 x 17.28)] x 0.6 x 0.2 x 9810

Me= 1140132 Nm

8.2) Inner vessel:

Maximum horizontal shear force at 0,00 CMP.

Fb=F (page 10) = 2053780 N

Maximum moment at 0,00 CMP.

Mb = M + F x Epi

Mb = 11919172 + 2053780 x 0.97

Mb = 13915447 Nm

8.3) Isolation and concrete under the inner tank:

Maximum horizontal shear force at 0,00 CMP.

Pi = P4 + P9

Pi = 5560 + 84000 **Pi = 89560 Kg**

Fi = Pi x C1 x Z x 9.81

Fi = 89560 x 0.6 x 0.2 x 9.81

Fi = 105431 N

Maximum moment at 0,00 CMP.

Mi = Fi x Epi / 2

Mi = 105431 x 0.49

Mi = 51239 Nm

8.4) TOTAL SHEAR FORCE AND MOMENT AT 0,00 CMP DUE TO THE EARTHQUAKE

FT = Fb + Fi + Fe

FT = 2053780 + 105431 + 128600

FT = 2287811 N

FT = 233 t

MT = Mb + Mi + Me

MT = 13915447 + 51239 + 1140132.32

MT = 15106818 Nm

MT = 1540 tm

ANCHOR BOLTS FOR OUTER CASING :

Data :

Anchor bolt diameter :	D3 =	14.55	m	
Anchor bolt number :	n =	16		
Anchor bolt section :	s =	1040	mm²	(M42)
Allowable stress in anchor bolt :	=	165.5	MPa	
Mass of shell and stiffeners of outer casing :	m5 =	36235	kg	
Mass of roof and roof beams :	m6 =	11966	kg	
External casing diameter :	D =	14750	mm	
Outer casing internal pressure :	p =	0.001	Mpa	
Maximum bending moment at the base of the shell :	M3 =	1140132	N.m	

Uplift force per anchor bolt due to seism :

uf1 = 1 / n x 4 x M3 / D3
uf1 = 1 / 16 x 4 x 1140132.32 / 14.55

uf1 = 19590 N

Uplift force per anchor bolt due to seism + internal pressure :

L = p x pi x D² / 4
L = 0.001 x pi x 14750² / 4

L = 170873 N

uf2 = 1 / n x [(4 x M3 / D3) + L - (m5 + m6) x g]
uf2 = 1 / 16 x [(4 x 1140132.32 / 14.55) + 170873.19 - (36235 + 11966) x 9.81)]

uf2 = 716 N

Tensile stress in anchor bolt :

Sp = MAX(uf1,uf2) / s
Sp = 19589.9 / 1040

Sp = 18.84 MPa < 165.50 MPa THEN OK

CMP ARLES
Constructions Métalliques
et Préfabrication d'Arles

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Dossier CMP Arles : 783	Page/*Sheet* 0.1
Client / *Customer* : MESSER *Engineered System N° :*	

1 RESERVOIR DE STOCKAGE LOX 1800MT

1 x 1800MT LOX STORAGE TANK

NOTE DE CALCUL MECANIQUE

MECHANICAL CALCULATION NOTE

2		01/09/05	HULIN	[signature]	01/09/05	HULIN	[signature]	01/09/05	LEBOUCQ	[signature]	
1		28/07/04	HULIN	[signature]	28/07/04	CABRELLI	[signature]	28/07/04	LEBOUCQ	[signature]	
EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC *STATUS*
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*			APPROBATEUR *APPROVED BY*			

Projet : *Project* ASU KOSICE	Classement CMP Arles : 783-NC02 *CMP Arles document N°*

CMP ARLES

N° CMP arles : 783 - NC 02

Item : 1 x 1800 MT LOX

Rev: A

Appareil / Item : 1 x 1800 MT LOX

Client : MESSER

Page	DESIGNATION *Desription*	INDICE DE REVISION *Revision number*								
		0	A	B	C	D	E	F	G	H
0.1	Page de garde / Front page	1	2							
0.2	Fiche d'état de révision / List of current revisions	1	2							
1	objets des modifications / Subject of modification	1	2							
2	Reference documents	1								
3	General data	1								
4	Geometry of equipement : OUTER CASING	1	2							
5	Geometry of equipement : INNER VESSEL	1	2							
6	Solicitations - Loading cases	1								
7	Allowable Stress	1								
8	Inner vessel under internal pressure : shell	1								
9	Inner vessel under internal pressure : shell	1								
10	Inner vessel under internal pressure : roof	1								
11	Inner vessel under internal pressure : roof	1								
12	Inner vessel under internal pressure : roof to shell jonction	1								
13	Inner vessel under internal pressure : drawing	1								
14	Inner vessel under internal pressure : roof to shell jonction	1								
15	Inner vessel under external pressure : shell	1	2							
16	Inner vessel under external pressure : shell	1	2							
17	Inner vessel under external pressure : shell	1	2							
18	Inner vessel under external pressure : shell	1	2							
19	Inner vessel under external pressure : shell	1	2							
20	Inner vessel under external pressure : roof	1								
21	Inner vessel anchorage	1								
22	Outer casing shell under internal pressure	1								
23	Outer casing roof under internal pressure	1								
24	Outer casing roof under wind and negative gaz pression	1								
25	Outer casing roof under wind and negative gaz pression	1								
26	Outer casing anchorage	1								
27	Outer casing anchorage	1								
28	Opening reinforcement	1								
29	Opening reinforcement	1	2							
30	Inner vessel shell under internal pressure according AL rules	1								
31	Inner vessel shell under internal pressure according AL rules	1								
32										
33										
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35										
36										
37										
38										
39										

CMP ARLES	N° CMP arles : 783 - NC 02 Item : 1X 1800 MT LOX	Rev: A Page 1

OBJET DES MODIFICATIONS :

(subject of modifications)

INDICE DE L'EDITION Edition n°	OBJET DE LA MODIFICATION (subject of modifications)
1	Premiere diffusion / First issue
2	Added geometry of equipement Changed stiffener spacing on inner vessel

DOCUMENTS DE REFERENCE

ET CONVENTIONS GENERALES

(Reference documents and generale conventions)

SPECIFICATION CLIENT :
Customer specification

PLAN CLIENT :
Customer drawing

PLAN CMP arles Drawing	783 - 01 783 - 02 783 - 03 783 - 04
CODE DE CALCUL : design code	API 620, edition 10, February 2002 (with App. Q) except inner shell against external pressure with AD MERKBLATT BO, B6
CONVENTIONS GENERALES : general conditions	S I system

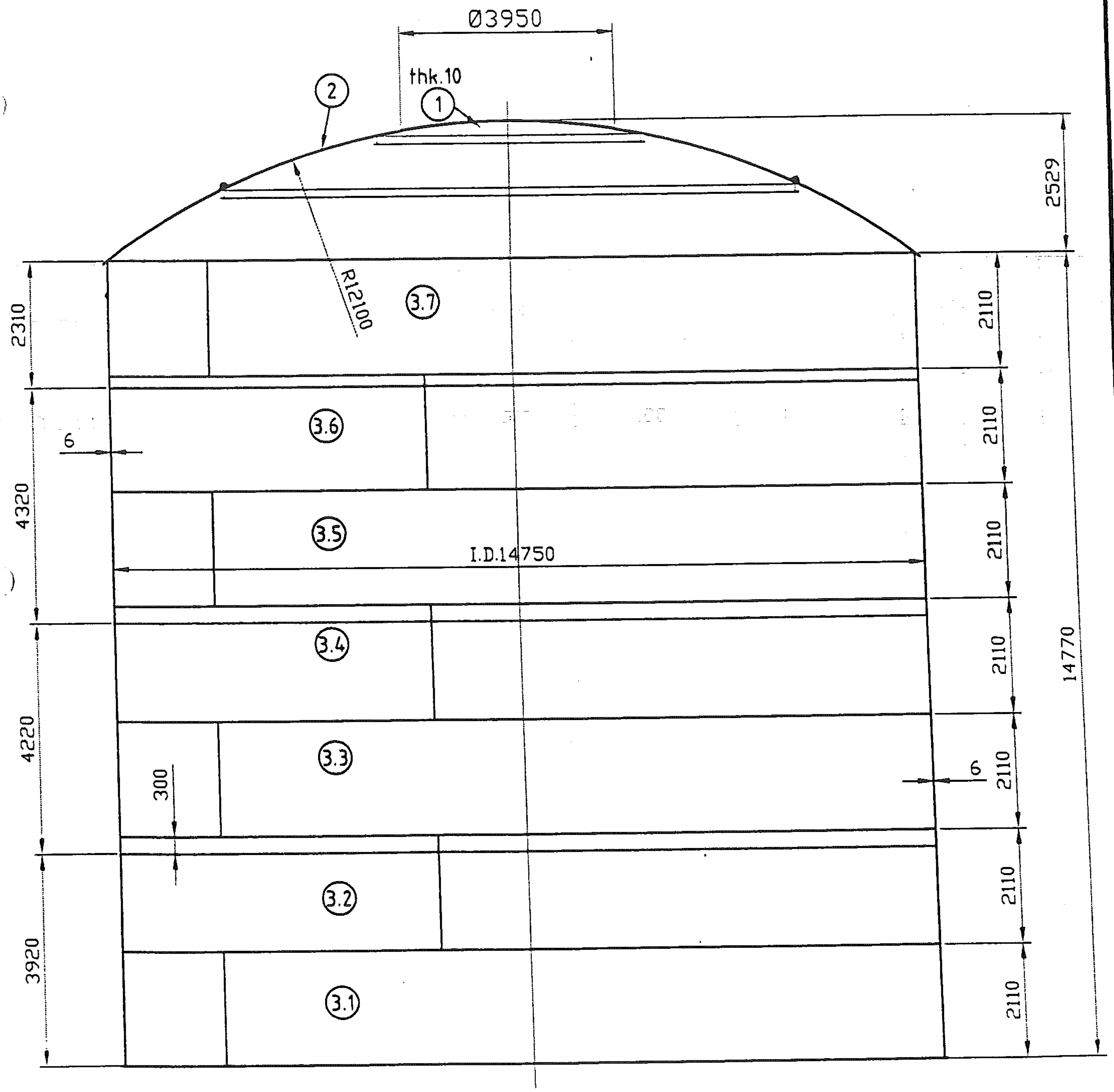
1) GENERAL DATA :

Rep. Items	Description	Ep. Thk.	Corro -sion	Contrôle testing	Coef.joint joint effic.	Densité(kg/m3) density(kg/m3)	Matière Material
3	Inner vessel shell	6 to 8	0		1	8000	A 240-304
1& 2	Inner vessel roof	6	0		0.35	8000	A 240-304
6	Compression ring	15	0		/	8000	A 240-304
4	Inner vessel bottom	5 & 7	0		/	8000	A 240-304
5	Inner vessel stiffeners	/	0		/	8000	A 240-304
	Inner vessel piping	/	0	SEE	0.85	8000	A 312 TP-304L
12	Inner vessel anchorage	10	0	CRYO	/	8000	A 240-304
3	Outer casing shell	6	0	SPEC	0.7	8000	A283 gr C
1 & 2	Outer casing roof	7 & 10	0	25	0.35	8000	A283 gr C
5	Outer casing stiffeners	/	0		/	8000	EN10025 S235 JRG2
	Outer vessel piping	/	0		0.85	8000	A106GrB or EN10025 S235 JRG2
	Bolt anchorage for outer casing	M42	0		/		A193 B7 or A194 2H

2) GEOMETRIE DE L'APPAREIL :

(Geometry of equipment)

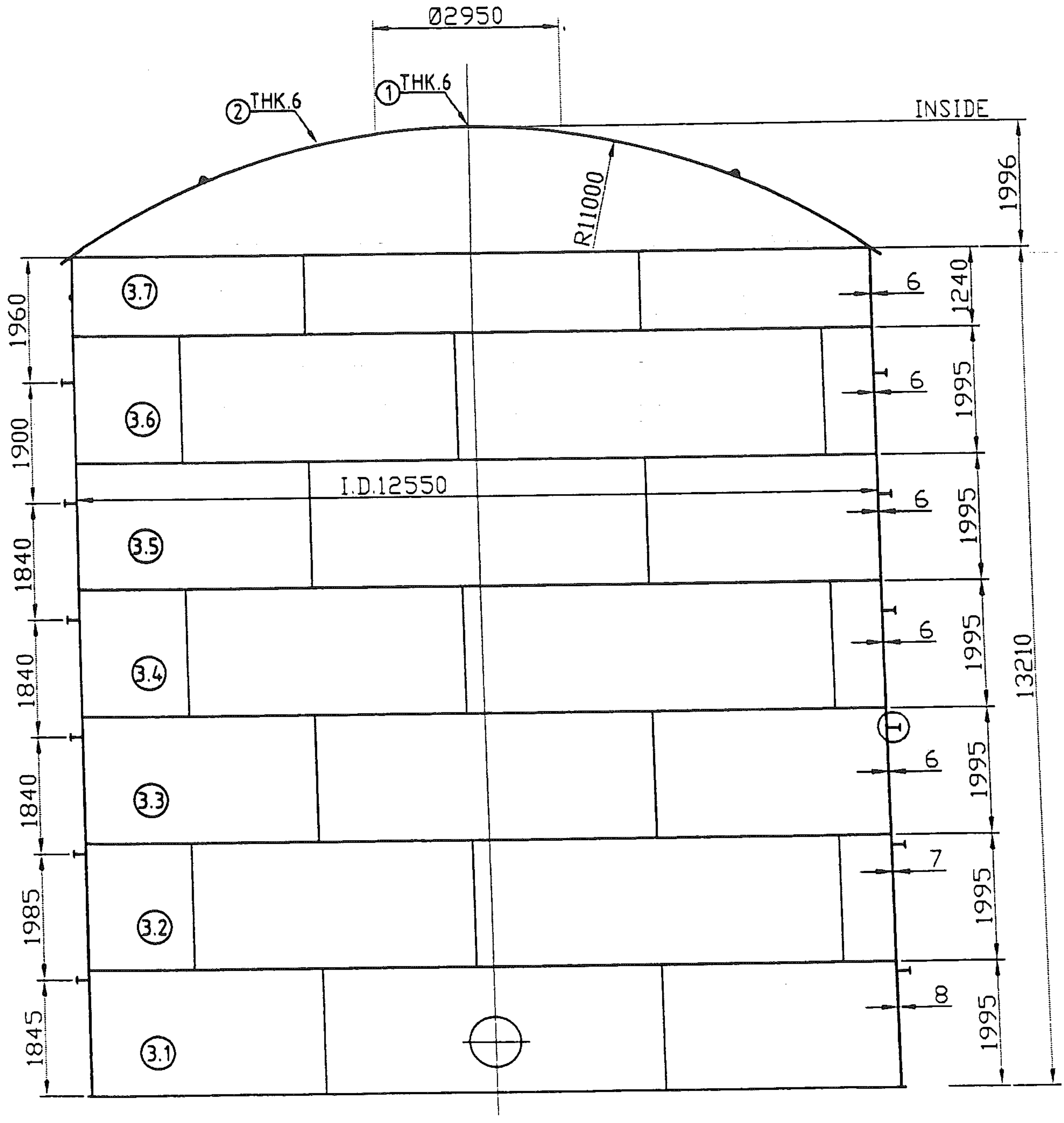
OUTER CASING



2) GEOMETRIE DE L'APPAREIL :

(Geometry of equipment)

INNER VESSEL



3) SOLLICITATIONS ;

solicitations

Items	sollicitations solicitations	Data Inner vesel		Outer casing
Tc	Temperature (°C)	20	-196	20
Dp	Internal pressure (MPa)	0.020		0.001
Pe	External pressure (MPa)	-0.001		/
Pps	Perlite compaction pressure for shell (MPa)	see p.16		0.0070
Ppr	Perlite compaction pressure for roof (MPa)	0.0006		/
Pv	Vacuum pressure (MPa)	-0.0005		-0.0005
Tp	Test pressure (MPa)	0.0250		0.00125
Ws	Wind velocity (N / m²)	/		1242
S	Snow (N /m²)	/		1373
dl	Specific gravity of the product (Kg/m^3)	1140		56
Hl	Service liquid height (mm)	12895		/

4) LOADING CASES :

Loading case	Concerned sollicitations	Conditions
A	Tc + dl.g.Hl + Dp + Pv(outer casing)	Internal vessel under internal pressure
B	Tc + 1000.g.Hl + Tp	Internal vessel under internal test pressure
C	Tc + Dp + Pps	Outer casing under internal pressure
E	Tc + (Pps or Ppr) + Pe + Pi(outer casing)	Internal vessel under external pressure
F	Tc + Ws + S + Pv	Outer casing under external pressure

Complementary verifications:

. For straps: 1,5 x max. burst pressure of 375 = 562.5mbar (without seismic) < 90% of yield strength
. For inner shell: max. burst pressure of 375mbar + liquid head < 90% of yield strength
. For inner roof: max. burst pressure of 375mbar < 90% of yield strength (the compression ring is only computed with 200 mbar)

5) ALLOWABLE STRESS :

MATERIAL : A 240-304 **(Inner vessel)**

Loading case	Temp. (°C)	Allowable stress Tensile	/ Compression	Origin of the stresses definition
A = DESIGN	-196	155.1 Mpa		see NOTE 1
B = TEST	20	186.1 Mpa		see NOTE 1

NOTE 1 : TENSILE : see API 620 App.Q Table Q3

MATERIAL : A283 gr C or equivalent **(Outer casing)**

Loading case	Temp. (°C)	Allowable stress Tensile	/ Compression	Origin of the stresses definition
C = DESIGN	20	104.8 Mpa		see NOTE 2

NOTE 2 : TENSILE : see API 620 Table 5.1 (15200 psi)

6) INNER VESSEL CALCULTION UNDER INTERNAL PRESSURE :

6.1) Inner vessel shell

According to API 620 section 5.10

API minimum thickness		Thk min =	4.76	mm
Joint efficiency (= 1 for test)		E =	1	
Inner vessel radius		Rc = Di / 2 =	6275	mm
Shell thickness		Thk =	in	mm
Shell and roof weight at each design level (design level = lower part of computed shell course)		Wm =	in	N
Liquid weight at each design level		WL =	in	N
Total weight	W = WL + Wm	W =	in	N
Hydrostatic pressure at each design level		PL =	in	Mpa
Internal pressure		Pg =	0.02	Mpa
Total pressure with gas pressure	P = PL + Pg	P =	in	Mpa
Unit force				
T1 = 0.5 x Rc x (P + (W / pi x Rc²))			in	N / mm
T2 = P x Rc			in	N / mm
Calculated stress	St = Max { T1 , T2 } / (E x Thk)			
		With St allowable =	155.1	Mpa

1) design conditions :

Shell	Thk(mm)	Wm (N)	WL (N)	W (N)	PL (MPa)	P (Mpa)
3.1	8	-393508	-17839083	-18232583	0.1442	0.1642
3.2	7	-344092	-15079179	-15423264	0.1219	0.1419
3.3	6	-300857	-12319274	-12620125	0.0996	0.1196
3.4	6	-263802	-9559369	-9823165	0.0773	0.0973
3.5	6	-226746	-6799465	-7026205	0.0550	0.0750
3.6	6	-189690	-4039560	-4229244	0.0327	0.0527
3.7	6	-152635	-1279655	-1432284	0.0103	0.0303

Shell	Thk(mm)	T1 (N/mm)	T2 (N/mm)	St (MPa)	St allowable	ratio
3.1	8	52.8	1030.417	128.8	155.1	1.2
3.2	7	54.0	890.417	127.2	155.1	1.2
3.3	6	55.1	750.416	125.1	155.1	1.2
3.4	6	56.1	610.415	101.7	155.1	1.5
3.5	6	57.0	470.414	78.4	155.1	2.0
3.6	6	57.9	330.413	55.1	155.1	2.8
3.7	6	58.9	190.413	31.7	155.1	4.9

We verify that the ratio is > 1

2) Test conditions :

This calculation is covered by the calculation in design condition:

water density = 1000 Kg / m^3 < liquide density= 1140 Kg / m^3

6.2) Inner vessel roof calculation under internal pressure :

According to API 620 section 5.10

API minimum thickness	Thk min =	4.76	mm
Joint efficiency	J =	0.35	
Roof weight	Wm =	-65243	N
Accessories weight on roof	WA =	4905	N
Roof thickness	Thk =	6.00	mm
Inner shell radius	Rc =	6275	mm
Roof spherical radius	Rs =	11000	mm

1) design conditions :

Hydrostatic pressure	PL =	0	Mpa
Total pressure	P = PL + Pg =	0.02	Mpa
Total weight	W = Wm + WA =	-60338	N

Unit force

$T1 = 0.5 \times Rs \times (P + W / (pi \times Rc^2)) =$ 108 N / mm

$T2 = P \times Rs - T1 =$ 112 N / mm

Calculated stress

$S = Max \{ T1 , T2 \} / (J \times Thk) =$ 53.4 MPa < 155.1 MPa

2) Test conditions :

Hydrostatic pressure PL = 0 Mpa

Total pressure P = PL + Pg = 0.0250 Mpa

Total weight W = Wm + WA = -60338 N

Unit force

T1 = 0.5 x Rs x (P + W / (pi x Rc²)) = 135 N / mm

T2 = P x Rs - T1 = 140 N / mm

Calculated stress

S = Max { T1 , T2} / (J x Thk) = 66.7 MPa < 186.1 MPa

2) Vérification according AL Rules: max. burst pressure of 375mbar = Pg

Hydrostatic pressure PL = 0 Mpa

Total pressure P = PL + Pg = 0.0375 Mpa

Total weight W = Wm + WA = -60338 N

Unit force

T1 = 0.5 x Rs x (P + W / (pi x Rc²)) = 204 N / mm

T2 = P x Rs - T1 = -209 N / mm

Calculated stress

S = Max { T1 , T2} / (J x Thk) = 99.5 MPa < 186.1 MPa

Inner vessel roof calculation under internal pressure

6.3) Roof to shell junction - compression ring :

Design according to API 620 section 5.12

Sketch of the compression area : See attached drawing p.13

Thk of the shell at the top = 6 mm

Permissible widths of plates making up the compression area :

$Wh = 0.6\ (Thk \times R)^{1/2}$ =	0.244	m
Where $Thk_{comp.\ ring}$ =	15.00	mm
$Wc = 0.6\ (Thk\ .Rc\ )^{1/2}$ =	0.116	
Where $Thk_{of\ shell}$ =	6.00	mm
$L\ <\ (16 \times Thk_{of\ comp.ring}\ )$ =	0.24	m

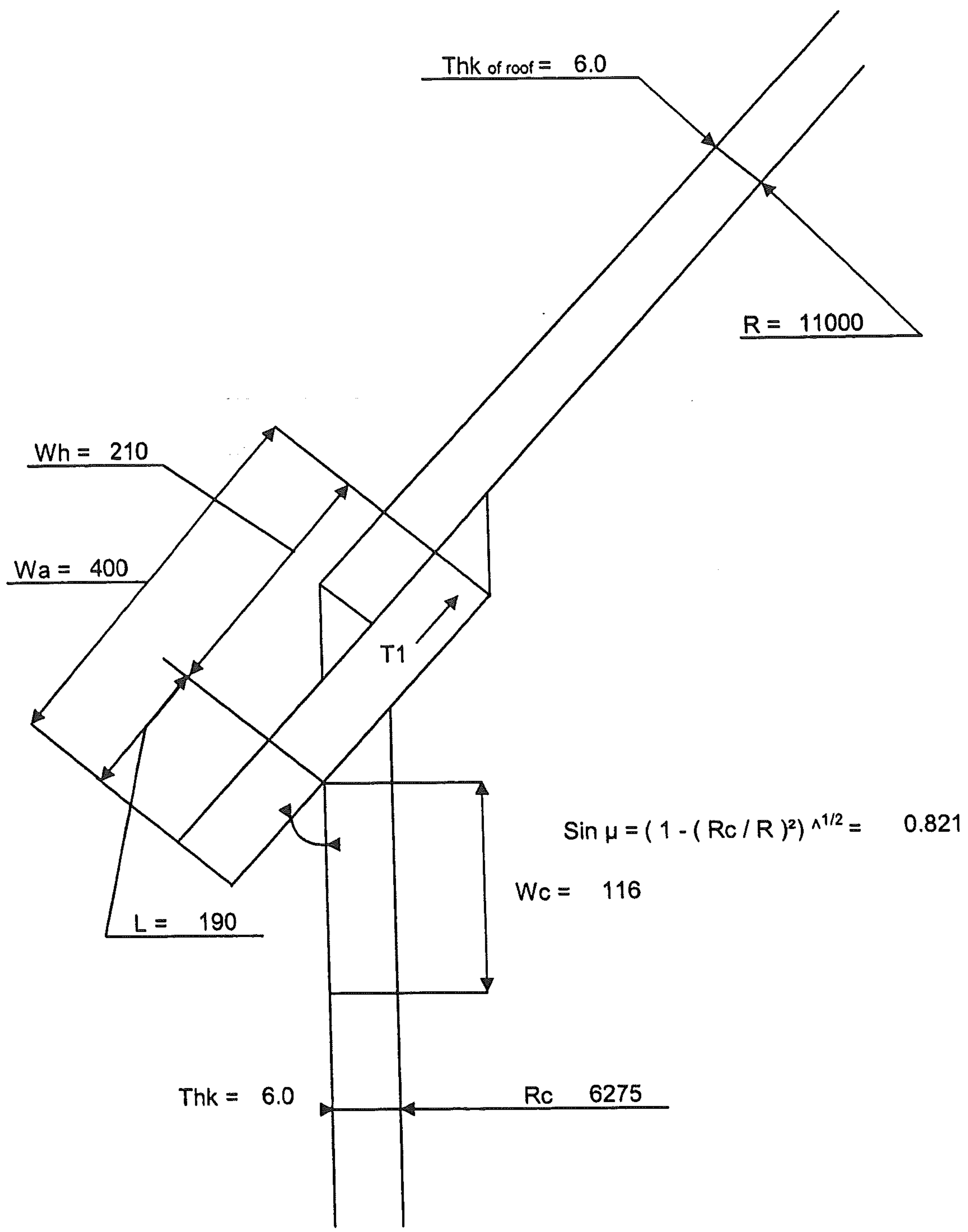
Actuel dimensions of the compression ring :

Wh =	210	mm
Wc =	116	mm
L =	190	mm

1) Under working conditions :

Gas design pressure	P=	20000	N /m²
Shell section	A =	123.8	m²
Proper mass of the roof	W =	65243	N
Roof meridional unit force :	T1 = R/2 x (P -W / A) =	107101	N / m
Roof circumferential unit force :	T2 = R x P - T1 =	112899	N / m
Shell circumferential unit force :	Tc = Rc x P =	125500	N / m

Roof to shell junction - compression ring :



Area of the interested compression zone:

$Sr = (L + Wh) \times Thk_{\text{of comp.ring}} + (Wc \times Thk_{\text{of shell}}) =$ 0.00670 m^2

Circumferential forces action on the above section :

$Q = -T1 \times Rc \times \sin\mu + ((T2 \times Wh) + Tc \times Wc) =$ -513717.27 N

Where $\sin\mu = (1 - (Rc/R)^2)^{1/2} =$ 0.821

Compression stress :

$n = -Q / Sr =$ 7.67E+07 N/m^2

OK !

This computed stress is under the minimum acceptable value required by the API 620 code i.e. :15000 psi or 10.34E+7 N/m^2.

2) Under testing conditions :

gas design pressure :	P =	25000	N/m^2
	T1 =	134601	N / m
	T2 =	140399	N / m
	Tc =	156875	N / m
	Q =	-653755	N
	n =	9.76E+07	N/m^2

OK !

This computed stress is under the minimum acceptable value required by the API 620 code i.e. :15000 psi or 10.34E+7 N/m^2.

7) Inner vessel calculation under external pressure :

(with A.D. B0 & B6 Jan. 95 Ed.)

7.1) Inner vessel shell :

Data :

Design temperature :	T =	20	°C
Young's modulus :	E =	196000	MPa
Poisson's ratio :	v =	0.3	
Yield strenght at 1% :	K =	230	MPa
Safety factor against elastic buckling for shell :	Sk1 =	2.6	
Safety factor against elastic buckling for stiffener :	Sk2 =	3	
Safety factor against plastic strain :	S =	1.6	
Out of roundnessfactor :	u =	1.5	%

For Di, dp and the types of stiffeners : see "loads on storage tank supporting slab" p.2 & 3

the length between two stiffeners from down to up : (Z =),
the minimum of thickness of the shell : (Thk =),
and the type of the stiffener at the top of the space (A or B).

CASE N°	Z (mm)	Thk (mm)	Stiffeners type A or B
1	1845	8	A
2	1985	7	A
3	1840	6	A
4	1840	6	A
5	1840	6	A
6	1900	6	A
7	1960	6	0

External pressure data for inner vessel :

External pressure : Pc

Pc = Pe + Pv + Pps

where Pe : pressure in outer casing
Pv : negative pressure in inner vessel
Pps : perlite compaction pressure

-> External pressure at the top of the inner vessel : Pc= 25.0 mbar

-> Between the top and 7 m of shell
Calculation according to formula : Pc= Pc1+ (dp x 9.81/100) x H
Denstity Perlite : dp = 56 Kg/m3

-> After 7 m , Pc = Pc(H=7m) = 63.5 mbar

Safety calculation :

Elastic bluckling :

Calculation according to formula :

$$P1 = (E / Sk1) \times \{ [20 / ((n^2 - 1) \times [1 + (n / z)^2]] \times (Thk / Da) + 80 / (12 (1 - v^2)) \times [n^2 - 1 + (2n^2 - 1 - v) / (1 + (n / z)^2] \times (Thk / Da)^3 \} \times 1000$$

where : $Da = Di + 2 \times Thk$
$z = 0.5 \times (pi \times Da / Z)$
$n = 1.63 \times [Da^3 / (Z^2 \times Thk)]^{1/4}$
n : number of ridges which may appear on the circumference in case of bluckling

We verify : P1 > Pc

Plastic deformation :

Calculation according to formula :

if Da / Z < 5 :
P2 = (20 x K / S) x (Thk / Da) x [1 + [(1.5 x u x (1 - 0.2Da / Z) x Da) x Da) / (100 x Thk)]]

if Da / Z > 5 :
P2 = (20 x K / S) x (Thk / Da)

We verify : P2 > Pc

RESULTS :

Pc mbar , P1 mbar , ratio P1/Pc , P2 mbar , ratio P2/Pc

CASE N°	Pc (mbar)	P1(mbar)	P1/Pc	P2(mbar)	P2/Pc
1	63.5	153.9	2.5	1830.4	28.9
2	63.5	101.77	1.7	1601.8	25.3
3	63.5	74.76	1.2	1373.2	21.7
4	63.5	74.76	1.2	1373.2	21.7
5	55.7	74.76	1.4	1373.2	24.7
6	45.6	72.07	1.6	1373.2	30.2
7	35.5	69.48	2	1373.2	38.7

We verify : P1/Pc > 1 and P2/Pc > 1

Stiffeners calculation :

Calculation according to formula :

$$Pe = (240 \times E \times im) / [(1 - v^2) \times (Da - Thk) \times Dm^2 \times L]$$

$$X = [(P \times Lm \times Da) / (20 \times Am)] + [(P \times L \times Da^2) / (8000 \times Wm)] \times [u / (1 - (Sk2 \times P / Pe))]$$

$$Lm = 1.1 \times (Da \times Thk)^{1/2} + Thk\ W0$$

where im is the geometrical moment of inertia,
Dm : the relevant centre-of-gravity diameter,
Lm : the length of the supporting part of the shell,
Wm : the section modulus
L : the shell lenght for the calculation of the stiffeners

We verify :

$Pe > P \times Sk2$

$K / S > X$

$Iyy > (W1 + Thk\ W2)^4 / 3000$

where Iyy = the geometrical moment of inertia relative
to the centre-of-gravity axis y-y

Calculation results in mm :

	W1	Thk W1	W2	Thk W2	Da	Thk	Dm	L
1	180	6	100	8	12566	8.0	12665	1915
2	180	6	100	8	12564	7.0	12676	1913
3	180	6	100	8	12562	6.0	12690	1840
4	180	6	100	8	12562	6.0	12690	1840
5	180	6	100	8	12562	6.0	12690	1870
6	180	6	100	8	12562	6.0	12690	1930

Results :

with the numerotation of the stiffeners from down to up

ratio 1 : 3000 x Iyy / (W1 + Thk W2)^4

N° stiffeners	Lm (mm)	Am (mm²)	Wm (mm^3)	im (mm^4)	Iyy (mm^4)	ratio 1
1	355	4718	196979	27302490	30437300	73
2	332	4206	193582	25518210	22058373	53
3	308	3728	189394	23471370	15278049	37
4	308	3728	189394	23471370	15278049	37
5	308	3728	189394	23471370	15278049	37
6	308	3728	189394	23471370	15278049	37

N° stiffeners	Pe (mbar)	P (mbar)	Pe / (P.Sk2)	X	K / S	ratio n° 2
1	365.9	63.5	1.9	51.5	143.8	2.8
2	341.8	63.5	1.8	53.6	143.8	2.7
3	326.1	63.5	1.7	54.9	143.8	2.6
4	326.1	55.7	2.0	47.7	143.8	3.0
5	320.9	45.6	2.3	39.6	143.8	3.6
6	310.9	35.5	2.9	32.4	143.8	4.4

We verify : ratio n°1 > 1 , Pe / (P.Sk2) > 1 , ratio n°2 > 1

7.2 / Inner vessel roof calculation under external pressure :

Vacuum pressure of the Inner tank :		P1 =	5	mbar
Internal pressure of the Outer tank :		P2 =	10	mbar
Hydrostatic head of the perlite :		P3 =	6.10	mbar
Weight of the roof :	P4 = 0.079 x 9.81 x Thk	P4 =	4.6	mbar
Design external pressure :	P = P1 + P2 + P3 + P4	P =	25.7	mbar
Roof Radius :		DRi =	11000	mm
Thickness :		Thk =	6.00	mm
Compressive stress :	St = (P x DRi) / 2Thk Scc = St x 145	St = Scc =	2.36 342.3	Mpa psi

According to **API 620 setion 5.5.4.3** the computed compressive stress, Scc, shall not exceed a value, Sca, established for the applicable thickness-to-radius ratio as follows :

If Thk / DRi < 0.00667 , Sca = 1 000 000 x Thk / DRi
If 0.00667 < Thk / DRi < 0.0175 , Sca = 5650 + 154.2 x Thk / DRi
If Thk / DRi > 0.0175 , Sca = 8340

Thk / DRi = 6.00 / 11000 = 0.00055 < 0.00667

So Sca = 1 000 000 x Thk / DRi = 545 psi

We verify : Scc < Sca -> OK !

8/ Inner vessel anchorage calculation :

1) Under design conditions :

Uplift force due to internal pressure

F = P x ((pi x D²) / 4) = 2474043 N

Weight of shell, shell stiffeners, bottom and roof of internal vessel (without perlite on roof)

W = 447770.53 N

Net uplift force

U = F - W = 2026273 N

Number of straps : n = 40

Strap section : a = 1000 mm²

Uplift force per strap : Ud = U / n = 50657 N

Tensile stress in Sd = Ud / a = 50.66 MPa < 155.1 MPa

OK !

2) AL Rules (1.5 x 375 = 562.5mbar / 90% yield strenght)

F' = 6958247.3 N

U' = 6510476.8 N

Ud' = U' / n = 162762 N

Sd' = Ud' / a = 162.8 MPa < 186.1 MPa

OK !

NOTA: Test condition is covered by AL Rules (250mbar < 562.5mbar)

9/ Outer casing shell calculation under internal pressure :

9.1) Outer casing shell :

Design according to API 620 section 5.10

API minimum thickness		Thk min =	4.76	mm
Joint efficiency		J =	0.7	
Outer casing radius		Rc = Di / 2 =	7375	mm
Shell thickness		Thk =	6.00	mm
Shell and roof weight at each design level (design level = lower part of computed shell course)		Wm =	in	N
Accessories on roof + shell		WA =	in	N
Total weight	W = Wa + Wm	W =	in	N
Internal pressure		P =	in	Mpa
Unit force	T1 = 0.5 x Rc x (P + (W / pi x Rc²))	T1 =	in	N / mm
	T2 = P x Rc	T2 =	in	N / mm

St = Max { T1 , T2 } / (J x Thk)   Calculated stress

We verify the lower part of shell with : Thk = 6 mm

Wm =	-472865	N
WA =	-39731	N
W =	-512596	N
P =	0.008	MPa
T1 =	18.44	N / mm
T2 =	59.00	N / mm

St = 14.0 MPa < 104.8 MPa

OK !

9.2) Outer casing roof calculation under internal pression :

Design according to API 620 section 5.10

API minimum thickness	Thk min =	4.76	mm
Joint efficiency	J =	0.35	
Outer casing radius	Rc = Di / 2 =	7375	mm
Roof spherical radius	Rs =	12100	mm
Roof thickness	Thk =	7.00	mm
Roof weight	Wm =	-117391	N
Accessories weight on roof	WA =	-14715	N
Total weight	W =	Wa + Wm	
	W =	-132106	N
Internal pressure	P =	0.001	Mpa

Unit force

$T1 = 0.5 \times Rs \times (P + (W / pi \times Rc^2))$

T1 = 1.37 N / mm

$T2 = P \times Rs - T1$

T2 = 10.73 N / mm

Calculated stress

$St = Max \{ T1 , T2 \} / (J \times Thk)$

St = 4.4 MPa < 104.8 MPa

OK !

10/ Outer casing calculation under wind + negative gas pression :

10.1) Outer casing shell :

Wind load				q =	1242	N /m²
Depression max.	P2 =	0.005	bar	P2 =	500	N /m²
Negative pressure	P = q + P2			P =	1742	N /m²
Wind velocity equivalent	$V = ((2 \times P) / 1.23)^{1/2}$			V =	53.2	m /s
	$V_{miles/h} = V_{m/s} / 0.447$			V =	119.1	miles / h

Maximum allowable distance between stiffeners

According to API 620 section 5.10.6

$$H = 6 \times (100 \times Thk)\,[100 / V]^2 \times [(100 \times Thk) / D]^{3/2}$$

With :					
	Thk =	6.00	mm =	0.236	inch
	D =	14750	mm =	48.40	feet
	V =	119.1	miles per hour		
	H =	34.00	feet =	10364	mm

Actual max. distance : H1max = 4700 mm = 15.5 feet

z = Required modulus of inertia of stiffener

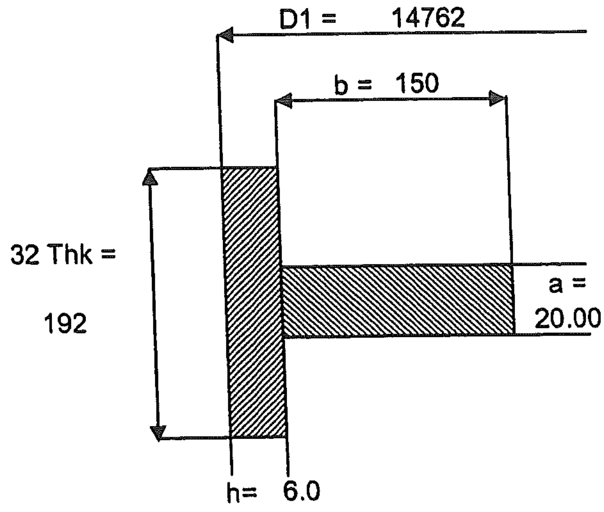
$$z = 0.0001 \times D^2 \times H1max\,(V / 100)^2$$

z = 5.14 cubic inch

z = 84213 mm^3

Actual modulus of inertia

= 110642 mm^3



10/ Outer casing calculation under wind + negative gas pression :

10.2) Outer casing roof calculation under external pressure :

Pressure due to the snow		Psn =	1373	N /m²
Pressure due to the wind		q =	1242	N /m²
Shape coefficient (pessimistic calc.)		cf =	1	
External loads	P1 = Psn + cf x q with a minimum of 1200 N / m²			
		P1 =	2616	N /m²
Proper weight of the roof		Pr =	542	N /m²
Negative gas pressure		Pnp =	500	N /m²
Accessories weight	Pa = - Wa / (pi x Rc²)	Pa =	86	N /m²
Design pressure	P = P1 + Pr + Pnp + Pa	P =	3744	N /m²

Compressive stress in the roof

St = P x R / (2 x Thk x 1 000 000) with R = 12100 mm

St = 3.2 Mpa = 469.3 psi

According to API 620 section 3.5.3 , the above computed compressive stress does not exceed the value Scs.

Scs = 1000000 x Thk / R

Scs = 579 psi OK !

We verify : 579 psi > 469.30 psi

11/ Outer casing anchorage calculation :

Loading case : wind + internal pressure + gravity

Horizontal wind shear

F = cf x q x D x H

with :

Pressure on outercasing	q =	1242	N /m²
force coefficient (pessimistic calc.)	cf =	0.80	
Outer casing diameter	D =	14.762	m
Total height of tank (with accessories)	H =	18.082	m

F = 265294 N

Overturning moment M = F x H / 2

M = 2398564 Nm

Moment of inertia of the bolts set

I / V =N x S x R / 2

With :	N = Number of anchoring bolts =	16	
	S = Sectional area of bolt =	1040	mm²
	R = Radius of the bolt circle =	7275	mm

Load per bolt due to the wind moment

Q = M / (I / V) x S = 2 M / N.R

Q = 41212 N

Stress in the bolts due to wind only = Q / S = 39.6 MPa

Uplift due to the wind on the roof

$$U = cf \times q \times pi\ D^2 / 4$$

with

cf =	0.60	
q =	1242	N / m^2
D =	14.762	m
U =	127576	N

Uplift due to the internal pressure :

$L = 1.25\ p \times pi \times D^2 / 4 =$			213939.2	N
With p =	0.001	MPa =	1000	N / m^2
Dead weight of the outer casing		W =	512596	N

Total maxi. load per bolt

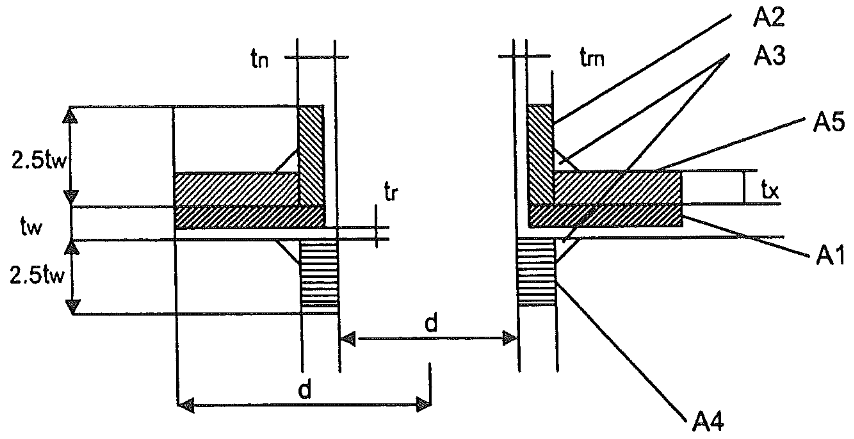
((U + L - W) / N) + Q =	30520	N

Stress in the bolts :

Maximum stress in the bolts :Smax =				165.5	MPa
30520	/	1040	=	29.3	MPa
			<	165.5	MPa

OK !

12/ Opening reinforcements for inner vessel nozzles :



trn = min. calculated thickness for nozzle

tr = min. calculated thickness for tank

A1 = (tw - tr) (d - 2 trn)

A2 = 2 (tn - trn) x 2.5 tw

A3 = welds are neglected

A4 = 2 tn x 2.5 tw

A5 = T x (d - 2 tn)

Total area available : Aa = A1 + A2 + A3 + A4 + A5

Required reinforcement area which is based on the piping resistance :

Internal pressure case Ar = (d.tr) / E x S plate / S piping with S = allowable stress

External pressure case Ar = (0.5 x d x tr) / E x S plate / S piping

Aa > Ar is verified.

NOZZLES

N° of the case	1	2	3	4
NOZZLE	K	G1-A1-A2	E1-R1-R2	R5-L3-L4
Emplacement	Roof	Roof	Roof	Roof
Pressure	External	External	External	External
Nozzle Diam.	762	168.3	88.9	88.9
P (MPa)	0.00257	0.00257	0.00257	0.00257
R (mm)	11000	11000	11000	11000
tn (mm)	6	7.11	5.49	5.49
Nozzle elevation (mm)	-	-	-	-
reinforcement diam	1000	0	0	0
Tx (mm)	6	0	0	0
S plate (MPa)	155.1	155.1	155.1	155.1
tw (mm)	6	6	6	6
d (mm)	750	154.08	77.92	77.92
S piping (MPa)	155.1	129.1	129.1	129.1
trn (mm)	2	1.5	1	1
tr (mm)	4.8	4.8	4.80	4.8
A1 (mm²)	900	181	91	91
A2 (mm²)	120	168	135	135
A3 (mm²)	0	0	0	0
A4 (mm²)	180	213	165	165
A5 (mm²)	1428	0	0	0
Aa (mm²)	2628	563	391	391
E	1	1	1	1
Ar (mm²)	1800	444	225	225
Aa / Ar	1.5	1.3	1.7	1.7
We verify :	Aa>Ar OK !	Aa>Ar OK !	Aa>Ar OK !	Aa>Ar OK !

A3 = 0 (welds are neglected)

VERIFICATION ACCORDING AL RULES

INNER VESSEL SHELL CALCULATION UNDER INTERNAL PRESSURE

(max. burst pressure = 375 mbar + hydrostatic head)

API minimum thickness		Thk min =	4.76	mm
Joint efficiency (= 1 for test)		E =	1	
Inner vessel radius		Rc = Di / 2 =	6275	mm
Shell thickness		Thk =	in	mm
Shell and roof weight at each design level (design level = lower part of computed shell course)		Wm =	in	N
Liquid weight at each design level		WL =	in	N
Total weight	W = WL + Wm	W =	in	N
Hydrostatic pressure at each design level		PL =	in	Mpa
Internal pressure		Pg =	0.0375	Mpa
Total pressure with gas pressure	P = PL + Pg	P =	in	Mpa
Unit force				
T1 = 0.5 x Rc x (P + (W / pi x Rc²))			in	N / mm
T2 = P x Rc			in	N / mm
Calculated stress	St = Max { T1 , T2 } / (E x Thk)			

With St allowable = 186.1 Mpa
(= 90% yield strength)

Shell	Thk(mm)	Wm (N)	WL (N)	W (N)	PL (MPa)	P (Mpa)
3.1	8	-393508	-17839083	-18232583	0.1442	0.1817
3.2	7	-344092	-15079179	-15423264	0.1219	0.1594
3.3	6	-300857	-12319274	-12620125	0.0996	0.1371
3.4	6	-263802	-9559369	-9823165	0.0773	0.1148
3.5	6	-226746	-6799465	-7026205	0.0550	0.0925
3.6	6	-189690	-4039560	-4229244	0.0327	0.0702
3.7	6	-152635	-1279655	-1432284	0.0103	0.0478

Shell	Thk(mm)	T1 (N/mm)	T2 (N/mm)	St (MPa)	St allowable	ratio
3.1	8	107.7	1140.230	142.5	186.1	1.3
3.2	7	108.9	1000.229	142.9	186.1	1.3
3.3	6	110.0	860.228	143.4	186.1	1.3
3.4	6	111.0	720.228	120.0	186.1	1.6
3.5	6	111.9	580.227	96.7	186.1	1.9
3.6	6	112.8	440.226	73.4	186.1	2.5
3.7	6	113.8	300.225	50.0	186.1	3.7

We verify that the ratio is > 1

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Dossier CMP Arles : 783	Page/*Sheet* 0.1
Client / *Customer* : MESSER *Engineered System N°* :	

1 RESERVOIR DE STOCKAGE LOX 1800MT

1 x 1800MT LOX STORAGE TANK

NOTE DE CALCUL THERMIQUE

THERMAL LOSSES CALCULATION NOTE

1		28/07/04	HULIN	[signature]	28/07/04	GABRELLI	[signature]	28/07/04	LEBOUCQ	[signature]		
EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC *STATUS*
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*			APPROBATEUR *APPROVED BY*			

Projet : *Object* ASU KOSICE

Classement CMP Arles : 783-NC03
CMP Arles document N°

CMP ARLES

N° CMP arles : 783 - NC 03

Item : 1 x 1800 MT LOX

Rev: 0

Page 0.2

Appareil / Item : 1 x 1800 MT LOX

Client : MESSER

Page	DESIGNATION *Desription*	INDICE DE REVISION *Revision number*								
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0.1	Page de garde / Front page	1								
0.2	Fiche d'état de révision / List of current revisions	1								
1	objets des modifications / Subject of modification	1								
2	Data	1								
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CMP ARLES

N° CMP arles : 783 - NC 03

Item : 1 x 1800 MT LOX

Rev: 0

Page 1

OBJET DES MODIFICATIONS :

(subject of modifications)

INDICE DE L'EDITION Edition n°	OBJET DE LA MODIFICATION (subject of modifications)
1	Premiere diffusion / First issue

DATA :

Liquide :	Product :		Oxygen
	Temperature :	T1 =	-183 deg.C
	Density:	W =	1140 kg/m^3
Heat of vaporisation :		L =	213 kJ/kg
External temperature :		T2 =	15 deg.C
Inner vessel :	Shell internal diameter :	D1 =	12.550 m
	Shell height :	H1 =	13.210 m
	Liquid height :	LH =	12.895 m
	Shell average thickness :	E1 =	0.006 m
	Roof external radius :	R1 =	11.006 m
	Roof height :	G1 =	1.964 m
Insulation Jacket :	Shell internal diameter :	D2 =	14.750 m
	Shell height :	H2 =	14.770 m
	Roof internal radius :	R2 =	12.100 m
	Roof height :	G2 =	2.507 m
Perlite thickness in the shell interspace :		E3 =	1.094 m
Perlite thickness in the roof interspace :		Er =	1.094 m
Foamglas thickness :	In the center :	E4 =	0.800 m
	At the periphery :	E'4 =	0.700 m
Foamglas external diameter :		D4 =	13.250 m
		D'4 =	11.650 m
Width of the reinforced concrete ring :		Lb =	0.800 m
Perlite specific gravity :		W3 =	56 kg/m3
Foamglas specific gravity :		W4 =	130 kg/m3
Number of inner vessel anchor bolt (or straps) :		Na =	40
Area of one anchor bolt (or strap) :		Sa =	0.001 m^2
Internal shell stiffeners :	Number :	Nr =	6
	External diameter :	Dr =	12.939 m
	Height :	Hr =	0.100 m
Outer shell stiffeners :	Number :	Ns =	3
	External diameter :	Ds =	14.450 m
	Thickness :	Hs =	0.020 m

RESULTS :

Mass of liquid : M = 0.99 x (PI x D1² x LH / 4) x W	M =	1800274	kg
Inner shell average diameter : Di = [(H1 - Nr x Hr) x (D1 + 2 x E1) + Nr x Hr x Dr] / H1	Di =	12.58	m
Outer shell average diameter : Do = [(H2 - Ns x Hs) x D2 + Ns x Hs x Ds] / H2	Do =	14.74878	m
Temperature difference : delta_T = T2 - T1	delta_T =	198.00	deg.C
Average temperature : Tm = (T1 + T2) / 2	Tm =	-84	deg.C
Stainless steel thermal conductivity :	Lambda =	14	W/m deg.C
Perlite thermal conductivity : lambda3 = (1.292E-4 + 0.2564E-6 x Tm) x (W3 + 400) - 0.019478	Lambda3 =	0.0296	W/m deg.C
Foamglas thermal conductivity : Foamglas quality : HLB1000	Lambda4 =	0.0320	W/m deg.C

CALCULATION OF AVERAGE SURFACES :

Foamglas :	S4 = PI x D'4² / 4	S4 =	106.60	m²
	(if there is a concrete ring) : S'4 = PI x D4² / 4 - S4	S'4 =	31.29	m²
Perlite :	Roof : Sr = [(2 x PI R1 x G1) x (2 x PI x R2 x G2)](1/2)	Sr =	160.91	m²
	Shell : S3 = PI x 0.5 x (Do + Di) x 0.5 x (H1 + H2)	S3 =	600.56	m²
Bottom :	SB = PI x [(0.5 x (Do + Di))² - D4²] / 4	SB =	8.76	m²
Anchor bolts (or straps) :	S7 = Na x Sa	S7 =	0.04	m²
Foamglas stainless steel belt :	S8 = PI x D4 x 0.0005	S8 =	0.02	m²
Piping (estimated) :		S6 =	0.025	m²

CALCULATION OF THERMAL LOSSES :

Foamglas :	Q4 = lambda4 x (S4 / E4 + S'4 / E'4) x delta_T	Q4 =	1129	W
Perlite :	Q3 = lambda3 x (Sr / Er + S3 / (0.5 x (Do - Di)) + SB / E'4) x delta_T	Q3 =	4183.44	W
Anchor bolts (or straps) :	Q7 = lambda x S7 x delta_T / E'5	Q7 =	158.4	W
Foamglas belt :	Q8 = lambda x S8 x delta_T / E'5	Q8 =	82.42	W
Piping :	Q6 = lambda x S6 x delta_T / E4	Q6 =	63.37	W
Total :	Q = Q3 + Q4 + Q6 +Q7 +Q9	Q =	5617	W

CALCULATION EVAPORATION RATE PER DAY :

E = Q x 86400 / (L x M x 1E3)

E = 0.13%