1, Rue Copernic - Z.I. Nord - 13200 ARLES
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CHAPTER 1

CALCULATION NOTES

Earthquake calculation note: 783-NC101
Mechanical calculation note: 783-NC102
Thermal losses calculation note: 783-NC103

CMP ARLES
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Dossier CMP Arles : 783 | Page/*Sheet* 0.1

Client / ***Customer*** **: MESSER** | ***Engineered System N° :***

1 RESERVOIR DE STOCKAGE LIN 1000MT

1 x 1000MT LIN 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 : ASU KOSICE
Project

Classement CMP Arles : 783-NC101
CMP Arles document N°

N° CMP arles : 783 - NC101

Item : 1 x 1000 MT LIN

Rev : 0

Page 0.2

Appareil / Item : 1 x 1000 MT LIN

Client : MESSER

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CMP ARLES

N° CMP arles : 783 - NC101

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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

CMP ARLES

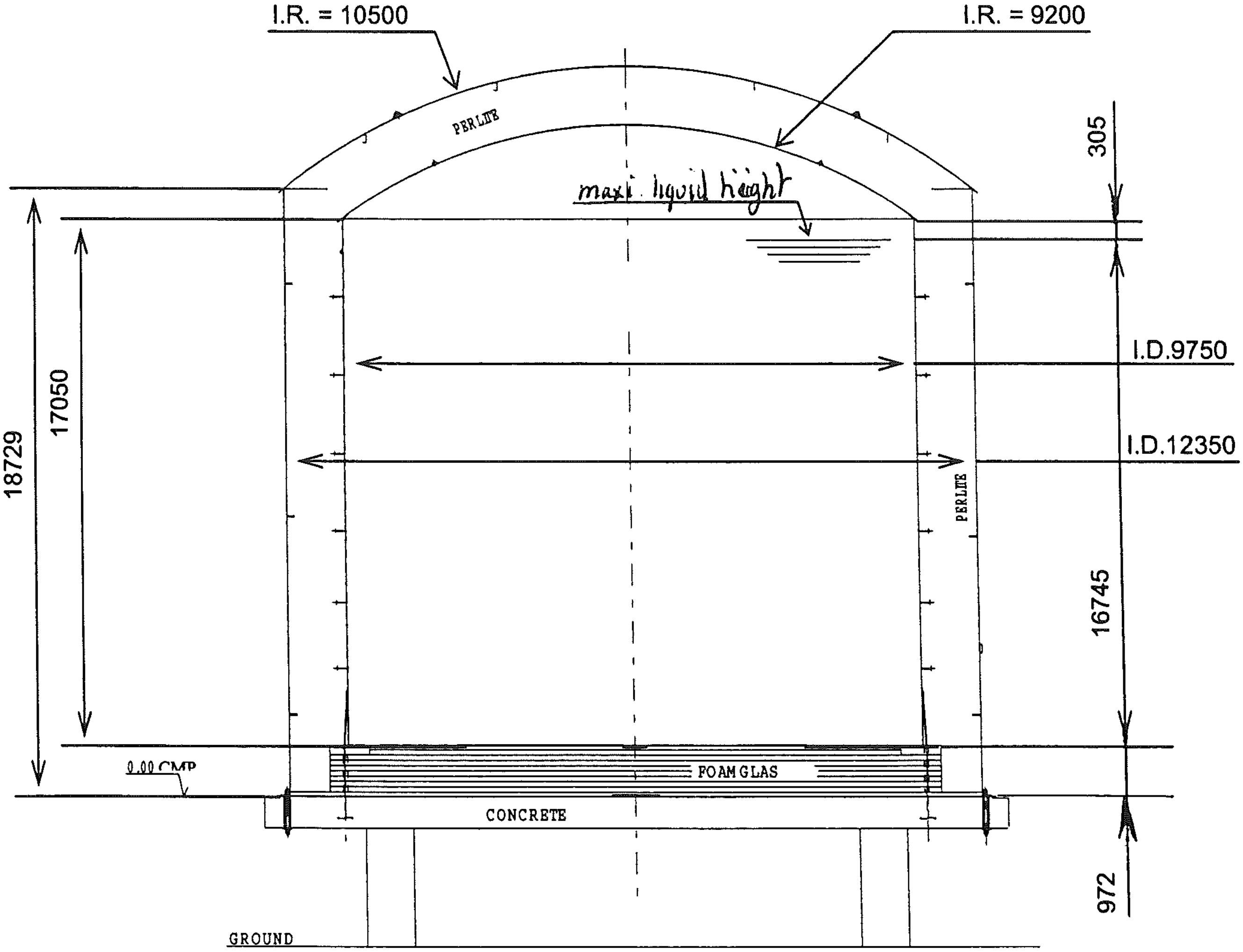
N° CMP arles : 783 - NC101

Item : 1 x 1000 MT LIN

Rev : 0

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 = 12350 mm

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	2081	mm	6.00	mm
↑	V2 =	2081	mm	6.00	mm
	V3 =	2081	mm	6.00	mm
	V4 =	2081	mm	6.00	mm
	V5 =	2081	mm	6.00	mm
	V6 =	2081	mm	6.00	mm
	V7 =	2081	mm	6.00	mm
	V8 =	2081	mm	6.00	mm
	V9 =	2081	mm	6.00	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 21542 mm

Shell stiffeners

	Width		Thk		Qte
V1 =	150	mm	20.00	mm	4
V2 =	0	mm	0.00	mm	0

Roof (Inner radius)	DRe =	10500	mm	6.00	mm
Central part of the roof	dR =	3950	mm	10.00	mm
Roof beams (UPN 140)	D1 =	5000	mm		
	D2 =	10000	mm		
	D3 =	0	mm		
Flat bottom (Y/N) Y	DBe =	12600	mm	5.00	mm
Anchoring ring N	Le =	0	mm	0.00	mm
Stairs	Ms =	2700	Kg		
Top equipements.	Me =	1500	Kg		

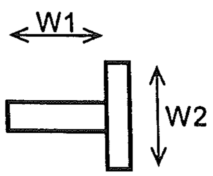
Inner vessel (id) Di = 9750 mm
Service liquid height Hl = 16745 mm

Mini yield strength
ftv = 206.50 N/mm²

Heights and thiknesses of shells

		H		Thk	
Bottom	V1 =	1995	mm	6.00	mm
↑	V2 =	1995	mm	6.00	mm
	V3 =	1995	mm	5.00	mm
	V4 =	1995	mm	5.00	mm
	V5 =	1995	mm	5.00	mm
	V6 =	1995	mm	5.00	mm
	V7 =	1995	mm	5.00	mm
	V8 =	1995	mm	5.00	mm
	V9 =	1090	mm	5.00	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	160.0	5.0	mm	80.0	5.0	mm	10
type B	0.0	0.0	mm	0.0	0.0	mm	0



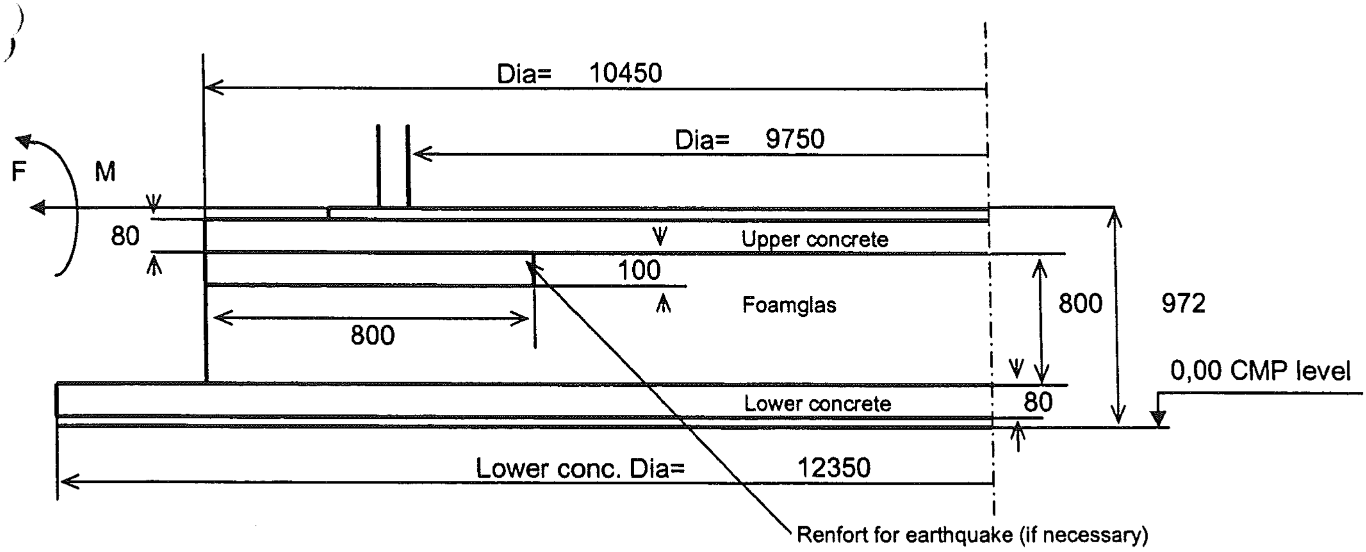
Roof (Inner radius)			DRi =	9200	mm	5.00	mm
Compression ring	Dia=	9800 mm		260.0	mm	15.00	mm
Bottom			DBi =	8520	mm	5.00	mm
Bottom annular ring			Li =	730	mm	7.00	mm
Accessories Piping			M3 =	1000	Kg		

2°) DATA: (Cont.)

Quantity, width and thikness of straps		n =	32	Wia =	100	Tha=	10	mm
	Mini yeld strength	Fby=	206.50	N/mm²				
Dia of the bottom insulation		Dbi =	10450	mm				
Width and thikness of upper concrete renfort for earthquake (if any)		Wuc =	800	mm		Thc=	100	mm
Densities	Steel	ds =	8000	Kg/m^3				
	Perlite	dp =	56	Kg/m^3				
	Liquid	dl =	812.0	Kg/m^3			Thk.	
	Upper concrete	dcs =	2500	Kg/m^3		cs=	80	mm
	Lower concrete	dci =	2500	Kg/m^3		ci=	80	mm
Foamglas								
	Density / thk	df =	130	Kg/m^3		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= 9750^2 x pi/4 x 0.02
P1= 1493238 N **P1 = 153 t**

P2= Uplift force acting on the roof of the vessel under test condition
P2= (Di^2 x pi / 4) x Tp
P2= 97502 x pi/4 x 0.03
P2= 1866548 N **P2 = 191 t**

P3= Weight of inner vessel exept bottom

Shell		21.88 t
Shell stiffeners		3.01 t
roof		3.30 t
Compression ring		0.96 t
Piping		1.00 t
Total P3	=	**30 t**

P4= Weight of inner vessel bottom

Flat bottom		2.28 t
Annular ring bottom		1.18 t
Total P4	=	**3 t**

P5= Weight of external casing exept bottom

Shell		34.90 t
Shell stiffeners		3.77 t
roof		6.88 t
Roof beams		0.75 t
Stairs + Top equipments		4.20 t
Total P5	=	**51 t**

P6= Weight of external flat bottom vessel (if any)
Total P6 = 4.99 t

P7= Weight of perlite on the roof of the inner vessel
Volum of perlite 125 m˘ **P7 = 7 t**

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

1 Volum of perlite	862 m˘		=	48.25 t
2 Volum of lower concrete	3 m˘		=	6.80
		P8	=	**55 t**

P9= Weight of bottom insulation

Volum of upper concrete	6.86 m˘		=	17.15 t
Volum of lower concrete	9.58 m˘		=	23.96 t
Volum of sismic renfort	2.43 m˘		=	6.06 t
Volum of foamglas	68.61 m˘		=	8.92 t
		Total P9	=	**57 t**

P10= Weight of liquid in working conditions
Volum of liquid 1250 m˘ **P10 = 1016 t**

P11= Weight of water during the test
Volum of liquid 1250 m˘ **P11 = 1251 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	=	51.0	t	=	P5
F2	=	55.1	t	=	P8
F3	=	37.1	t	=	P3 + P7
F4	=	1081.4	t	=	C + P10
F5	=	0.0	t	=	0

4.2 °) FULL OF LIQUID WITH GAZ PRESSURE:

F1	=	51.0	t	=	P5
F2	=	55.1	t	=	P8
F3	=	0.0	t	=	If A<0: F3=0. If A>0: F3=A
F4	=	1234.4	t	=	C + P10 + P1
F5	=	115.9	t	=	If A<0: F5=A. If A>0: F5=0

4.3 °) HYDROPNEUMATIC TEST:

F1	=	51.0	t	=	P5
F2	=	6.8	t	=	P8 + weight of perlite
F3	=	0.0	t	=	If B<0: F3=0. If B>0: F3=B
F4	=	1507.4	t	=	C + P11 + P2
F5	=	160.9	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 = 18.0 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	=	290.8	tm

4.6 °) LOADS DUE TO EARTHQUAKE:

To be added to loads 4.1 , 4.2 & 4.3 cases

SHEAR FORCE	=	142	t
MOMENT at 0.00 CMP	=	1223.9	tm

F5 = 12.51 t per strap x 32 = 400.5 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	=	24.88 t
Height of centroid of the shell	H2	=	8268 mm
Roof of the inner vessel	m3	=	4.26 t
Height of centroid of the roof	H3	=	17756 mm
Flat bottom of the inner tank	m4	=	3.46 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	=	38.67 t
Height of centroid of the shell	H5	=	9367 mm
Roof and roof beams	m6	=	7.64 t
Height of centroid of the roof	H6	=	19738 mm
Perlite on the roof of the vessel	m7	=	7.00 t
Centroid of the perlite in th roof	H7	=	19738 mm
Perlite in the annular space	m8	=	48.25 t
Centroid of the perlite in this space	H8	=	9622 mm
Bottom of the casing	P6	=	4.99 t
Stairs	m10	=	2.70 t
Centroid fo the stairs	H10	=	9367 mm
Accessories on the casing top	m11	=	1.50 t
Centroid of the accessories	H11	=	20743 mm

5.3) Mass and height of centroids of supporting slab

Weight of concrete	m12	=	23.96 t
Height of centroid concrete	H12	=	40 mm
Weight of bottom insulation + upper concrete	m13	=	32.14 t
Height of centroid of bottom insulation	H13	=	781 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	=	1250.2	m^3
G=	Density of tank contents	=	812	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	=	8.2329	m
Wr+s=	Mass of tank shell and roof including attachements	=	30142	Kg
Ht=	Total height of tank shell	=	17.050	m
D=	Internal diameter of tank	=	9.750	m
H=	Maximum design product height	=	16.745	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	=	6.00	mm
n=	Number of anchorages	=	32	
Sa=	Section of anchorages	=	1000.00	mm^2
Da=	Diameter of anchorcircle	=	9.900	m
X=	Width of the bottom annular plate (inside)	=	0.665	m

B) FACTORS :(According to API 620 curves)

D/H=	9.75 / 16.75 =		**0.58**	
Wt=	1250.21 x 812 =		**1015000**	Kg
FIGURE L-2	W1 / Wt	=	**0.89**	
	W2 / Wt	=	**0.14**	
W1=	Wt x 0.89	=	**903092**	Kg
W2=	Wt x 0.14	=	**145976**	Kg
FIGURE L-3	X1 / H	=	**0.44**	
	X2 / H	=	**0.81**	
X1=	16.75 x 0.44	=	**7.39**	m
X2=	16.75 x 0.81	=	**13.50**	m
FIGURE L-4	k = 0.6			
T=	$k \times D^{1/2}$	=	**3.39**	
C1=		=	**0.60**	
C2=	0,75x S/T if T<4,5 or 3,375x S/T²	=	**0.3315**	

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 30142.15 x 8.23) + (0.6 x 903092.29 x 7.39)
+ (0.33 x 145976.34 x 13.5)] x 9.81

M= 9432625 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 30142.15 + 0.6 x 903092.29 + 145976.34 x 0.33) x 9.81

F= **1193552 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 812 x 16.75)^(1/2)

WL= **279631 N/m**

WL< 1,25 x G x H x D x 9,81
WL< 1.25 x 812 x 16.75 x 9.75 x 9.81
WL< **1625642 N/m** THEN OK

tb<= MAX(53,35,t) 7.0 <= 6.0 if it is not the case; see the following check

X > 2,79.10^{-03} x WL / (G x H)
X= 0.67 > 0.00279 x 279630.74 / (812 x 16.75)
X= 0.67 > **0.0574 m** THEN OK

E) SHELL COMPRESSION

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

b= Wr + s x g / (PI x D) + (1,273 x M / D²)
b= 30142.1521148468 x 9.81 / (PI x 9.75) + (1.273 x 9432624.79 / 9.75²)

b= **135968** **N/m**

Compression stress:

b x 10^3 / t = 135967.66 x 1000 / 6
F= **22661277** **N/m² = 22.66 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 x G x H x D² / t² in métric units.

R = 5640.13

If R <= 6894.76 Fa= 33,094834 x t / D + 7,4931208 x (G x H)$^{1/2}$
Fa= **48.00** **Mpa**

If R > 6894.76 Fa = 82,737084 x t / D
Fa = **0.00** **Mpa**

Then Fa = **48.00** **Mpa >22.66 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 9.75² x 1000000 - (30142.15) x 9.81

P= **1197544** N

UPLIFT DUE TO EARTHQUAKE

E= 1,273 x M / D²
E= 1.273 x 9432624.79 / 9.75²

E= **126314** N/m

UPLIFT FORCE PER ANCHORAGE

Due to internal pressure

Ap= P / n
Ap= 1197543.75 / 32

Ap= **37423** N

Stress due to internal pressure

Ap/Sa= 37423.24 / 1000
Ap/Sa= **37.42** **N/mm²**

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

Due to earthquake

Ae= (E x PI x Da) / n
Ae= (126314.07 x 3.14 x 9.9) / 32

Ae= **122768** N

Stress due to earthquake

Ae/Sa= 122768.46 / 1000
Ae/Sa= **122.77** **N/mm²**

ACTUAL STRESS

Ae/sa+Ap/sa= 122.77 + 37.42 **N/mm²**
Ae/sa+Ap/sa= **160.19** **N/mm²**

ALLOWABLE TENSIL STRESS (90% yield strength)

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

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 0.33 x 3.39² x tanh (4.77 x (16.75 / 9.75)^(1/2)

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

ACTUAL SUPPLEMENTARY HEIGHT:

Ha= Ht-H
Ha= 17.05 - 16.75
[Ha= 0.305] > 0.305 THEN OK

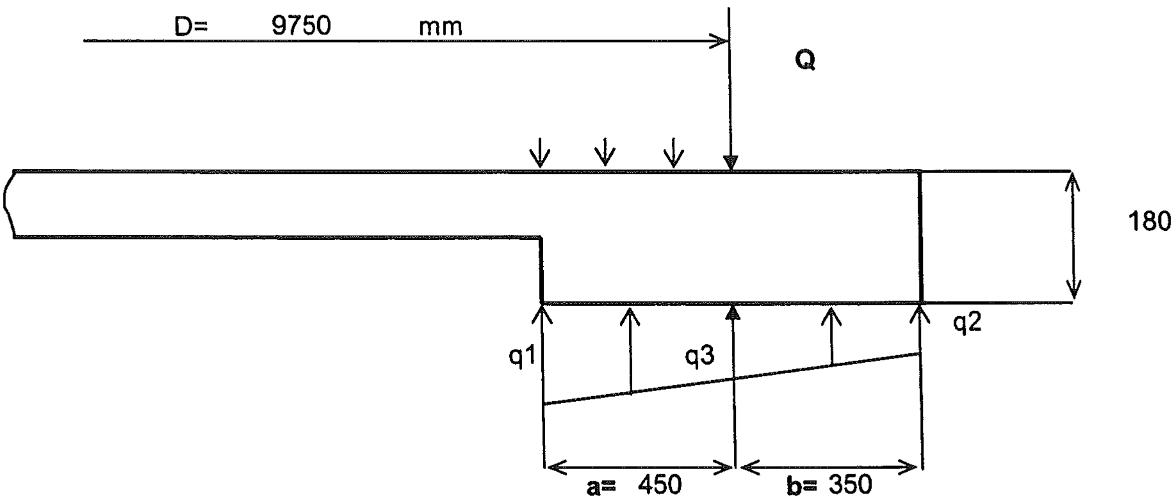
STRESSES IN CONCRETE RING AND FOAMGLAS

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 = 135991 N

$p = G \times g \times H$
p = 133386 N/m²



$C1 = q1 + q2$
$= (2 / (a + b)) \times (Q + a \times p)$
C1 = 490038 N/m²

$C2 = q1 + 2 \times q2$
$= (6 \times a / (a+ b)^2) \times (Q + a \times p /2)$
C2 = 700326 N/m²

$q2 = C2 - C1$
q2 = 210289 N/m²
$q1 = C1 - q2$
q1 = 279749 N/m²

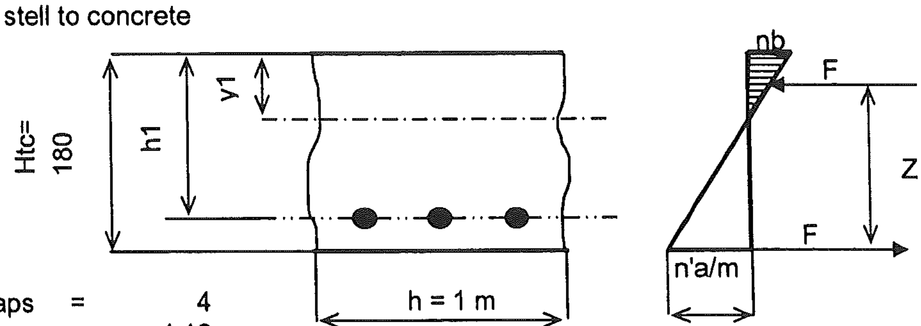
$q3 = (q1 \times b + q2 \times a) / (a + b)$
q3 = 240678 N/m²

Flexural moment in the concrete ring per unit of length

$Mf = b^2 / 6 \times (2 \times q2 + q3)$
Mf = 13501 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	=	4.12	
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'**	=	**827.47**	**mm²**

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

Mo = h1 / 2 x m x w'
Mo = 6.04

Nu = 1 / 2 x ((1 + 4 x Mo)$^{1/2}$) -1)
Nu = 2.008

y1 = h1 / (1 + Nu)
y1 = 0.050 m

Z = h1 - y1 / 3
Z = 0.133 m

F = M f / Z
F = 101219 N/m

n'a = F / w'
n'a = 122.32 N/mm²

nb = 2 x F / y1
nb = 4.06 N/mm²

Allowable stresses

n'a	**122.32**	**=<**	**172**	**N/mm²**	**Then OK**
nb	**4.06**	**=<**	**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 = 284164 N/m²
P = 0.28416 N/mm²

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= 0.2851 **MPa**

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

Calculated safety factor = 2.42 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= (38.67 + 7.64 + 7 + 48.25 + 4.99 + 2.7 + 1.)x 0.12 x 9810

Fe= 130372 N

Maximum moment at 0,00 CMP.

Me= [(38.67 x 9.37) + (7.64 x 19.74) + (7 x 19.74) + (48.25 x 9.62)
+ (2.7 x 9.37) + (1.5 x 20.74)] x 0.6 x 0.2 x 9810

Me= 1379485 Nm

8.2) Inner vessel:

Maximum horizontal shear force at 0,00 CMP.

Fb=F (page 10) = 1193552 N

Maximum moment at 0,00 CMP.

Mb = M + F x Epi

Mb = 9432625 + 1193552 x 0.97

Mb = 10592757 Nm

8.3) Isolation and concrete under the inner tank:

Maximum horizontal shear force at 0,00 CMP.

Pi = P4 + P9
Pi = 3456 + 57000 **Pi = 60456 Kg**
Fi = Pi x C1 x Z x 9.81
Fi = 60456 x 0.6 x 0.2 x 9.81
Fi = 71168 N

Maximum moment at 0,00 CMP.

Mi = Fi x Epi / 2
Mi = 71168 x 0.49
Mi = 34588 Nm

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

FT = Fb + Fi + Fe
FT = 1193552 + 71168 + 130372
FT = 1395093 N

FT = 142 t

MT = Mb + Mi + Me
MT = 10592757 + 34588 + 1379485.29
MT = 12006830 Nm

MT = 1224 tm

ANCHOR BOLTS FOR OUTER CASING :

Data :

Anchor bolt diameter :	D3 =	12.15	m	
Anchor bolt number :	n =	12		
Anchor bolt section :	s =	1040	mm²	(M42)
Allowable stress in anchor bolt :	=	165.5	MPa	
Mass of shell and stiffeners of outer casing :	m5 =	38666	kg	
Mass of roof and roof beams :	m6 =	7638	kg	
External casing diameter :	D =	12350	mm	
Outer casing internal pressure :	p =	0.001	Mpa	
Maximum bending moment at the base of the shell :	M3 =	1379485	N.m	

Uplift force per anchor bolt due to seism :

uf1 = 1 / n x 4 x M3 / D3
uf1 = 1 / 12 x 4 x 1379485.29 / 12.15

uf1 = 37846 N

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

L = p x pi x D^2 / 4
L = 0.001 x pi x 12350^2 / 4

L = 119791 N

uf2 = 1 / n x [(4 x M3 / D3) + L - (m5 + m6) x g]
uf2 = 1 / 12 x [(4 x 1379485.29 / 12.15) + 119790.89 - (38666 + 7638) x 9.81)]

uf2 = 9975 N

Tensile stress in anchor bolt :

Sp = MAX(uf1,uf2) / s
Sp = 37845.96 / 1040

Sp = 36.39 MPa < 165.50 MPa THEN OK

CMP ARLES
Constructions Métalliques et Préfabrication d'Arles
1, Rue Copernic - Z.I. Nord - 13200 ARLES
☎: 04.90.93.33.30 - Téléfax:04.90.93.33.31
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DEPARTEMENT CRYOGENIE SOISSONS
13, Avenue de Coucy
02200 SOISSONS
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Mail: cryo.soissons@cmparles.com

Dossier CMP Arles : 783

Client / *Customer* **: MESSER** *Engineered System N° :*

1 RESERVOIR DE STOCKAGE LIN 1000MT

1 x 1000MT LIN STORAGE TANK

NOTE DE CALCUL MECANIQUE

MECHANICAL CALCULATION NOTE

EDITION *EDITION N°*	REFERENCE *CLIENT REF.*	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	DATE	NOM *NAME*	SIGN.	ETAT D'AVANC. *STATUS*
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]	
		REDACTEUR *DRAWN UP BY*			VERIFICATEUR *CHECKED BY*			APPROBATEUR *APPROVED BY*			

Projet : *Project* ASU KOSICE

Classement CMP Arles : *CMP Arles document N°* 783-NC102

CMP ARLES

N° CMP arles : 783 - NC102

Item : 1 x 1000 MT LIN

Rev: A

Page 0.2

Appareil / Item : 1 x 1000 MT LIN

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 : shell	1								
11	Inner vessel under internal pressure : roof	1								
12	Inner vessel under internal pressure : roof	1								
13	Inner vessel under internal pressure : roof to shell jonction	1								
14	Inner vessel under internal pressure : drawing	1								
15	Inner vessel under internal pressure : roof to shell jonction	1								
16	Inner vessel under external pressure : shell	1								
17	Inner vessel under external pressure : shell	1								
18	Inner vessel under external pressure : shell	1								
19	Inner vessel under external pressure : shell	1								
20	Inner vessel under external pressure : shell	1								
21	Inner vessel under external pressure : roof	1								
22	Inner vessel anchorage	1								
23	Outer casing shell under internal pressure	1								
24	Outer casing roof under internal pressure	1								
25	Outer casing roof under wind and negative gaz pression	1								
26	Outer casing roof under wind and negative gaz pression	1								
27	Outer casing anchorage	1								
28	Outer casing anchorage	1								
29	Opening reinforcement	1								
30	Opening reinforcement	1	2							
31	Inner vessel shell under internal pressure according AL rules	1								
32	Inner vessel shell under internal pressure according AL rules	1								
33										
34										
35										
36										
37										
38										
39										

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

DOCUMENTS DE REFERENCE

ET CONVENTIONS GENERALES

(Reference documents and generale conventions)

SPECIFICATION CLIENT :
Customer specification

PLAN CLIENT :
Customer drawing

PLAN CMP arles Drawing	783 - 101 783 - 102 783 - 103 783 - 104
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 : eral conditions	S I system

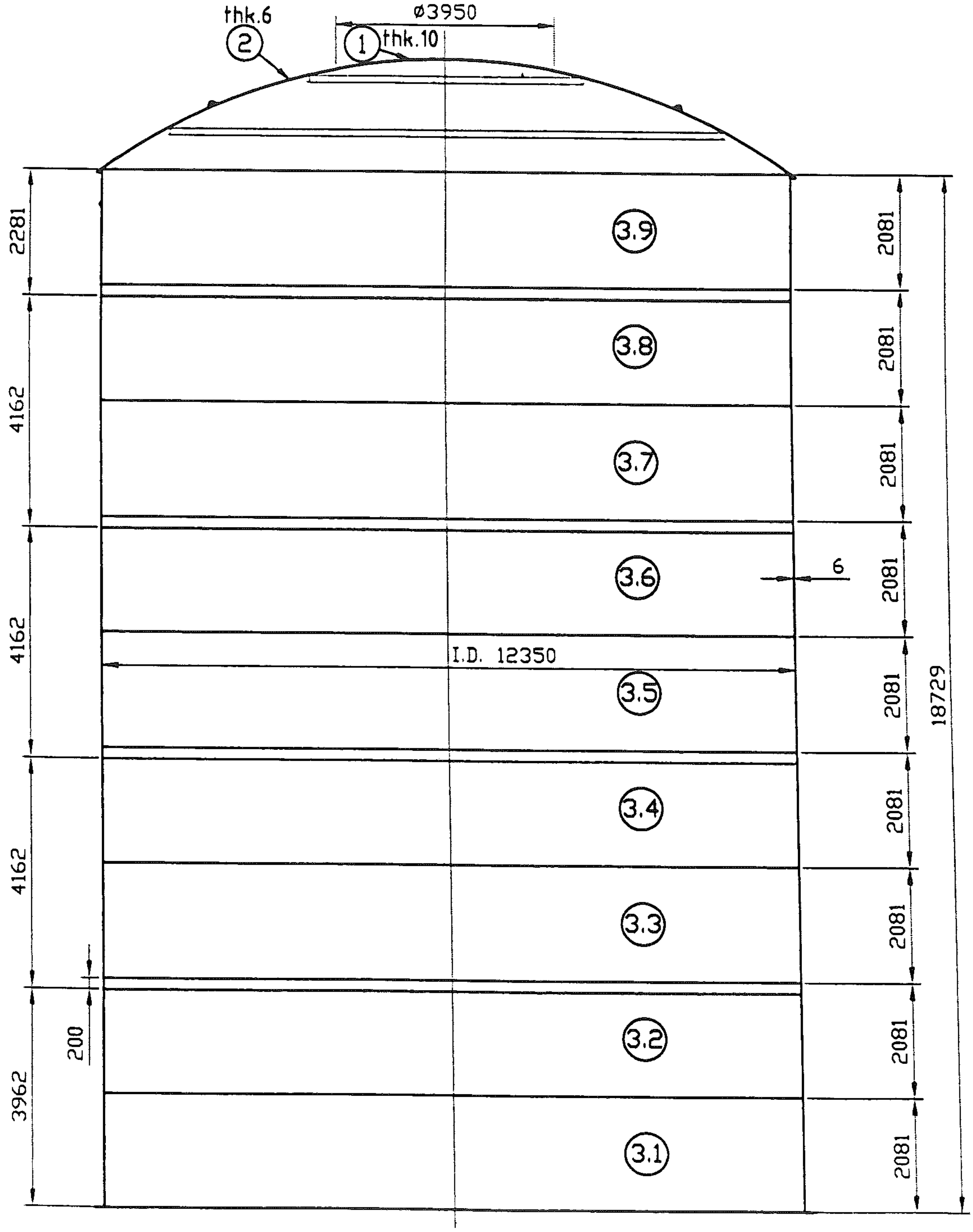
1) GENERAL DATA :

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	5 to 6	0		1	8000	A 240-304
1& 2	Inner vessel roof	5	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	6 & 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)

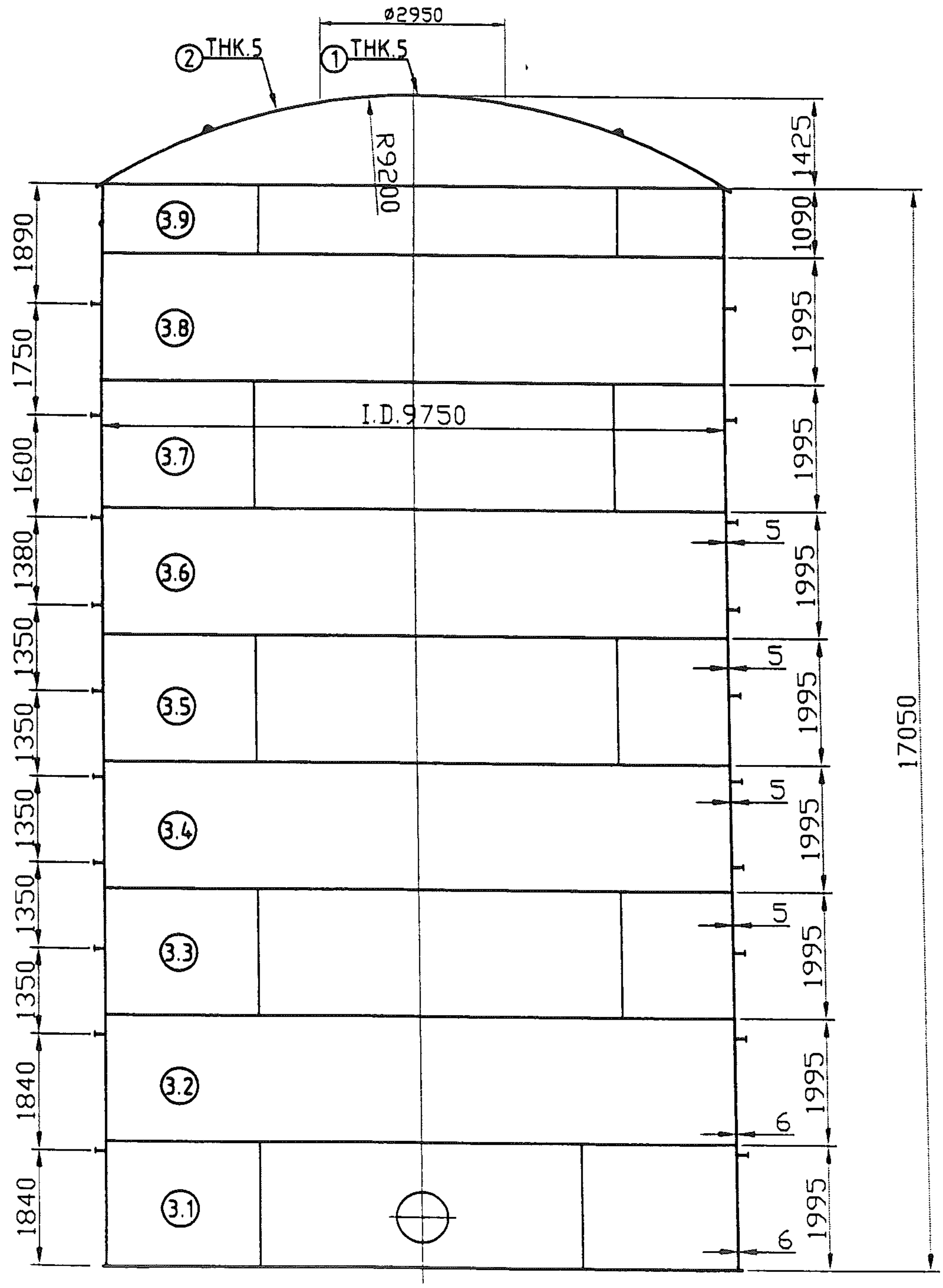
OUTER CASING



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.17		0.0070
Ppr	Perlite compaction pressure for roof (MPa)	0.0007		/
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/m³)	812		56
Hl	Service liquid height (mm)	16745		/

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 =	4875	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	6	-295930	-9958853	-10254777	0.1334	0.1534
3.2	6	-267138	-8772354	-9039487	0.1175	0.1375
3.3	5	-238346	-7585856	-7824197	0.1016	0.1216
3.4	5	-214355	-6399358	-6613708	0.0857	0.1057
3.5	5	-190364	-5212860	-5403219	0.0698	0.0898
3.6	5	-166373	-4026362	-4192730	0.0539	0.0739
3.7	5	-142382	-2839864	-2982241	0.0380	0.0580
3.8	5	-118391	-1653366	-1771752	0.0221	0.0421
3.9	5	-94400	-466868	-561262	0.0063	0.0263

Shell	Thk(mm)	T1 (N/mm)	T2 (N/mm)	St (MPa)	St allowable	ratio
3.1	6	39.1	747.757	124.6	155.1	1.2
3.2	6	40.0	670.285	111.7	155.1	1.4
3.3	5	41.0	592.813	118.6	155.1	1.3
3.4	5	41.8	515.342	103.1	155.1	1.5
3.5	5	42.5	437.870	87.6	155.1	1.8
3.6	5	43.3	360.399	72.1	155.1	2.2
3.7	5	44.1	282.927	56.6	155.1	2.7
3.8	5	44.9	205.455	41.1	155.1	3.8
3.9	5	45.7	127.984	25.6	155.1	6.1

We verify that the ratio is > 1

2) **Test conditions :**

We use water for the test calculation

water density = 1000 Kg / m^3 > liquide density= 812 Kg / m^3

See page 10 for test results.

2) **Test conditions :**

Shell	Thk(mm)	Wm (N)	WL (N)	W (N)	PL (MPa)	P (Mpa)
3.1	6	-295930	-12264597	-12560521	0.1643	0.1843
3.2	6	-267138	-10803392	-11070524	0.1447	0.1647
3.3	5	-238346	-9342188	-9580529	0.1251	0.1451
3.4	5	-214355	-7880983	-8095333	0.1056	0.1256
3.5	5	-190364	-6419778	-6610137	0.0860	0.1060
3.6	5	-166373	-4958574	-5124942	0.0664	0.0864
3.7	5	-142382	-3497369	-3639746	0.0468	0.0668
3.8	5	-118391	-2036165	-2154551	0.0273	0.0473
3.9	5	-94400	-574960	-669355	0.0077	0.0277

Shell	Thk(mm)	T1 (N/mm)	T2 (N/mm)	St (MPa)	St allowable	ratio
3.1	6	39.1	898.309	149.7	186.1	1.2
3.2	6	40.0	802.900	133.8	186.1	1.4
3.3	5	41.0	707.492	141.5	186.1	1.3
3.4	5	41.8	612.084	122.4	186.1	1.5
3.5	5	42.5	516.675	103.3	186.1	1.8
3.6	5	43.3	421.267	84.3	186.1	2.2
3.7	5	44.1	325.858	65.2	186.1	2.9
3.8	5	44.9	230.450	46.1	186.1	4.0
3.9	5	45.7	135.042	27.0	186.1	6.9

We verify that the ratio is > 1

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 =	-32341	N
Accessories weight on roof	WA =	4905	N
Roof thickness	Thk =	5.00	mm
Inner shell radius	Rc =	4875	mm
Roof spherical radius	Rs =	9200	mm

1) design conditions :

Hydrostatic pressure	PL =	0	Mpa
Total pressure	P = PL + Pg =	0.02	Mpa
Total weight	W = Wm + WA =	-27436	N

Unit force

T1 = 0.5 x Rs x (P + W / (pi x Rc²)) = 91 N / mm

T2 = P x Rs - T1 = 93 N / mm

Calculated stress

S = Max { T1 , T2 } / (J x Thk) = 53.2 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 =	-27436	N
Unit force			
	T1 = 0.5 x Rs x (P + W / (pi x Rc²)) =	114	N / mm
	T2 = P x Rs - T1 =	116	N / mm

Calculated stress

S = Max { T1 , T2} / (J x Thk) = 66.3 MPa < 186.1 MPa

3) Vérification according AL rules :

max. burst pressure of 375 mbar = Pg

Hydrostatic pressure	PL =	0	Mpa
Total pressure	P = PL + Pg =	0.0375	Mpa
Total weight	W = Wm + WA =	-27436	N
Unit force			
	T1 = 0.5 x Rs x (P + W / (pi x Rc²)) =	-171	N / mm
	T2 = P x Rs - T1 =	-174.2	N / mm

Calculated stress

S = Max { T1 , T2} / (J x Thk) = 99.6 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.14

Thk of the shell at the top = 5 mm

Permissible widths of plates making up the compression area :

$Wh = 0.6\,(Thk \times R)^{1/2}$ =	0.223	m
Where $Thk_{comp.\ ring}$ =	15.00	mm
$Wc = 0.6\,(Thk\ .Rc\,)^{1/2}$ =	0.093	
Where $Thk_{of\ shell}$ =	5.00	mm
$L < (16 \times Thk_{of\ comp.ring})$ =	0.24	m

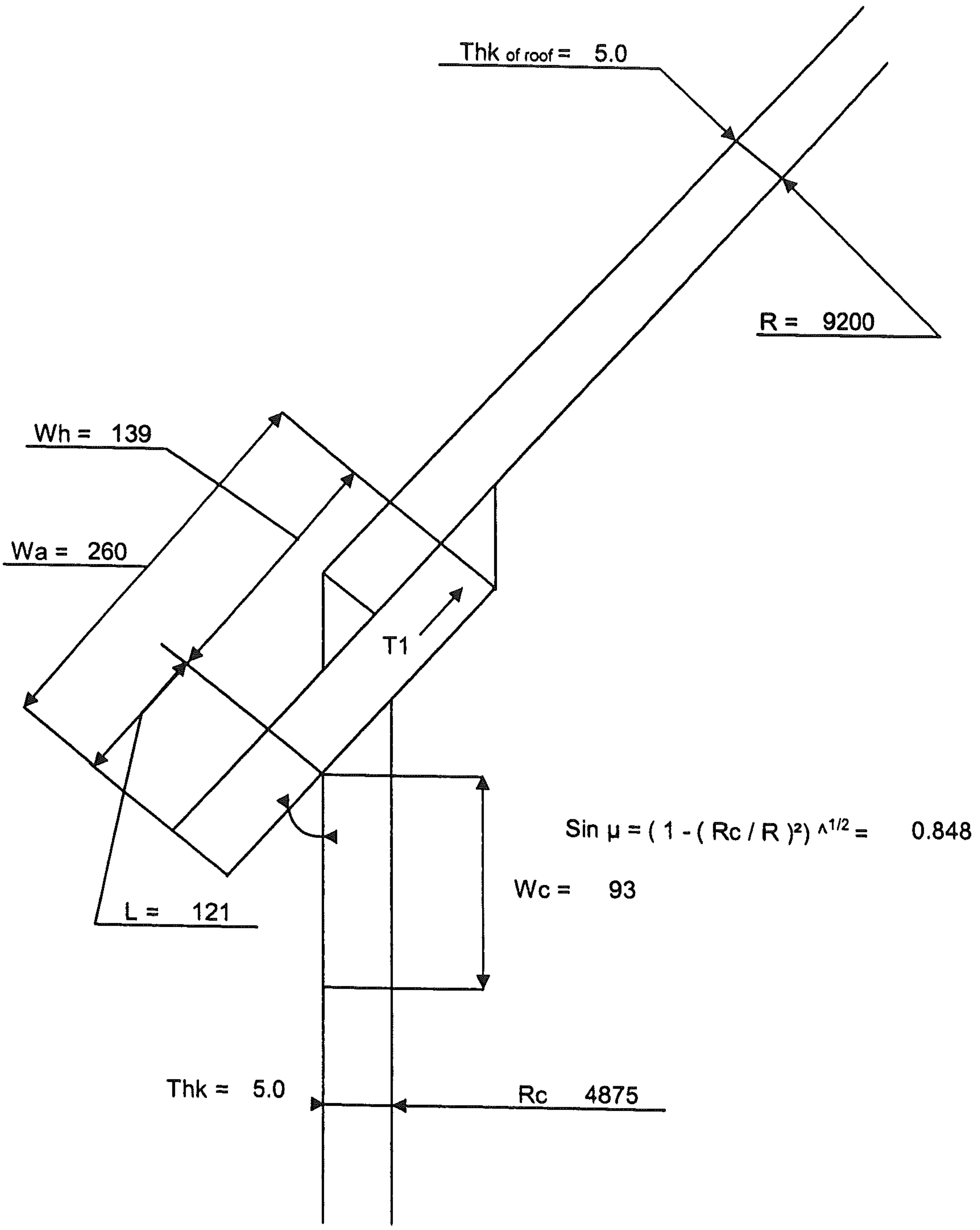
Actuel dimensions of the compression ring :

Wh =	139	mm
Wc =	93	mm
L =	121	mm

1) Under working conditions :

Gas design pressure	P=	20000	N /m²
Shell section	A =	74.7	m²
Proper mass of the roof	W =	32341	N
Roof meridional unit force :	T1 = R/2 x (P -W / A) =	90008	N / m
Roof circumferential unit force :	T2 = R x P - T1 =	93992	N / m
Shell circumferential unit force :	Tc = Rc x P =	97500	N / m

Roof to shell junction - compression ring :



Area of the interested compression zone:

$Sr = (L + Wh) \times Thk_{\text{ of comp.ring}} + (Wc \times Thk_{\text{ of shell}}) =$ 0.00437 m²

Circumferential forces action on the above section :

$Q = -T1 \times Rc \times \sin\mu + ((T2 \times Wh) + Tc \times Wc) =$ -349991.39 N

Where $\sin\mu = (1 - (Rc/\ R)^2)^{1/2} =$ 0.848

Compression stress :

$n = - Q / Sr =$ 8.02E+07 N / m²

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 / m².

2) Under testing conditions :

gas design pressure :	P =	25000	N / m²
	T1 =	113008	N / m
	T2 =	116992	N / m
	Tc =	121875	N / m
	Q =	-440787	N
	n =	1.01E+08	N / m²

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 / m².

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	1840	6	A
2	1840	6	A
3	1350	5	A
4	1350	5	A
5	1350	5	A
6	1350	5	A
7	1350	5	A
8	1380	5	A
9	1600	5	A
10	1750	5	A
11	1890	5	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= 26.0 mbar

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

-> After 7 m , Pc = Pc(H=7m) = 64.5 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	64.5	107.96	1.7	1767.1	27.4
2	64.5	107.96	1.7	1767.1	27.4
3	64.5	95.55	1.5	1472.9	22.9
4	64.5	95.55	1.5	1472.9	22.9
5	64.5	95.55	1.5	1472.9	22.9
6	64.5	95.55	1.5	1472.9	22.9
7	64.5	95.55	1.5	1472.9	22.9
8	59.5	92.96	1.6	1472.9	24.8
9	52	78.63	1.6	1472.9	28.4
10	44.5	71.6	1.7	1472.9	33.1
11	35.7	66.31	1.9	1472.9	41.3

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	160	5	80	5	9762	6.0	9850	1840
2	160	5	80	5	9762	6.0	9850	1595
3	160	5	80	5	9760	5.0	9863	1350
4	160	5	80	5	9760	5.0	9863	1350
5	160	5	80	5	9760	5.0	9863	1350
6	160	5	80	5	9760	5.0	9863	1350
7	160	5	80	5	9760	5.0	9863	1365
8	160	5	80	5	9760	5.0	9863	1490
9	160	5	80	5	9760	5.0	9863	1675
10	160	5	80	5	9760	5.0	9863	1820

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	271	2827	98768	11960779	10190310	41
2	271	2827	98768	11960779	10190310	41
3	248	2440	96155	10904070	6570255	27
4	248	2440	96155	10904070	6570255	27
5	248	2440	96155	10904070	6570255	27
6	248	2440	96155	10904070	6570255	27
7	248	2440	96155	10904070	6570255	27
8	248	2440	96155	10904070	6570255	27
9	248	2440	96155	10904070	6570255	27
10	248	2440	96155	10904070	6570255	27

N° stiffeners	Pe (mbar)	P (mbar)	Pe / (P. Sk2)	X	K / S	ratio n° 2
1	355.0	64.5	1.8	55.6	143.8	2.6
2	409.5	64.5	2.1	52.1	143.8	2.8
3	440.0	64.5	2.3	51.2	143.8	2.8
4	440.0	64.5	2.3	51.2	143.8	2.8
5	440.0	64.5	2.3	51.2	143.8	2.8
6	440.0	64.5	2.3	51.2	143.8	2.8
7	435.1	59.5	2.4	47.7	143.8	3.0
8	398.6	52.0	2.6	43.5	143.8	3.3
9	354.6	44.5	2.7	39.4	143.8	3.7
10	326.3	35.7	3.0	33.8	143.8	4.3

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 =	7.20	mbar
Weight of the roof :	P4 = 0.079 x 9.81 x Thk	P4 =	3.9	mbar
Design external pressure :	P = P1 + P2 + P3 + P4	P =	26.1	mbar
Roof Radius :		DRi =	9200	mm
Thickness :		Thk =	5.00	mm
Compressive stress :	St = (P x DRi) / 2Thk	St =	2.40	Mpa
	Scc = St x 145	Scc =	347.8	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 = 5.00 / 9200 = 0.00054 < 0.00667

So Sca = 1 000 000 x Thk / DRi = 543 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) = 1493238 N

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

W = 329594.08 N

Net uplift force

U = F - W = 1163644.2 N

Number of straps : n = 32

Strap section : a = 1000 mm²

Uplift force per strap : Ud = U / n = 36364 N

Tensile stress in Sd = Ud / a = 36.36 MPa < 155.1 MPa

OK !

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

F' = 4199732.6 N

U' = 3870138.5 N

Ud' = U' / n = 120942 N

Sd' = Ud' / a = 120.9 MPa < 186.1 MPa

OK !

NOTA : The 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 =	6175	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 =	-454257	N
WA =	-41202	N
W =	-495459	N
P =	0.008	MPa
T1 =	11.93	N / mm
T2 =	49.40	N / mm

St = 11.8 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 =	6175	mm
Roof spherical radius	Rs =	10500	mm
Roof thickness	Thk =	6.00	mm
Roof weight	Wm =	-74938	N
Accessories weight on roof	WA =	-14715	N
Total weight	W =	Wa + Wm	
	W =	-89653	N
Internal pressure	P =	0.001	Mpa

Unit force

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

T1 = 1.32 N / mm

$T2 = P \times Rs - T1$

T2 = 9.18 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 =	12350	mm =	40.53	feet	
	V =	119.1	miles per hour			
	H =	44.38	feet =	13527	mm	

Actual max. distance : H1max = 4500 mm = 14.8 feet

z = Required modulus of inertia of stiffener

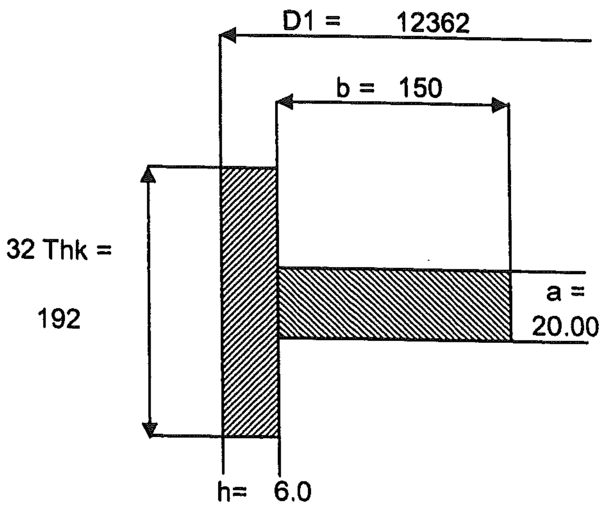
$z = 0.0001 \times D^2 \times H1max (V / 100)^2$

z = 3.45 cubic inch

z = 56525 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 =	465	N /m²
Negative gas pressure		Pnp =	500	N /m²
Accessories weight	Pa = - Wa / (pi x Rc²)	Pa =	123	N /m²
Design pressure	P = P1 + Pr + Pnp + Pa	P =	3704	N /m²

Compressive stress in the roof

St = P x R / (2 x Thk x 1 000 000) with R = 10500 mm

St = 3.2 Mpa = 469.9 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 = 571 psi OK !

We verify : 571 psi > 469.90 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 =	12.362	m
Total height of tank (with accessories)	H =	21.542	m

F = 264665 N

Overturning moment M = F x H / 2

M = 2850661 Nm

Moment of inertia of the bolts set

I / V =N x S x R / 2

With :	N = Number of anchoring bolts =	12	
	S = Sectional area of bolt =	1040	mm²
	R = Radius of the bolt circle =	6075	mm

Load per bolt due to the wind moment

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

Q = 78207 N

Stress in the bolts due to wind only = Q / S = 75.2 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 =	12.362	m
U =	89466	N

Uplift due to the internal pressure :

$L = 1.25\ p \times pi \times D^2 / 4 =$				150029.7	N
With p =	0.001	MPa	=	1000	N / m^2
Dead weight of the outer casing			W =	495459	N

Total maxi. load per bolt

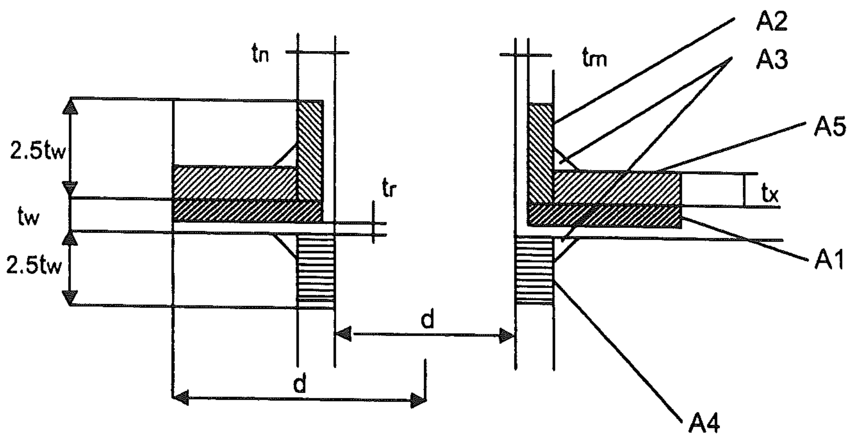
$((U + L - W) / N) + Q =$	56877	N

Stress in the bolts :

Maximum stress in the bolts :Smax =				165.5	MPa
56877	/	1040	=	54.7	MPa
			<	165.5	MPa

OK !

12/ Opening reinforcements for inner vessel nozzles :



trn = min. calculated thickness for nozzle

tr = min. calculated thickness for tank

$A1 = (t_w - t_r) (d - 2 t_{rn})$

$A2 = 2 (t_n - t_{rn}) \times 2.5 t_w$

A3 = welds are neglected

$A4 = 2 t_n \times 2.5 t_w$

$A5 = T \times (d - 2 t_n)$

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

Required reinforcement area which is based on the piping resistance :

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

External pressure case $Ar = (0.5 \times d \times tr) / E \times S$ plate / S piping

Aa > Ar is verified.

NOZZLES

N° of the case	1	2	3	4
NOZZLE	K	G1-A1-A2	E1-E2-G2	R4 to R6
Emplacement	Roof	Roof	Roof	Roof
Pressure	External	External	External	External
Nozzle Diam.	762	168.3	88.9	88.9
P (MPa)	0.00261	0.00261	0.00261	0.00261
R (mm)	9200	9200	9200	9200
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)	5	5	5	5
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)	4.1	4.1	4.10	4.1
A1 (mm²)	675	136	68	68
A2 (mm²)	100	140	112	112
A3 (mm²)	0	0	0	0
A4 (mm²)	150	178	137	137
A5 (mm²)	1428	0	0	0
Aa (mm²)	2353	454	318	318
E	1	1	1	1
Ar (mm²)	1538	379	192	192
Aa / Ar	1.5	1.2	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 =	4875	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	6	-295930	-9958853	-10254777	0.1334	0.1709
3.2	6	-267138	-8772354	-9039487	0.1175	0.1550
3.3	5	-238346	-7585856	-7824197	0.1016	0.1391
3.4	5	-214355	-6399358	-6613708	0.0857	0.1232
3.5	5	-190364	-5212860	-5403219	0.0698	0.1073
3.6	5	-166373	-4026362	-4192730	0.0539	0.0914
3.7	5	-142382	-2839864	-2982241	0.0380	0.0755
3.8	5	-118391	-1653366	-1771752	0.0221	0.0596
3.9	5	-94400	-466868	-561262	0.0063	0.0438

Shell	Thk(mm)	T1 (N/mm)	T2 (N/mm)	St (MPa)	St allowable	ratio
3.1	6	81.7	833.069	138.8	186.1	1.3
3.2	6	82.7	755.598	125.9	186.1	1.5
3.3	5	83.6	678.126	135.6	186.1	1.4
3.4	5	84.4	600.654	120.1	186.1	1.5
3.5	5	85.2	523.183	104.6	186.1	1.8
3.6	5	86.0	445.711	89.1	186.1	2.1
3.7	5	86.8	368.240	73.6	186.1	2.5
3.8	5	87.5	290.768	58.2	186.1	3.2
3.9	5	88.3	213.296	42.7	186.1	4.4

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 LIN 1000MT

1 x 1000MT LIN STORAGE TANK

NOTE DE CALCUL THERMIQUE

THERMAL LOSSES CALCULATION NOTE

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 : ASU KOSICE
)ect

Classement CMP Arles : 783-NC103
CMP Arles document N°

CMP ARLES

N° CMP arles : 783 - NC103

Item : 1 x 1000 MT LIN

Rev: 0

Appareil / Item : 1 x 1000 MT LIN

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	Data	1								
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CMP ARLES

N° CMP arles : 783 - NC103

Item : 1 x 1000 MT LIN

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 :		Nitrogen
	Temperature :	T1 =	-196 deg.C
	Density:	W =	812 kg/m^3
Heat of vaporisation :		L =	199.199 kJ/kg
External temperature :		T2 =	15 deg.C
Inner vessel :	Shell internal diameter :	D1 =	9.750 m
	Shell height :	H1 =	17.050 m
	Liquid height :	LH =	16.745 m
	Shell average thickness :	E1 =	0.005 m
	Roof external radius :	R1 =	9.205 m
	Roof height :	G1 =	1.397 m
Insulation Jacket :	Shell internal diameter :	D2 =	12.350 m
	Shell height :	H2 =	18.729 m
	Roof internal radius :	R2 =	10.500 m
	Roof height :	G2 =	2.008 m
Perlite thickness in the shell interspace :		E3 =	1.295 m
Perlite thickness in the roof interspace :		Er =	1.295 m
Foamglas thickness :	In the center :	E4 =	0.800 m
	At the periphery :	E'4 =	0.700 m
Foamglas external diameter :		D4 =	10.450 m
		D'4 =	8.850 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 =	32
Area of one anchor bolt (or strap) :		Sa =	0.001 m^2
Internal shell stiffeners :	Number :	Nr =	10
	External diameter :	Dr =	10.090 m
	Height :	Hr =	0.080 m
Outer shell stiffeners :	Number :	Ns =	4
	External diameter :	Ds =	12.050 m
	Thickness :	Hs =	0.020 m

RESULTS :

Mass of liquid : M = 0.99 x (PI x D1² x LH / 4) x W	M =	1005022	kg
Inner shell average diameter : Di = [(H1 - Nr x Hr) x (D1 + 2 x E1) + Nr x Hr x Dr] / H1	Di =	9.776	m
Outer shell average diameter : Do = [(H2 - Ns x Hs) x D2 + Ns x Hs x Ds] / H2	Do =	12.34872	m
Temperature difference : delta_T = T2 - T1	delta_T =	211.00	deg.C
Average temperature : Tm = (T1 + T2) / 2	Tm =	-90.5	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 =	0.0289	W/m deg.C
Foamglas thermal conductivity : Foamglas quality : HLB1000	Lambda4 =	0.0315	W/m deg.C

CALCULATION OF AVERAGE SURFACES :

Foamglas :	S4 = PI x D'4² / 4	S4 =	61.51	m²
	(if there is a concrete ring) :			
	S'4 = PI x D4² / 4 - S4	S'4 =	24.25	m²
Perlite :	Roof : Sr = [(2 x PI R1 x G1) x (2 x PI x R2 x G2)](1/2)	Sr =	103.45	m²
	Shell : S3 = PI x 0.5 x (Do + Di) x 0.5 x (H1 + H2)	S3 =	621.72	m²
Bottom :	SB = PI x [(0.5 x (Do + Di))² - D4²] / 4	SB =	10.35	m²
Anchor bolts (or straps) :	S7 = Na x Sa	S7 =	0.032	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 =	740	W
Perlite :	Q3 = lambda3 x (Sr / Er + S3 / (0.5 x (Do - Di)) + SB / E'4) x delta_T	Q3 =	3519.05	W
Anchor bolts (or straps) :	Q7 = lambda x S7 x delta_T / E'5	Q7 =	135.04	W
Foamglas belt :	Q8 = lambda x S8 x delta_T / E'5	Q8 =	69.27	W
Piping :	Q6 = lambda x S6 x delta_T / E4	Q6 =	57.04	W
Total :	Q = Q3 + Q4 + Q6 +Q7 +Q9	Q =	4521	W

CALCULATION EVAPORATION RATE PER DAY :

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

E = 0.20%