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Calc.nr.	**72031_T101_30**		
Client	**Joontjes B.V.**		
Project	**K3 storage tanks 1.500 m³**		
Location	**Meppel**		
Ordernr.	**72031**		
Date	**29-05-20**	Rev	**-**
Item	**T-101**	Page	**1**

Subject	**Static Calculation**
Item	**K3 storage tanks T-101 with volume 1.500 m³**
Clients reference	**-**

Description

Vertical carbon steel storage tank with conical bottom, cylindrical shell and conical fixed-roof.
Design in accordance with EN 14015:2004.

Tank design data

Volume (gross)		1.526,814	m^3	
Volume (available)	100%	1.526,814	m^3	
Medium			Diesel/Fame/HVO/GTL	
Class PGS 29		3	-	
Design density		1,000	kg/dm^3	
Density test medium		1,000	kg/dm^3	
Shell diameter		12.000,000	mm	
Shell height		13.500,000	mm	
Fill height max	100%	13.500,000	mm	
Fill height min	0%	0,000	mm	
Slope cone roof		11,310	°	
Slope cone roof		0,197	rad	
Total height of tank top		14.711,207	mm	
Corrosion allowance bottom		0,000	mm	
Corrosion allowance shell		0,000	mm	
Corrosion allowance roof		0,000	mm	
Corrosion allowance rafters		0,000	mm (total)	
Insulation shell		0,000	mm	
Insulation roof		0,000	mm	
Working pressure min/max		ATM	mbarg	
Working temperature min/max		AMB	°C	
Design pressure		10,000	mbarg	
Design vacuum		5,000	mbarg	
Design temperature max		50,000	°C	
Design temperature min		-10,000	°C	
Test pressure		10,000	mbarg full of water	
Wind velocity		45,000	m/s	
LODMAT 30 years		-15,000	°C	
Required min.design temperature		-10,000	°C	
Pump filling rate		350,000	m^3/h	*HOLD: to be confirmed*
Pump discharging rate		250,000	m^3/h	*HOLD: to be confirmed*
Position of tank			outside	
Seismic zone	n.a.	0,000	*g*	

**TER GOEDKEURING
FOR APPROVAL**

Revision	Date	Description	Calc'd	Chk'd	Appr'd
-	29-05-20	First issue	PWK	JCB	PWK

ms excel / EN 14015:2004 / version 20191216

Material Data

Roof, bottom and shell plates (material 1)

Material	S 235 JR	
According to	EN 10025-93	
Rm	340	MPa
Re	235	MPa
Re(θm)	235	MPa
E	192.000	MPa
E(θm)	192.000	MPa

Roof, bottom and shell plates (material 2)

Material	-	
According to	-	
Rm	0	MPa
Re	0	MPa
Re(θm)	0	MPa
E	0	MPa
E(θm)	0	MPa

Top curb profile and windgirder

Material	S 235 JR	
According to	EN 10025	
Rm	340	MPa
Re	235	MPa
Rm(θm)	340	MPa
Re(θm)	235	MPa
E	192.000	MPa
E(θm)	192.000	MPa

Roof supporting profiles

Material	S 235 JR	
According to	EN 10025	
Rm	340	MPa
Re	235	MPa
Rm(θm)	340	MPa
Re(θm)	235	MPa
E	192.000	MPa
E(θm)	192.000	MPa

Tubelures tn ≤ 10 mm

Material	A 106 grade B	
According to	ASTM A-106/SA-106	
Rm	415	MPa
Re	240	MPa
Re(θm)	240	MPa

Tubelures tn > 10 mm

Material	A 333 grade 6	
According to	API / ASTM	
Rm	415	MPa
Re	240	MPa
Re(θm)	240	MPa

Reinforcing plates (1)

Material	S 235 JR	
According to	EN 10025-93	
Rm	340	MPa
Re	235	MPa
Re(θm)	235	MPa

Reinforcing plates (2)

Material	-	
According to	-	
Rm	0	MPa
Re	0	MPa
Re(θm)	0	MPa

Anchor bolts

Material	4.6	
According to	NEN 914	
Rm	390	MPa
Re	235	MPa

Contents

Conclusion/summary

Shell

course	height [m]	thickness [mm]	material
1	2,700	6,0	S 235 JR
2	2,700	6,0	S 235 JR
3	2,700	6,0	S 235 JR
4	2,700	6,0	S 235 JR
5	2,700	8,0	S 235 JR

shell plate thickness required as indicated for each ring
no secondary windgirder required
profile of secondary windgirder n.a.

Bottom annular ring

plate thickness	8,000	mm
minimum size inside tank (la + lw)	582,558	mm
minimum width	655,558	mm

Cone roof

supported cone roof	5,000	mm
roof slope	11,310	°
top curb angle	L 60 x 60 x 8	

for external loading roof supporting required

Roof trusses

20	rafters	IPE 160	L=	4.946	mm
centerring	UNP 180		D=	2.300	mm
bracings				1	
cross bracings				0	

roof trusses are acceptable for external loading
centerring acceptable for forces of trusses
top cub is acceptable for forces of trusses
roof plating on supporting structure is acceptable for external loading
axial shell stress due to roof loads acceptable

Anchors

quantity	14,000	pcs
diameter	30,000	mm
diameter of anchor circle	12,200	m

Shell nozzles

mark	nominal	tube size Dn [mm]	tn [mm]	reinforcing ring Dv [mm]	t [mm]
N1, N2	DN 200	219,1	12,7	430,0	8,0
M1	Ø 600	609,6	12,7	1.100,0	8,0

Frangible joint

calculation according BS 2654 appendix F.4.1. for anchored tanks
roof to shell joint is not frangible

Venting ATM tank

nozzle diameter	219,100	mm
nozzle wall thickness	8,200	mm
number of nozzles	1,000	pcs

Vent nozzle(s) are acceptable for vacuum and pressure

Calculation **Cylindrical Shell**
According to EN 14015

D	=	diameter tank	=	12,000 m
H	=	cylindrical height of tank	=	13,500 m
c	=	corrosion allowance	=	0,000 mm
t;min up	=	min. specified shell thickness upper courses	=	6,000 mm
t;min low	=	min. specified shell thickness lowest course	=	8,000 mm
w	=	design density	=	1,000 kg/dm³
wt	=	density test medium	=	1,000 kg/dm³
p	=	pressure	=	10,000 mbarg
pt	=	test pressure	=	10,000 mbarg
Vw	=	design wind velocity	=	45,000 m/s
v	=	vacuum	=	5,000 mbar
G	=	extra loading	=	0,000 N
v;eq	=	vacuum equivalent to G	=	0,000 mbar
pv	=	design vacuum	=	5,000 mbar
η	=	joint efficiency factor	=	1,000 -
ec	=	formula shell plate thickness design [mm]		
et	=	formula shell plate thickness testing [mm]		
t;tol	=	plate thickness tolerance [mm]		
ts;min	=	minimum allowed gross design thickness [mm]		
ts	=	selected gross shell plate thickness [mm]		
t;net	=	net shell thickness [mm]		
h	=	height of course [m]		
Hc	=	fill height above lower of ring [m]		
He	=	equivalent stable height of each course with t;min [m]		
HE	=	equivalent stable full shell height at t;min [m]		
Hp	=	max. permitted spacing of rings on shell at t;min [m]		
K	=	a factor [-]		

<u>Internal and external loading</u>

material	=			1 S 235 JR		2 -	
quality	=			working	test	working	test
Re(θm)	=	yield strength	[MPa]	235,000	235,000	0,000	0,000
σ	=	design stress	[MPa]	156,667	176,250	0,000	0,000
the smallest value of:		1) η x % x Re(θm)	[MPa]	156,667	176,250	0,000	0,000
		2) 260 MPa (see 7.1.1)	[MPa]	260,000	260,000	260,000	260,000

#	σ	σ [MPa]	h [m]	Hc [m]	ec [mm]	et [mm]	t;tol [mm]	ts;min [mm]	ts [mm]	t;net [mm]	He [m]
1	1	156,67	2,700	2,700	0,939	0,835	0,400	6,000	6,000	6,000	2,700
2	1	156,67	2,700	5,400	1,952	1,735	0,400	6,000	6,000	6,000	2,700
3	1	156,67	2,700	8,100	2,966	2,636	0,400	6,000	6,000	6,000	2,700
4	1	156,67	2,700	10,800	3,979	3,537	0,400	6,000	6,000	6,000	2,700
5	1	156,67	2,700	13,500	4,993	4,438	0,500	8,000	8,000	8,000	1,315

K = 9,392 Hp = 19,923 HE = 12,115
number of secondary wind girders = 0
minimum required profile of windgirder(s) = n.a.

Conclusion: shell plate thickness required as indicated for each ring in column 'ts'
no secondary windgirder required

Calculation	**Bottom Plating**
According to	EN 14015

D	=	diameter tank	=	12,000	m
H	=	fill height liquid	=	13,500	m
e_1	=	thickness first shell course (excl.corr.all.)	=	8,000	mm
c	=	corrosion allowance bottom	=	0,000	mm
l_w	=	lap annular plate to membrane	=	60,000	mm
l_d	=	stick out of bottom	=	65,000	mm

<u>Thickness of annular plates or bottom under shell</u>

e_a	=	minimum thickness [mm]		=	8,000	mm
the greater of:		1) 3 + e1/3		=	5,667	mm
		2) minimum according code		=	6,000	mm
		3) project specification	##	=	8,000	mm
$e_a + c$	=	minimum thickness + corrosion allowance		=	8,000	mm

<u>Design bottom thickness</u>

			working	test	
tb	=	design bottom thickness	8,000	8,000	mm

<u>Minimum width annular plates (if applicable)</u>

l_a	=	minimum width		=	522,558	mm
the greater of:		1) ea x 240/√H		=	522,558	mm
		2) minium according code		=	500,000	mm
		3) project specification	##	=	0,000	mm
$l_w + l_a + e_1 + l_d$		total minimum width of annular plate		=	655,558	mm

<u>Liquid ring</u>

material	=			1	S 235 JR	2	-
quality	=			working	test	working	test
σ	=	design stress	[MPa]	156,667	176,250	0,000	0,000
the smallest value of:		1) % x Re(θm)	[MPa]	156,667	176,250	0,000	0,000
		2) 260 MPa (see poin	[MPa]	260,000	260,000	260,000	260,000

					working	test	
material	=	1	Reb	=	156,667	176,250	MPa
tba	=				8,000	8,000	mm
ws	=				1,000	1,000	g/ml
HT=hlr	=				0,000	13,500	m
D	=				12,000	12,000	m
wl	=				0,000	32,400	kN/m
the smallest value of:		1)			0,032	39,023	
		2)			0,000	32,400	
m lr	=				0,001	1.221,415	kN
d	=				11,500	11,500	m
wlr	=				0,250	0,250	m

Calculation **Conical Roof without supporting**
According to EN 14015

Θ	=	roof slope	=	0,197	rad
Θ	=	roof slope	=	11,310	°
c	=	corrosion allowance	=	0,000	mm
R	=	tank radius	=	6,000	m
tr;b	=	gross roof plate thickness	=	5,000	mm
tr;tol	=	tolerance	=	0,400	mm
tr;m	=	minimum roof plate thickness	=	5,000	mm
tr;n	=	net roof plate thickness	=	4,600	mm
R1	=	radius of curvature of roof	=	30,594	m
t;ins;shell	=	insulation thickness roof	=	0,000	mm
p	=	design pressure	=	10,000	mbarg
η	=	joint efficiency factor	=	0,350	-

<u>Internal loading</u>

material	=				1	2
quality	=				S 235 JR	-
Re(θm)	=	design stress	[MPa]	=	156,667	0,000
the smallest value of:		1) 0,67 x Re(θm)	[MPa]	=	156,667	0,000
		2) 260 MPa (see point 7.1.1)	[MPa]	=	260,000	260,000

material	=	1	σ	=	156,667 MPa
tr	=	p x R1/(10 x σ x η)		=	0,558 mm

<u>External loading</u>

					new	corroded
c	=	corrosion allowance roof	[mm]	=	0,000	0,000
E	=	modulus of elasticy	[MPa]	=	192.000,000	192.000,000
pe	=	the sum of the following values	[Pa]	=	2.082,590	2.082,590
		1) external loading	[Pa]	=	1.200,000	1.200,000
		2) weigth roof plates	[Pa]	=	382,590	382,590
		3) weigth insulation	[Pa]	=	0,000	0,000
		4) negative design pressure	[Pa]	=	500,000	500,000
		5) other loading	[Pa]	=	0,000	0,000
tr	=	$40 \times R1(10 \times pe/E)^{0,5}$	[mm]	=	12,745	12,745

Conclusion: roof thickness acceptable for pressure
for external loading roof supporting required

Calculation **Junction Cone Roof to Shell**
According to EN 14015

R	=	radius of shell	=	6,000	m
R1	=	radius of roof curvature	=	30,594	m
Θ	=	roof slope	=	0,197	rad
p	=	pressure	=	10,000	mbarg

<u>Internal and external loading</u>

σ_c	=	allowable compressive stress	=	120,000	MPa
σ	=	allowable tensile stress	=	156,667	MPa
the smallest value of:		1) roof plating	=	156,667	MPa
		2) top curb	=	156,667	MPa
p_{calc}	=	calc.press. = p - 0,77tr;n	=	6,458	mbarg
pe_{calc}	=	calc.external loading	=	21,132	mbarg
A	=	required compression area	=	1.213,957	mm^2
the greater value of:		1) see 10.5 table 18 L 60 x 60 x 8	=	903,000	mm^2
		2) 50 x p_{calc} x $R^2/(\sigma_c$ x tan$\Theta)$	=	484,347	mm^2
		3) 50 x pe_{calc} x $R^2/(\sigma$ x tan$\Theta)$	=	1.213,957	mm^2

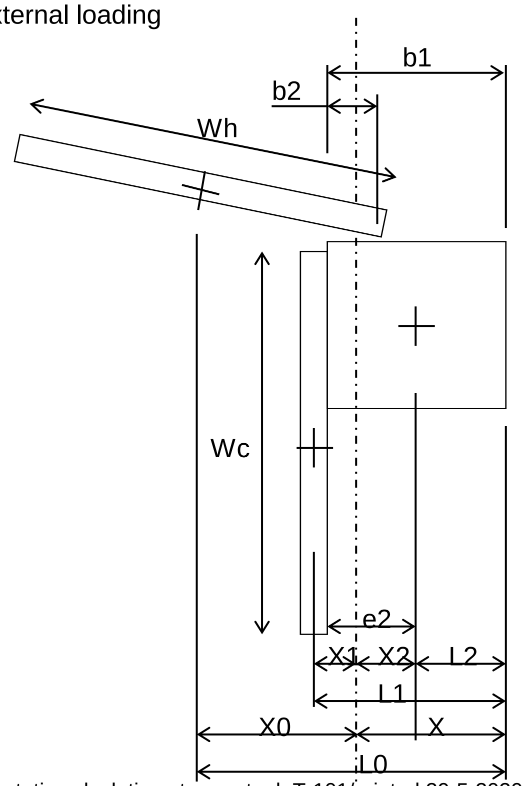
<u>Compression area</u>

					new	corroded
tr;n	=	net roof plate thickness	[mm]	=	4,600	4,600
t;net	=	net shell plate thickness of top course	[mm]	=	5,600	5,600
Wc	=	$0,6 (1000 \times R \times t;net)^{0,5}$	[mm]	=	109,982	109,982
Wh	=	$0,6 (1000 \times R1 \times tr;n)^{0,5}$	[mm]	=	225,086	225,086
A0	=	$(Wh + Wh_{outside})$ x tr;n	[mm^2]	=	1.035,394	1.035,394
A1	=	Wc x t;net	[mm^2]	=	615,898	615,898
A2	=	angle ring 5,42 L 60 x 60 x 8	[mm^2]	=	903,000	903,000
A3	=	insulation support	[mm^2]	=	0,000	0,000
Aw	=	available cross sectional area	[mm^2]	=	2.554,292	2.554,292

Conclusion:
The roof to shell junction is acceptable for pressure and external loading

<u>Section modulus</u>

b1	=	80,000	mm
b2	=	25,000	mm
b3	=	0,000	mm
e2	=	23,400	mm
Iz_{angle}	=	875.000,000	mm^4
L0	=	165,357	mm
L1	=	82,800	mm
L2	=	56,600	mm
L3	=	0,000	mm
X	=	107,003	mm
X0	=	58,355	mm
X1	=	24,203	mm
X2	=	50,403	mm
X3	=	107,003	mm
Iz0	=	7.729.050,252	mm^4
Iz1	=	362.384,350	mm^4
Iz2	=	3.169.009,350	mm^4
Iz3	=	0,000	mm^4
Iz	=	11.260.443,952	mm^4
e	=	168,712	mm
Wz	=	66.743,619	mm^3



Calculation	**Roof Supporting Structure**
Item	Loadings
According to	EN 1993 and Roark

D	=	diameter tank		=	12,000	m
D2	=	diameter centerring		=	2,300	m
n	=	number of rafters		=	20,000	

<u>Design loadings</u>					new	corroded
Corrosion					0,000	0,000
l	=		[m]	=	4,850	4,850
pe	=	roof loading	[Pa]	=	2.082,590	2.082,590
Θ	=	roof angle	[rad]	=	0,197	0,197
q1	=	external loading	[kN/m]	=	3,926	3,926
q2	=	dead load	[kN/m]	=	0,158	0,158
F	=	extra loading		=	0,000	0,000
Q1	=	external loading per bean	[kN]	=	11,777	11,777
Q2	=	dead load per beam	[kN]	=	0,767	0,767
Q3	=	weight of centerring per ra	[kN]	=	0,077	0,077
Q4	=	extra loading per beam		=	0,000	0,000
ls	=	length of rafters	[l / cosΘ]	=	4,946	4,946
Mb1	=	0,128 x Q1 x l	[kNm]	=	7,311	7,311
Mb2	=	Q2 x l / 8		=	0,465	0,465
$M_{y;rep}$	=	Mb1 + Mb2		=	7,776	7,776
Fh	=	(Q1 x D1/(6 x l) + Q2/2 + Q3 + Q4/n)/tanΘ			26,582	26,582
F_{rep}	=	Fh / cosΘ		=	27,108	27,108

Calculation	**Roof Supporting Structure**
Item	Roof Trusses
According to	EN 1993

Steel section:		IPE 160			new	corroded
Corrosion			[mm]	=	0,00	0,00
A	=	cross section	$[mm^2]$	=	2.010,00	2.010,00
O	=	circumference profile	[mm]	=	623,00	
m	=	mass	[kg/m]	=	15,80	15,80
h	=	heigth	[mm]	=	160,00	160,00
b	=	width	[mm]	=	82,00	82,00
tf	=	thicknes flange	[mm]	=	7,40	7,40
tw	=	thicknes web	[mm]	=	5,00	5,00
Iy	=	second moment of area	$[mm^4]$	=	8.690.000,00	8.690.000,00
Wy	=	section modulus	$[mm^3]$	=	109.000,00	109.000,00
i_y	=	radius of gyration	[mm]	=	65,80	65,80
Iz	=	second moment of area	$[mm^4]$	=	683.000,00	683.000,00
Wz	=	section modulus	$[mm^3]$	=	16.700,00	16.700,00
i_z	=	radius of gyration	[mm]	=	18,40	18,40
$l_{y;buc}$	=	buckling length	[mm]	=	4.946,05	4.946,05
$\lambda_{y;re}$	=			=	0,84	0,84
$\omega_{y;buc}$	=			=	0,70	0,70
n	=	number of bracings	[pcs]	=	1,00	1,00
$l_{z;buc}$	=	buckling length	[mm]	=	2.473,03	2.473,03
$\lambda_{z;re}$	=			=	1,50	1,50
$\omega_{z;buc}$	=			=	0,37	0,37
$f_{y;d}$	=	yield strength	[MPa]	=	235,00	235,00
E_d	=	modulus of elasticy	[MPa]	=	192.000,00	192.000,00
λ_{re}	=	$1{,}32\ (l \times h \times f_{y;d}/(b \times tf \times E_d))^{0{,}5}$		=	1,18	1,18
ω_{kip}	=			=	0,54	0,54
$N_{c;s;d}$	=	$\gamma_f \times F_{rep}$ ($\gamma_f = 1{,}2$)	[kN]	=	32,53	32,53
$M_{y;equ;s;d}$	=	$\gamma_f \times M_{y;rep}$ ($\gamma_f = 1{,}2$)	[kNm]	=	9,33	9,33
$N_{c;u;d}$	=	$f_{y;d} \times A$	[kN]	=	472,35	472,35
$M_{y;u;d}$	=	$f_{y;d} \times Wy$	[kNm]	=	25,62	25,62

The following values shall be smaller than 1:

1) $1{,}1 \times N_{c;s;d}/(\omega_{y;buc} \times N_{p;l;d}) + 1{,}1 \times M_{y;equ;s;d}/(\omega_{kip} \times M_{y;u;d})$ =	0,85	0,85
2) $1{,}1 \times N_{c;s;d}/(\omega_{z;buc} \times N_{p;l;d}) + 1{,}1 \times M_{y;equ;s;d}/(\omega_{kip} \times M_{y;u;d})$ =	0,94	0,94

Conclusion: roof trusses are acceptable for external loading

Calculation	**Roof Supporting Structure**
Item	Center Ring
According to	Roark

Steel section:		UNP 180			new	corroded
Corrosion			mm (total) =		0,00	0,00
A	=		[mm^{2}]	=	2.800,00	2.800,00
O	=		[mm]	=	611,00	
m	=				22,00	22,00
h	=		[mm]	=	180,00	180,00
b	=		[mm]	=	70,00	70,00
tf	=		[mm]	=	11,00	11,00
tw	=		[mm]	=	8,00	8,00
ez	=		[mm]	=	19,20	19,20
Iz	=	available second moment	[mm^{4}]	=	1.140.000,00	1.140.000,00
Wz	=		[mm^{3}]	=	22.400,00	22.400,00
i_z	=		[mm]	=	20,20	20,20
R	=	(D2 - 2 x ez)/ 2		=	1.130,800	1.130,800

Strength according to Roark table 18 case 3

W	=	Fh	[N]	=	26.581,74	26.581,74
θ	=		[rad]	=	0,16	0,16
ϕ	=		[rad]	=	0,00	0,00
σ_a	=	allowable stress		=	156,67	156,67
E	=	modulus of elasticity		=	192.000,00	192.000,00
Mz	=	W x 2R sinθ/8		=	1.175.550,31	1.175.550,31
σ	=	Mz / Wz		=	52,48	52,48

Stability according to Roark table 34 case 8

p'	=	n x W / (2 x r x π)		=	74,83	74,83
I;min	=	p' x r^3 / (3 x E)	[mm^{4}]	=	187.837,78	187.837,78

Conclusion: centerring acceptable for forces of trusses

Calculation **Roof Supporting Structure**
Item Junction Roof to Shell
According to Roark table 17 case 7

External loading

Iz	=	second moment of area	=	11.260.443,952 mm^4
Aw	=	cross section area of top curb	=	2.554,292 mm^2
Wz	=	section modulus	=	66.743,619 mm^3
σ_a	=	allowable stress	=	156,667 MPa
R	=	D/2 - X1	=	6.000,000 mm
W	=	Fh = horizontal	=	26.581,736 N
S	=	stress [MPa]		
θ	=	π / n	=	0,157 rad
M_A	=	W x R (1/sinθ - 1/θ) / 2	=	2.093.748 Nmm
N_A	=	W / 2sinθ	=	84.961,322 N
S_A	=	M_A / Wz + N_A / Aw	=	64,632 MPa
M_B	=	W x R (1/θ - cotθ) / 2	=	4.182.330 Nmm
N_B	=	W x cosθ / 2sinθ	=	83.915,309 N
S_B	=	M_B / Wz + N_B / Aw	=	95,515 MPa

Conclusion: top cub is acceptable for forces of trusses

Calculation **Roof Supporting Structure**
Item Roof Plating on Trusses
According to Roark table 26 case 6a

External loading

σ_a	=	0,67 x Re(θm)	=	156,667 MPa
pe	=	external roof loading	=	2.082,590 Pa
θ	=	π / n	=	0,157 rad
a	=	(D1 - D2)/2cosΘ	=	4.946,050 mm
b	=	2 x (D/3) x tanθ	=	1.267,074 mm
σ	=	stress [MPa]		
a/b	=	3,904 β	=	0,500
σ	=	β x pe x b^2 / tr;n^2	=	79,006 MPa

Conclusion: roof plating on supporting structure is acceptable for external loading

Calculation	**Roof Supporting Structure**
Item	Shell stability under axial loads
According to	EEMUA 159

t	=	nett shell thickness	=	6,000	mm
D	=	diameter of tank	=	12,000	m
R	=	nominal shell radius	=	6.000,000	mm
C	=	factor carbon steel standard	=	12.411,000	-
Eθm/E	=	correction factor (Eθm/210.000)	=	0,914	-
Wt	=	the total of dead load and live load on roof			
fa	=	calculated axial compression			
Fa	=	allowable axial compression			

Wt	=	the sum of the following values	=	2.249,510	Pa
		1) external loading	=	1.200,000	Pa
		2) weigth roof plates	=	382,590	Pa
		3) weigth roof supports	=	149,128	Pa
		4) weigth top curb	=	17,793	Pa
		5) weigth insulation	=	0,000	Pa
		6) negative design pressure	=	500,000	Pa
		7) other loading	=	0,000	Pa

q	=	maximum loading due to Wt	=	6,749	N/mm
fa	=	q / t	=	1,125	MPa
Fa	=	C x (t / R) x (Eθm/E)	=	11,347	MPa

Conclusion: axial shell stress due to roof loads acceptable

Calculation **Weight Calculation**

According to -

D	=	tankdiameter	=	12,000 m
H	=	cilindrical height	=	13,500 m
t;ins;shell	=	insulation thickness shell	=	0,000 mm
t;ins;roof	=	insulation thickness roof	=	0,000 mm
G	=	weight [N]		

Subject	Working conditions	Test conditions	Total empty weight	
Corrosion	corroded	new	new	
Bottom	5.680	5.680	70.704	N
Shell	249.234	249.234	249.234	N
Roof (cone)	44.127	44.127	44.127	N
Roof (dome)	0	0	0	N
Roof trusses	16.866	16.866	16.866	N
Radial folded rafters	0	0	0	N
Radial roof rafters	0	0	0	N
Connections	12.000	12.000	12.000	N
Spiral staircase	0	0	0	N
Caged ladder	0	0	0	N
Platform(s)	0	0	0	N
Handrailing(s)	4.335	4.335	4.335	N
Insulation shell	0	0	0	N
Insulation roof	0	0	0	N
Insulation support(s)	0	0	0	N
Top curb (cone)	2.012	2.012	2.012	N
Top curb (dome)	0	0	0	N
Primary windgirder	0	0	0	N
Secondary windgirder(	0	0	0	N
Heating coil	0	0	0	N
Others				N
Total weight G	328.575	328.575	399.279	N

Total weight

Operation	Tank	399 kN	40,701 ton
	Insulation	0 kN	0,000 ton
	Medium	14.978 kN	1.526,814 ton
	Tank + medium	15.377 kN	1.567,515 ton
	Tank + insulation	399 kN	40,701 ton
	Tank + insulation + medium	15.377 kN	1.567,515 ton
Testing	Tank	399 kN	40,701 ton
	Testmedium	14.978 kN	1.526,814 ton
	Tank + testmedium	15.377 kN	1.567,515 ton

Calculation **Overturning Stability**
According to EN 14015 and Stoomwezen 'Rules' D1201

D	=	tankdiameter	=	12,000	m
H	=	cylindrical height	=	13,500	m
Hw	=	height of tankwall	=	0,000	m
t;ins;shell	=	insulation thickness shell	=	0,000	mm
t;ins;roof	=	insulation thickness roof	=	0,000	mm
Cw;m	=	drag coefficient shell	=	0,700	
Cw;s	=	drag coefficient steel structure	=	1,000	
Cw;d	=	coefficient of friction by wind	=	0,040	
hl min	=	minimum product liquid level	=	0,000	m
pw formule	=	wind pressure standard	=	1,288	kN/m^2
pw project	=	wind pressure alternative (NEN 6702)	=	0,000	kN/m^2

			working	test	
p	=	internal pressure	1,000	1,000	kN/m^2
pw	=	wind pressure	1,288	0,966	kN/m^2
wlr	=	width of liquid ring	0,250	0,250	m
hlr	=	height of liquid ring	0,000	13,500	m
w	=	density medium	1,000	1,000	kg/dm^3

	A [m^2]	Ha [m]	Mw [kNm]	Mw;test [kNm]
Shell	162,000	6,750	986,05	739,54
Ladder(s)/stair(s)	4,455	7,250	41,61	31,21
Handrail/structure(s)	5,520	14,000	99,55	74,66
Roof	115,337	14,700	87,36	65,52
Others	0,000	0,000	0,00	0,00

			working	test	
Mw	=	wind moment (total)	1.214,58	910,93	[kNm]
Pr	=	int' press on roof plates	113,10	113,10	[kN]
Pb	=	int' press. on annular plates	9,22	9,22	[kN]
Gl	=	liquid ring	0,00	1.221,42	[kN]
Gt	=	tank weight	328,57	328,57	[kN]
F	=	loading on bottom-shell joint	4,78	-30,31	[kN/m]

Conclusion: anchors required for working conditions
no anchors required for test conditions

Calculation **Anchoring**
According to Stoomwezen 'Rules' D1302

D	=	diameter of tank	=	12,000	m
ts	=	thickness lowest course	=	0,000	mm
Dc	=	diameter of anchor circle	=	12,200	m
Da	=	diameter of anchors	=	30,000	mm
n	=	number of anchor bolts	=	14,000	pcs
As	=	cross section area of bolt	=	519,000	mm^2
σ_a	=	allowable stress (working conditions)	=	94,000	MPa
the smallest of:		1) 0,40 x Re	=	94,000	MPa
		2) 0,33 x Rm	=	128,700	MPa
$\sigma_{a;test}$	=	all. stress (test conditions) 0,85 x Re	=	199,750	MPa
σ	=	stress in bolt [MPa]			

Due to overturning			working	test	
F_{anchor}	=	4 Mw / (Dc x n) - (Gt - Pr) / n	13,053	0,000	kN
σ_{anchor}	=	1000 x F_{anchor} / As	25,151	0,000	MPa

Conclusion: anchors acceptable for overturning

Calculation **Frangible Roof to Shell joint anchored tank**
According to BS 2654 appendix F.4.1

D	=	tankdiameter	=	12,000	m
R	=	radius of shell	=	6,000	m
f	=	fillet weld roof plates to top curb profile	=	5,000	mm
Θ	=	roof slope	=	0,197	rad
Aw	=	available compression area	=	2.554,292	mm²
Sc	=	failure compressive stress	=	220,000	MPa
Dc	=	diameter of anchor circle	=	12,200	m
n	=	number of anchor bolts	=	14,000	
As	=	cross section area of bolt	=	519,000	mm^2
σ_a	=	allowable stress (working conditions)	=	94,000	MPa
p	=	failure pressure [mbar]			
p	=	A x Sc x tan Θ / (50 x R²)	=	62,439	mbar

Weight calculation

c	=	corrosion allowance	[mm]	=	0,000	0,000
T	=	the sum of the following weights	[kN]	=	268,113	268,113
		1) shell	[kN]	=	249,234	249,234
		2) roof supporting (if supported by shell)	[kN]	=	16,866	16,866
		3) top curb profile	[kN]	=	2,012	2,012
		4) secondary windgirders	[kN]	=	0,000	0,000
		5) further	[kN]	=	0,000	0,000

Anchor check

c	=	corrosion allowance	[mm]	=	0,000	0,000
Mw	=	wind moment (total)	[kNm]	=	1.214,575	1.214,575
Pr	=	int' press on roof plates	[kN]	=	706,164	706,164
Gt	=	tank weight	[kN]	=	268,113	268,113
F_{anchor}	=	4 Mw / (Dc x n) - (Gt - Pr) / n	[kN]	=	59,734	59,734
σ_{anchor}	=	1000 x F_{anchor} / As	[Mpa]	=	115,094	115,094

Conclusie: roof to shell joint is not frangible

Calculation **Openings in Cylindrical Shell**
According to EN 14015

Dn	=	outside diameter nozzle [mm]
tn	=	nozzle thickness [mm]
c	=	corrosion allowance [mm]
tn;tol	=	nozzle tolerance [mm]
tn;net	=	net nozzle thickness [mm]
tm	=	minimum specified nozzle thickness [mm]
tl	=	net thickness internal [mm]
ln	=	calc. lenght internal [mm]
the smallest value of		1) 4 x tn;net
		2) internal lenght
An	=	2 x (tn;net - tm;net)(4 x tn;net + t;net) [mm^2]
Al	=	2 x ln x tl [mm^2]
Dv	=	outside diameter reinforcing pad [mm]
Dg	=	inside diameter reinforcing pad[mm]
tv	=	thickness reinforcing pad [mm]
tv;tol	=	tolerance reinforcing pad [mm]
tv;net	=	net thickness reinforcing pad [mm]
Av	=	(Dv - Dg) tv;net [mm^2]
Dw	=	diameter hole in shell [mm]
t;net	=	net thickness shell [mm]
A	=	available area = An + Al + Av [mm^2]
Amin	=	required area = 0,75 x Dw x t;net [mm^2]

Mark		N1, N2	M1
Nominal		DN 200	Ø 600
Dn	=	219,100	609,600
tn	=	12,700	12,700
c	=	0,000	0,000
tn;tol	=	1,588	1,588
tn;net	=	11,113	11,113
tm	=	12,500	12,500
tm;net	=	10,938	10,938
tl	=	11,113	11,113
ln	=	0,000	0,000
An	=	18,182	18,182
Al	=	0,000	0,000
Dv	=	430,000	1.100,000
Dg	=	219,100	609,600
tv	=	8,000	8,000
tv;tol	=	0,400	0,400
tv;net	=	7,600	7,600
Av	=	1.602,840	3.727,040
course	=	5,000	5,000
Dw	=	219,100	609,600
t;net	=	7,500	7,500
A	=	1.621,023	3.745,223
Amin	=	1.232,438	3.429,000

Calculation	**Venting atmospherical tank**
According to	BS 2654-1989 Appendix F

Nozzle data

De_{nozzle}	=	external diameter of nozzle	=	219,10	mm
t_{nozzle}	=	wall thickness of nozzle	=	8,20	mm
Di_{nozzle}	=	internal diameter of nozzle	=	202,70	mm
A_{nozzle}	=	cross section of venting nozzle	=	0,0323	m^2
n	=	number of venting nozzles	=	1,00	pcs
v_{max}	=	maximum allowable velocity in nozzle	=	10,00	m/s

Vacuum

$\phi_{pump;out}$	=	pump capacity by emptying	=	250,00	m^3/h
V	=	volume of tank	=	1526,81	m^3
A	=	surface area	=	622,04	m^2
$\boldsymbol{\phi_{req\ pumping}}$	=	required capacity for emptying	=	250,00	m^3/h
$\boldsymbol{\phi_{req\ temp.}}$	=	required capacity for temp.decr.	=	274,83	m^3/h
$\boldsymbol{\phi_{req\ total}}$	=	total required venting capacity	=	524,83	m^3/h
v_{nozzle}	=	velocity of air in nozzle	=	4,52	m/s

Pressure

$\phi_{pump;in}$	=	pump capacity by filling	=	350,00	m^3/h
		flash point lower than 38^oC ?	=	no	
$\phi_{req\ pumping}$	=	required capacity for filling	=	374,50	m^3/h
$\phi_{req\ total}$	=	total required venting capacity	=	539,40	m^3/h
v_{nozzle}	=	velocity of air in nozzle		4,65	m/s

Conclusion: Vent nozzle(s) are acceptable for vacuum and pressure