MERCON B.V.

Order: P24100

Client JPB

Project Glycerine tank

Subject **Tank Calculation**
ø 12,6 x H 28,5 m V = 3553,7 m3

Document no.: P24100-000-901-0

Lloyd's reg.no.: -

Pages: 30

0	01-10-2024	For Approval
Rev.	Date	Status

Prepared:	Checked:	Approved:
[redacted]	[redacted]	

1 Design data

1.1 Main design data

Type of tank		=	FRT		(Fixed Roof Tank)			
Tank diameter	Inside	=	12,600	m				
Tank height		=	28,500	m	V_{gross}	=	3553,7	m^3
Type of roof		=	Cone		V_{net}	=	3553,7	m^3
Roof structure		=	External	(only for info)				
Dimension of roof plate on top curb		=	25	mm				
Roof slope		1 :	5,000		H	=	1,266	m
Maximum design liquid level		=	28,500	m		=		m (or test level)
Maximum design temperature		=	100	°C				
Minimum Design Metal Temperature		=	-10,0	°C	(MDMT)			
Lowest One Day Mean Ambient Temp.		=		°C	(LODMAT)			
Design Pressure		=	25,0	mbar		=	0,0250	barg
Operating pressure	(only for info)	=		mbar		=		barg
Design Vacuum		=	5,0	mbar		=	0,0050	barg
Additional vacuum		=	2,5	mbar		=	0,0025	barg
Operating vacuum	(only for info)	=		mbar		=		barg
Test pressure		=	27,5	mbar		=	0,0275	barg
Wind gust velocity		=	45,00	m/s		=	162,00	km/hr
Corrosion allowance bottom		=	0,0	mm				
Corrosion allowance annularring		=	0,0	mm				
Corrosion allowance shell		=	0,0	mm				
Corrosion allowance roof plates		=	0,0	mm				
Density of product		=	1,250	kg/l				
Density of testing		=	1,000	kg/l				
Plate finish	(H-r)	=	Hot-rolled		(1D)			
Plate form			Coil		(tolerance NEN-EN-ISO 9444-2)			
Tank shell calculation according		=	EN14015					
Tank needs to be Frangible		=	n	y/n				
Tank free vented (used for overturning)		=	n	y/n				
Adjusted wind velocity		=	n	y/n				
Calculation Liquid Load needed		=	y		(Load Case 1 and 2)			
Calculation Wind stability needed		=	y	y/n	(Load Case 3)			
Calculation Axial Load needed		=	y	y/n	(Load Case 4)			
Calculation Earthquake		=	n	y/n	N.A. AgS <0,05g acc.NPR-webtool			
Joint efficiency factor		=	1,00	[-]				acc.spec.
Primary windgirder at a height of		=		mm				
E-modulus steel @ 100 ^{0}C		=	200000	N/mm^2				
E-modulus @100 Gr. Celsius		=	193778	N/mm^2				N/mm^2

Material shell	= See section 2	
Material bottom	= See section 3	
Material roof	= See section 5	
Thickness shell plates	= See section 2	
Thickness bottom plates	= 5,0 mm	(incl.CA)
Thickness annular plates	= 7,0 mm	(incl.CA)
Thickness roof plates	= 5,0 mm	(incl.CA)

1.2 Design loads

1	Roof plates	=	0,39 kN/m²	
2	Internal negative pressure (vacuum)	=	0,75 kN/m²	
3	Snow load (based on S_k=0,7 KN/m^2)	=	0,56 kN/m²	kN/m² (acc.spec.)
4	Live Load, only for fixed roof	=	1,00 kN/m²	kN/m² (acc.spec.)
	(LL over an area of 10m2, and a max.length of 5 m)			
5	Positive internal pressure (pressure)	=	2,50 kN/m²	

1.3 Roof load combination according EN14015, article 9.3.3.9

	Vacuum + Snow load	2 + 3	=	1,31 kN/m²	
or	Vacuum + Live Load	2 + 4	=	1,75 kN/m²	
	Decisive Load case		**=**	**1,31 kN/m² ***	**> 1,2 kN/m²**

**** Diameter tank is greater than 12,5 m therefor decisive load case is Va+SL***

Stability check needed with regards to increased vertical axial loads because load combination according EN14015, article 9.3.3.9 is > 1,2 KN/m2

1.4 Wind load according NEN-EN 1991-1-4

Building details

Height	h	=	28,500	m	
Reference period	R	=	50	jr.	
Wind area		=	**2**	[-]	*Figure NB.1 and NB.2*
Terrain category		=	**2**	[-]	*Unbuilt area*

Basic wind speed

Annual probability of exceedance	p	=	0,020	/jr.	
Form factor	K	=	0,234		*Table NB.2*
Exponent	n	=	0,50		*Table NB.2*
Probability factor	c_{prob}	=	1,000		
Fundamentele basic wind speed	vb.0	=	27,0	m/s	*Table NB.1*
Seasonal influence	c_{season}	=	1,0	[-]	
Influence of wind direction	c_{dir}	=	1,0	[-]	*standard*
Basic wind speed	vb	=	**27,0**	m/s	

Average wind speed

Roughness length	z_0	=	0,2	m	*Table NB.3 - 4.1*
Threshold value	z_{min}	=	4	m	*Table NB.3 - 4.1*
Height above ground level	z	=	29	m	*Building height*
Terrain factor	k_r	=	0,209		*z0;II = 0,05*
Roughness factor	$c_r(z)$	=	1,038		
Orography factor	$c_o(z)$	=	1,0		*Standard*
Average wind speed	$v_m(z)$	=	**28,0**	m/s	*on height z*

Wind turbulence

Specific mass of air	r	=	1,25	kg/m3
Turbulence factor	k l	=	1,0	
Turbulence intensity	$I_v(z)$	=	**0,202**	

Extreme thrust	$q_p(z)$	=	**1,184**	kN/m2	
			43,53	m/s	three second wind gust
			45,00	m/s	min. three second wind gust according EN14015

Adjusted wind velocity: n
(only for existing storage tanks)

	m/s	wind speed acc.factsheets

2.3 Shell stability (case 3) according EN14015

For shell stability the following formula is used:
$95000 / (3{,}563 \times V_w^2) + (580 \times P_v)$

Factor for wind stability		=	8,214	[-]
Elastic Modulus for Stainless Steel @20°C		=	200000	N/mm²
Max. height of unstiffened shell	*Hp*	=	5,877	m
E-modulus @100 Degrees Celsius		=	193778	N/mm²
Hp @ 100 Degrees Celsius		=	5,694	m

According to EN14015 table 17, the minimum dimension of the sec.windgirder shall be L100x65x8 or as an alternative a different kind of profile with an equal section modulus.

Shell course	Plate height mm	t min. calc. mm	He mm		Object/ wall height*	
TOS						
26						
25						
24						
23						
22						
21						
20						
19	1500,0	4,0	1500			
18	1500,0	4,0	1500			
17	1500,0	4,0	1500			
16	1500,0	4,0	1500			
15	1500,0	4,0	1500			
14	1500,0	4,0	1500			
13	1500,0	4,0	1500			
12	1500,0	5,0	859			
11	1500,0	5,0	859			
10	1500,0	6,0	544			
9	1500,0	6,0	544			
8	1500,0	7,0	370			
7	1500,0	7,0	370			
6	1500,0	8,0	265			
5	1500,0	8,0	265			
4	1500,0	9,0	198			
3	1500,0	9,0	198			
2	1500,0	10,0	152			
1	1500,0	10,0	152			
Σ	28500	H_E	15275	mm	0	mm

** Reduction tank shell height in case of obstruction by object/ pit wall.*

Amount of secondairy wind girders

Required amount of secondary windgirders	2	, because Hp < He		
Distance from bottom to top of windgirder profile(s)		1 =	18316	mm
		2 =	23408	mm
		3 =	N.A.	mm
		4 =	N.A.	mm
		5 =	N.A.	mm
		6 =	N.A.	mm

2 Tank shell design

Design according		=	EN14015	
Tank diameter	Inside	=	12,600	m
Tank height		=	28,500	m
Type of roof		=	Cone	
Design liquid level		=	28,500	m
Design Pressure		=	25,0	mbar
Test pressure		=	27,5	mbar
Design Vacuum		=	5,0	mbar
Additional vacuum		=	2,5	mbar
Wind gust velocity		=	45,00	m/s
Wind gust velocity		=	162	km/hr
Corrosion allowance shell		=	0,0	mm
Density of product		=	1,25	kg/l
Density of testwater		=	1,00	kg/l
Joint efficiency factor		=	1,00	-
Maximum design temperature		=	100	°C
E-modulus @ design temperature		=	193778	N/mm^2
Plate finish	(Material Cold Formed)	=	Hot-rolled	(1D)
Plate form		=	Coil	(tolerance NEN-EN-ISO 9444-2)

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2.1 Shell thickness calculation (case 1 and 2)

Case 1 = Hydrostatic load + pressure based on product conditions
Case 2 = Hydrostatic load + pressure based on test conditions

course	Plate Height mm	Calc. height mm	Test height mm	Material quality	Yield stress N/mm²	S_d Design N/mm²	S_t Test N/mm²	C.A. mm	e_c case 1 mm	e_t case 2 mm
TOS										
26										
25										
24										
23										
22										
21										
20										
19	1500	1500	1500	14362	350,00	233,33	260,00	0,0	0,46	0,35
18	1500	3000	3000	14362	350,00	233,33	260,00	0,0	0,96	0,71
17	1500	4500	4500	14362	350,00	233,33	260,00	0,0	1,46	1,06
16	1500	6000	6000	14362	350,00	233,33	260,00	0,0	1,95	1,42
15	1500	7500	7500	14362	350,00	233,33	260,00	0,0	2,45	1,78
14	1500	9000	9000	14362	350,00	233,33	260,00	0,0	2,95	2,13
13	1500	10500	10500	14362	350,00	233,33	260,00	0,0	3,44	2,49
12	1500	12000	12000	14362	350,00	233,33	260,00	0,0	3,94	2,84
11	1500	13500	13500	14362	350,00	233,33	260,00	0,0	4,43	3,20
10	1500	15000	15000	14362	350,00	233,33	260,00	0,0	4,93	3,56
9	1500	16500	16500	14362	350,00	233,33	260,00	0,0	5,43	3,91
8	1500	18000	18000	14362	350,00	233,33	260,00	0,0	5,92	4,27
7	1500	19500	19500	14362	350,00	233,33	260,00	0,0	6,42	4,63
6	1500	21000	21000	14362	350,00	233,33	260,00	0,0	6,91	4,98
5	1500	22500	22500	14362	350,00	233,33	260,00	0,0	7,41	5,34
4	1500	24000	24000	14362	350,00	233,33	260,00	0,0	7,91	5,69
3	1500	25500	25500	14362	350,00	233,33	260,00	0,0	8,40	6,05
2	1500	27000	27000	14362	350,00	233,33	260,00	0,0	8,90	6,41
1	1500	28500	28500	14362	350,00	233,33	260,00	0,0	9,39	6,76
Total	28500									

2.2 Thickness to purchase

Shell course	Plate height mm	Material quality	Thickn. to buy mm	Shell course mass kg	Tole-rance mm	Calc. Thickn. incl.tol. mm	Corr. thickn. - C.A.	Corr. Mass kg	*Test stress <100% of Sd Table 15 +1gr	Quality	NEN-EN ISO
TOS											
26											
25											
24											
23											
22											
21											
20											
19	1500	14362	4,0	1853	0,34	2,33	4,0	1853	90,0%	14162	9444
18	1500	14362	4,0	1853	0,34	2,39	4,0	1853	90,0%	14162	9444
17	1500	14362	4,0	1853	0,34	2,45	4,0	1853	90,0%	14162	9444
16	1500	14362	4,0	1853	0,34	2,51	4,0	1853	90,0%	14162	9444
15	1500	14362	4,0	1853	0,34	2,79	4,0	1853	90,0%	14162	9444
14	1500	14362	4,0	1853	0,34	3,29	4,0	1853	90,0%	14162	9444
13	1500	14362	4,0	1853	0,34	3,78	4,0	1853	90,0%	14162	9444
12	1500	14362	5,0	2317	0,36	4,30	5,0	2317	90,0%	14162	9444
11	1500	14362	5,0	2317	0,36	4,79	5,0	2317	90,0%	14162	9444
10	1500	14362	6,0	2780	0,38	5,31	6,0	2780	90,0%	14162	9444
9	1500	14362	6,0	2780	0,38	5,81	6,0	2780	90,0%	14162	9444
8	1500	14362	7,0	3244	0,40	6,32	7,0	3244	90,0%	14162	9444
7	1500	14362	7,0	3244	0,40	6,82	7,0	3244	90,0%	14162	9444
6	1500	14362	8,0	3707	0,40	7,31	8,0	3707	90,0%	14162	9444
5	1500	14362	8,0	3707	0,40	7,81	8,0	3707	90,0%	14162	9444
4	1500	14362	9,0	4171	0,44	8,35	9,0	4171	90,0%	14162	9444
3	1500	14362	9,0	4171	0,44	8,84	9,0	4171	90,0%	14162	9444
2	1500	14362	10,0	4635	0,44	9,34	10,0	4635	90,0%	14162	9444
1	1500	14362	10,0	4635	0,44	9,83	10,0	4635	90,0%	14162	9444
	28500		Total	47267	kg		Total	47267	kg		

Minimum specified nominal shell thickness according EN14015 | 4,0 | mm according table 16

If necessary use area below for extra comments:

2.4 Corroded shell under roof load condition (case 4)

Live load		**** LL>= 1,2 kN/m2; Stability check required***					
According art.9.3.3.9 *	=	1,31	kN/m²	=	4,13	N/mm	
Tank parts							Spec. thickness
Roof plate thickness	=	5,0	mm	=	0,964	N/mm	mm
Weight of roof structure	=	1479	kg	=	0,366	N/mm	
Weight of roof plates and beams	=		kg/m²	=		N/mm	
Weight top curb angle	=	9,66	kg/m	=	0,095	N/mm	
Additional items							Specify loads:
Additional weight (spec.by client)	=		kg/m²	=		N/mm	
Additional weight (spec.by client)	=		kg/m²	=		N/mm	
Additional weight (spec.by client)	=		kg/m	=		N/mm	
Additional weight (spec.by client)	=		kg/m	=		N/mm	
Weight of insulation (roof)	=	38,3	kg/m²	=	1,184	N/mm	150 + 2 mm
Weight of insulation (shell)	=	0,0	kg/m²	=	0,000	N/mm	0 + 0 mm
Total acting roof load					6,74	N/mm	

Calculation method according = **EEMUA159**

$$t = \sqrt{\frac{q * R}{12411 * \left(\frac{E}{210000}\right)}}$$

E@100 Degrees Celsius = 193777,8 N/mm2

Thickness calculation

Shell course	Plate height mm	t corr. mm	q total N/mm	R mm	t_{min} per ring mm	Check
TOS						
26						
25						
24						
23						
22						
21						
20						
19	1500	4,0	7,195	6300	1,99	**OK**
18	1500	4,0	7,654	6300	2,05	**OK**
17	1500	4,0	8,113	6300	2,11	**OK**
16	1500	4,0	8,573	6300	2,17	**OK**
15	1500	4,0	9,032	6300	2,23	**OK**
14	1500	4,0	9,491	6300	2,28	**OK**
13	1500	4,0	9,950	6300	2,34	**OK**
12	1500	5,0	10,524	6300	2,41	**OK**
11	1500	5,0	11,099	6300	2,47	**OK**
10	1500	6,0	11,788	6300	2,55	**OK**
9	1500	6,0	12,477	6300	2,62	**OK**
8	1500	7,0	13,280	6300	2,70	**OK**
7	1500	7,0	14,084	6300	2,78	**OK**
6	1500	8,0	15,003	6300	2,87	**OK**
5	1500	8,0	15,922	6300	2,96	**OK**
4	1500	9,0	16,956	6300	3,05	**OK**
3	1500	9,0	17,989	6300	3,15	**OK**
2	1500	10,0	19,138	6300	3,24	**OK**
1	1500	10,0	20,287	6300	3,34	**OK**
Total	28500					

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2.5 EARTHQUAKE DETERMINING VALUES

Design according			=	N.A.				
Tank diameter	Inside		=	12,600	m			
Tank height			=	28,500	m			
Type of roof			=	Cone				
Density of product			=	1,250	kg/l			
Maximum liquid level		H_t	=	28,500	m	V	=	3553,7 m^3

NPR 9998 - Determining Elastic Responce Center

Dataset Hazard		=	v6 d.d.2020-07-01 Maaiveld		
Time period		=	T6	[-]	1/10/2023-30/9/2029
Peak ground acc. @475 year	$a_g S$	=	0,040	g	**N.A. AgS <0,05g acc.NPR-webtool**
Return period of seismic action	$T_{LS;ref}$	=	475	year	NPR 9998:2020, table 2.1/2.2
Peak ground acc. @475 year	$a_g S$	=	0,040	g	
Factor for formula (5.2)	k	=	3	[-]	NEN-EN 1998-1-1:2022 formula (5.2)
Structural Complexity Class		=	SCC2	[-]	
Limit State		=	NC		NPR 9998:2020, table 2.1/2.2
Consequence Class		=	CC2	[-]	
Importance factor (new building)	γ_1	**=**	**1,2**	[-]	Table 2.4
Importance factor (new building)	γ_{SD}	=	1,0	[-]	NPR 9998:2020 - L.3.1 (L.2)
Peak ground acc. incl. soil factor	$a_{g;d}$	=	0,048		NPR 9998:2020 - L.3.1 (L.2)
Ratio: PGA and platform value	p	=	2,296	[-]	by Client
Site parameter	T_B	=	0,286	s	by Client
Site parameter	T_C	=	0,438	s	by Client
Site parameter	T_D	=	0,580	s	by Client
Peak ground acc. @30m depth	$a_g Ref$	=		g	by Client

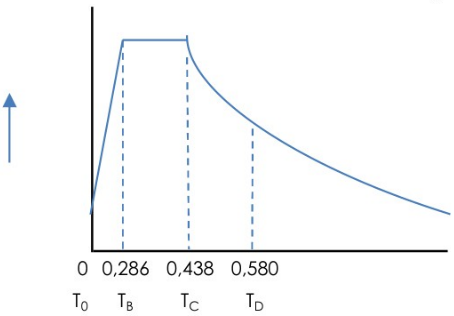
NOTE: *PGA = Peak Ground Acceleration*

$a_g S \times \gamma_1 = a_{g;d}$ γ_1 = Client seismic data or table 2.4 of NPR 9998:2020

Viscous damping ratio	ξ	=	5,0	%	NPR 9998 (3.16)
Damping correction factor	η	=	1,0	[-]	≥ 0,55

<u>Determining of horizontal elastic responce spectrum:</u>

$S_e(T)$	$0 \leq T \leq T_B$		=	g	=		m/s^2	(3.3)
$S_e(T)$	$T_B < T \leq T_C$	T_B	=	g	=		m/s^2	(3.4)
$S_e(T)$	$T_C < T \leq T_D$	T_C	=	g	=		m/s^2	(3.5)
$S_e(T)$	$T_D < T \leq 4$	T_D	=	g	=		m/s^2	(3.6)



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RESPONCE SPECTRUM DATA downloaded from NEN Webtool NPR 9998

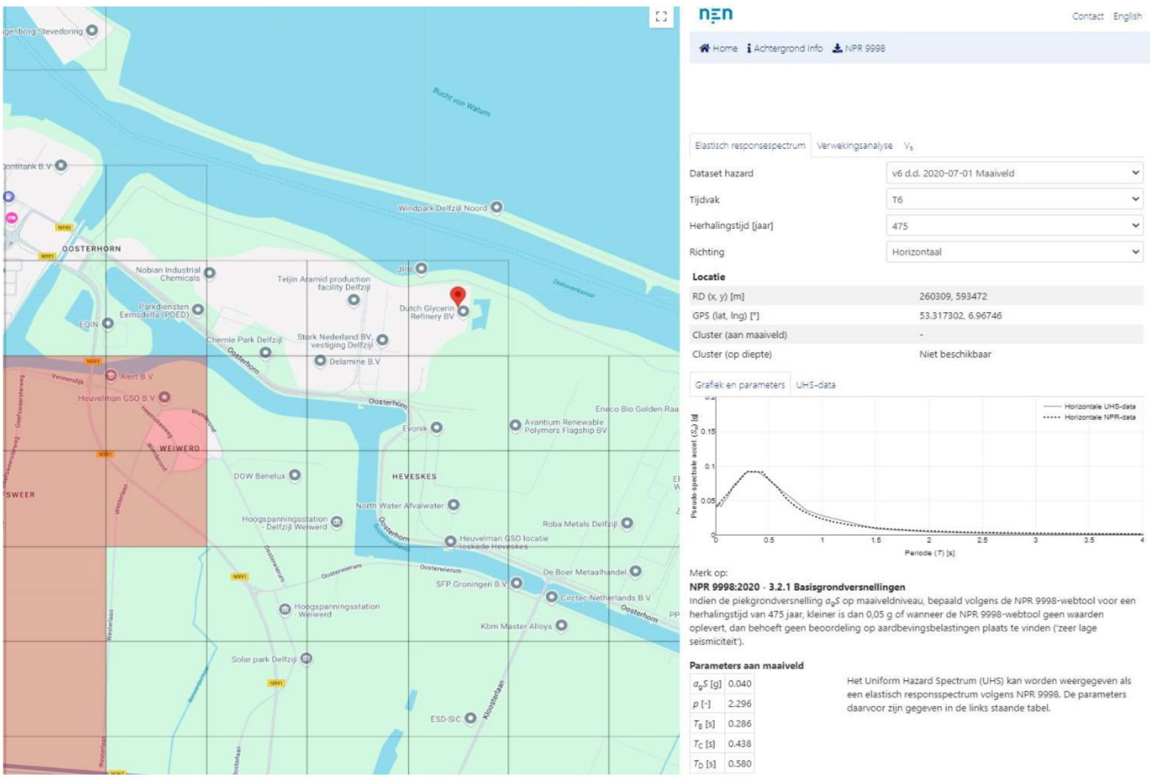
https://seismischekrachten.nen.nl/map.php

Datum van download: 2024-09-16 14:45
Dataset: 2020-07-01_GMMv6_Surf
Richting: Horizontaal

Locatie
RD (x, y) [m]: 260309, 593472
GPS (lat, lng) [gra]: 53.317302, 6.96746

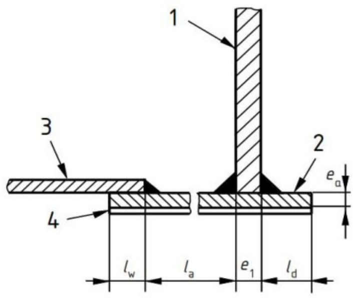
NPR 9998:2020 parameters

Time period	T6	[-]
Repetition time	475	yr
a_g S	0,040	[g]
p	2,296	[-]
T_B	0,286	s
T_C	0,438	s
T_D	0,580	s



3 Bottom plate design according EN14015

Tank diameter	Inside	=	12600	mm	
Tank height		=	28500	mm	
Design liquid level		=	28500	mm	
Design Vacuum		=	5,00	mbar	
Additional vacuum		=	2,50	mbar	
Thickness first shell course	e_1	=	10,0	mm	(excl.CA)
Corrosion allowance shell		=	0,0	mm	
Corrosion allowance bottom		=	0,0	mm	
Corrosion allowance annularring		=	0,0	mm	
Width bottom shell projection	l_d	=	75	mm	(min.50, max.100 mm)
Annularring in design		=	Yes		
Tank bottom, Lap or Butt welded		=	BW		
Material bottom plates		=	14162		
Material annular plates		=		14162	
Specific mass bottom plates		=	7,80	kg/dm^3	
Specific mass annular plates		=	7,80	kg/dm^3	



3.1 Bottom plates

NEN-EN 14015:2004 - 8.2.3

Minimum allowable thickness of bottom sketch plate		=	3,0	mm	(excl.CA)
Calculated minimum thickness	=	=	3,0	mm	(incl.CA)
Adopted thickness		=	5,0	mm	(incl.CA)
Minimum bottom plate overlap		=	N.A.	mm	
Applied bottom plate overlap	= (Minimum + 20 mm)	=	N.A.	mm	
Own defined bottom plate overlap	=			mm	

3.2 Annular plates

NEN-EN 14015:2004 - 8.3.1

Minimum allowable thickness of bottom annular plate		=	6,3	mm	(excl.CA)
Calculated minimum thickness		=	6,3	mm	(incl.CA)
Adopted thickness		=	7,0	mm	(incl.CA)
Minimum annular plate overlap	l_w	=	60	mm	
Adopted annular plate overlap		=	100	mm	
Minimum calculated width (based on adopted thickness)	l_a	=	500	mm	
Minimum width (for other (client) std) =				mm	
Minimum annular plate width		=	685	mm	
Adopted annular plate width		=	700	mm	

3.3 Shell-/ bottom connection

NEN-EN 14015:2004 - 8.4.5

Applied first shell course thickness	=	10,0	mm	(uncorroded condition)
Annular plate thickness	=	7,0	mm	(uncorroded condition)
Fillet weld throat thickness, a	=	7,0	mm	

4 Compression area design

Design according			=	EN14105		
Tank diameter	Inside		=	12,600	m	
Roof type			=	Cone		
Profile available @ top corner ring			=	Yes		
Top curb angle on top of shell plate			=	No		
Dimension of roof plate on top curb			=	25	mm	
Dimension of shell plate below top			=	0	mm	
Design pressure			=	25,0	mbar	
Design pressure			=	2,5	kPa	
Roof slope			1 :	5,0		
Shell plate thickness (corroded)		e	=	4,0	mm	= 4,0 mm
Roof plate thickness (corroded)		ep	=	5,0	mm	(incl.CA)
Yield strength (roof plate)				400,0	N/mm²	
Minimum size acc.table 18			=	H60/60/8		Mat. = 14301
Area of profile			=	903	mm^2	
Size of choosen top corner ring			=	H80/80/8		
Area of profile for compression			=	1230	mm^2	
Extra added profile	width	w	=		mm	
	height	h	=		mm	
Area of extra added profile		A	=	0	mm^2	
Extra added curb angle			=			
Area of extra added curb angle		A	=	0	mm^2	
Allowable compressive stress		Sc	=	120,0	N/mm²	N/mm²

(fill in Sc if otherwise specified)

4.1 Required compression area

Tank radius, R		=	6,300	m
Hoek		=	11,310	°
Tan	θ	=	0,200	-
Roofplate area		=	128,17	m²
Roof plate weight		=	4999	kg
P (internal pressure-roof plate weight)		=	21,150	mbar
A_{min}		**=**	**1748,8**	**mm²**

4.2 Available compression area

For Ls effective length is reduced due to top detail

R_1			=	32,12	m
L_s	Effective shell length		=	95,2	mm
L_r	Effective roof length		=	240,5	mm
$L_{top\ corner\ when\ no\ TCA}$		16ep	=	N.A.	mm
A_{shell}		Ls	=	381,0	mm^2
A_{roof}		Lr	=	1202,3	mm^2
$A_{Top\ Curb\ Area}$			=	1230,0	mm^2
$A_{available}$			**=**	**2813,3**	**mm²**
A_{min} / $A_{available}$			**=**	**0,622**	**OK**

5 Design roof plates

Tank diameter Inside		=	12,600 m		
Roof type		=	Cone	Roof slope = 1 : 5	
Dimension of roof plate on top curb		=	25 mm		
Thickness top shell course		=	4,0 mm (incl.CA)		
Design pressure	p	=	25,0 mbar		
Design vacuum	v	=	5,0 mbar		
Additional vacuum		=	2,5 mbar		
Roof load acc.article 9.3.3.9		=	1,75 KN/m²		
Radius of curvature of roof	R_1	=	32,272 m		
Tan θ		=	0,200 [-]		
Degrees		=	11,310 °		
Material roof plates		=	14162		
Yield strength (roof plate)		=	400,0 N/mm²	=	N/mm²
Allowable design stress	S	=	266,7 N/mm²		
Roof plate thickness (incl.CA)	tr	=	5,0 mm	=	5,0 mm
Corrosion allowance roof		=	0,0 mm		
Joint efficiency factor	J	=	0,35 [-]	*0,35 single fillet weld*	
E-modulus @0,35 Gr. Celsius		=	193778 N/mm²	*0,50 double fillet weld*	
				1,00 butt weld	

5.1 For spherical roofs

Min. calculated thickness acc.10.4.2	e_p	=	N.A. mm	(excl.CA)
Min. roof plate thickness acc.10.3.3	e_p	=	N.A. mm	(excl.CA)
ep / t_r		=	N.A.	

5.2 For conical roofs

Min. calculated thickness acc.10.4.2	e_p	=	0,86 mm	(excl.CA)
Min. roof plate thickness acc.10.3.3	e_p	=	3,00 mm	(excl.CA)
ep / t_r		=	0,60 **OK**	

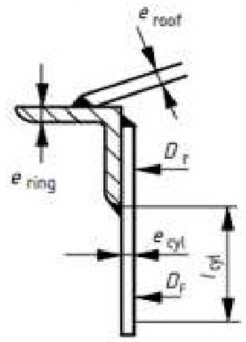
5.3 For buckling (only for unsupported tank roofs) *EN14015 - 10.4.2 - formula (14)*

Roof structure		=	Yes		
Live load:		=	N.A. kN/m2		
Additional load(s)		=	kg	**=**	0,000 KN/m2
Internal negative pressure:		=	N.A. mbar	**=**	N.A. kN/m2
Weight roof plates: (s.g. 7,85 kg/m³)		=	N.A. mbar	**=**	N.A. kN/m2
Radius of curvature of roof, R_1:	R_1	=	N.A. m		
Youngs modulus, E:	E	=	N.A. N/mm²		
Total load for buckling		=	N.A. kN/m2		
Min. roof plate thickness	e_p	=	N.A. mm (incl.CA)		
UC: ep / $t_r \geq 1$ =		=	N.A.		

6 Frangibility according EN14015

6.1 Input

Tank Diameter	D_f	=	12600	mm	
Roof type		=	Cone		
Roof slope		1 :	5,0		
Thickness top course	e_{cyl}	=	4,0	mm	*(non-corroded)*
Thickness lower course	e_{cylb}	=	10,0	mm	*(corroded)*
tan θ		=	0,200	[-]	
Thickness annular/bottom plate	e_a	=	7,0	[-]	*(corroded)*
e_{ring}		=	8,0	mm	*(non-corroded)*
e_{roof}		=	5,0	mm	*(non-corroded)*
Figure used	K	=	3		
Min. unstiffened length, l_{cyl}		=	0,397	m	
Min. unstiffened length, l_{cylb}		=	0,627	m	



6.2 Roof failure pressure

a_1		=	21750000	[-]
a_2		=	1,253	[-]
a_3		=	0,18	[-]
a_4		=	0,14	[-]
Roof failure pressure	pr	=	288,35	mbar

6.3 Bottom failure pressure

ε		=	0,603161	[-]
X		=	0,000556	[-]
Y		=	0,700000	[-]
β_0		=	37,40	[-]
β_1		=	756000	[-]
β_2		=	1,48E+08	[-]
Bottom failure pressure	p_b	=	303,44	mbar

6.4 Unity check

γ	condition; $1 < \gamma \leq 1{,}5$	acc.A2	=	1,50	[-]	Adjusted safety factor
U.C.	$p_b = 2{,}0 \cdot \gamma \cdot p_r$		**=**	**2,851**	**[-]**	**Tank not frangible**

6.5 Design rules

Tank is anchored	**=**	**Yes**	**Method Not Allowed**

7 Design Calculation, Cone Roof

(For Cone Roof with supporting structure)

7.1 Design Data

Diameter tank		D	=	12,600	m
Cilindrical height		H	=	28,500	m
Capacity		V	=	3554	m^3
Roof type	Cone	1	:	5,0	
Design pressure			=	25,0	mbar
Negative pressure			=	5,0	mbar
Additional vacuum			=	2,5	mbar
Roof plate thickness			=	5,0	mm (incl.CA)
Shell plate thickness (top ring)			=	4,0	mm (excl.CA)
Measure of roof plate on top curb			=	25	mm
Top curb angle on top of shell plate			=	y	y/n
Corrosion allow. Roof			=	0,0	mm
Roofplate area			=	128,2	m²
Permanent load factor			=	1,2	[-]
Variable load factor			=	1,5	[-]

7.2 Materials

		Quality			Yield strength		
Roof plates	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Roof beams	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Center ring	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Compressing ring (top corner ring)	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Polygon ring(s)	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Top corner ring	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.
Upper shell course	=	14162	f_y	=	400	N/mm^2	@100 Degr.C.

7.3 Profiles

Roof beams (profile)	=	K110/110/5/5	UC OK	(0,760)	*Wy = 83,68 cm3*
Roof beam hot rolled or welded	=	Welded	and Cold formed		
Amount of roof beams	=	20	[-]	Minimum 20 beams required	
Amount of intermediate rafters	=	0	[-]	*(No rafters; leave cel empty)*	
Distance between roof beams	=	1,979	m		
Center ring (profile)	=	U110/110/5	UC OK	(0,383)	*Wy = 62,74 cm3*
Centre ring cold formed or welded	=	Welded			
Diameter of center ring	=	1,300	m	Practical (D/10) = 1,260 m	
Polygon ring(s) (profile)	=				
Amount of polygon rings	=		[-]		
Profile(s) @Top area	=	H80/80/8			
Check TCA regarding horizontal forces	=	N.A.			

Profiles including CA

			Uncorroded	Corroded
Roof beams (profile)	=			
Center ring (profile)	=			

7.4 Design loads

Live Load (over an area of $10m^2$, and a max.length of 5 m)			=	1000,0	N/m^2
Snow load (based on S_k=0,7 KN/m^2)			=	560,0	N/m^2
Vacuum Load			=	750,0	N/m^2
Roof load combination according EN14015, article 9.3.3.9			=	1310,0	N/m^2

Roof plates	=	395,8	N/m^2	=	49351,0	N
Roof supporting structure	=	116,3	N/m^2	=	14504,3	N
Polygon rings	=	0,0	N/m^2	=	0,0	N
Insulation	=	375,7	N/m^2	=	46848,8	N
Miscellaneous	=	100,0	N/m^2	=	12469,0	N
		987,8	N/m^2	=	123173,2	N

According NEN-EN 1990:

p_s = 1,35 * permanent	=	166283,8	N	=	1333,6	N/m^2
p_s = 1,2 * permanent + 1,5 * variable	=	392823,3	N	=	3150,4	N/m^2

Total of LL/Vac./Perm.loads	q	=	3,150	kN/m^2	(incl.the greater of LL or SL)
Concentrated Loads	F	=	2,0	kN	(according NEN-EN 1991-1-2)
Length of beam (hor.proj.)	L	=	5,650	m	
radius to F (to centre of tank)	x	=	3,262	m	

In case of installation extra equipment in center of roof:

	Mb	=		Nm
	Fv	=		N
	Fh	=		N

8 Roof Structure

Number of roof beams	=	20			
Profile of beams	=	K110/110/5/5	G =	12,8 kg/m	
Rafter depth	=	110,0 mm	L =	5,762 m	(Lhor=5,650)
number of polygonal ringstiffeners	=	0			
Profile centrering :	=	U110/110/5	G =	12,8 kg/m	
Diameter of Center Ring	=	1,300 m			

8.1 Rafters

Slope	Θ	=	0,1974	rad =	11,3099 deg
sin Θ		=	0,19612		
cos Θ		=	0,98058	Aroof =	127,159 m^2
tan Θ		=	0,200		
Horizontal projection of rafter	R	=	5,650 m		

8.2 Loading

Ratio D center ring : D tank →	=	8,692 [-]	
Normative roof load 1 - uniform	=	0,268 kN/m	(variable)
Normative roof load 2 - triangle	=	2,325 kN/m	(variable, value 0 @center)
Roof loads 1 - uniform	=	0,178 kN/m	(permanent)
Roof loads 2 - triangle	=	1,547 kN/m	(permanent, value 0 @center)
Roof beams	=	0,125 kN/m	(permanent)
Center ring	=	0,026 kN	(permanent)
F	=	2,000 kN	(permanent)

8.3 Reactions

				Caused by center equipment
Rv_B	=	22,24 kN	=	0,00 kN
Rh_B	=	44,49 kN	=	0,00 kN

8.4 Section Forces

				Caused by center equipment
Nmax	=	47,991 kN	=	0,00 kN
Mmax	=	17,722 kNm	=	
a	=	2,881 m	*distance from tankshell*	

8.5 Code check of Rafter according NEN-EN 1993-1-4

Profile	:	K110/110/5/5		Material quality	:	14162	(Duplex)
Compression	:	47,991	kN				
$M_{y;max;s;d}$		17,722	kNm	Young's modulus	:	193778	N/mm^2
$M_{y;mid;s;d}$	:	17,722	kNm	$M_{z;mid;s;d}$	:	0,000	kNm
non-sway		yes		non-sway		yes	
length y- as (=l_g)	:	5761,89	mm	length z- as (=l_1)	:	5761,89	mm

8.6 Profile-data

h	=	110	mm					
b	=	110	mm					
tf	=	5	mm	I_t	=	579,48	cm^4	
tw	=	5	mm	Yield strength	=	400,0	N/mm^2	
A	=	2950	mm^2	$N_{c;u;d}$	=	1.180	kN	@100 Degr.C.

8.7 Classification profiles

Section classification			3	[-]	fixed value	(table 5.2, NEN-EN 1993-1-4)
ψ		=	0	[-]	fixed value	(table 4.1, NEN-EN 1993-1-5)
k_σ		=	7,81	[-]	fixed value	(table 4.1, NEN-EN 1993-1-5)
c/t	(flange)	=	22,0	<=	29,85	OK
c/t	(web)	=	22,0	<=	29,85	OK

Staalsoort	14301	14401	Duplex
f_e	210	220	460
ε	1,03	1,01	0,698

8.8 Flexural buckling

y-y				z-z				
I_y	=	606,0	cm^4	I_z	=	1165,2	cm^4	
W_y	=	83,7	cm^3	W_z	=	86,3	cm^3	
i_y	=	4,5	cm	i_z	=	6,3	cm	
l_{CR}	=	5761,9	mm	l_{CR}	=	5761,9	mm	
M_{RD}	=	33,473	kNm	M_{RD}	=	34,525	kNm	
M_{ED}	=	17,722	kNm	M_{ED}	=	0,0	kNm	
N_{CR}	=	349,1	kN	N_{CR}	=	671,2	kN	
N_{ED}	=	48,0	kN					
γ_{M0}	=	1,00	[-]					
γ_{M1}	=	1,00	[-]					
γ_{M2}	=	1,25	[-]					
λ_1	=	69,15	[-]					
$\bar{\lambda}$	=	1,84		$\bar{\lambda}$	=	0,84		(5.9)
$\bar{\lambda}_0$	=	0,40		$\bar{\lambda}_0$	=	0,40		(table 5.3)
α	=	0,49		α	=	0,49		(table 5.3)
φ	=	2,54		φ	=	0,96		(5.7)
χ	=	0,23		χ	=	0,70		(5.6)
$N_{b,Rd,y}$	=	274,5	kN	$N_{b,Rd,z}$	=	828,4	kN	(6.47)

8.9 Lateral torsional buckling

k_{red}	=	1,0	[-]	(acc. NB.NB.7)
S	=	-	mm	
I_W	=	nvt	cm^6	(NB.NB.3)
C_1	=	1,13	[-]	fixed value
load @	=	T		T = top flanges, L = lower flange
C_2	=	-0,45	[-]	
C	=	-	[-]	(NB.NB.4.3)
υ	=	0,3		(Poisson coefficient)
G	=	74.530	N/mm^2	
M_{cr}	=	-	kNm	(NB.NB.2)
h/b	=	1,0		
$\bar{\lambda}_0$	=	0,2		
$\bar{\lambda}_{LT}$	=	-	[-] (5.12)	
α_{LT}	=	0,340	(table 5.3)	
φ_{LT}	=	-	[-] (5.11)	
χ_{LT}	=	1,000	[-] (6.57)	
$M_{b,Rd}$	=	33,47	kNm	

k_{yy} = 1,10 k_{zy} = 0,000

8.10 Verification

UC6.2		=	0,704	[-]	$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$
UC 6.3.1.1	y-y	=	0,175	[-]	$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0$
	z-z	=	0,058	[-]	
UC 6.54		=	0,529	[-]	$\frac{M_{Ed}}{M_{b,Rd}} \leq 1,0$
UC 6.61		=	0,760	[-]	$\frac{N_{Ed}}{\frac{\chi_y N_{Rk}}{\gamma_{M1}}} + k_{yy}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_{M1}}} + k_{yz}\frac{M_{z,Ed}+\Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{M1}}} \leq 1$
UC 6.62		=	0,058	[-]	$\frac{N_{Ed}}{\frac{\chi_z N_{Rk}}{\gamma_{M1}}} + k_{zy}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_{M1}}} + k_{zz}\frac{M_{z,Ed}+\Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{M1}}} \leq 1$

9 Compression Ring (top area)

9.1 Data

Profile

Number of roof beams @top area	:	20		
Horizontal Force	:	44,49	kN	Reaction from Rafter
Distance between rafters	:	1,979	m	
Angle between rafters a =	:	9	°	
Angle between rafters a =	:	0,157	rad.	

9.2 Section Forces

According to "Formulas for Stress and Strain" by Roark

Under the Loads

$M_{z;s;d}$	:	-7,35	kNm
$N_{t;s;d}$	:	140,46	kN
$V_{y;s;d}$	:	22,25	kN

Between the Loads

$M_{z;s;d}$	:	3,68	kNm
$N_{t;s;d}$	:	142,21	kN

9.3 Profile

A_{totaal}	:	2813	mm^2
W_{1} (at the outside)	:	132436	mm^3
W_{2} (at the inside)	:	81142	mm^3

9.4 Stress verification

At Rafter location

								UC
s_{1} (outside)	:	49,93	+	0,00	=	49,93	N/mm^2	
s_{2} (inside)	:	49,93	+	-90,59	=	-40,66	N/mm^2	

Between Rafters

s_{1} (outside)	:	50,55	+	-27,79	=	22,76	N/mm^2
s_{2} (inside)	:	50,55	+	45,35	=	95,90	N/mm^2

Conclusion: **N.A.**

9 Centre Ring

9.1 Data

Number of roof beams @centre ring	:	20		
Horizontal Force	:	44,49	kN	Reaction from Rafter
Profile centrering	:	U110/110/5		

9.2 Classification profile

Section classification			3	[-]	fixed value	(table 5.2, NEN-EN 1993-1-4)
ψ		=	0	[-]	fixed value	(table 4.1, NEN-EN 1993-1-5)
k_σ		=	7,81	[-]	fixed value	(table 4.1, NEN-EN 1993-1-5)
c/t	(flange)	=	21,0	<=	32,58	OK

Staalsoort	14301	14401	Duplex
f_e	210	220	460
ε	1,03	1,01	0,698

9.2 Section Forces

According to "Formulas for Stress and Strain" by Roark

Between the Loads

$M_{z;s;d}$	:	0,380	kNm
$N_{t;s;d}$	:	142,21	kN

Under the Loads

$M_{z;s;d}$	:	-0,758	kNm
$N_{t;s;d}$	:	140,46	kN
$V_{y;s;d}$	:	-22,25	kN

9.3 Profile

A_{totaal}	:	1600	mm^2
W_1 (at the outside)	:	53316	mm^3
W_2 (at the inside)	:	28816	mm^3

9.4 Stress verification

Between Rafters

								UC
s_1 (aan de buitenzijde)	:	88,88	+	-7,12	=	81,76	N/mm^2	0,31
s_2 (aan de binnenzijde)	:	88,88	+	13,18	=	102,06	N/mm^2	0,38

At Rafter location

s_1 (aan de buitenzijde)	:	87,79	+	14,22	=	102,01	N/mm^2	0,38
s_2 (aan de binnenzijde)	:	87,79	+	-26,32	=	61,47	N/mm^2	0,23

Conclusion: **Centre Ring Area OK**

12 Overturning stability

Design according = EN14015

12.1 Data for overturning

Tank diameter	Inside	(D)	=	12,600 m	
Tank height		(H)	=	28,500 m	
Roof type			=	Cone	
Dimension of roof plate on top curb			=	25 mm	
Roof slope			= 1 :	5,0	
Roof angle			=	11,310 °	Tan θ = 0,200 -
Thickness roof plates			=	5,0 mm	(excl.CA)
Corrosion allowance roof			=	0,0 mm	
Annular bottom/ plate thickness			=	7,0 mm	(excl.CA)
Corrosion allowance bottom			=	0,0 mm	
Thickness top shell course			=	4,0 mm	(incl.CA)
$A_{\text{roof vert}}$			=	7,9 m²	
A_{shell}			=	359,1 m²	
A_{bottom}			=	124,7 m²	
A_{annular}			=	27,9 m²	(based on a width of 0,75 m)
$A_{\text{bottom area - liquid area (12.1.a)}}$			=	96,8 m²	
Density of product			=	1,3 kg/l	
Density of testwater			=	1,0 kg/l	
Design pressure		(D_p)	=	25,0 mbar	
Operating pressure			=	mbar	
Test pressure			=	27,5 mbar	
Dimension of roof plate on top curb			=	25 mm	
Roof height		(H_r)	=	1,260 m	
Roofplate netto area			=	128,2 m²	
Tank free vented			=	n	
V_{ref}			=	45 m/s	
Seismic design			=	No	
q_{ref}			=	1265,6 N/m²	*NEN-EN 1991-1-4 - 4.5*
$C_{pe; shell}$			=	0,7 [-]	*EN 14015 - 12.1*
$C_{pe; roof}$			=	0,6 [-]	

12.2 Weights

Tank weight						
Roof plates *(corroded)*	=	49,0	kN	=	4998,6	kg
Shell plates *(corroded)*	=	463,7	kN	=	47267,5	kg
Annular *area (width 750 mm) (corroded)*	=	0,0	kN	=	0,0	kg
Roofstructure	=	14,5	kN	=	1478,5	kg
Polygon rings (no)	=	0,0	kN	=	0,0	kg
Top angle (H80/80/8)	=	3,8	kN	=	382,4	kg
Hand railing 20 kg/m	=	7,8	kN	=	791,7	kg
Fixed tank parts						
Nozzles	=	4,9	kN	=	500,0	kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg
	=		kN	=		kg

NOTE: for the resistance of the tank against overturning according EN14015, 12.1 there are not taken into account any removable parts and parts installed on the tank bottom.

12.3 Resistance weights against overturning

Tank weight				
Total weight of tank	(G_t)	=	**543,7**	KN
		=	**13,7**	KN/m
Liquid weight during operation				
Height of liquid present		=	0,000	m *("0" for "no liquid")*
Density of product		=	1,250	kg/dm³
Liquid Area		=	27,9	m²
Weight of liquid area	(G_l)	=	**0,0**	kN
		=	**0,0**	KN/m
Liquid weight for earthquake				
Weight of liquid	(T_T)	=	**9825,7**	kN
		=	**248,2**	KN/m
Liquid weight during testing				
Height of liquid present		=	28,500	m
Density of product		=	1000	kg/m³
Netto volume of liquid		=	795,7	m³
Weight of liquid area	(G_l)	=	**7806,3**	kN
		=	**197,2**	KN/m

12.4 Uplift by wind pressure

q_{shell} = q_{ref} * C_{pe}	(q_r)	=	885,9	N/m^2
$Z_{\ shell}$	(Z)	=	14,250	m
Wind acting on tank shell	(M_{ws})	=	**4533,5**	kNm
		=	**36,4**	KN/m
q_{roof} = q_{ref} * C_{rf}	(q_s)	=	759,4	N/m^2
$Z_{\ roof}$	(Z_1)	=	28,9	m
Wind acting on roof	(M_{wr})	=	**174,3**	kNm
		=	**1,4**	KN/m
Total wind load		=	**37,8**	KN/m

12.5 Uplift by internal pressure

Design pressure	(d_p or d_t)	=	2500,0	N/m²
		=	**241,9**	kN
		=	**6,1**	KN/m

12.6 Uplift by internal test pressure

Test pressure	(d_p or d_t)	=	2750,0	N/m²
		=	**266,1**	kN
		=	**6,7**	KN/m

12.6 Uplift by earthquake

Overturning moment		=		KNm
		=	**0,0**	KN/m

12.7 Sliding by wind pressure

q_{shell}	(q_r)	=	885,9	N/m^2	=	318,1	KN
q_{roof}	(q_s)	=	759,4	N/m^2	=	6,0	KN
			Max.wind pressure		=	324,2	KN (sliding force)

Amount of anchors		=	14,0	pcs
Anchor size		=	M30	
Cross sectional area (> 500 mm^2)	(As)	=	519,0	mm² (uncorroded area)
Yield strength		=	180,0	N/mm^2 (0,4 of Rm)
Maximum allowed sliding force	(F)	=	1307,9	KN

Resistance against sliding is sufficient

12.7 Conditions (article 12.1)

a) Uplift on a empty tank due to internal pressure counteracted by the effective weight of the corroded tank.
b) Uplift due to internal pressure in combination with wind loads counteracted by the effective weight of the corroded tank plus the effective weight of product considered by purchaser to be always present in the tank.
c) Uplift on a empty tank due to wind loads counteracted by the effective weight of the corroded tank.
d) If required by Appendix G.

12.8 Condition a)

Uplift on a empty tank due to internal pressure counteracted by the effective weight of the corroded tank.

$UC = d_p / G_t + G_L$ = 6,1 / (13,7 + 0,0) = **0,445 No anchors required**
(Uplift by Design Pressure)

$UC = d_p / G_t + G_L$ = 6,7 / (13,7 + 197,2) = **0,032 No anchors required**
(Uplift by Test Pressure)

12.9 Condition b)

Uplift due to internal pressure in combination with wind loads counteracted by the effective weight of the corroded tank plus the effective weight of product considered by purchaser to be always present in the tank. *($M_{wind} = M_{ws+} M_{wr}$)*

$$UC = \frac{M_w + d_p}{G_t + G_L} = \frac{37{,}8 + 6{,}1}{13{,}7 + 0{,}0}$$ = **3,194 Anchors required**
(Uplift by Design Press.+Wind)

$$UC = \frac{M_w + d_p}{G_t + G_L} = \frac{37{,}8 + 6{,}7}{13{,}7 + 197{,}2}$$ = **0,211 No anchors required**
(Uplift by Test Press.+Wind)

12.10 Condition c)

Uplift on a empty tank due to wind loads counteracted by the effective weight of the corroded tank.

$UC = M_w / G_t$ *($M_{wind} = M_{ws+} M_{wr}$)*

$$UC = \frac{37{,}8}{13{,}7}$$ (counter weight incl.operational liquid load) = **2,749 Anchors required**
(Uplift by Wind)

12.11 Condition d)

When earthquake is required then use Appendix G

Check $\frac{M}{D^2(W_L + W_t)}$ = **Anchors required**
(Uplift by Earthquake)

13 Tank anchorage

Tank diameter	Inside	(D)	=	12,600	m
Tank height		(H)	=	28,500	m

13.1 Uplift force anchors

Wind moment	M_w	=	4707825	Nm			
Anchor bolt circle	d	=	12,820	m	Choosen amount		
Number of anchors	N	=	14	[-]	=		[-]
Distance between anchors		=	2,877	m			
Weight of shell, roof and structure	G_a	=	543658	N			
Uplift by internal pressure	U_p	=	241922	N			
Earthquake moment	M	=	N.A.	Nm			

$t_b = \frac{4*M_W}{D*N} - \frac{(G_a - U_p)}{N}$ [Overturning]

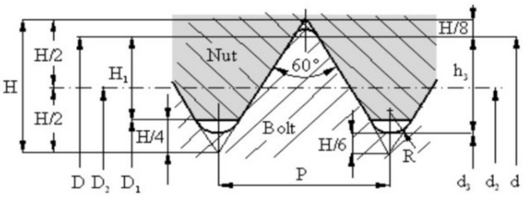
$t_b = \frac{M}{D*N} - \frac{(T_t + T_t + T_T)}{N}$ [Earthquake]

Tension load p/anchor (Overturning)	t_b	=	83369	N	=		N (Uplift force)
Tension load p/anchor (Frangibility)	t_b	=		N	=		N (3x Failure Pressure)
Tension load p/anchor (Earthquake)	t_b	=	N.A.	N	=		N (Uplift force)

13.2 Anchor calculation

	d	d_2	d_3
M30	30	27,727	25,706
M33	33	30,727	28,706
M36	36	33,402	31,093
M39	39	36,402	34,093

free space for other diameters



Quality of anchors		=	A4-50/70	
Size of anchor		=	M30	
Corrosion Allowance (if applicable)		=	N.A.	mm
Nominal size	(d)	=	30	mm
Flank diameter	(d_2)	=	27,727	mm
Core diameter	(d_3)	=	25,706	mm
Cross sectional area (> 500 mm^2)	(As)	=	519,0	mm^2 (uncorroded area)
Corroded cross sectional area	(As)	=	N.A.	mm^2
Yield strength	(Re)	=	450	N/mm^2 N/mm^2
Tensile strength	(Rm)	=	700	N/mm^2 N/mm^3

Check anchors:

F_{anchor} / Ac = 83369 / 519 = 160,64 N/mm^2 < 225,00 N/mm^2

Diameter and number of anchors OK (0,5 of Re)

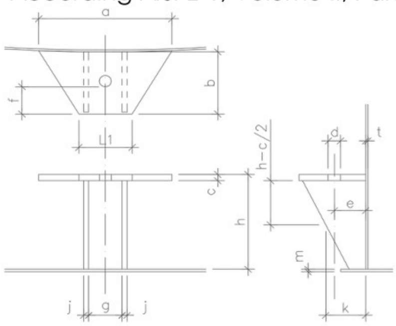
Annex G.5.2.3 = / = N.A. N/mm^2 >= N.A. N/mm^2

(1,33x85%Rm)

14 Calculation anchor brackets

14.1 Local stress in shell due to anchor load

According AISI E-1, Volume II, Part VIII



Anchor force/ design load	**P**	**=**	**83369**	**N**	**=**	**18,7**	**kips**	
Top-plate width	a	=	400	mm	=	15,75	in	
Top-plate length	b	=	300	mm	=	11,81	in	
Top-plate thickness	c	=	12	mm	=	0,47	in	
Anchor bolt diameter	d	=	30	mm	=	1,18	in	
Anchor-bolt eccentricity	e	=	110	mm	=	4,33	in	**OK**
Dist.outside top pl.to edge hole	f	=	173,5	mm	=	6,83	in	**OK**
Distance inbetween vertical plates	g	=	120	mm	=	4,72	in	**OK**
Height anchor chair	h	=	305	mm	=	12,01	in	**OK**
Vertical-plate thickness	j	=	13	mm	=	0,51	in	**OK**
Vertical-plate width	k	=	150	mm	=	5,91	in	
Bottom-/annular plate thickness	m	=	7,0	mm	=	0,28	in	
Tank radius	R	=	6300	mm	=	248,03	in	
Critical stress top plate	S_{ctp}	=	128,1	N/mm²	=	18,58	ksi	
Local stress just above top of chair	S	=	32,7	N/mm²	=	4,74	ksi	**OK**
Maximum allowed stress	S_{max}	=	350,0	N/mm²	=	50,76	ksi	
Tank shell thickness	t	=	10	mm	=	0,39	in	
Reinforcement plate behind chair		=	y	[-]				
Thickness tank shell + reinf.pl.	t	=	20	mm	=	0,79	in	
Anchor-bolt eccentricity	min e	=	41,1	mm	=	1,6	in	
Dist.outside top pl.to edge hole	min f	=	18,2	mm	=	0,7	in	
Distance between vert.plates	min g	=	55	mm	=	2,18	in	
Recommended chair height	min h	=	304,8	mm	=	12,0	in	
Vertical-plate thickness	min j	=	12,7	mm	=	0,5	in	
	j.k	=	3,02	in	**j.k ≥ P/25**			**OK**
	P/25	=	0,75	in				
Radius anchor bolts		=	6430	mm	=	252,8	in	
Outside length top plate	L_1	=	200	mm	=	7,9	in	
Outside length top plate (adjusted)	L_1	=	200	mm				
Diameter bolt hole (bolt + 3 mm)	D	=	33	mm				
Reduction factor	Z	=	0,9633	-				