Design Calculation

Diesel Storage Tank
with
Collection Basin

OMV Rumania

V = 13000 m³

D = 32 m / 36 m
H = 16.7 m / 13 m

Customer	Manufacturer
PETROM Member of OMV Group	CONFIND srl CAMPINA

Project: Refinery BRAZZI/Ploesti Tanks T11N; 602N	**Rev.:**	0	1	2	3	4	5
	Date:						
Serial No.:	**Prepared**	.					
	Checked	.					
Purchase Order No.:	**QC-Department**						
Manufacturer Order No.:	**Document No.:**					Page 1	of 136

Revisions:

Date	Rev. No.	

Content:

1.) General Project Description

STORAGE TANK with COLLECTION BASIN 13000m^3

Client	Petrom OMV Rumania
Destination	Petrom Refinery BRAZZI/Ploesti

Built on site, overground, standing, cylindrical, welded flat bottom steel tank

stored medium: Diesel

2.) General Data:

2.1.) Dimensons

2.1.1.) Collecting Basin:

$D_{col} := 36m$

$h_{col} := 13m$

2.1.2.) Storage Tank:

$D_{tank} := 32m$

$h_{tank} := 16.7m$

Roof type:

Dome segment roof rafters on the inside

Rafters must not be welded to the roof plates.
Roof plates overlap and are welded through.

$h_{roof} := 2.745m$

girth of the cylinders:

$U_{col} := D_{col} \cdot \pi$

$U_{col} = 113.1\,m$

$U_{tank} := D_{tank} \cdot \pi$

$U_{tank} = 100.53\,m$

section areas

$A_{col} := D_{col}^2 \cdot \frac{\pi}{4}$

$A_{col} = 1017.876\,m^2$

$A_{tank} := D_{tank}^2 \cdot \frac{\pi}{4}$

$A_{tank} = 804.248\,m^2$

calculated volume:

$V := A_{tank} \cdot h_{tank}$

$V = 13430.937\,m^3$

used volume:

$V_{nutz} := 13000m^3$

2.2.) Requirements:

$mbar := 100 \frac{N}{m^2}$

design underpressure $p_u := 20mbar$

design overpressure $p_ü := 20mbar$

tank type: closed tank

Tank with very high pressure (acc. DIN EN 14015; Tab. 3)
--> shell calculated acc. to DIN 18800 (Stability)

highest design temperatur: $T_{HDM} := 25 \ °$

weld factor $v_{test} := 0.85$ not used!!

Density of stored medium: $\gamma_{diesel} := 8.6 \frac{kN}{m^3}$

2.3.) Standards

EN 14015 (Edition 2005-05-01)

VdTÜV Merkblatt "Tankanlagen" Merkblatt 960-2002/1, 05.2003

DIN 18800 (11.90)

DIN 1055

2.4.) Material

0.2% yield strength acc. to EN 10025

S355; 1.0570	355	N/mm²
S235; 1.0116	235	N/mm²

$f_{y\_k\_1.0570\_T20°} := 355 \frac{N}{mm^2}$

$f_{y\_k\_1.0116\_T20°} := 235 \frac{N}{mm^2}$

3.) Loads:

3.1.) Main Loads

3.1.1.) Dead Loads

steel:

Plates (shell, roof) see below

formwork see below

structural steelwork (first assumption):
manholes
gangways
guardrail
stairway

$F_{structure} := 100kN$

insulation

NO INSULATION

3.1.2.) live loads

stored medium: Diesel

max. density: $\gamma_{diesel} = 8.6\frac{kN}{m^3}$

density of test fluid (water) $\gamma_t := 10.0\frac{kN}{m^3}$ authoritative

design overpressure $p_{ü} = 20\,mbar$ $p_{ü} = 2000\frac{N}{m^2}$

design underpressure $p_u = 20\,mbar$ $p_u = 2000\frac{N}{m^2}$

testpressure $p_t := 25mbar$ $p_t = 2500\frac{N}{m^2}$

3.2.) Additional Loads

Snow load acc. to specification:

Snow load is claculated acc. to the "50 year" high.

$$s_k := 2\frac{kN}{m^2}$$

Wind load acc. to EN14015:

velocity acc. to specification: $v_{spec} := 31\frac{m}{s}$

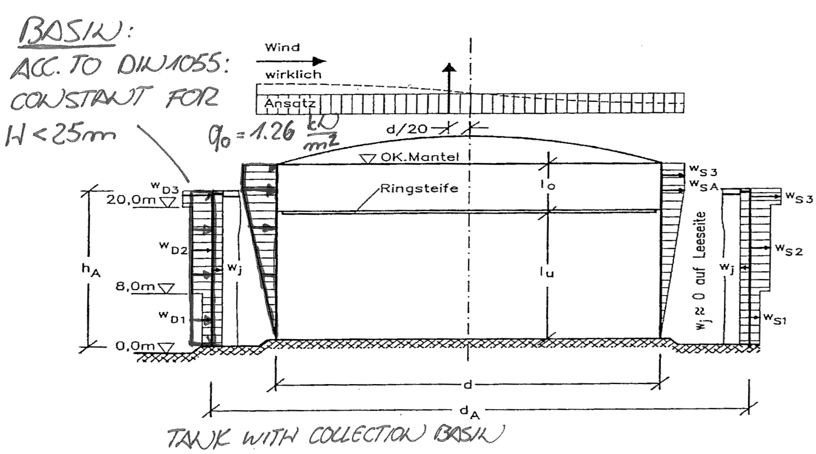
minimum velocity acc. to EN14015/7.2.10: $v_{min} := 45\frac{m}{s}$

calculation velocity: $v_{cal} := \max(v_{spec}, v_{min})$

wind pressure:

$$q_0 := \frac{v_{cal}^{\;2}}{1600}\left(\frac{kN \cdot s^2}{m^4}\right)$$

$$q_0 = 1.266\frac{kN}{m^2}$$



Earthquake acc. to specification and international earthquake maps

see chapter "Earthquake"

4.) Roof:

executed as dome with a maximal rafter distance of 2 m (acc. to VdTÜV)

Calculation acc. to VdTÜV-Merkblatt

girth $U_{tank} = 100.531\,m$

number of steel girders $n_{form} := \frac{U_{tank}}{2m}$ $n_{form} = 50.3$

choosen number of girders $n_{form} := 52$

shell thickness $s_{roof} := 6mm$

radius of the roof $r_{roof} := 48m$

4.1.) Loads

4.1.1.)Deads Loads

$R := 0$

roof plates

surface domeroof:

$s_{roof} = 6\,mm$

$$O_{dome} := 2 \cdot r_{roof} \cdot \pi \cdot \left(r_{roof} - r_{roof} \cdot \cos\left(\operatorname{asin}\left(\frac{\frac{D_{tank}}{2}}{1.5 \cdot D_{tank}} \right) \right) \right)$$

$$O_{dome} = 827.923\,m^2$$

$$\gamma_{steel} := 78.5 \frac{kN}{m^3}$$

$$G_{plate} := O_{dome} \cdot s_{roof} \cdot \gamma_{steel} \qquad G_{plate} = 389.952\,kN$$

$$g_{pl} := \frac{G_{plate}}{O_{dome}} \qquad g_{pl} = 471 \frac{N}{m^2}$$

formwork

first assumption of the possible weight of the rafters (should be higher than the real weight, must be checked later):

$F_{form} := 520kN$

$$g_{form} := \frac{F_{form}}{O_{dome}} \qquad g_{form} = 628.078 \frac{N}{m^2}$$

Sum of dead loads for calculation of the roof shell:

$EG1 := g_{pl}$

$EG1 = 471 \frac{N}{m^2}$

Sum of the dead loads for the calculation of the girders

roof + formwork: first assumption

$G_{structure} := 150kN$ contains crown ring, corner ring and additional steel structure

$EG2 := G_{plate} + F_{form} + G_{structure}$

$EG2 = 1059.952\,kN$ $\frac{EG2}{O_{dome}} = 1280.254 \frac{N}{m^2}$

first assumption dead load: incl. crown ring, corner ring, roof shell, rafters:

$EG2 := 1300 \frac{N}{m^2}$

4.1.2.) Live Loads

operating overpressure

$BÜ := p_{ü}$ $BÜ = 2000 \frac{N}{m^2}$

operating underpressure

$BU := p_u$ $BU = 2000 \frac{N}{m^2}$

underpressure due to wind

$WU := 0.4 \cdot q_0$ $WU = 506.25 \frac{N}{m^2}$ acc. to DIN 4119

wind suction

$WS := 0.6 \cdot q_0$ $WS = 759.375 \frac{N}{m^2}$ acc. to DIN 4119

snow

$S := s_k$ s Seite 7 $S = 2000 \frac{N}{m^2}$ Includes possible other live loads which might appear, if there is no snow.

4.2.) Load Combinations

acc to Bußhaus "Die Standsicherheit von Flachbodentanks":

$RP_1 := 1.35 \cdot EG1 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_2 := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_3 := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_4 := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_5 := 1.35 \cdot EG1 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_6 := 1.35 \cdot EG1 + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_7 := 1.35 \cdot EG1 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_8 := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_9 := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{10} := 1.35 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{11} := 1.35 \cdot EG1 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{12} := 1.35 \cdot EG1 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{13} := 1.35 \cdot EG1 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{14} := 1.00 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 1.0 \cdot 1.35 \cdot 0.9 \cdot BÜ$

$RP_{15} := 1.00 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RP_{16} := 1.00 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RP_{17} := 1.00 \cdot EG1 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RP_i =$ $\frac{N}{m^2}$

5765.85
1644.131
3164.991
294.131
5765.85
3065.85
3335.85
1756.162
3446.006
635.85
6035.85
6335.85
3335.85
-2984.156
-668.063
-2229
-3368.063

$RP_{max} := max(RP)$ $\quad RP_{max} = 6335.85 \frac{N}{m^2}$

$RP_{min} := min(RP)$ $\quad RP_{min} = -3368.063 \frac{N}{m^2}$

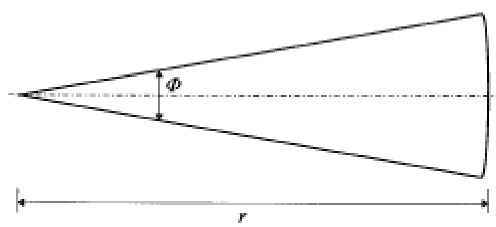
4.3.) Evaluation of plate thickness

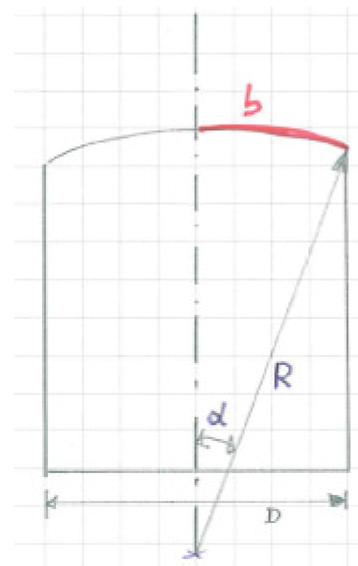
4.3.1.) Evaluation of the requiered thickness for the roof plates for the authoritative load combination

apex angle $\phi := \frac{360}{n_{form}}$ $\phi = 6.92$ ° in case of $n_{form} = 52$ girders

$f_{md} := 0.00766$ "Vorfaktor Feldmoment" linear interpolated, see Bußhaus p. 59

3. Im Grundriß hat das Dachblech zwischen den Gespärreträgern die Form eines Kreisausschnitts, wie in anschließender Abbildung gezeigt:





$\alpha := 19.47$ $r_{roof} = 48\,m$ radius of dome roof

$b := \frac{r_{roof} \cdot \pi \cdot \alpha}{180}$ $b = 16.311\,m$ arc length of dome

$r_{real} := b$

$r := 13m$ choosen radius to provide 6 mm roof plate thickness; the remaining length is supported by a polygone stiffener (see below)

$l_{remain} := b - r$ $l_{remain} = 3.3\,m$

$\gamma_m := 1.1$ partial safety factor for material

$f_{y\_k\_1.0570\_T20°} = 355 \frac{N}{mm^2}$ yield strength for S355J2G3

$\alpha_w := 0.95$ weld factor acc. to DIN 18800 T1, Tab 21

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks", p. 55, (5-91)

$$t_{D\_eff} := \sqrt{f_{md} \cdot \frac{RP_{max} \cdot r^2 \cdot \gamma_m}{1.5 \cdot f_{y\_k\_1.0570\_T20°} \cdot \alpha_w}} \qquad t_{D\_eff} = 4.223\,mm$$

choosen $t_D := 6mm$

$c_1 := 0.3mm$ $c_2 := 1mm$

$t_{D.cal} := t_D - c_1 - c_2$

4.3.2.) simplified proof of integrity of lasting roof area (acc. to Pieper/Martens) and add. support ring:

support type of the roof area: 6 with IPE 300

$b_{rafter} := 150mm$

$l_1 := \frac{U_{tank}}{n_{form}} - b_{rafter}$ $\qquad l_1 = 1.78\,m$

$l_2 := \frac{l_{remain}}{2}$ $\qquad l_2 = 1.66\,m$

$l_y := \max(l_1, l_2)$ $\qquad l_x := \min(l_1, l_2)$

$\frac{l_y}{l_x} = 1.08$

$f_x := 30.2$ $\quad f_y := 45$ $\quad s_x := 17.1$ $\quad s_y := 17.55$

field moments:

$m_{xm} := RP_{max} \cdot \frac{l_x^2}{f_x}$ $\qquad m_{xm} = 0.575\frac{kN \cdot m}{m}$

$b_{eff} := 1m$

$M_{xm} := m_{xm} \cdot b_{eff}$ $\qquad M_{xm} = 0.575\,kN \cdot m$

support moment:

$m_{xe} := RP_{max} \cdot \frac{l_x^2}{s_x}$ $\qquad m_{xe} = 1.016\frac{kN \cdot m}{m}$

$M_{xe} := m_{xe} \cdot b_{eff}$ $\qquad M_{xe} = 1.016\,kN \cdot m$

$W_{roof} := \frac{t_{D.cal}^2 \cdot b_{eff}}{6}$ $\qquad W_{roof} = 3.68\,cm^3$

bending stresses in field:

$\sigma_{roof} := \frac{M_{xm}}{W_{roof}}$ $\qquad \sigma_{roof} = 156.189\frac{N}{mm^2}$ $\quad \le \quad$ $\frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m} = 322.727\frac{N}{mm^2}$

bending stresses near support rafter:

$\sigma_{sup} := \frac{M_{xe}}{W_{roof}}$ $\qquad \sigma_{sup} = 275.843\frac{N}{mm^2}$ $\quad \le \quad$ $\frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m} = 322.727\frac{N}{mm^2}$

4.4.) Proof of Stability for Buckling Pressure Roof Plates acc. to VdTÜV (additional)

Evaluation of authoratative load:

1. $q_s := s_k$ $\quad q_s = 2000\,\frac{N}{m^2}$ snow/others

$p_{Ri\_d1} := 1.5 \cdot q_s$ $\quad \boxed{p_{Ri\_d1} = 3000\,\frac{N}{m^2}}$ Gl21 – 11

2. $f_{y\_k\_1.0570\_T20°} = 355\,\frac{N}{mm^2}$ 1 % yield point

buckling pressure of the reinforced roof shell - the following value is calculated iterative (see below):

$$p_B := 2.3\,\frac{kN}{m^2}$$

$$\sigma_{xSi} := p_B \cdot \frac{r_{roof}}{2 \cdot t_D}$$ see DIN 18800, Teil 4, chapter 7

$$\sigma_{xSi} = 9.2\,\frac{N}{mm^2}$$

$$\lambda_{Sx} := \sqrt{\frac{f_{y\_k\_1.0570\_T20°}}{\sigma_{xSi}}}$$ see DIN 18800-4 Gl. 1

$$\lambda_{Sx} = 6.21$$

$$\kappa_2 := \frac{0.2}{\lambda_{Sx}^2}$$ κ - factor for very sensible shells to imperfections (DIN 18800-4 Gl. 8)

$$\kappa_2 = 0.00518$$

$$\gamma_{M2} := 1.45$$ safety factor for resistance (DIN 18800-4 Gl. 13)

$$q_{H\_d} := RP_{max}$$

$$p_{Ri\_d2} := q_{H\_d} - p_B \cdot \frac{\kappa_2 \cdot \lambda_{Sx}^2}{\gamma_{M2}}$$

$$\boxed{p_{Ri\_d2} = 6018.609\,\frac{N}{m^2}}$$

3. $q_{H\_d} := RP_{max}$ $\quad q_{H\_d} = 6335.85 \frac{N}{m^2}$ maximum load combination of chapter 4.2

$p_{Ri\_d3} := 0.5 \cdot q_{H\_d}$ $\quad p_{Ri\_d3} = 3167.925 \frac{N}{m^2}$ Gl21 – 13

authoratative load value from above:

$p_{Ri\_d} := \max(p_{Ri\_d1}, p_{Ri\_d2}, p_{Ri\_d3})$

$p_{Ri\_d} = 6018.609 \frac{N}{m^2}$

Verification of the buckling pressure of the reinforced roof shell:

$$l_B := D_{tank} \cdot \frac{\sin\left(\frac{\pi}{n_{form}}\right)}{1 + \sin\left(\frac{\pi}{n_{form}}\right)}$$ Gl 21-20

$l_B = 1.82 m$

$c_2 := 1mm$

$$\kappa := \frac{l_B^2}{58.4 \cdot r_{roof} \cdot (t_D - c_2)} \quad \kappa = 0.237 \quad < 1$$ Gl 21-14

$E_{cal} := 212000 \frac{N}{mm^2}$ $\quad E_{20} := 212000 \frac{N}{mm^2}$

$$\eta := \frac{E_{cal}}{E_{20}} \quad \eta = 1$$ Gl 21-18

$$\delta := \frac{10^4 \cdot (t_D - c_2)}{r_{roof}} \quad \delta = 1.0417$$ Gl 21-17

$$p_{B0} := \frac{kN}{m^2} \cdot 0.55 \cdot \eta \cdot \delta^{2.125} \quad p_{B0} = 0.6 \frac{kN}{m^2}$$ Gl 21-16

buckling pressure of reinforced roof shell

$$p_B := 0.5 \cdot \left(\kappa + \frac{1}{\kappa}\right) \cdot p_{B0} \quad p_B = 1.337 \frac{kN}{m^2}$$ Gl 21-15

$p_B = 1.337 \frac{kN}{m^2}$ $\quad . < . \quad$ $5 \cdot p_{B0} = 2.999 \frac{kN}{m^2}$ $\quad$ fulfilled

4.5.) Rafters: Proof of Integrity acc. to EN14015; 10.3

Rafters: IPE 360 (S355J2G3) not welded to roof (EN14015: 10.3.2)

$g_{form\_real} := 0.571\frac{kN}{m}$ IPE360 only

$h_{cor} := 358mm$

$t_{1.cor} := 10.7mm$ $b_{1.cor} := 168mm$

$t_{2.cor} := t_{1.cor}$ $b_{2.cor} := b_{1.cor}$

$s_{cor} := 6mm$ $h_s := 334.6mm$

$A := 58.3cm^2$

$J_y := 13347cm^4$ $I_z := 847cm^4$

$$I_T := \frac{b_{1.cor} \cdot t_{1.cor}^3 + b_{2.cor} \cdot t_{2.cor}^3 + h_s \cdot s_{cor}^3}{3}$$

$I_T = 16.13\,cm^4$

$I_1 := \frac{t_{1.cor} \cdot b_{1.cor}^3}{12}$ $I_1 = 422.796\,cm^4$ $I_2 := I_1$

$$I_\omega := \left(\frac{I_1 \cdot I_2}{I_1 + I_2}\right) \cdot h_{cor}^2$$

$I_\omega = 270935.825\,cm^6$

$i_y := \sqrt{\frac{J_y}{A}}$ $i_z := \sqrt{\frac{I_z}{A}}$ $i_y = 0.151\,m$

$e_{max} := 165mm$ $z_p := 0$ $i_z = 0.038\,m$

$$W_y := \frac{J_y}{e_{max}}$$

$W_y = 808.909\,cm^3$

4.5.1.) Load combinations (acc. to Bußhaus "Die Standsicherheit von Flachbodentanks")

alternative 1:

$$p_{Ri\_d1} = 3000 \frac{N}{m^2}$$

alternative 2:

$RS_1 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_2 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_3 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_4 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_5 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_6 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_7 := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_8 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_9 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{10} := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{11} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{12} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{13} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{14} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 1.0 \cdot 1.35 \cdot 0.9 \cdot BÜ$

$RS_{15} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RS_{16} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RS_{17} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RS_i =$

6885.00
2763.28
4284.14
1413.28
6885.00
4185.00
4455.00
2875.31
4565.16
1755.00
7155.00
7455.00
4455.00
-2155.16
160.94
-1400.00

$\frac{N}{m^2}$

maximal resulting pressure:

$$RS_{max} := \max(RS) \qquad RS_{max} = 7455 \frac{N}{m^2}$$

$$q_{H\_d} := RS_{max}$$

minimal resulting pressure:

$$RS_{min} := \min(RS) \qquad RS_{min} = -2539.063 \frac{N}{m^2}$$

$$p_{Ri\_d2} := q_{H\_d} - p_B \cdot \frac{\kappa_2 \cdot \lambda_{Sx}^2}{\gamma_{M2}}$$

$$p_{Ri\_d2} = 7270.558 \frac{N}{m^2}$$

alternative 3:

$$p_{Ri\_d3} := 0.5 \cdot q_{H\_d} \qquad p_{Ri\_d3} = 3727.5 \frac{N}{m^2}$$ Gl21 – 13

authoritative load value from above:

$$p_{Ri\_d} := \max(p_{Ri\_d1}, p_{Ri\_d2}, p_{Ri\_d3})$$

$$p_{Ri\_d} = 7270.558 \frac{N}{m^2}$$

4.5.2.) Anlaysis of the stress resultants (1. Order; acc. to VdTÜV)

axial force in rafters:

$$N_{P\_d} := 0.375 \cdot \frac{\frac{D_{tank}}{2}}{h_{roof}} \cdot \frac{p_{Ri\_d} \cdot \pi \cdot \left(\frac{D_{tank}}{2}\right)^2}{n_{form}} \qquad N_{P\_d} = 245.789\,kN$$ Gl 21-23

axial force in rafters by their own dead load:

$F_{form} = 520\,kN$

$$N_{G\_d} := (0.513 - 0.375) \cdot \frac{\frac{D_{tank}}{2}}{h_{roof}} \cdot F_{form} \qquad N_{G\_d} = 418.273\,kN \qquad \text{Gl 21-24}$$

maximum field moment in rafters:

$p_{Ri\_d} = 7270.6\,\frac{N}{m^2}$

$$f_M := 0.0375 + 0.00075 \cdot \frac{p_{Ri\_d}}{\frac{kN}{m^2}} \qquad \text{nondimensional factor} \qquad \text{Gl 21-27}$$

$$M_{I\_d} := f_M \cdot \frac{D_{tank}}{2} \cdot \frac{p_{Ri\_d} \cdot \pi \cdot \left(\frac{D_{tank}}{2}\right)^2}{n_{form}} \qquad M_{I\_d} = 77.28\,kN \cdot m \qquad \text{Gl 21-26}$$

4.5.3.) Anlaysis of the stress resultants (2. Order; acc. to VdTÜV)

axial force II. Order

$$N_{II\_d} := \left(N_{G\_d} + N_{P\_d}\right) \cdot \left[1 + 0.075 \cdot \left(\frac{1}{\eta} - 1\right)\right] \qquad N_{II\_d} = 664.063\,kN \qquad \text{Gl 21-25}$$

$\gamma_m = 1.1$

$$\varepsilon := \gamma_m \cdot N_{II\_d} \cdot \frac{\left(0.6 \cdot \frac{D_{tank}}{2}\right)^2}{\pi^2 \cdot E_{cal} \cdot J_y} \qquad \varepsilon = 0.2411 \qquad \text{Gl21} - 28$$

moments II. Order

$$M_{II\_d} := \frac{M_{I\_d}}{1 - \varepsilon} \qquad M_{II\_d} = 101.826\,kN \cdot m \quad \text{Gl 21-29}$$

4.5.4.) Proof of intergrity of formwork:

The rafters are loaded with distributed load causing bending moment and a axial force

safety factor on material acc. to EN1993-1-1; 6.1

$\gamma_M := 1.1$

resisting pressure force:

$$N_{c.Rd} := \frac{A \cdot f_{y\_k\_1.0570\_T20°}}{\gamma_M}$$

$N_{c.Rd} = 1881.5\,kN$

$$\frac{N_{II\_d}}{N_{c.Rd}} = 0.353$$

$$M_{c.Rd} := \frac{W_y \cdot f_{y\_k\_1.0570\_T20°}}{\gamma_M}$$

$M_{c.Rd} = 261.057\,kN \cdot m$

$$\frac{M_{II\_d}}{M_{c.Rd}} = 0.39$$

$$\frac{N_{II\_d}}{N_{c.Rd}} + \frac{M_{II\_d}}{M_{c.Rd}} = 0.743$$

fulfilled

4.6.) Proof of Stability: Formwork (EN1993-1-1: 6.3.2)

$N_{II\_d} = 664.063\,kN$ $\quad M_{II\_d} = 101.826\,kN \cdot m$ $\quad M_{Ed} := M_{II\_d}$

$$\sigma_o := \frac{N_{II\_d}}{A} + \frac{M_{II\_d}}{W_y} \qquad \sigma_u := \frac{N_{II\_d}}{A} - \frac{M_{II\_d}}{W_y}$$

$$\sigma_o = 239.785 \frac{N}{mm^2} \qquad \sigma_u = -11.976 \frac{N}{mm^2}$$

$$\psi := \frac{\sigma_u}{\sigma_o} \qquad \psi = -0.05$$

classification of section IPE360:

$c_{web} := 248$

$t_{web} := 7.1$

$$\frac{c_{web}}{t_{web}} = 34.93$$

$\varepsilon_1 := 0.81$ — acc. to EN1993-1-1; Tab.5.2

$$\frac{42 \cdot \varepsilon_1}{0.67 + 0.33 \cdot \psi} = 52.057$$

section class web: 3

$c_{flange} := 56.45$

$t_{flange} := 10.7$

$$\frac{c_{flange}}{t_{flange}} = 5.276$$

$9 \cdot \varepsilon_1 = 7.29$

section class flange: 1

choosen buckling length between two support point:

$b_0 := 2.85m$ $\quad s_k := 2850mm$

factors for calculating the resisting moment against lateral torsional buckling:

$\alpha_{LT} := 0.21$ $\quad \lambda_{LT.0} := 0.4$ $\quad \beta := 0.75$

safety factor on material acc. to EN1993-1-1; 6.1

$\gamma_M = 1.1$

calculating the ideal lateral torsional buckling moment acc. to DIN18800-2:

$\xi := 1.12$ acc. to DIN18800-2 Tab.10

$$N_{Ki.z} := \frac{\pi^2 E_{cal} \cdot I_z}{b_0^{\,2}} \qquad N_{Ki.z} = 2181.872\,kN$$

$$c := \sqrt{\frac{I_\omega + 0.039 \cdot b_0^{\,2} \cdot I_T}{I_z}}$$

$$M_{cr} := \xi \cdot N_{Ki.z} \cdot \left(\sqrt{c^2 + 0.25 \cdot z_p^{\,2}} + 0.5 \cdot z_p\right)$$ ideal lateral torsional buckling moment

$M_{cr} = 476.491\,kN \cdot m$

factors for calculating the resisting moment against lateral torsional buckling

$$\lambda_{LT} := \sqrt{\frac{W_y \cdot f_{y\_k\_1.0570\_T20°}}{M_{cr}}} \qquad \lambda_{LT} = 0.776$$

$$\Phi_{LT} := 0.5 \cdot \left[1 + \alpha_{LT} \cdot \left(\lambda_{LT} - \lambda_{LT.0}\right) + \beta \cdot \lambda_{LT}^{\,2}\right]$$

$$X_{LT} := \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^{\,2} - \left(\beta \cdot \lambda_{LT}\right)^2}} \qquad X_{LT} = 0.792$$

$$M_{b.Rd} := X_{LT} \cdot W_y \cdot \frac{f_{y\_k\_1.0570\_T20°}}{\gamma_M} \qquad M_{b.Rd} = 206.776\,kN \cdot m$$

check against lateral torsional buckling:

$$\frac{M_{Ed}}{M_{b.Rd}} = 0.492$$ fulfilled

$$N_{Ki.z} := \frac{\pi^2 E_{cal} \cdot I_z}{s_k^{\,2}} \qquad N_{Ki.z} = 2181.872\,kN$$

$$z_p := \frac{-148mm}{2}$$

$i_z := 3.79cm$

$$k_{LT} := 1 - \frac{\mu_{LT} \cdot N_{Sd}}{X_z \cdot \frac{A \cdot f_{y\_k}}{\gamma_M}} \qquad N_{Sd} := N_{II\_d}$$

$$\mu_{LT} := 0.15 \cdot \lambda_z \cdot \beta_{M.LT} - 0.15$$

$$\lambda_z := \frac{s_k}{i_z} \qquad \lambda_z = 75.198$$

$$\lambda_{z\_strich} := \frac{\lambda_z}{76.4}$$ for S355J2G3

$$\lambda_{z\_strich} = 0.984 \qquad X_z := 0.675$$

$$\beta_{M.LT} := 1.3$$

$$\mu_{LT} := 0.15 \cdot \lambda_{z\_strich} \cdot \beta_{M.LT} - 0.15 \qquad \mu_{LT} = 0.042$$

$$k_{LT} := 1 - \frac{\mu_{LT} \cdot N_{Sd}}{X_z \cdot \frac{A \cdot f_{y\_k\_1.0570\_T20°}}{\gamma_M}} \qquad k_{LT} = 0.978$$

$$\xi := 1.12$$

$$c := \sqrt{\frac{I_\omega + 0.039 \cdot s_k^2 \cdot I_T}{I_z}} \qquad N_{Ki.z} = 2181.872\,kN$$

$$M_{cr} := \xi \cdot N_{Ki.z} \cdot \left(\sqrt{c^2 + 0.25 \cdot z_p^2} + 0.5 \cdot z_p\right)$$ ideal lateral torsional buckling moment

$$M_{cr} = 394.576\,kN \cdot m \qquad \alpha_{LT} := 0.21$$

factors for calculating the resisting moment against lateral torsional buckling:

$$\lambda_{LT} := \sqrt{\frac{W_y \cdot f_{y\_k\_1.0570\_T20°}}{M_{cr}}} \qquad \lambda_{LT} = 0.853$$

$$\Phi_{LT} := 0.5 \cdot \left[1 + \alpha_{LT} \cdot (\lambda_{LT} - 0.2) + \lambda_{LT}^2\right]$$

$$X_{LT} := \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}} \qquad X_{LT} = 0.764$$

$$\frac{N_{II\_d}}{X_z \cdot A \cdot \frac{f_{y\_k\_1.0570\_T20°}}{\gamma_M}} + \frac{k_{LT} \cdot M_{II\_d}}{X_{LT} \cdot W_y \cdot \frac{f_{y\_k\_1.0570\_T20°}}{\gamma_M}} = 1.02$$

4.7. Polygone Rings

action on polygone ring:

$RP_{max} := 6348 \frac{N}{m^2}$ distributed surface load on roof

$b_0 = 2.85\,m$ distance between two rings

$q_{poly} := RP_{max} \cdot b_0 \quad q_{poly} = 18.092 \frac{kN}{m}$ load on one polygone ring

$l_{max.poly} := 2m$ max. length of on polygon edge

$M_{poly} := \frac{q_{poly} \cdot l_{max.poly}^2}{8}$ bending moment in polygone edge

$M_{poly} = 9.046\,kN \cdot m$

$W_{poly.min} := \frac{M_{poly}}{\frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m}}$ minimal need section modulus

$W_{poly.min} = 28.03\,cm^3$

choosen porfile: L150x75x9 $g_{poly} := 0.154 \frac{kN}{m}$

$I_{poly.cor} := 361.5cm^4$ Moment of Inertia in corroded condition

$z_{max} := 96mm$

$W_{poly.cor} := \frac{I_{poly.cor}}{z_{max}}$ section modulud in corroded condition

proof of integrity:

$\frac{W_{poly.min}}{W_{poly.cor}} = 0.744$ < 1 fulfilled

4.8.) Cross bracing against Rotation: Proof of Integrity and Stability

assumption: The inner wo fields of each segment with cross bracing are not taken into consideration, as the bracings have a very large length/height ratio.

choosen Profile: U160 out of S355J2G3 $A_{cor} := 18.6\,cm^2$ $g_{cb} := 0.188\,\frac{kN}{m}$

$n_{supseg} := 4$ number of segments with cross bracing

$N_{cb} := \frac{N_{II\_d}}{100} \cdot \frac{n_{form}}{n_{supseg}}$ $N_{cb} = 86.328\,kN$

$l_{cb} := 3.057\,m$ length of cross bracing

$b_{field} := 2.88\,m$ middled width of field

$F_{cb} := N_{cb} \cdot \frac{l_{cb}}{b_{field}}$ $F_{cb} = 91.634\,kN$

<u>proof of integrity:</u>

$A_{min} := \frac{F_{cb}}{f_{y\_k\_1.0570\_T20°}} \cdot \gamma_m$ $A_{min} = 2.839\,cm^2$

$\frac{A_{cor}}{A_{min}} = 6.551$ > 1 fulfilled

<u>proof of stability:</u>

$I_{z.cor} := 62.5\,cm^4$

$i_{z.cor} := \sqrt{\frac{I_{z.cor}}{A_{cor}}}$ $i_{z.cor} = 1.833\,cm$

$s_k := l_{cb}$

$\lambda_z := \frac{s_k}{i_{z.cor}}$ $\lambda_z = 166.768$

$\lambda_{z\_strich} := \frac{\lambda_z}{76.4}$ for S355J2G3 $\lambda_{z\_strich} = 2.183$

$X := 0.169$

$N_{b.rd} := \frac{X \cdot A_{cor} \cdot f_{y\_k\_1.0570\_T20°}}{\gamma_m}$ $N_{b.rd} = 101.446\,kN$

$N_{Sd} := F_{cb}$

$\frac{N_{Sd}}{N_{b.rd}} = 0.903$ < 1 fulfilled

4.9.) Dead Load of Roof Support Construction

main rafters:

$F_{rafter} := b \cdot n_{form} \cdot g_{form\_real}$ $\qquad F_{rafter} = 484.311\,kN$

support rings:

$F_{poly1} := (D_{tank} - 2 \cdot l_2) \cdot \pi \cdot g_{poly}$ $\qquad F_{poly1} = 13.88\,kN$ $\qquad l_2 = 1.656\,m$

$F_{poly2} := (D_{tank} - 4 \cdot l_2) \cdot \pi \cdot g_{poly}$ $\qquad F_{poly2} = 12.278\,kN$

$$F_{sup1} := \frac{D_{tank} - 4 \cdot l_y - 2 \cdot b_0}{2} \cdot \pi \cdot g_{poly} \qquad F_{sup1} = 4.637\,kN$$

$$F_{sup2} := \frac{D_{tank} - 4 \cdot l_y - 4 \cdot b_0}{2} \cdot \pi \cdot g_{poly} \qquad F_{sup2} = 3.258\,kN$$

$F_{cb} := 4 \cdot 4 \cdot l_{cb} \cdot g_{cb}$ $\qquad F_{cb} = 9.195\,kN$

$F_{sup4} := 0$ $\qquad F_{sup4} = 0\,kN$

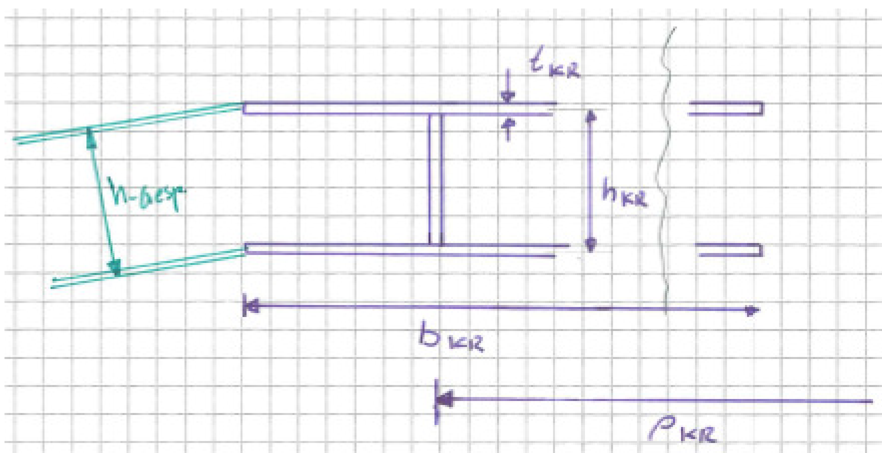
$F_{form\_real} := F_{rafter} + F_{poly1} + F_{poly2} + F_{sup1} + F_{sup2} + F_{cb} + F_{sup4}$ $\qquad F_{form\_real} = 527.558\,kN$

5.) Roof: Crown Ring acc. to VdTÜV

profile formwork: IPE 360

diameter crown ring $D_{KR} := 0.1 \cdot D_{tank}$ $D_{KR} = 3.2\,m$ Rafters are welded completly to crown ring

radius crown ring $\rho_{KR} := \frac{D_{KR}}{2}$ $\rho_{KR} = 1.6\,m$



heigth: $h_k := 330mm$

width $b_k := 720mm$ .... $> 2 \cdot h_k$

flange thickness: $t := 30mm$

no. of rafters $n_{form} = 52$

J.y of rafters (incl. roof shell) $J_y = 13347\,cm^4$

$A_o := t \cdot b_k$ $A_u := t \cdot b_k$

$A_o = 21600\,mm^2$ $A_u = 21600\,mm^2$

conditions:

$h_k^2 \cdot \frac{A_o \cdot A_u}{A_o + A_u} = 117612\,cm^4$ $>$ $\frac{n_{form}}{2 \cdot \pi} \cdot J_y = 110460.533\,cm^4$ Gl 21-36

moments II. Order at crown ring

$$M_{K\_II\_d} := \left(1 - \frac{\rho_{KR}}{\frac{D_{tank}}{2}}\right) \cdot M_{II\_d}$$ Gl 21-37

$M_{K\_II\_d} = 91.644\,kN \cdot m$

horizontal force at lower crown ring flange

$$e_o := \frac{h_k}{2}$$

$$H_{u\_d} := \frac{e_o}{h_k} \cdot N_{II\_d} + \frac{M_{K\_II\_d}}{h_k} \qquad N_{II\_d} = 664.063\,kN \qquad \text{Gl 21-38}$$

$$H_{u\_d} = 609.739\,kN$$

moment at lower crown ring flange

$$M_{u\_d} := \left(\frac{n_{form}}{\pi} - \frac{1}{\tan\left(\frac{\pi}{n_{form}}\right)}\right) \cdot \rho_{KR} \cdot H_{u\_d} \cdot 0.5 \qquad \text{Gl 21-39}$$

$$M_{u\_d} = 9.826\,kN \cdot m$$

section modulus of lower crown ring flange

$$W_u := \frac{A_u \cdot b_k}{6} \qquad \text{Gl 21-40}$$

$$W_u = 2592\,cm^3$$

ring force in lower crown ring flange

$$R_{u\_d} := \frac{H_{u\_d}}{2 \cdot \frac{\pi}{n_{form}}} \qquad \text{Gl 21-41}$$

$$R_{u\_d} = 5046.235\,kN$$

proof of integrity of crown rings

$$\frac{\frac{R_{u\_d}}{A_u} + \frac{M_{u\_d}}{W_u}}{\frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m}} = 0.74 \qquad . < 1$$

$$G_{crown} := \left[b_k \cdot t \cdot D_{KR} \cdot \pi + 2 \cdot \left[\left(D_{KR} + b_k\right)^2 - \left(D_{KR} - b_k\right)^2\right] \cdot \frac{\pi}{4} \cdot t\right] \cdot \gamma_{steel}$$

$$G_{crown} = 51.138\,kN$$

6.) Roof: Corner Ring acc. to VdTÜV

6.1.) Design

distance between rafters:

$$\frac{D_{tank} \cdot \pi}{n_{form}} = 1.93\,m$$ $n_{form} = 52$

$t_M := 9mm$ shell thickness of last round

$t_D = 6\,mm$ thickness of roof plates at corner ring

$c_1 := 0.40mm$ $c_2 := 1mm$ corrosion allowance and manufacturing tolerance

effective width of shell plate:

$$b_{mM} := 0.78 \cdot \sqrt{\frac{D_{tank}}{2} \cdot (t_M - c_1 - c_2)}$$ $D_{tank} = 32\,m$

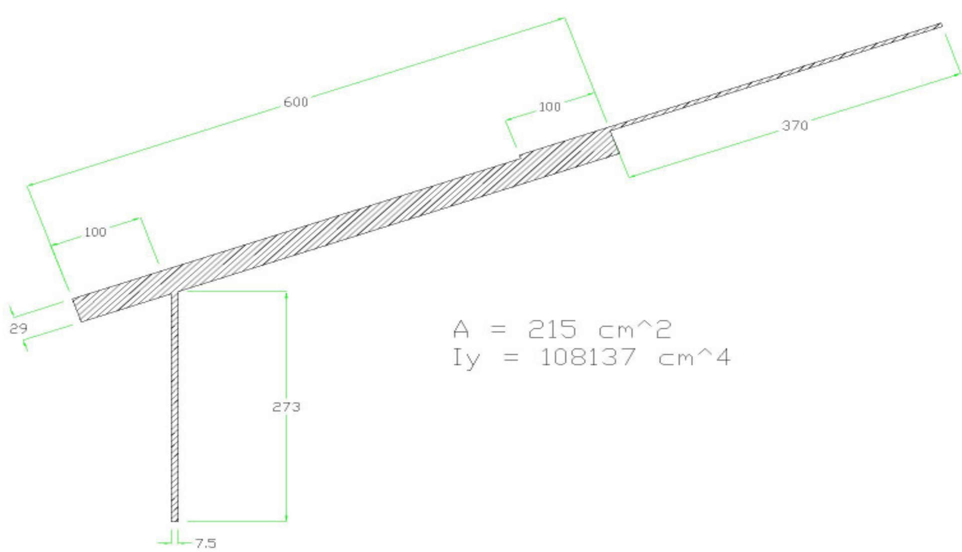
$b_{mM} = 271.995\,mm$

effective width of roof plate:

$$b_{mD} := 0.78 \cdot \sqrt{r_{roof} \cdot (t_D - c_1 - c_2)}$$ $r_{roof} = 48\,m$ allowed if: double welded overlaps on tension or butt welded joints

$b_{mD} = 366.517\,mm$

sketch:



$b_{corner} := 600mm$ $t_{corner} := 30mm$ $U_{corner} := D_{tank} - b_{corner} + 100mm$

$G_{corner} := b_{corner} \cdot t_{corner} \cdot U_{corner} \cdot \gamma_{steel}$ $G_{corner} = 44.509\,kN$

load combinations for roof corner ring design:

$RCoR_1 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_2 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_3 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_4 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_5 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_6 := 1.35 \cdot EG2 + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_7 := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_8 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_9 := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{10} := 1.35 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{11} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{12} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{13} := 1.35 \cdot EG2 + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{14} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS - 1.0 \cdot 1.35 \cdot 0.9 \cdot BÜ$

$RCoR_{15} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 0.0 \cdot 0.00 \cdot 0.0 \cdot BÜ$

$RCoR_{16} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RCoR_{17} := 1.00 \cdot EG2 + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS - 1.0 \cdot 1.35 \cdot 1.0 \cdot BÜ$

$RCoR_i =$

6885
2763
4284
1413
6885
4185
4455
2875
4565
1755
7155
7455
4455
-2155
161
-1400
-2539

$\frac{N}{m^2}$

$RCoR_{max} := max(RCoR)$ $\quad RCoR_{max} = 7455 \frac{N}{m^2}$

$RCoR_{min} := |min(RCoR)|$ $\quad RCoR_{min} = 2539.063 \frac{N}{m^2}$

ring forces

The maximum load combination that evokes axial tension force: EK12

$$RCoR_{max} = 7455 \frac{N}{m^2}$$

$$p_d := RCoR_{max}$$

$$N_{R\_d} := \frac{p_d \cdot D_{tank}^2}{8 \cdot \tan\left(\alpha \cdot \frac{\pi}{180}\right)} \qquad N_{R\_d} = 2699.181\,kN$$

proof of integrity:

$$A_p := 215cm^2$$

$$A_R := A_p \qquad A_R = 215\,cm^2$$

$$N_{R\_d} = 2699.181\,kN \quad < \quad A_R \cdot \frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m} = 6938.636\,kN \quad \text{Gl 21-47}$$

The maximum load combination that evokes axial tension force: EK17

$$EK_{druck} := 2540 \frac{N}{m^2}$$

$$p_d := EK_{druck}$$

$$N_{R\_d} := \frac{p_d \cdot D_{tank}^2}{8 \cdot \tan\left(\alpha \cdot \frac{\pi}{180}\right)}$$

$$N_{R\_d} = 919.641\,kN$$

$$s_K := \pi \cdot \frac{\frac{D_{tank}}{2}}{\sqrt{3}}$$ Knicklänge Gl 19-17

$$s_K = 29.021\,m$$

$A_{ER} := A_R$ $A_{ER} = 215\,cm^2$ section area

$I_{ER} := 108137cm^4$ Moment of Inertia for the vertical axís

$$\lambda_K := s_K \cdot \sqrt{\frac{A_{ER}}{I_{ER}}}$$ $\lambda_K = 129.402$ Gl 19-18

$$\lambda_a := \pi \cdot \sqrt{\frac{E_{cal}}{f_{y\_k\_1.0570\_T20°}}}$$ $\lambda_a = 76.772$ Gl 19-19

Weil $\lambda_K > \lambda_a$ gilt Gl 19-20

$$N_{R\_d} = 919.641\,kN \quad < \quad \frac{\pi^2 \cdot E_{cal} \cdot I_{ER}}{2 \cdot \gamma_m \cdot s_K^2} = 1221.149\,kN$$ Gl. 19-20

6.2.) Dimensions of the tear seam:

$EK_{druck} = 2540 \frac{N}{m^2}$

$O_{dome} = 827.923\,m^2$ surface of dome

$F_{horiz} := EK_{druck} \cdot O_{dome}$

$F_{horiz} = 2102.923\,kN$

$\alpha = 19.47$

$F_{shear} := \frac{F_{horiz}}{\sin\left(\alpha \cdot \frac{\pi}{180}\right)}$

$F_{shear} = 6309.15\,kN$

$a := 3mm$

$\tau := \frac{F_{shear}}{D_{tank} \cdot \pi \cdot a}$ weld thickness of tear seam

$\tau = 20.919 \frac{N}{mm^2}$

$S_d := \tau$ Einwirkung (bereits mit Teilsicherheitsbeiwert aufgewertet)

$\alpha_w := 0.8$ weld factor DIN 18800 for shear stresses

$\gamma_m = 1.1$

$R_d := \alpha_w \cdot \frac{f_{y\_k\_1.0570\_T20°}}{\gamma_m}$

$R_d = 258.182 \frac{N}{mm^2}$

$\frac{S_d}{R_d} = 0.08$ $S_d = 20.919 \frac{N}{mm^2}$. < . $R_d = 258.182 \frac{N}{mm^2}$

6.3.) Verification of Construction Details

6.3.1.) Weld between roof plates

$a_{w.roof} \geq 3mm$ welded from the outside only

6.3.2.) Force transmission via bolt: Formwork/Shell (during construction)

$EG2 = 1300 \frac{N}{m^2}$

$F_{vert} := EG2 \cdot \frac{D_{tank}^2 \cdot \pi}{4}$ $F_{vert} = 1045.522\,kN$

$F_{bolt\_shear} := \frac{F_{vert}}{n_{form}}$ $F_{bolt\_shear} = 20.106\,kN$

Bolts choosen: 52 x M22 $F_{bolt\_shear\_ult} := 82.9kN$ in each shear joint

$F_{bolt\_shear\_ult\_res} := 2 \cdot F_{bolt\_shear\_ult}$

$\frac{F_{bolt\_shear}}{F_{bolt\_shear\_ult\_res}} = 0.121$ < 1

6.3.2.) Force transmission via bolt: bolt/rip (during construction)

$F_{bore\_ult} := 51.6kN$ for distance bore hole to edge of the rip in force direction > 30 mm; rip thickness > 10 mm

$\frac{F_{bolt\_shear}}{F_{bore\_ult}} = 0.39$ < 1

7.) Shell

acc. to VdTÜV

7.1.) Minimum shell thickness

$t_{min} := 6mm$ acc. to specification

7.2.) Proof of Integrity for shell

condition: operating overpressure + filling

operating overpressure $BÜ = 2000 \frac{N}{m^2}$

max. density of filling $\gamma_{diesel} = 8.6 \frac{kN}{m^3}$

tolerance - corrosion $c_1 = 0.4\,mm$ $c_2 = 1\,mm$

The heigth of the tank is divided into 7 rounds:

round no.	height	thickness	material
7	2,3	9	1.0116
6	2,4	9	1.0116
5	2,4	10	1.0570
4	2,4	11	1.0570
3	2,4	11	1.0570
2	2,4	12	1.0570
1	2,4	13	1.0570
H =	16,7	m	

Wall thickness acc. to EN14015:

rounds i: $i := 1 .. 7$

elevation of the lower edge of the round meassured from the top edge of the cylindrical height of the tank:

$H_{c_1} := 16.7$ $H_{c_2} := 14.3$ $H_{c_3} := 11.9$ $H_{c_4} := 9.5$ $H_{c_5} := 7.1$ $H_{c_6} := 4.7$

$H_{c_7} := 2.3$

thickness for operating conditions:

$$e_{c_i} := \frac{D_{tank}}{20m \cdot 236} \cdot \left[98 \cdot 0.86 \cdot \left(H_{c_i} - 0.3\right) + 20\right] + 1$$

$e_{c_i} =$

10.506
9.135
7.764
6.392
5.021
3.65
2.278

thickness for test conditions:

$$e_{ct_i} := \frac{D_{tank}}{20m \cdot 322} \cdot \left[98 \cdot 1.0 \cdot \left(H_{c_i} - 0.3\right) + 20\right] + 1$$

$e_{ct_i} =$

9.085
7.917
6.748
5.579
4.411
3.242
2.073

choosen thicknesses due to buckling effects:

$t_1 := 13mm$ $\quad t_5 := 10mm$

$t_2 := 12mm$ $\quad t_6 := 9mm$

$t_3 := 11mm$ $\quad t_7 := 9mm$

$t_4 := 11mm$

7.3.) Proof of Stability: Shell

7.3.1.) Buckling Field 1a:

7.3.1.1. Actions at h = 0 m:

axial directions:

G dead load:

roof: $EG2 = 1300 \frac{N}{m^2}$ as there are no changes over the height, this value is not mentioned in further steps

$EG_{Dach} := EG2 \cdot O_{dome}$ $EG_{Dach} = 1076.299 kN$

shell plates: $\gamma_{St} := 7850 \frac{kg}{m^3}$ $u := 9.81 \cdot \frac{m}{s^2}$

S7 $t_7 = 9mm$ $h_7 := 2.3m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 160.3kN$

S_6 $t_6 = 9mm$ $h_6 := 2.4m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 167.3kN$

S_5 $t_5 = 10mm$ $h_5 := 2.4m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 185.9kN$

S_4 $t_4 = 11mm$ $h_4 := 2.4m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 204.5kN$

S_3 $t_3 = 11mm$ $h_3 := 2.4m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 204.5kN$

S_2 $t_2 = 12mm$ $h_2 := 2.4m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 223kN$

S_1 $t_1 = 13mm$ $h_1 := 2.4m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 241.6kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 1387.018kN$

steel structure: $F_{structure} = 100kN$

$$T_t := \frac{E_{MG} + F_{structure}}{kN} \cdot \frac{1000}{9.81}$$ $T_t = 151581.839$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 2563.317kN$ $G_{Tank.1} := G$

BU operating underpressure; as there are no changes over the height, this value is not mentioned in further steps

$$BU := p_u \cdot D_{tank}^2 \cdot \frac{\pi}{4}$$

$BU = 1608.495kN$

S snow/other load; as there are no changes over the height, this value is not mentioned in further steps:

$$s_s := 2000 \frac{N}{m^2}$$

$$T_r := \frac{EG_{Dach} + 0.0S}{kN} \cdot \frac{1000}{9.81}$$

$$S := s_s \cdot D_{tank}^2 \cdot \frac{\pi}{4} \qquad S = 1608.495\,kN$$

WU underpressure due to wind; as there are no changes over the height, this value is not mentioned in further steps:

$$WU := 0.4 \cdot q_0 \cdot \left(D_{tank}^2 \cdot \frac{\pi}{4}\right)$$

$$WU = 407.15\,kN$$

WS relieving wind suction; as there are no changes over the height, this value is not mentioned in further steps:

$$WS_1 := 0.6 \cdot q_0 \cdot \left(D_{tank}^2 \cdot \frac{\pi}{4}\right)$$

$$WS_1 = 610.726\,kN$$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266 \frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H1} := c \cdot q_0 \cdot D_{tank} \cdot 13m \cdot 0.5 \qquad F_{W\_H1} = 216.685\,kN$$

$$F_{W\_H2} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H2} = 146.679\,kN$$

$$F_{W.1} := F_{W\_H1} + F_{W\_H2} \qquad F_{W.1} = 363.364\,kN$$

wind: suction

$$F_{W\_So} := WS_1 \qquad F_{W\_So} = 610.726\,kN$$

wind: moment

$M_W := F_{W\_H1} \cdot \frac{2}{3} \cdot 13m + F_{W\_H2} \cdot 15.2m$ $\quad M_W = 4107.462\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ VdTÜV $\quad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges.1} := M_W + M_{w\_Sog}$

$M_{w\_ges.1} = 5084.623\,kN \cdot m$ $\quad A := D_{tank}^{\,2} \cdot \frac{\pi}{4}$ $\quad U := D_{tank} \cdot \pi$

$MW_1 := \frac{M_{w\_ges.1}}{A} \cdot U$

$MW_1 = 635.578\,kN$

radial directions:

BU operating underpressure; as there are no changes over the height, this value is not mentioned in further steps

$BU_{rad} := p_u$ $\quad BU_{rad} = 2000\,\frac{N}{m^2}$

WU underpressure due to wind; as there are no changes over the height, this value is not mentioned in further steps:

Windunterdruck

$WU_{rad} := 0.4 \cdot q_0$ $\quad WU_{rad} = 506.25\,\frac{N}{m^2}$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 2.0m$

middled wall thickness over buckling field: $t_m := 13mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\delta = 1.231$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \ge 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\quad W := \delta \cdot q_0$ $\quad W = 1265.625\,\frac{N}{m^2}$

7.3.1.2. Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]: $j := 1..19$

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_1 - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_1 - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_1 - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

6534.085	kN
7603.044	
6534.085	
7603.044	
5448.351	
5129.416	
5923.549	
4043.682	
6751.232	
7820.191	
5665.498	
6875.597	
8063.329	
5631.947	
5314.854	
6197.223	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 8063.329\,kN$$

radial direction:

$k := 1 .. 12$

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$

$\frac{N}{m^2}$
4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\ \text{mbar}$

Calculation of Buckling: Appendix A

7.3.2. Buckling Field 1b: not calculated!

7.3.2.1. Actions at $h_{field} := 2.0m$

axial direction:

G dead load:

S7 $t_7 = 9\,mm$ $h_7 := 2.3m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 160.3\,kN$

S_6 $t_6 = 9\,mm$ $h_6 := 2.4m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 167.3\,kN$

S_5 $t_5 = 10\,mm$ $h_5 := 2.4m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 185.9\,kN$

S_4 $t_4 = 11\,mm$ $h_4 := 2.4m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 204.5\,kN$

S_3 $t_3 = 11\,mm$ $h_3 := 2.4m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 204.5\,kN$

S_2 $t_2 = 12\,mm$ $h_2 := 2.4m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 223\,kN$

S_1 $t_1 = 13\,mm$ $h_1 := 0.4m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 40.3\,kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 1185.651\,kN$

steel structure: $F_{structure} = 100\,kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 2361.95\,kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266 \frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 211.557\,kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679\,kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 358.236\,kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot \left(13m - h_{field}\right) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 3810.274\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ $\qquad$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 4787.435\,kN \cdot m$ $\qquad A := D_{tank}^{\;2} \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 598.429\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ $\qquad$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1m$

middled wall thickness over buckling field:

$t_m := 12mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right) \qquad \delta = 1.572 \qquad . < .1$$

$$\delta := \begin{cases} 1 & \text{if } \delta \ge 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.2.2.) load combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

6212.089	kN
7306.124	
6212.089	
7306.124	
5126.355	
4807.42	
5626.628	
3721.686	
6429.236	
7523.27	
5343.502	
6548.029	
7763.623	
5360.102	
4987.286	
5897.517	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 7763.623\,kN$$

radial direction:

$$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$$RAD_{max} := \max(RAD)$$

$$RAD_{max} = 45.984\,\text{mbar}$$

7.3.3. Buckling Field 2

7.3.3.1. Actions at $h_{field} := 3.0m$

axial direction:

G dead load:

S7	$t_7 = 9mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$	$E_7 = 160.3kN$
S_6	$t_6 = 9mm$	$h_6 := 2.4m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$	$E_6 = 167.3kN$
S_5	$t_5 = 10mm$	$h_5 := 2.4m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$	$E_5 = 185.9kN$
S_4	$t_4 = 11mm$	$h_4 := 2.4m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$	$E_4 = 204.5kN$
S_3	$t_3 = 11mm$	$h_3 := 2.4m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$	$E_3 = 204.5kN$
S_2	$t_2 = 12mm$	$h_2 := 1.8m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$	$E_2 = 167.3kN$
S_1	$t_1 = 13mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$	$E_1 = 0kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$	$E_{MG} = 1089.616kN$
			steel structure:	$F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $\quad G = 2265.915kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$q_0 = 1.266\frac{kN}{m^2}$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 205.146kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 351.825kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 3626.498\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 4603.659\,kN \cdot m$ $\qquad A := D_{tank}^2 \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 575.457\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1.9m$

middled wall thickness over buckling field:

$t_m := 12mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right) \qquad \delta = 1.267$$

. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625 \frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625 \frac{N}{m^2}$

7.3.3.2.) load combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

6051.43	kN
7160.97	
6051.43	
7160.97	
4965.696	
4646.761	
5481.475	
3561.027	
6268.577	
7378.117	
5182.842	
6383.924	
7616.747	
5230.455	
4823.181	
5750.641	

$F_{AX} := \max(AX)$

$F_{AX} = 7616.747\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$

RAD_k ($\frac{N}{m^2}$)
4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := max(RAD)$

$RAD_{max} = 45.984\ mbar$

7.3.4. Buckling Field 3:

7.3.4.1.) Actions at $h_{field} := 4.9m$

axial direction

→ G dead load:

S7 $t_7 = 9\,mm$ $h_7 := 2.3m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 160.3\,kN$

S_6 $t_6 = 9\,mm$ $h_6 := 2.4m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 167.3\,kN$

S_5 $t_5 = 10\,mm$ $h_5 := 2.4m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 185.9\,kN$

S_4 $t_4 = 11\,mm$ $h_4 := 2.4m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 204.5\,kN$

S_3 $t_3 = 11\,mm$ $h_3 := 2.3m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 195.9\,kN$

S_2 $t_2 = 12\,mm$ $h_2 := 0m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 0\,kN$

S_1 $t_1 = 13\,mm$ $h_1 := 0m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 0\,kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 913.813\,kN$

steel structure: $F_{structure} = 100\,kN$

→ $G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 2090.112\,kN$

→ MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\,\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 185.9\,kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679\,kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 332.58\,kN$$

wind: suction

$F_{W\_So} := WS_1$ $\quad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\quad M_W = 3262.722\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\quad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 4239.883\,kN \cdot m$ $\quad A := D_{tank}^2 \cdot \frac{\pi}{4}$ $\quad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 529.985\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 2m$

middled wall thickness over buckling field:

$t_m := 11mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\delta = 1.263$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625 \frac{N}{m^2}$ $\quad W := \delta \cdot q_0$ $\quad W = 1265.625 \frac{N}{m^2}$

7.3.4.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_j =$

5752.709	kN
6892.943	
5752.709	
6892.943	
4666.974	
4348.04	
5213.447	
3262.305	
5969.856	
7110.09	
4884.121	
6078.382	
7345.308	
4993.12	
4517.638	
5479.202	

$F_{AX} := \max(AX)$

$F_{AX} = 7345.308\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\ \text{mbar}$

7.3.5. Buckling Field 4

7.3.5.1.) Actions at $h_{field} := 6.9m$

axial direction:

G dead load:

S7 $t_7 = 9mm$ $h_7 := 2.3m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 160.3kN$

S_6 $t_6 = 9mm$ $h_6 := 2.4m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 167.3kN$

S_5 $t_5 = 10mm$ $h_5 := 2.4m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 185.9kN$

S_4 $t_4 = 11mm$ $h_4 := 2.4m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 204.5kN$

S_3 $t_3 = 11mm$ $h_3 := 0.3m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 25.6kN$

S_2 $t_2 = 12mm$ $h_2 := 0m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 0kN$

S_1 $t_1 = 13mm$ $h_1 := 0m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 0kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 743.436kN$

steel structure: $F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1919.735kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$q_0 = 1.266\frac{kN}{m^2}$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 155.641kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 302.321kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 2891.802\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3868.963\,kN \cdot m$ $\qquad A := D_{tank}^2 \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 483.62\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 2.0m$

middled wall thickness over buckling field:

$t_m := 12mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right) \qquad \delta = 1.246 \qquad . < .1$$

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.5.2.) **Load Combinations**

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

5460.107	kN
6631.638	
5460.107	
6631.638	
4374.373	
4055.438	
4952.142	
2969.704	
5677.254	
6848.784	
4591.52	
5778.825	
7080.526	
4763.112	
4218.082	
5214.42	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 7080.526\,kN$$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ ($\frac{N}{m^2}$)

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\ \text{mbar}$

7.3.6. Buckling Field 5

7.3.6.1.) Action at $h_{field} := 8.9m$

axial direction

G dead load:

S7	$t_7 = 9mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7)\cdot\pi\cdot t_7\cdot h_7\cdot\gamma_{St}\cdot u$	$E_7 = 160.3kN$
S_6	$t_6 = 9mm$	$h_6 := 2.4m$	$E_6 := (D_{tank} + t_6)\cdot\pi\cdot t_6\cdot h_6\cdot\gamma_{St}\cdot u$	$E_6 = 167.3kN$
S_5	$t_5 = 10mm$	$h_5 := 2.4m$	$E_5 := (D_{tank} + t_5)\cdot\pi\cdot t_5\cdot h_5\cdot\gamma_{St}\cdot u$	$E_5 = 185.9kN$
S_4	$t_4 = 11mm$	$h_4 := 0.7m$	$E_4 := (D_{tank} + t_4)\cdot\pi\cdot t_4\cdot h_4\cdot\gamma_{St}\cdot u$	$E_4 = 59.6kN$
S_3	$t_3 = 11mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3)\cdot\pi\cdot t_3\cdot h_3\cdot\gamma_{St}\cdot u$	$E_3 = 0kN$
S_2	$t_2 = 12mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2)\cdot\pi\cdot t_2\cdot h_2\cdot\gamma_{St}\cdot u$	$E_2 = 0kN$
S_1	$t_1 = 13mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1)\cdot\pi\cdot t_1\cdot h_1\cdot\gamma_{St}\cdot u$	$E_1 = 0kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$	$E_{MG} = 573.059kN$
			steel structure:	$F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $\quad G = 1749.359kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100\cdot\frac{D_{tank} + w}{D_{tank}} - 90.2}\right)\cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c\cdot\frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right)\cdot D_{tank}\cdot(13m - h_{field}) \qquad F_{W\_H3} = 115.125kN$$

$$F_{W\_H4} := c\cdot q_0\cdot D_{tank}\cdot 4.4m \qquad F_{W\_H4} = 146.679kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 261.804kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 2573.535\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3550.696\,kN \cdot m$ $\qquad A := D_{tank}^{2} \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 443.837\,kN$

→ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1.1m$

middled wall thickness over buckling field:

$t_m := 10mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\qquad \delta = 1.57$ $\qquad . < .1$

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.6.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

5176.391	kN
6374.775	
5176.391	
6374.775	
4090.657	
3771.722	
4695.28	
2685.988	
5393.538	
6591.922	
4307.803	
5489.142	
6820.68	
4533.103	
3928.398	
4954.574	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 6820.68\,\text{kN}$$

radial direction:

$$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$$RAD_{max} := \max(RAD)$$

$$RAD_{max} = 45.984\,\text{mbar}$$

7.3.7. Buckling Field 6

7.3.7.1.) Action at $h_{field} := 10m$

axial direction

G dead load:

S7	$t_7 = 9\,mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$	$E_7 = 160.3\,kN$
S_6	$t_6 = 9\,mm$	$h_6 := 2.4m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$	$E_6 = 167.3\,kN$
S_5	$t_5 = 10\,mm$	$h_5 := 2.1m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$	$E_5 = 162.6\,kN$
S_4	$t_4 = 11\,mm$	$h_4 := 0m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$	$E_4 = 0\,kN$
S_3	$t_3 = 11\,mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$	$E_3 = 0\,kN$
S_2	$t_2 = 12\,mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$	$E_2 = 0\,kN$
S_1	$t_1 = 13\,mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$	$E_1 = 0\,kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$	$E_{MG} = 490.195\,kN$
			steel structure:	$F_{structure} = 100\,kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $\qquad G = 1666.494\,kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$q_0 = 1.266\,\frac{kN}{m^2}$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 88.469\,kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679\,kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 235.148\,kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 2435.798\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3412.959\,kN \cdot m$ $\qquad A := D_{tank}^{\ 2} \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 426.62\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1.5m$

middled wall thickness over buckling field:

$t_m := 10mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\qquad \delta = 1.41$ $\qquad . < .1$

$$\delta := \begin{cases} 1 & \text{if } \delta \ge 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.7.2.) Load Combinations

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_j =$

5041.281
6251.287
5041.281
6251.287
3955.546
3636.612
4571.791
2550.878
5258.428
6468.434
4172.693
5351.449
6695.9
4421.236
3790.706
4829.794

kN

$F_{AX} := \max(AX)$

$F_{AX} = 6695.9\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\,\text{mbar}$

7.3.8. Buckling Field 7

7.3.8.1.) Action at $h_{field} := 11.5m$

axial direction:

G dead load:

S7	$t_7 = 9\,mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$	$E_7 = 160.3\,kN$
S_6	$t_6 = 9\,mm$	$h_6 := 2.4m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$	$E_6 = 167.3\,kN$
S_5	$t_5 = 10\,mm$	$h_5 := 0.6m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$	$E_5 = 46.5\,kN$
S_4	$t_4 = 11\,mm$	$h_4 := 0m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$	$E_4 = 0\,kN$
S_3	$t_3 = 11\,mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$	$E_3 = 0\,kN$
S_2	$t_2 = 12\,mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$	$E_2 = 0\,kN$
S_1	$t_1 = 13\,mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$	$E_1 = 0\,kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$	$E_{MG} = 374.033\,kN$
			steel structure:	$F_{structure} = 100\,kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1550.332\,kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\,\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 47.119\,kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679\,kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 193.799\,kN$$

wind: suction

$F_{W\_So} := WS_1$ $F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $M_W = 2305.979\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3283.14\,kN \cdot m$ $A := D_{tank}{}^2 \cdot \frac{\pi}{4}$ $U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 410.393\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 0.7m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\delta = 1.888$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $W := \delta \cdot q_0$ $W = 1265.625\,\frac{N}{m^2}$

7.3.8.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

4862.555	kN
6083.514	
4862.555	
6083.514	
3776.82	
3457.886	
4404.019	
2372.151	
5079.702	
6300.661	
3993.967	
5170.289	
6526.91	
4264.417	
3609.546	
4660.804	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 6526.91\,kN$$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\,mbar$

7.3.9. Buckling Field 8

7.3.9.1.) Action at $h_{field} := 12.3m$

axial direction

G dead load:

S7	$t_7 = 9mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$	$E_7 = 160.3kN$
S_6	$t_6 = 9mm$	$h_6 := 2.3m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$	$E_6 = 160.3kN$
S_5	$t_5 = 10mm$	$h_5 := 0m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$	$E_5 = 0kN$
S_4	$t_4 = 11mm$	$h_4 := 0m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$	$E_4 = 0kN$
S_3	$t_3 = 11mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$	$E_3 = 0kN$
S_2	$t_2 = 12mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$	$E_2 = 0kN$
S_1	$t_1 = 13mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$	$E_1 = 0kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 320.598kN$

steel structure: $F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1496.897kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 22.707kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679k$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 169.386kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 2269.456\,kN \cdot$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3246.617\,kN \cdot m$ $\qquad A := D_{tank}^2 \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 405.827\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 0.7m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\delta = 1.888$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.9.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

4784.255	kN
6008.296	
4784.255	
6008.296	
3698.521	
3379.586	
4328.8	
2293.852	
5001.402	
6225.443	
3915.667	
5091.304	
6451.35	
4192.28	
3530.561	
4585.244	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 6451.35\,kN$$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\,\text{mbar}$

7.3.10. Buckling Field 9

7.3.10.1.) Action at axial direction: $h_{field} := 12.73m$ A different heigth of the buckling ring is possible, if the heigth does not varies more than -250 mm

G dead load:

S7 $t_7 = 9mm$ $h_7 := 2.3m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 160.3kN$

S_6 $t_6 = 9mm$ $h_6 := 1.66m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 115.7kN$

S_5 $t_5 = 10mm$ $h_5 := 0m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 0kN$

S_4 $t_4 = 11mm$ $h_4 := 0m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 0kN$

S_3 $t_3 = 11mm$ $h_3 := 0m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 0kN$

S_2 $t_2 = 12mm$ $h_2 := 0m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 0kN$

S_1 $t_1 = 13mm$ $h_1 := 0m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 0kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 275.993kN$

steel structure: $F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1452.293kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$$F_{W\_H3} := c \cdot \frac{q_0}{2}\left(\frac{h_{field}}{13m} + 1\right) \cdot D_{tank} \cdot (13m - h_{field}) \qquad F_{W\_H3} = 8.907kN$$

$$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 4.4m \qquad F_{W\_H4} = 146.679kN$$

$$F_W := F_{W\_H3} + F_{W\_H4} \qquad F_W = 155.586kN$$

wind: suction

$F_{W\_So} := WS_1$ $\qquad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H3} \cdot \frac{2}{3} \cdot (13m - h_{field}) + F_{W\_H4} \cdot 15.4m$ $\qquad M_W = 2260.463\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\qquad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 3237.624\,kN \cdot m$ $\qquad A := D_{tank}^{\,2} \cdot \frac{\pi}{4}$ $\qquad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 404.703\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 0.9m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right) \qquad \delta = 1.719 \qquad . < .1$$

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

7.3.10.2.) Load Combiantion

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial direction:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

4722.521	kN
5947.32	
4722.521	
5947.32	
3636.786	
3317.852	
4267.825	
2232.117	
4939.668	
6164.467	
3853.933	
5029.401	
6390.29	
4132.064	
3468.658	
4524.184	

$$F_{AX} := \max(AX)$$

$$F_{AX} = 6390.29\,kN$$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := max(RAD)$

$RAD_{max} = 45.984\,mbar$

7.3.11 Buckling Field 10

7.3.11.1.) Action at $h_{field} := 13.64m$

axial:

G dead load:

S7	$t_7 = 9mm$	$h_7 := 2.3m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$		$E_7 = 160.3kN$
S_6	$t_6 = 9mm$	$h_6 := 0.76m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$		$E_6 = 53kN$
S_5	$t_5 = 10mm$	$h_5 := 0m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$		$E_5 = 0kN$
S_4	$t_4 = 11mm$	$h_4 := 0m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$		$E_4 = 0kN$
S_3	$t_3 = 11mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$		$E_3 = 0kN$
S_2	$t_2 = 12mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$		$E_2 = 0kN$
S_1	$t_1 = 13mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$		$E_1 = 0kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$		$E_{MG} = 213.267kN$
			steel structure:		$F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1389.567kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$q_0 = 1.266 \frac{kN}{m^2}$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 3.6m$ $F_{W\_H4} = 120.01kN$

$F_W := F_{W\_H4}$ $F_W = 120.01kN$

wind: suction

$F_{W\_So} := WS_1$ $\quad$ $F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H4} \cdot 14.85m$ $\quad$ $M_W = 1782.152\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ $\quad$ DIN 4119 $\quad$ $M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 2759.313\,kN \cdot m$ $\quad$ $A := D_{tank}^{\,2} \cdot \frac{\pi}{4}$ $\quad$ $U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 344.914\,kN$

W $\quad$ rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ $\quad$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $\quad$ $h_{field} := 0.96m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$

$\delta = 1.679$ $\quad$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\quad$ $W := \delta \cdot q_0$ $\quad$ $W = 1265.625\,\frac{N}{m^2}$

7.3.11.2.) Load combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_j =$

4557.126	kN
5822.283	
4557.126	
5822.283	
3471.392	
3152.457	
4142.788	
2066.723	
4774.273	
6039.43	
3688.539	
4855.038	
6260.769	
4047.384	
3294.295	
4394.663	

$F_{AX} := \max(AX)$

$F_{AX} = 6260.769\,kN$

radial direction:

$$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$$

$$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$$

$$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$$

$$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$$

$$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$$

$$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$$RAD_{max} := \max(RAD)$$

$$RAD_{max} = 45.984\ \text{mbar}$$

7.3.12. Buckling field 11

7.3.12.1.) Action at $h_{field} := 14.6m$

axial:

G dead load:

S7 $t_7 = 9\,mm$ $h_7 := 2.16m$ $E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$ $E_7 = 150.5\,kN$

S_6 $t_6 = 9\,mm$ $h_6 := 0m$ $E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$ $E_6 = 0\,kN$

S_5 $t_5 = 10\,mm$ $h_5 := 0m$ $E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$ $E_5 = 0\,kN$

S_4 $t_4 = 11\,mm$ $h_4 := 0m$ $E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$ $E_4 = 0\,kN$

S_3 $t_3 = 11\,mm$ $h_3 := 0m$ $E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$ $E_3 = 0\,kN$

S_2 $t_2 = 12\,mm$ $h_2 := 0m$ $E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$ $E_2 = 0\,kN$

S_1 $t_1 = 13\,mm$ $h_1 := 0m$ $E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$ $E_1 = 0\,kN$

$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$ $E_{MG} = 150.542\,kN$

steel structure: $F_{structure} = 100\,kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $G = 1326.841\,kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$F_{W\_H3} = 8.907\,kN$

$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 2.7m$ $F_{W\_H4} = 90.008\,kN$

$F_W := F_{W\_H4}$ $F_W = 90.008\,kN$

wind: suction

$F_{W\_So} := WS_1$ $\quad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H4} \cdot 15.35m$ $\quad M_W = 1381.618\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \frac{D_{tank}}{20}$ DIN 4119 $\quad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 2358.779\,kN \cdot m$ $\quad A := D_{tank}^{\,2} \cdot \frac{\pi}{4}$ $\quad U := D_{tank} \cdot \pi$

$MW := \frac{M_{w\_ges}}{A} \cdot U$

$MW = 294.847\,kN$

→ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1.0m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$ $\delta = 1.655$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\quad W := \delta \cdot q_0$ $\quad W = 1265.625\,\frac{N}{m^2}$

7.3.12.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

4404.856
5703.808
4404.856
5703.808
3319.122
3000.187
4024.313
1914.453
4622.003
5920.955
3536.269
4695.258
6138.539
3962.704
3134.515
4272.433

kN

$$F_{AX} := \max(AX)$$

$$F_{AX} = 6138.539\,kN$$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ ($\frac{N}{m^2}$)

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\ \text{mbar}$

7.3.13. Buckling field 12

7.3.13.1.) Action at $h_{field} := 15.6m$

axial:

G dead load:

S7	$t_7 = 9mm$	$h_7 := 1.16m$	$E_7 := (D_{tank} + t_7) \cdot \pi \cdot t_7 \cdot h_7 \cdot \gamma_{St} \cdot u$	$E_7 = 80.8kN$
S_6	$t_6 = 9mm$	$h_6 := 0m$	$E_6 := (D_{tank} + t_6) \cdot \pi \cdot t_6 \cdot h_6 \cdot \gamma_{St} \cdot u$	$E_6 = 0kN$
S_5	$t_5 = 10mm$	$h_5 := 0m$	$E_5 := (D_{tank} + t_5) \cdot \pi \cdot t_5 \cdot h_5 \cdot \gamma_{St} \cdot u$	$E_5 = 0kN$
S_4	$t_4 = 11mm$	$h_4 := 0m$	$E_4 := (D_{tank} + t_4) \cdot \pi \cdot t_4 \cdot h_4 \cdot \gamma_{St} \cdot u$	$E_4 = 0kN$
S_3	$t_3 = 11mm$	$h_3 := 0m$	$E_3 := (D_{tank} + t_3) \cdot \pi \cdot t_3 \cdot h_3 \cdot \gamma_{St} \cdot u$	$E_3 = 0kN$
S_2	$t_2 = 12mm$	$h_2 := 0m$	$E_2 := (D_{tank} + t_2) \cdot \pi \cdot t_2 \cdot h_2 \cdot \gamma_{St} \cdot u$	$E_2 = 0kN$
S_1	$t_1 = 13mm$	$h_1 := 0m$	$E_1 := (D_{tank} + t_1) \cdot \pi \cdot t_1 \cdot h_1 \cdot \gamma_{St} \cdot u$	$E_1 = 0kN$
			$E_{MG} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$	$E_{MG} = 80.846kN$
			steel structure:	$F_{structure} = 100kN$

$G := EG_{Dach} + E_{MG} + F_{structure}$ $\qquad G = 1257.146kN$

MW moment evoked by wind pressure on shell behind collection basin acc. to fig. 15-2 VdTÜV

$$q_0 = 1.266\frac{kN}{m^2}$$

$c_f := 0.7$ factor for total wind force acc. to DIN EN14015

$w := 9.6m$ distance to neighbouring objects

$$c := \left(1 + \frac{7}{100 \cdot \frac{D_{tank} + w}{D_{tank}} - 90.2}\right) \cdot c_f \qquad c = 0.823 \qquad \text{Gl 15-2}$$

wind: horizontal

$F_{W\_H3} = 8.907kN$

$F_{W\_H4} := c \cdot q_0 \cdot D_{tank} \cdot 2.7m$ $\qquad F_{W\_H4} = 90.008kN$

$F_W := F_{W\_H4}$ $\qquad F_W = 90.008kN$

wind: suction

$F_{W\_So} := WS_1$ $\quad F_{W\_So} = 610.726\,kN$

wind: moment

$M_W := F_{W\_H4} \cdot 15.35m$ $\quad M_W = 1381.618\,kN \cdot m$

$M_{w\_Sog} := F_{W\_So} \cdot \dfrac{D_{tank}}{20}$ DIN 4119 $\quad M_{w\_Sog} = 977.161\,kN \cdot m$

$M_{w\_ges} := M_W + M_{w\_Sog}$

$M_{w\_ges} = 2358.779\,kN \cdot m$ $\quad A := D_{tank}^{\,2} \cdot \dfrac{\pi}{4}$ $\quad U := D_{tank} \cdot \pi$

$MW := \dfrac{M_{w\_ges}}{A} \cdot U$

$MW = 294.847\,kN$

→ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_\phi := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 1m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_\phi \cdot \frac{\frac{D_{tank}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$

$\delta = 1.655$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \ge 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625\,\dfrac{N}{m^2}$ $\quad W := \delta \cdot q_0$ $\quad W = 1265.625\,\dfrac{N}{m^2}$

7.3.13.2.) Load Combination

acc. to Bußhaus "Die Standsicherheit von Flachbodentanks" [kN]:

axial

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_j =$

4310.768	kN
5609.72	
4310.768	
5609.72	
3225.033	
2906.099	
3930.224	
1820.364	
4527.914	
5826.867	
3442.18	
4601.17	
6044.45	
3868.616	
3040.427	
4178.344	

$F_{AX} := \max(AX)$

$F_{AX} = 6044.45\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

4138.594
3284.297
2392.031
1196.016
4138.594
3554.297
4598.438
3649.219
2700
2657.813
1328.906
2700

$RAD_{max} := \max(RAD)$

$RAD_{max} = 45.984\,\text{mbar}$

7.4.) Stiffener: Design

Constant loads on stiffener acc. to "Beulringberechnung nach VdTÜV"

Acc to. Bußhaus "Die Standsicherheit von Flachbodentanks" the tank bottom and the tank roof is regarded as stiffner.

Evaluation of radial loads over the buckling field height:

BU

$BU_{rad} = 2000 \frac{N}{m^2}$ constant over height

WU

$WU_{rad} = 506.25 \frac{N}{m^2}$ constant over height

7.4.1. Buckling Field 1:

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

$D := 32m$

$l_{BF} := 4.9m$ height of buckling field

weighted wall thickness in buckling field 1

	round	h[m]	t[mm]
	7	0,00	0
	6	0,00	0
H=3,85m	5	0,00	0
	4	0,00	0
	3	0,10	11
	2	2,40	12
	1	2,40	13
w eighted t			12,47

$t_m := 12.47mm$

$$\delta_1 := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{tank}}{2}}{l_{BF}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right) \qquad \delta_1 = 0.96$$

$\delta := \min(\delta_1, 1)$

$\delta = 0.957$

$W_{P\_BF} := \delta \cdot q_0$

$W_{P\_BF} = 1211.822 \frac{N}{m^2}$

Load combination for buckling field 1:

$P\_BF_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_3 := 0.00 \cdot 0.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$P\_BF_4 := 0.00 \cdot 0.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$P\_BF_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.0 \cdot 0.0 \cdot 0.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_{10} := 0.00 \cdot 0.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W_{P\_BF} + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$P\_BF_{11} := 0.00 \cdot 0.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$P\_BF_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.0 \cdot 0.0 \cdot 0.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad}$

$P\_BF_k =$

4066	$\frac{N}{m^2}$
3248	
2319	
1160	
4066	
3518	
4518	
3609	
2700	
2577	
1289	
2700	

$P_{U\_1} := \max(P\_BF)$

$P_{U\_1} = 4517.732 \frac{N}{m^2}$

Stiffener 1 acc. to VdTÜV:

choosen profile : U140 or bigger

$g_{U140} := 0.16 \frac{kN}{m}$

$J_{stif} := 605cm^4$ $A_{stif} := 20.4cm^2$

$t_m := 11mm$ thickness of shell segment attached to stiffener

$a_j := 1.9m$ minimal distance to next stiffener

$$m_{B\_analytic} := \sqrt{4.13 \cdot \frac{\frac{D_{tank}}{2}}{h_{tank}} \cdot \sqrt{0.606 \cdot \frac{D_{tank}}{2} \cdot \sqrt{\frac{a_j \cdot t_m}{J_{stif}}}}} \qquad m_{B\_analytic} = 9.719$$

$m_{B\_pract} := 10$ rounded up

$$s_k := \frac{\pi \cdot \frac{D_{tank}}{2}}{m_{B\_pract}} \qquad s_k = 5.027\,m$$

Proof of Stability:

$$N_{ER\_d} := \frac{D_{tank}}{2} \cdot \left(P_{U\_1} \cdot \frac{l_{BF}}{2}\right) \qquad N_{ER\_d} = 177.095\,kN$$

$$\lambda_k := s_k \cdot \sqrt{\frac{A_{stif}}{J_{stif}}} \qquad \lambda_k = 92.301$$

$f_{y\_k} := 355 \frac{N}{mm^2}$ $E := 210000 \frac{N}{mm^2}$

$$\lambda_a := \pi \cdot \sqrt{\frac{E}{f_{y\_k}}} \qquad \lambda_a = 76.409$$

$\gamma_m := 1.1$ partial saftey factor

case 1

$\lambda_k < \lambda_a$

$N_{ER\_d} = 177.095\,kN$. < . $\dfrac{\pi^2 \cdot E \cdot J_{stif}}{2 \cdot \gamma_m \cdot s_k^2} = 225.586\,kN$

case 2

$\lambda_a < \lambda_k$

$N_{ER\_d} = 177.095\,kN$. < . $\dfrac{f_{y\_k} \cdot A_{stif}}{\gamma_m} \cdot \left(1 - 0.5 \cdot \dfrac{\lambda_k}{\lambda_a}\right) = 260.717\,kN$

Assumed to be the worst case, all stiffeners are done as U140 or bigger.

8. Collection Basin:

Main Stiffener at the open end acc. to EN14015:

$$Z := \frac{0.058 \cdot cm^3}{m^3} \cdot D_{col}^2 \cdot h_{col} \cdot \frac{v_{cal}^2}{\left(45\frac{m}{s}\right)^2}$$

$$b_{mM1} := 0.78 \cdot \sqrt{\frac{D_{col}}{2} \cdot 9mm}$$

$$b_{mM1} = 0.314\,m$$

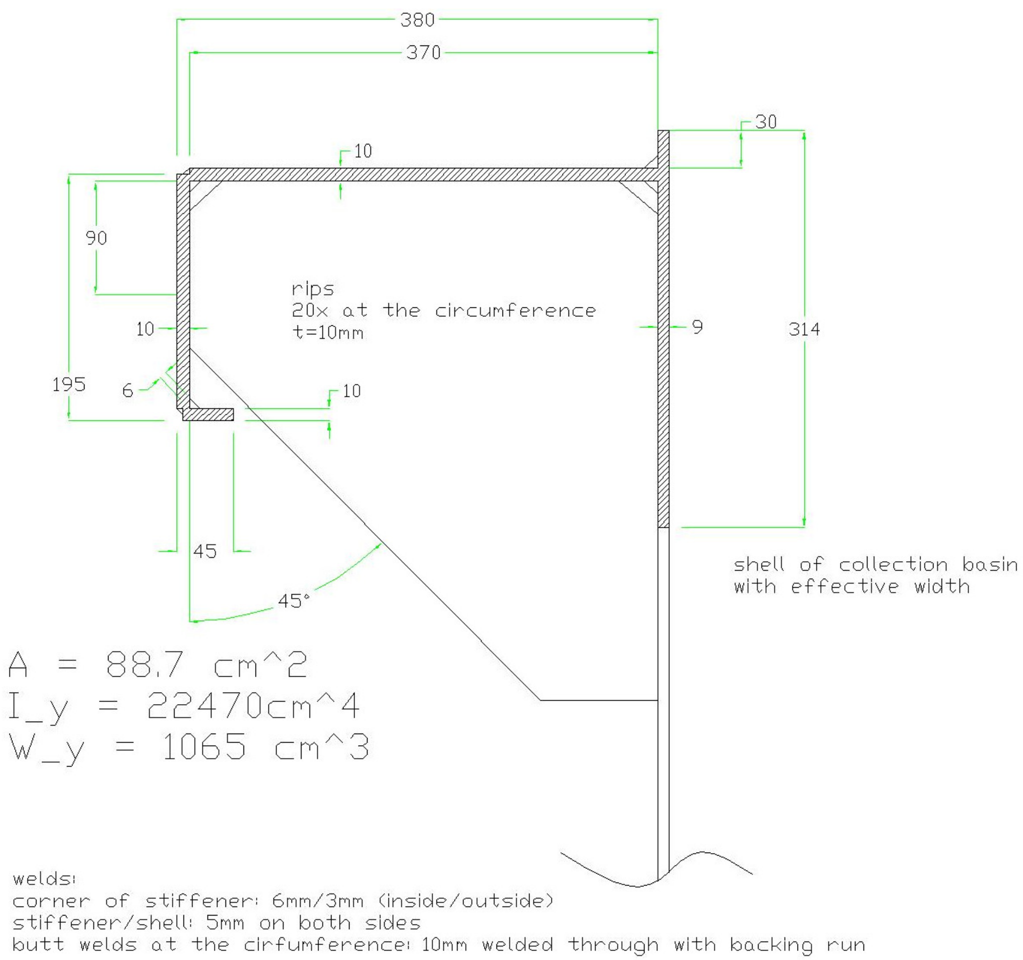
$$Z = 977.184\,cm^3$$

choosen: U400 or other profiles that guarantee the needed value

$$g_{U400} := 0.718\frac{kN}{m} \quad W_{stif.col} := 1020cm^3$$

$$G_{U400} := g_{U400} \cdot U_{col}$$

$$G_{U400} = 81.204\,kN$$



8.1.) Shell

acc. to VdTÜV

8.1.1.) Minimal Wall Thickness

$t_{min.col} := 6mm$ acc. to specification

8.1.2.) Proof of Integrity for shell

stored fluid: Diesel

max. density (stored fluid) $\gamma_{diesel} = 8.6 \frac{kN}{m^3}$

tolerance - corrosion: $c_1 := 0.4mm$ $c_2 := 1mm$

The shell is divided in 6 rounds:

	6	1,8	9	1.0116
H=13 m	5	2,0	9	1.0570
	4	2,0	9	1.0570
	3	2,4	9	1.0570
	2	2,4	9	1.0570
	1	2,4	10	1.0570
		13,0		

Wall thickness acc. to EN14015:

$j := 1..6$

elevation of the lower edge of the round meassured from the top edge of the cylindrical height of the tank:

$H_{c_1} := 13$ $H_{c_2} := 10.6$ $H_{c_3} := 8.2$ $H_{c_4} := 5.8$ $H_{c_5} := 3.8$ $H_{c_6} := 1.8$

operating conditions:

$$e_{c_j} := \frac{D_{col}}{20m \cdot 236} \cdot \left[98 \cdot 0.86 \cdot \left(H_{c_j} - 0.3\right) + 20\right] + 1$$

$e_{c_j} =$

9.316
7.774
6.231
4.688
3.402
2.117

test conditions:

$$e_{ct_j} := \frac{D_{col}}{20m \cdot 322} \cdot \left[98 \cdot 1.0 \cdot \left(H_{c_j} - 0.3\right) + 20\right] + 1$$

$e_{ct_j} =$

8.069
6.754
5.44
4.125
3.029
1.934

choosen wall thickness due to buckling issues:

$t_{1.col} := 10mm$ $t_{5.col} := 9mm$

$t_{2.col} := 9mm$ $t_{6.col} := 9mm$

$t_{3.col} := 9mm$

$t_{4.col} := 9mm$

8.2.) Proof of Stability for bassin shell:

8.2.1. Buckling Field 1

8.2.1.1.) Action at $h_{field} := 0m$

axial:

S_6 $t_{6.col} = 9\,mm$ $h_{6.col} := 1.8m$ $E_6 := (D_{col} + t_{6.col}) \cdot \pi \cdot t_{6.col} \cdot h_{6.col} \cdot \gamma_{St} \cdot u$ $E_6 = 141.1\,kN$

S_5 $t_{5.col} = 9\,mm$ $h_{5.col} := 2.0m$ $E_5 := (D_{col} + t_{5.col}) \cdot \pi \cdot t_{5.col} \cdot h_{5.col} \cdot \gamma_{St} \cdot u$ $E_5 = 156.8\,kN$

S_4 $t_{4.col} = 9\,mm$ $h_{4.col} := 2.0m$ $E_4 := (D_{col} + t_{4.col}) \cdot \pi \cdot t_{4.col} \cdot h_{4.col} \cdot \gamma_{St} \cdot u$ $E_4 = 156.8\,kN$

S_3 $t_{3.col} = 9\,mm$ $h_{3.col} := 2.4m$ $E_3 := (D_{col} + t_{3.col}) \cdot \pi \cdot t_{3.col} \cdot h_{3.col} \cdot \gamma_{St} \cdot u$ $E_3 = 188.2\,kN$

S_2 $t_{2.col} = 9\,mm$ $h_{2.col} := 2.4m$ $E_2 := (D_{col} + t_{2.col}) \cdot \pi \cdot t_{2.col} \cdot h_{2.col} \cdot \gamma_{St} \cdot u$ $E_2 = 188.2\,kN$

S_1 $t_{1.col} = 10\,mm$ $h_{1.col} := 2.4m$ $E_1 := (D_{col} + t_{1.col}) \cdot \pi \cdot t_{1.col} \cdot h_{1.col} \cdot \gamma_{St} \cdot u$ $E_1 = 209.1\,kN$

$E_{MG.col} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6$

$E_{MG.col} = 1040.175\,kN$

main stiffener: $G_{U400} = 81.204\,kN$

structure: $F_{structure} = 100\,kN$

$G := E_{MG.col} + F_{structure} + G_{U400}$ $G = 1221.379\,kN$

$G_{1.col} := G$ $T_{t.col} := \frac{G_{1.col}}{kN} \cdot \frac{1000}{9.81}$

→ WU underpressure due to wind; as there are no changes over the height, this value is not mentioned in further steps:

included in q0.col:

$$q_{0.col} := q_0 \cdot 1$$

$$q_{0.col} = 1.266 \frac{kN}{m^2}$$

→ MW moment evoked by wind pressure on shell of collection basin acc. to fig. 15-2 VdTÜV

$$c_{f.col} := 0.8$$

$$w := 9.6m$$

$$c_{col} := \left(1 + \frac{7}{100 \cdot \frac{D_{col} + w}{D_{col}} - 90.2}\right) \cdot c_{f.col} \qquad c_{col} = 0.954 \qquad \text{Gl 15-2}$$

Windhorizontalkraft

$$F_{W\_H1.col} := c_{col} \cdot q_{0.col} \cdot D_{col} \cdot 13m \qquad F_{W\_H1.col} = 564.808\,kN$$

$$F_{W.col.1} := F_{W\_H1.col} \qquad F_{W.col.1} = 564.808\,kN$$

Windmoment

$$M_{W.col} := F_{W\_H1.col} \cdot \frac{1}{2} \cdot 13m \qquad M_{W.col} = 3671.255\,kN \cdot m$$

$$M_{w\_ges.col.1} := M_{W.col}$$

$$M_{w\_ges.col.1} = 3671.255\,kN \cdot m \qquad A := D_{col}^{\,2} \cdot \frac{\pi}{4} \qquad U := D_{col} \cdot \pi$$

$$MW_{col.1} := \frac{M_{w\_ges.col.1}}{A_{col}} \cdot U$$

$$MW_{col.1} = 407.917\,kN$$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 3.7m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{col}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{col}}{2}}{t_m}}}\right)$$

$\delta = 1.139$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625 \frac{N}{m^2}$ $W := \delta \cdot q_0$ $W = 1265.625 \frac{N}{m^2}$

8.2.1.2.) Load Combinations

axial:

$BU := 0 \quad S := 0 \quad WU := 0 \quad WS_1 := 0 \quad j := 1..19$

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col.1} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col.1} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col.1} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS$

$AX_j =$

2199.549	kN
1924.205	
2199.549	
1924.205	
2199.549	
2199.549	
1924.205	
2199.549	
2199.549	
1924.205	
2199.549	
2260.737	
1954.799	
1648.861	
2260.737	
1954.799	

$F_{AX} := \max(AX)$

$F_{AX} = 2260.737\,kN$

radial direction:

$BU_{rad} := 0$ $WU_{rad} := 0$

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

1708.594
854.297
1708.594
854.297
1708.594
854.297
1898.438
949.219
0
1898.438
949.219
0

$RAD_{max} := \max(RAD)$

$RAD_{max} = 18.984\ \text{mbar}$

8.2.2. Buckling Field 2

8.2.2.1.) Action at $h_{field} := 3.2m$

axial:

S_6 $t_{6.col} = 9mm$ $h_{6.col} := 1.8m$ $E_6 := (D_{col} + t_{6.col}) \cdot \pi \cdot t_{6.col} \cdot h_{6.col} \cdot \gamma_{St} \cdot u$ $E_6 = 141.1kN$

S_5 $t_{5.col} = 9mm$ $h_{5.col} := 2.0m$ $E_5 := (D_{col} + t_{5.col}) \cdot \pi \cdot t_{5.col} \cdot h_{5.col} \cdot \gamma_{St} \cdot u$ $E_5 = 156.8kN$

S_4 $t_{4.col} = 9mm$ $h_{4.col} := 2.0m$ $E_4 := (D_{col} + t_{4.col}) \cdot \pi \cdot t_{4.col} \cdot h_{4.col} \cdot \gamma_{St} \cdot u$ $E_4 = 156.8kN$

S_3 $t_{3.col} = 9mm$ $h_{3.col} := 2.4m$ $E_3 := (D_{col} + t_{3.col}) \cdot \pi \cdot t_{3.col} \cdot h_{3.col} \cdot \gamma_{St} \cdot u$ $E_3 = 188.2kN$

S_2 $t_{2.col} = 9mm$ $h_{2.col} := 1.6m$ $E_2 := (D_{col} + t_{2.col}) \cdot \pi \cdot t_{2.col} \cdot h_{2.col} \cdot \gamma_{St} \cdot u$ $E_2 = 125.4kN$

S_1 $t_{1.col} = 10mm$ $h_{1.col} := 0m$ $E_1 := (D_{col} + t_{1.col}) \cdot \pi \cdot t_{1.col} \cdot h_{1.col} \cdot \gamma_{St} \cdot u$ $E_1 = 0kN$

$E_{MG.col} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6$

$E_{MG.col} = 768.366kN$

main stiffener: $G_{U400} = 81.204kN$

structure: $F_{structure} = 100kN$

$G := E_{MG.col} + F_{structure} + G_{U400}$ $G = 949.57kN$

→ MW moment evoked by wind pressure on shell of collection basin acc. to fig. 15-2 VdTÜV

$c_{f.col} := 0.8$

$w := 9.6m$

$$c_{col} := \left(1 + \frac{7}{100 \cdot \frac{D_{col} + w}{D_{col}} - 90.2}\right) \cdot c_{f.col}$$

$c_{col} = 0.954$ Gl 15-2

Windhorizontalkraft

$F_{W\_H1.col} := c_{col} \cdot q_{0.col} \cdot D_{col} \cdot (13m - h_{field})$ $F_{W\_H1.col} = 425.779kN$

$F_{W.col} := F_{W\_H1.col}$ $F_{W.col} = 425.779kN$

Windmoment

$M_{W.col} := F_{W\_H1.col} \cdot \frac{1}{2} \cdot (13m - h_{field})$ $\qquad M_{W.col} = 2086.315\,kN \cdot m$

$M_{w\_ges.col} := M_{W.col}$

$M_{w\_ges.col} = 2086.315\,kN \cdot m$ $\qquad A := D_{col}{}^{2} \cdot \frac{\pi}{4}$ $\qquad U := D_{col} \cdot \pi$

$$MW_{col} := \frac{M_{w\_ges.col}}{A_{col}} \cdot U$$

$MW_{col} = 231.813\,kN$

W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 3.5m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{col}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{col}}{2}}{t_m}}}\right)$$

$\delta = 1.158$. < .1

$$\delta := \begin{vmatrix} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{vmatrix}$$

$\delta = 1$

$q_0 = 1265.625\,\frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625\,\frac{N}{m^2}$

8.2.2.2.) Load Combinations

axial:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$
$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$
$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$
$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

1594.867
1438.393
1594.867
1438.393
1594.867
1594.867
1438.393
1594.867
1594.867
1438.393
1594.867
1629.639
1455.779
1281.919
1629.639
1455.779

kN

$F_{AX} := \max(AX)$

$F_{AX} = 1629.639\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$

1708.594
854.297
1708.594
854.297
1708.594
854.297
1898.438
949.219
0
1898.438
949.219
0

$\frac{N}{m^2}$

$RAD_{max} := \max(RAD)$

$RAD_{max} = 18.984\,mbar$

8.2.3. Buckling Field 3

8.2.3.1.) Action at $h_{field} := 6.7m$

axial:

S_6 $t_{6.col} = 9mm$ $h_{6.col} := 1.8m$ $E_6 := (D_{col} + t_{6.col}) \cdot \pi \cdot t_{6.col} \cdot h_{6.col} \cdot \gamma_{St} \cdot u$ $E_6 = 141.1kN$

S_5 $t_{5.col} = 9mm$ $h_{5.col} := 2.0m$ $E_5 := (D_{col} + t_{5.col}) \cdot \pi \cdot t_{5.col} \cdot h_{5.col} \cdot \gamma_{St} \cdot u$ $E_5 = 156.8kN$

S_4 $t_{4.col} = 9mm$ $h_{4.col} := 2.0m$ $E_4 := (D_{col} + t_{4.col}) \cdot \pi \cdot t_{4.col} \cdot h_{4.col} \cdot \gamma_{St} \cdot u$ $E_4 = 156.8kN$

S_3 $t_{3.col} = 9mm$ $h_{3.col} := 0.5m$ $E_3 := (D_{col} + t_{3.col}) \cdot \pi \cdot t_{3.col} \cdot h_{3.col} \cdot \gamma_{St} \cdot u$ $E_3 = 39.2kN$

S_2 $t_{2.col} = 9mm$ $h_{2.col} := 0m$ $E_2 := (D_{col} + t_{2.col}) \cdot \pi \cdot t_{2.col} \cdot h_{2.col} \cdot \gamma_{St} \cdot u$ $E_2 = 0kN$

S_1 $t_{1.col} = 10mm$ $h_{1.col} := 0m$ $E_1 := (D_{col} + t_{1.col}) \cdot \pi \cdot t_{1.col} \cdot h_{1.col} \cdot \gamma_{St} \cdot u$ $E_1 = 0kN$

$E_{MG.col} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6$

$E_{MG.col} = 493.95kN$

main stiffener: $G_{U400} = 81.204kN$

structure: $F_{structure} = 100kN$

$G := E_{MG.col} + F_{structure} + G_{U400}$ $G = 675.154kN$

MW moment evoked by wind pressure on shell of collection basin acc. to fig. 15-2 VdTÜV

$c_{f.col} := 0.8$

$w := 9.6m$

$$c_{col} := \left(1 + \frac{7}{100 \cdot \frac{D_{col} + w}{D_{col}} - 90.2}\right) \cdot c_{f.col}$$

$c_{col} = 0.954$ Gl 15-2

Windhorizontalkraft

$F_{W\_H1.col} := c_{col} \cdot q_{0.col} \cdot D_{col} \cdot (13m - h_{field})$ $F_{W\_H1.col} = 273.715kN$

$F_{W.col} := F_{W\_H1.col}$ $F_{W.col} = 273.715kN$

Windmoment

$M_{W.col} := F_{W\_H1.col} \cdot (0.5 \cdot h_{field})$ $\qquad M_{W.col} = 916.945\,kN \cdot m$

$M_{w\_ges.col} := M_{W.col}$

$M_{w\_ges.col} = 916.945\,kN \cdot m$ $\qquad A := D_{col}^{2} \cdot \frac{\pi}{4}$ $\qquad U := D_{col} \cdot \pi$

$$MW_{col} := \frac{M_{w\_ges.col}}{A_{col}} \cdot U$$

$MW_{col} = 101.883\,kN$

→ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 3.7m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{col}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{col}}{2}}{t_m}}}\right)$$ $\qquad \delta = 1.139$ $\qquad . < .1$

$$\delta := \begin{cases} 1 & \text{if } \delta \ge 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625 \frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625 \frac{N}{m^2}$

8.2.3.2.) Load Combinations

axial:

$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$

$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$

$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$

$AX_j =$

1048.999	kN
980.228	
1048.999	
980.228	
1048.999	
1048.999	
980.228	
1048.999	
1048.999	
980.228	
1048.999	
1064.281	
987.869	
911.457	
1064.281	
987.869	

$F_{AX} := \max(AX)$

$F_{AX} = 1064.281\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

1708.594
854.297
1708.594
854.297
1708.594
854.297
1898.438
949.219
0
1898.438
949.219
0

$RAD_{max} := max(RAD)$

$RAD_{max} = 18.984\,mbar$

8.2.4. Buckling Field 4

8.2.4.1.) Action at $h_{field} := 10.2m$

axial:

S_6 $t_{6.col} = 9mm$ $h_{6.col} := 1.8m$ $E_6 := (D_{col} + t_{6.col}) \cdot \pi \cdot t_{6.col} \cdot h_{6.col} \cdot \gamma_{St} \cdot u$ $E_6 = 141.1kN$

S_5 $t_{5.col} = 9mm$ $h_{5.col} := 1.0m$ $E_5 := (D_{col} + t_{5.col}) \cdot \pi \cdot t_{5.col} \cdot h_{5.col} \cdot \gamma_{St} \cdot u$ $E_5 = 78.4kN$

S_4 $t_{4.col} = 9mm$ $h_{4.col} := 0m$ $E_4 := (D_{col} + t_{4.col}) \cdot \pi \cdot t_{4.col} \cdot h_{4.col} \cdot \gamma_{St} \cdot u$ $E_4 = 0kN$

S_3 $t_{3.col} = 9mm$ $h_{3.col} := 0m$ $E_3 := (D_{col} + t_{3.col}) \cdot \pi \cdot t_{3.col} \cdot h_{3.col} \cdot \gamma_{St} \cdot u$ $E_3 = 0kN$

S_2 $t_{2.col} = 9mm$ $h_{2.col} := 0m$ $E_2 := (D_{col} + t_{2.col}) \cdot \pi \cdot t_{2.col} \cdot h_{2.col} \cdot \gamma_{St} \cdot u$ $E_2 = 0kN$

S_1 $t_{1.col} = 10mm$ $h_{1.col} := 0m$ $E_1 := (D_{col} + t_{1.col}) \cdot \pi \cdot t_{1.col} \cdot h_{1.col} \cdot \gamma_{St} \cdot u$ $E_1 = 0kN$

$E_{MG.col} := E_1 + E_2 + E_3 + E_4 + E_5 + E_6$

$E_{MG.col} = 219.533kN$

main stiffener: $G_{U400} = 81.204kN$

structure: $F_{structure} = 100kN$

$G := E_{MG.col} + F_{structure} + G_{U400}$ $G = 400.737kN$

MW moment evoked by wind pressure on shell of collection basin acc. to fig. 15-2 VdTÜV

$c_{f.col} := 0.8$

$w := 9.6m$

$$c_{col} := \left(1 + \frac{7}{100 \cdot \frac{D_{col} + w}{D_{col}} - 90.2}\right) \cdot c_{f.col}$$

$c_{col} = 0.954$ Gl 15-2

Windhorizontalkraft

$F_{W\_H1.col} := c_{col} \cdot q_{0.col} \cdot D_{col} \cdot (13m - h_{field})$ $F_{W\_H1.col} = 121.651kN$

$F_{W.col} := F_{W\_H1.col}$ $F_{W.col} = 121.651kN$

Windmoment

$M_{W.col} := F_{W\_H1.col} \cdot (0.5 \cdot h_{field})$ $\qquad M_{W.col} = 620.42\,kN \cdot m$

$M_{w\_ges.col} := M_{W.col}$

$M_{w\_ges.col} = 620.42\,kN \cdot m$ $\qquad A := D_{col}^{2} \cdot \frac{\pi}{4}$ $\qquad U := D_{col} \cdot \pi$

$$MW_{col} := \frac{M_{w\_ges.col}}{A_{col}} \cdot U$$

$MW_{col} = 68.936\,kN$

➡ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

estimated buckling field heigth: $h_{field} := 2.8m$

middled wall thickness over buckling field:

$t_m := 9mm$

$$\delta := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{col}}{2}}{h_{field}} \cdot \sqrt{\frac{\frac{D_{col}}{2}}{t_m}}}\right)$$

$\delta = 1.24$. < .1

$$\delta := \begin{cases} 1 & \text{if } \delta \geq 1 \\ \delta & \text{if } \delta < 1 \end{cases}$$

$\delta = 1$

$q_0 = 1265.625 \frac{N}{m^2}$ $\qquad W := \delta \cdot q_0$ $\qquad W = 1265.625 \frac{N}{m^2}$

8.2.4.2.) Load Combinations

axial:

$$AX_1 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_2 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_3 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_4 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_5 := 1.35 \cdot G + 1.35 \cdot 0.9 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_6 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_7 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.5 \cdot 1.5 \cdot 0.9WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_8 := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 1.0 \cdot 1.5 \cdot 0.9WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_9 := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{10} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 0.9 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{11} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 0.9 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 0.9 \cdot WS_1$$

$$AX_{12} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{13} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{14} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{15} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 1.0 \cdot 1.5 \cdot 1.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{16} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.5 \cdot 1.5 \cdot 1.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{17} := 1.35 \cdot G + 1.35 \cdot 1.0 \cdot BU + 0.0 \cdot 0.0 \cdot 0.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.0 \cdot 0.0 \cdot 0.0 \cdot MW_{col} - 0.0 \cdot 0.0 \cdot 0.0 \cdot WS_1$$

$$AX_{18} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 0.5 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 1.0 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 1.0 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$$AX_{19} := 1.35 \cdot G + 0.00 \cdot 0.0 \cdot BU + 1.0 \cdot 1.5 \cdot 1.0 \cdot S + 0.0 \cdot 0.0 \cdot 0.0WU + 0.5 \cdot 1.5 \cdot 1.0 \cdot MW_{col} - 0.5 \cdot 1.5 \cdot 1.0 \cdot WS_1$$

$AX_j =$

634.058	kN
587.527	
634.058	
587.527	
634.058	
634.058	
587.527	
634.058	
634.058	
587.527	
634.058	
644.398	
592.697	
540.995	
644.398	
592.697	

$F_{AX} := \max(AX)$

$F_{AX} = 644.398\,kN$

radial direction:

$RAD_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_3 := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_4 := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad}$

$RAD_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W + 0 \cdot WU_{rad}$

$RAD_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W + 0.0 \cdot WU_{rad}$

$RAD_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0 \cdot WU_{rad}$

$RAD_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_{10} := 0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{11} := 0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad}$

$RAD_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0W + 0 \cdot WU_{rad}$

$RAD_k =$ $\frac{N}{m^2}$

1708.594
854.297
1708.594
854.297
1708.594
854.297
1898.438
949.219
0
1898.438
949.219
0

$RAD_{max} := \max(RAD)$

$RAD_{max} = 18.984\ \text{mbar}$

8.3.) Stiffener: Design

Constant loads on stiffener acc. to "Beulringberechnung nach VdTÜV"

Acc to. Bußhaus "Die Standsicherheit von Flachbodentanks" the tank bottom and the tank roof is regarded as stiffner.

Evaluation of radial loads over the buckling field height:

→ WU

$WU_{rad.col} := q_0$

constant over height

$WU_{rad.col} = 1265.625 \frac{N}{m^2}$

8.3.1.) Buckling Field 2:

→ W rotation sym. substitute wind pressure acc. to DIN 18800 T 4:

$Cd_{\phi} := 1.0$ Tab . 2 DIN 18800 T4

$D_{col} = 36\,m$

$l_{BF} := 8m$ height of buckling field

weighted wall thickness in buckling field 2

	round	h[m]	t[mm]
	7	0,50	9
	6	2,00	9
H=3,85m	5	2,00	9
	4	2,40	9
	3	2,40	9
	2	1,10	9
	1	0,00	10
w eighted t	9,00		

$t_m := 9.00mm$

$$\delta_1 := 0.46 \cdot \left(1 + 0.1 \cdot \sqrt{Cd_{\phi} \cdot \frac{\frac{D_{tank}}{2}}{l_{BF}} \cdot \sqrt{\frac{\frac{D_{tank}}{2}}{t_m}}}\right)$$

$\delta_1 = 0.88$. < .1

$\delta := \min(\delta_1, 1)$

$\delta = 0.882$

$W_{P\_BF} := \delta \cdot q_0$

$W_{P\_BF} = 1116.81 \frac{N}{m^2}$

Load combination for buckling field 1:

$P\_BF_1 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_2 := 1.35 \cdot 0.9 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_3 := 0.00 \cdot 0.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 1.0 \cdot 1.5 \cdot 0.9 \cdot WU_{rad.col}$

$P\_BF_4 := 0.00 \cdot 0.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.5 \cdot 1.5 \cdot 0.9 \cdot WU_{rad.col}$

$P\_BF_5 := 1.35 \cdot 0.9 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_6 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 0.9W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_7 := 1.35 \cdot 1.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_8 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_9 := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.0 \cdot 0.0 \cdot 0.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_{10} := 0.00 \cdot 0.0 \cdot BU_{rad} + 1.0 \cdot 1.5 \cdot 1.0W_{P\_BF} + 1.0 \cdot 1.5 \cdot 1.0 \cdot WU_{rad.col}$

$P\_BF_{11} := 0.00 \cdot 0.0 \cdot BU_{rad} + 0.5 \cdot 1.5 \cdot 1.0W_{P\_BF} + 0.5 \cdot 1.5 \cdot 1.0 \cdot WU_{rad.col}$

$P\_BF_{12} := 1.35 \cdot 1.0 \cdot BU_{rad} + 0.0 \cdot 0.0 \cdot 0.0W_{P\_BF} + 0.0 \cdot 0.0 \cdot 0.0 \cdot WU_{rad.col}$

$P\_BF_k =$ $\frac{N}{m^2}$

1508
754
3216
1608
1508
754
1675
838
0
3574
1787
0

$P_{U\_2} := \max(P\_BF)$

$P_{U\_2} = 3573.653 \frac{N}{m^2}$

Stiffener 2 acc. to VdTÜV:

choosen profile : U140 or bigger

$J_{stif} := 605cm^4$ $\quad A_{stif} := 20.4cm^2$

$t_m := 9mm$ thickness of shell segment attached to stiffener

$a_j := 4m$ minimal distance to next stiffener

$$m_{B\_analytic} := \sqrt{4.13 \cdot \frac{\frac{D_{col}}{2}}{h_{col}} \cdot \sqrt{0.606 \cdot \frac{D_{col}}{2} \cdot \sqrt{\frac{a_j \cdot t_m}{J_{stif}}}}} \qquad m_{B\_analytic} = 12.879$$

$m_{B\_pract} := 13$ rounded up

$$s_k := \frac{\pi \cdot \frac{D_{col}}{2}}{m_{B\_pract}} \qquad s_k = 4.35\,m$$

Proof of Stability:

$$N_{ER\_d} := \frac{D_{col}}{2} \cdot \left(P_{U\_2} \cdot \frac{l_{BF}}{2} \right) \qquad N_{ER\_d} = 257.303\,kN$$

$$\lambda_k := s_k \cdot \sqrt{\frac{A_{stif}}{J_{stif}}} \qquad \lambda_k = 79.876$$

$$f_{y\_k} := 355 \frac{N}{mm^2} \qquad E := 210000 \frac{N}{mm^2}$$

$$\lambda_a := \pi \cdot \sqrt{\frac{E}{f_{y\_k}}} \qquad \lambda_a = 76.409$$

$\gamma_m := 1.1$ partial saftey factor

case 1 $\lambda_k < \lambda_a$

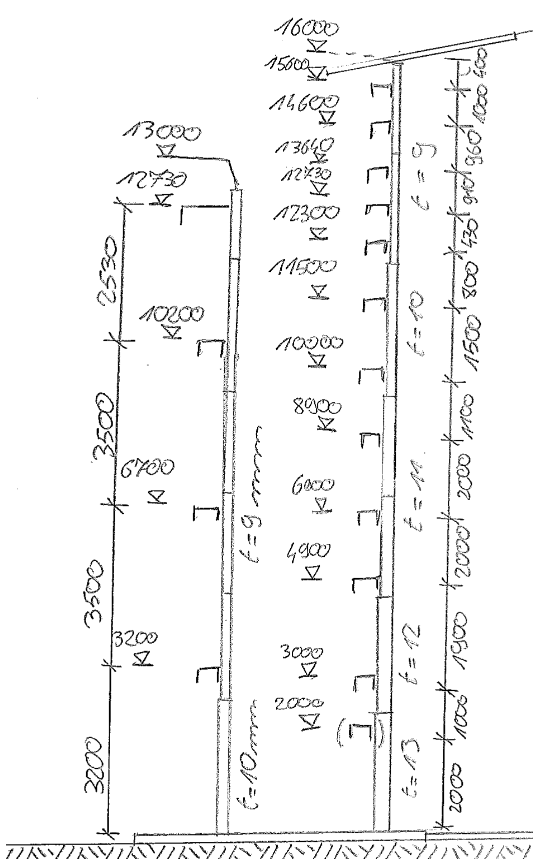
$N_{ER\_d} = 257.303\,kN$. < . $\dfrac{\pi^2 \cdot E \cdot J_{stif}}{2 \cdot \gamma_m \cdot s_k^2} = 301.227\,kN$

case 2 $\lambda_a < \lambda_k$

$N_{ER\_d} = 257.303\,kN$. < . $\dfrac{f_{y\_k} \cdot A_{stif}}{\gamma_m} \cdot \left(1 - 0.5 \cdot \dfrac{\lambda_k}{\lambda_a}\right) = 314.246\,kN$

Assumed to be the worst case, all stiffeners are done as U140 or bigger. $g_{U140} := 0.16\,\dfrac{kN}{m}$

8.4.) Stiffeners Overview



9.) Bottom Plates

9.1.) Bottom Middle Plates

9.1.1.) Plate Thickness

Support under whole bottom plate area

minimal thickness acc. to VdTÜV: 5mm

$t_{Bottom} := 7mm$

The bottom middle plates has minimal thickness of 7 mm and overlapping.

9.1.2.) Overlap acc. to EN14015: Fig.3

$o_{middle} > 5 \cdot t_{Bottom}$ $\qquad$ $o_{middle} > 35mm$

9.2.) Minimal filling to avoid uplift of the bottom plates

operating underpressure

$BU := p_u$ $\qquad$ $BU = 2000 \frac{N}{m^2}$

dead load of bottom plates:

$u = 9.81 \frac{m}{s^2}$ $\quad$ $D_{tank} = 32 m$

$E_{Boden} := D_{tank}^2 \cdot \frac{\pi}{4} t_{Bottom} \cdot \gamma_{St} \cdot u$ $\qquad$ $E_{Boden} = 433.537 kN$

$E_G := \frac{E_{Boden}}{D_{tank}^2 \cdot \frac{\pi}{4}}$ $\qquad$ $E_G = 539.059 \frac{N}{m^2}$

resulting uplift due to operating underpressure with safty factor of 1.5:

$BU \cdot 1.5 = 3000 \frac{N}{m^2}$

minimal filling height:

$\gamma := 860 \frac{kg}{m^3}$

$h_{min} := \frac{BU \cdot 1.5}{\gamma \cdot u}$

$h_{min} = 355.593 mm$ $\quad$ < 1000 mm $\qquad$ minimal filling height acc. to specification

9.3.) Annular Ring Plates acc. to EN14015 Chapter 8:

9.3.1.) Thickness

$e_1 := t_1$ — t.1: wall thickness of round 1

$e_{a1} := 6mm$

$e_{a2} := 3mm + \frac{e_1}{3}$ $\quad e_{a2} = 7.333\,mm$

$e_a := \max(e_{a1}, e_{a2})$

$e_a = 7.333\,mm$

choosen thickness: $t_{AR} := 10mm$ including tolerance and corrosion

9.3.2.) Minimal width of annular ring acc. to EN14015 Fig. 3:

distance between tank shell and bottom middle plates:

$l_{a1} := \frac{240}{\sqrt{h_{tank} \cdot m}} \cdot e_a \cdot m$ $\quad l_{a1} = 430.68\,mm$

$l_{a2} := 500mm$

$l_{eq} := 870mm$ — value of earthquake calculation (see below)

$l_a := \max(l_{a1}, l_{a2}, l_{eq})$ $\quad l_a = 870\,mm$

distance between outside tank shell and outer edge of bottom border plate:

$50mm < l_d < 100mm$

overlap annular/middle plate:

$l_w > 60mm$

9.3.3.) weld at bottom-shell-corner:

$a_{w.corner} := \min(t_{AR}, 9.5mm)$

$a_{w.corner} = 9.5\,mm$

Fillet weld with a.w.corner on both sides of tank wall!

9.3.4.) weld between overlapping bottom plates

$a_{w.middle} \geq 4mm$ — acc. to VdTÜV 6.3.4.6

10.) Earthquake

10.1) Earthquake: Tank

Acc. to EN 14015:

10.1.1.) Loads

$D := 32$ diameter in [m]

$H_y := 16.7$ height in [m]

$a_h := 2.75 \frac{m}{s^2}$ vertical acceleration acc. to specification

$g := 9.81 \frac{m}{s^2}$ standard earth gravity

$\varepsilon := \frac{a_h}{g}$ $\varepsilon = 0.28$ ratio of accelerations

$G_1 := \varepsilon$ $G_1 = 0.28$

$\frac{D}{H_y} = 1.9$ $K_s := 0.59$ acc. Fig. G3

$T_s := 1.8 \cdot K_s \cdot D^{\frac{1}{2}}$ $T_s = 6.008$ Eigenperiode of motivated oscillation of the fluid in [s]

$j := 1.2$ amplification factor acc. to Tab G.1

$G_2 := \frac{5.625 \cdot G_1 \cdot j}{T_s^{\,2}}$ Gl. 3; T.s > 4.5 Gl. 2

$G_2 = 0.052$

$T_t = 151581.839$ weight of tank shell [kg]

$H_L := 16.7$ height of tank shell [m]

$T_r = 109714.509$ weight of roof + snow/others [kg] $T_r := \frac{EG_{Dach} + 0.0S}{kN} \cdot \frac{1000}{9.81}$

$H_T := 16.7$ maximal filling height [m]

$\gamma := 860$ density of filling [kg/m^3]

$T_T := D^2 \cdot \frac{\pi}{4} \cdot H_T \cdot \gamma$ weight of filling [kg]

$T_T = 11550605.745$

$\frac{D}{H_T} = 1.916$

$\frac{T_1}{T_T} := 0.575$ Fig. G1

$\frac{T_2}{T_T} := 0.42$ Fig. G1

$T_1 := T_T \cdot 0.575$

effective mass moving in tank [kg]

$T_1 = 6641598.303$

$T_2 := T_T \cdot 0.42$

effective fluid mass moving in tank [kg]

$T_2 = 4851254.413$

$\frac{X_1}{H_T} := 0.37$ Fig. G2

$\frac{X_2}{H_T} := 0.618$ Fig. G2

$X_1 := H_T \cdot 0.37$ height of tank shell to center of gravity of seismic horizontal force T.1

$X_1 = 6.179$

$X_2 := H_T \cdot 0.618$ height of tank shell to center of gravity of seismic horizontal force T.2

$X_2 = 10.321$

$X_s := 8.35$ height of lower tank edge to center of gravity of whole tank [m]

$$M_{tank} := \frac{G_1 \cdot \left(T_t \cdot X_s + T_r \cdot H_L + T_1 \cdot X_1\right) + G_2 \cdot T_2 \cdot X_2}{102}$$

$M_{tank} = 147035.013$ tilitng moment at lower tank edge in [kNm]

$$F_{EH.tank} := \frac{G_1 \cdot \left(T_t + T_r + T_1\right) + G_2 \cdot T_2}{102}$$

$F_{EH.tank} = 21464.773$ seismic horizontal force [kN]

10.1.2.) Restistance against tilting

filling

$R_{eb} := 355$ — yield stress of bottom border plate in [N/mm^2]

$W_s := 0.86$ — max density of filling

$t_{AR} := \frac{t_{AR}}{mm}$ — thickness of annular ring plate in [mm]; in this case without corrosion, because the ring plate has no contact to the filling

$W_L := 0.1 \cdot t_{AR} \cdot \sqrt{R_{eb} \cdot W_s \cdot H_T}$

$W_L = 71.404$ — max. acting force of filling against tilting in kN/m

$W_{L\_max} := 0.2 \cdot W_s \cdot H_T \cdot D$ $\quad W_{L\_max} = 91.917$

$W_L = 71.404$ $\quad < \quad$ $W_{L\_max} = 91.917$ $\quad$ proof fulfilled

minimal annnular ring plate width:

$$0.1744 \cdot \frac{W_L}{W_s \cdot H_T} = 0.867$$

10.1.3.) pressure load shell

tank without ancors:

$M_{tank} = 147035.013$

$W_{L.cal} := W_L$ — reduced value due to smaller annular ring than calculated above

$T_t + T_r = 261296.347$ — total weight of tank and roof in [kg]

$W_t := \frac{(T_t + T_r) \cdot 9.81}{1000}$ $\quad W_t = 2563.317$ — total weight force in [kN]

$U := D \cdot \pi$ $\quad U = 100.531$ — girth [m]

$W_t := \frac{W_t}{U}$ $\quad W_t = 25.498$ — [kN/m]

$$\frac{M_{tank}}{D^2 \cdot (W_{L.cal} + W_t)} = 1.482$$

> 0.785 but <1.5: W.b from Fig. G.4

$W_{b.tank} := 3.85 \cdot (W_t + W_L) - W_L$

$W_{b.tank} = 301.667$

maximale pressure under tank shell in [kN/m] without anchorage: the proof below will show that an anchorage is necessary!

<u>allowable pressure force in tank shell:</u>

$t_{bs} := \frac{t_1 - c_2}{mm}$ thickness of lowest round [mm]

$\frac{W_s \cdot H_T \cdot D^2}{t_{bs}^2} = 102.13$ > 44 --> eq. G.9

$F_a := 83 \cdot \frac{t_{bs}}{D}$

$F_a = 31.125$ allowable axial pressure in tank shell [N/mm^2]

$R_{es} := 355$ yield stress of lowest round [N/mm^2]

$\frac{W_{b.tank}}{t_{bs}} = 25.139$ $<$ $F_a = 31.125$ fulfilled

$F_a = 31.125$ $<$ $0.5 \cdot R_{es} = 177.5$ proof fullfilled

10.2) Earthquake: Collection Basin

Acc. to EN 14015:

10.2.1.) Loads

$D := 36$ diameter in [m]

$H_y := 13$ height in [m]

$a_h := 2.75 \frac{m}{s^2}$ vertical acceleration acc. to specification

$g := 9.81 \frac{m}{s^2}$ standard earth gravity

$\varepsilon := \frac{a_h}{g}$ $\quad \varepsilon = 0.28$ ratio of accelerations

$G_1 := \varepsilon \quad G_1 = 0.28$

$\frac{D}{H_y} = 2.769$ $\quad K_s := 0.63$ acc. Fig. G3

$T_{s.col} := 1.8 \cdot K_s \cdot D^{\frac{1}{2}}$ $\quad T_s = 6.008$ Eigenperiode of motivated oscillation of the fluid in [s]

$j := 1.2$ amplification factor acc. to Tab G.1

$G_2 := \frac{5.625 \cdot G_1 \cdot j}{T_{s.col}^2}$ Gl. 3; T.s > 4.5 Gl. 2

$G_2 = 0.041$

$T_{t.col} = 124503.439$ weight of tank shell [kg]

$H_L := 16.7$ height of tank shell [m]

$T_{r.col} := 0$ no roof

$H_T := 12.8$ maximal filling height [m]

$\gamma := 860$ density of filling [kg/m^3]

$T_T := D^2 \cdot \frac{\pi}{4} \cdot H_T \cdot \gamma$ weight of filling [kg]

$T_T = 11204779.226$

$\frac{D}{H_T} = 2.813$

$\frac{T_1}{T_T} := 0.42$ Fig. G1

$\frac{T_2}{T_T} := 0.56$ Fig. G1

$T_1 := T_T \cdot 0.42$

$T_1 = 4706007.275$ effective mass moving in tank [kg]

$T_2 := T_T \cdot 0.56$

$T_2 = 6274676.366$ effective fluid mass moving in tank [kg]

$\frac{X_1}{H_T} := 0.37$ Fig. G2

$\frac{X_2}{H_T} := 0.56$ Fig. G2

$X_1 := H_T \cdot 0.37$ height of tank shell to center of gravity of seismic horizontal force T.1

$X_1 = 4.736$

$X_2 := H_T \cdot 0.56$ height of tank shell to center of gravity of seismic horizontal force T.2

$X_2 = 7.168$

$X_s := 6.5$ height of lower tank edge to center of gravity of whole tank [m]

$M_{col} := \frac{G_1 \cdot \left(T_t \cdot X_s + T_r \cdot H_L + T_1 \cdot X_1\right) + G_2 \cdot T_2 \cdot X_2}{102}$ tilitng moment at lower tank edge in [kNm]

$M_{col} = 87019.463$

$F_{EH.col} := \frac{G_1 \cdot \left(T_t + T_r + T_1\right) + G_2 \cdot T_2}{102}$

$F_{EH.col} = 16165.996$ seismic horizontal force [kN]

10.2.2.) Restistance against tilting

filling

$R_{eb} := 355$ — yield stress of bottom border plate in [N/mm^2]

$W_s := 0.86$ — max density of filling

$t_{AR} = 10$ — thickness of annular ring in [mm]

$$W_{L.col} := 0.1 \cdot t_{AR} \cdot \sqrt{R_{eb} \cdot W_s \cdot H_T}$$

$W_{L.col} = 62.513$ — max. acting force of filling against tilting in kN/m

$$W_{L\_max} := 0.2 \cdot W_s \cdot H_T \cdot D$$

$W_{L.col} = 62.513$ $<$ $W_{L\_max} = 79.258$ — proof fulfilled

bottom plate

$$0.1744 \cdot \frac{W_{L.col}}{W_s \cdot H_T} = 0.99$$

10.2.3.) Pressure load on shell

tank without ancors:

$M_{col} = 87019.463$

$W_{L.col} = 62.513$ — Reduction of W.L.col due to smaller width than calculated

$T_{t.col} = 124503.439$ — total weight of basin [kg]

$W_{t.col} := \frac{T_{t.col} \cdot 9.81}{1000}$ $\quad W_t = 25.498$ — total weight force in [kN]

$U := D \cdot \pi$ $\quad U = 113.097$ — girth [m]

$W_{t.col} := \frac{W_{t.col}}{U}$ $\quad W_{t.col} = 10.799$ — [kN/m]

$\frac{M_{col}}{D^2 \cdot (W_{L.col} + W_{t.col})} = 0.916$ — 0.785 < 1.16 < 1.5 --> W.b acc. to Fig. G.4

$$W_{b.col} := 2.82 \cdot (W_{t.col} + W_{L.col}) - W_{L.col}$$

$W_{b.col} = 144.227$ — maximale pressure under tank shell in [kN/m] allowable pressure force in tank shell:

$t_{bs.col} := \frac{t_{1.col} - c_2}{mm}$ thickness of lowest round [mm]

$\frac{W_s \cdot H_T \cdot D^2}{t_{bs.col}^2} = 176.128$ > 44 --> eq. G.9

$F_a := 83 \cdot \frac{t_{bs.col}}{D}$

$F_a = 20.75$ allowable axial pressure in tank shell [N/mm^2]

$R_{es} := 355$ yield stress of lowest round [N/mm^2]

$\frac{W_{b.col}}{t_{bs.col}} = 16.025$	$<$	$F_a = 20.75$	proof fulfilled
$F_a = 20.75$	$<$	$0.5 \cdot R_{es} = 177.5$	proof fullfilled

11.) Anchorage

$D := 32m$

acc. to EN14015; Chap. 12

load combination a - inner overpressure

$$overpressure := \frac{D^2 \cdot \pi}{4} \cdot p_{ü} \qquad overpressure = 1608.495\,kN$$

dead load

roof $\quad EG_{Dach.cor} := EG_{Dach} \cdot 0.8$

shell $\quad EG_{Mantel.cor} := 1680kN \cdot \frac{9.24}{10.24} \qquad EG_{Mantel.cor} = 1515.938\,kN$

rest filling: $\quad EG_{Füll} := A \cdot 1m \cdot \gamma_{diesel} \qquad EG_{Füll} = 8753.734\,kN$

$h = 1m$

$$\frac{EG_{Dach.cor} + EG_{Mantel.cor}}{overpressure} = 1.478 \qquad . > 1$$

no anchorage necessary

load combination b - inner overpressure, wind and minimal filling height

$Wind_{Sog} := WS_1 \qquad WS_1 = 0\,kN$

$Wind_{Moment} := MW_1 \qquad MW_1 = 635.578\,kN$

$$\frac{EG_{Mantel.cor} + EG_{Dach.cor} + EG_{Füll}}{overpressure + Wind_{Sog} + Wind_{Moment}} = 4.96 \qquad . > 1$$

no anchorage necessary

load combination c - wind

$$\frac{EG_{Mantel.cor} + EG_{Dach.cor}}{Wind_{Sog} + Wind_{Moment}} = 3.74 \qquad . > 1$$

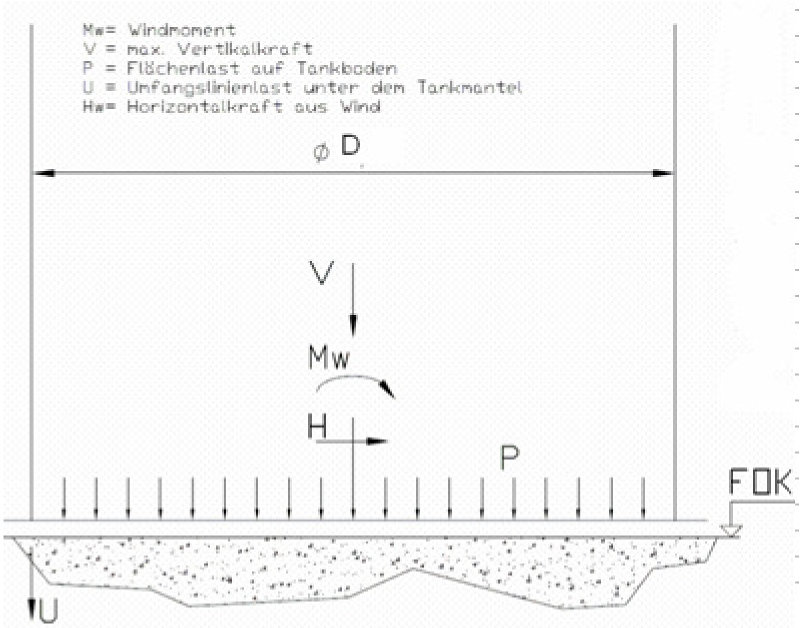
no anchorage necessary

load combination d - earthquake

$$\frac{M_{tank} \cdot m^2}{D^2 \cdot (W_L + W_t)} = 1.482 \qquad < 1.5$$

no anchorage necessary

12.) Foundation Loads



12.1.) Tank

12.1.1.)Distributed Load under Tank

theoratical volume $13000m^3$

practical volume $V_{real} := D_{tank}^2 \cdot \frac{\pi}{4} \cdot h_{tank}$ $V_{real} = 13430.937\,m^3$

filling Diesel

max. density $\gamma := 10\,\frac{kN}{m^3}$

$h_{tank} = 16.7\,m$

$F_{Füllung} := V_{real} \cdot \gamma$ $F_{Füllung} = 134309.369\,kN$

$p_{Boden.tank} := \gamma \cdot h_{tank}$ $p_{Boden.tank} = 167\,\frac{kN}{m^2}$

10% addition

$p_{Boden.tank} := p_{Boden.tank} \cdot 1.1$ $p_{Boden.tank} = 183.7\,\frac{kN}{m^2}$

12.1.2.) Dirstributed Load under Tank Shell

operating underpressure $p_u = 2000\,\frac{N}{m^2}$

$P_u := p_u \cdot A_{tank}$ $\quad P_u = 1608.495\,kN$

dead load $G_{Tank.1} = 2563.317\,kN$

$G_{stif} := 11 \cdot g_{U140} \cdot U_{tank}$ $\quad G_{stif} = 176.934\,kN$

$G_{res} := G_{stif} + G_{Tank.1}$

$G_{res} = 2740.252\,kN$

WIND:

wind horizontal load $F_{W.1} = 363.364\,kN$

max. wind moment $M_{w\_ges.1} = 5084.623\,kN \cdot m$

resulting axial force $MW_1 = 635.578\,kN$

wind suction: $WS_1 = 0\,kN$

EARTHQUAKE:

earthquake horizontal load $F_{EH.tank} := F_{EH.tank} \cdot 1kN$ $\quad F_{EH.tank} = 21464.773\,kN$

tilting moment at lower edge $M_{tank} := M_{tank} \cdot 1kN \cdot m$ $\quad M_{tank} = 147035.013\,kN \cdot m$

max. pressure load on shell $W_{b.tank} := W_{b.tank}\,\frac{kN}{m}$ $\quad W_{b.tank} = 301.667\,\frac{kN}{m}$

$F_E := W_{b.tank} \cdot D \cdot \pi$ $\quad F_E = 30326.921\,kN$

resulting $EG_{tank} := G_{stif} + F_E + P_u$ $\quad EG_{tank} = 32112.351\,kN$

$UG_{tank} := \frac{EG_{tank}}{D \cdot \pi}$ $\quad UG_{tank} = 319.427\,\frac{kN}{m}$

filling $F_{Füllung} = 134309.369\,kN$

distribution area: width $t_1 = 13\,mm$

$t_{AR} \cdot mm = 10\,mm$

$B_{tank} := 3.5t_{AR} \cdot mm + t_1$ $\quad B_{tank} = 48\,mm$

distributed load (incl. 10% add.) out of dead load:

$$p_{EG.tank} := \frac{UG_{tank}}{B_{tank}} \cdot 1.1$$

$$p_{EG.tank} = 7.32 \frac{N}{mm^2}$$

distributed load (incl. 10% add.) out of filling:

$$p_{Fill} := p_{Boden.tank}$$

$$p_{Fill} = 0.184 \frac{N}{mm^2}$$

<u>resulting distributed load under tank shell:</u>

$$p_{shell\_res} := p_{EG.tank} + p_{Fill}$$

$$p_{shell\_res} = 7.504 \frac{N}{mm^2}$$

<u>Results: Tank</u>

Wind suction force		611	kN
resulting wind moment		5085	kNm
resulting wind hor. Force		365	kN
resulting earthquake moment		154560	kNm
resulting earthquake hor. Force		21915	kN
max. ver. force (dead + live loads)		137100	kN
min. ver. force (dead load)		2800	kN
max. distr. Load	bottom middle	0,19	N/mm^2
	annular ring	8,92	N/mm^2

12.2.) Collection Basin

12.2.1.) Distributed Load under Basin

theoratical volume $13000 m^3$

practical volume $V_{real} := D_{col}^2 \cdot \frac{\pi}{4} \cdot h_{col}$ $V_{real} = 13232.388 \, m^3$

filling Diesel

max. density $\gamma := 10 \frac{kN}{m^3}$

$h_{col} = 13 \, m$

$F_{Füllung} := V_{real} \cdot \gamma$ $F_{Füllung} = 132323.883 \, kN$

$p_{Boden.col} := \gamma \cdot h_{col}$ $p_{Boden.tank} = 183.7 \frac{kN}{m^2}$

10% addition

$p_{Boden.col} := p_{Boden.col} \cdot 1.1$ $p_{Boden.tank} = 183.7 \frac{kN}{m^2}$

12.2.2.) Dirstributed Load under Basin Shell

dead load $G_{1.col} = 1221.379 \, kN$

$G_{stif.col} := 3 \cdot g_{U140} \cdot U_{col}$

$G_{res.col} := G_{stif.col} + G_{1.col}$

$G_{res.col} = 1275.665 \, kN$

WIND:

wind horizontal load $F_{W.col.1} = 564.808 \, kN$

max. wind moment $M_{w\_ges.col.1} = 3671.255 \, kN \cdot m$

resulting axial force $MW_{col.1} = 407.917 \, kN$

EARTHQUAKE:

earthquake horizontal load $F_{EH.col} := F_{EH.col} \cdot 1kN$ $F_{EH.col} = 16165.996\,kN$

tilting moment at lower edge $M_{col} := M_{col} \cdot 1kN \cdot m$ $M_{col} = 87019.463\,kN \cdot m$

max. pressure load on shell $W_{b.col} := W_{b.col} \frac{kN}{m}$ $W_{b.col} = 144.227 \frac{kN}{m}$

$F_{E.col} := W_{b.col} \cdot D \cdot \pi$ $F_{E.col} = 14499.314\,kN$

resulting $EG_{col} := G_{stif.col} + F_{E.col}$ $EG_{col} = 14553.6\,kN$

$UG_{col} := \frac{EG_{col}}{D_{col} \cdot \pi}$ $UG_{col} = 128.682 \frac{kN}{m}$

filling $F_{Füllung} = 132323.883\,kN$

distribution area: width $t_{1.col} = 10\,mm$

$t_{AR} \cdot mm = 10\,mm$

$B_{col} := 3.5t_{AR} \cdot mm + t_{1.col}$ $B_{col} = 45\,mm$

distributed load (incl. 10% add.) out of dead load:

$p_{EG.col} := \frac{UG_{col}}{B_{col}} \cdot 1.1$

$p_{EG.col} = 3.146 \frac{N}{mm^2}$

distributed load (incl. 10% add.) out of filling:

$p_{Fill} := p_{Boden.col}$

$p_{Fill} = 0.143 \frac{N}{mm^2}$

<u>resulting distributed load under tank shell:</u>

$p_{shell\_res} := p_{EG.col} + p_{Fill}$

$p_{shell\_res} = 3.289 \frac{N}{mm^2}$

Results: Basin

Wind suction force			-	kN
resulting wind moment			3675	kNm
resulting wind hor. Force			565	kN
resulting earthquake moment			94555	kNm
resulting earthquake hor. Force			16616	kN
max. ver. force (dead + live loads)			135300	kN
min. ver. force (dead load)			1300	kN
max. distr. Load		bottom middle	0,15	N/mm^2
		annular ring	3,3	N/mm^2

13.) Summary

13.1. Tank

Element	Part	Dimensions	Thickness	Material	Grade
roof	crown ring	335x720	25	S355J2G3	B
	plates		6	S355J2G3	B
	corner ring	600	30	S355J2G3	B
	cross bracing	U160		S355J2G3	
	polygone rings	L150x75x9		S235J2G3	
	rafters	IPE360		S355J2G3	
shell	round 7	2300x6000	9	S355J2G3	B
	round 6	2400x6000	9	S355J2G3	B
	round 5	2400x6000	10	S355J2G3	B
	round 4	2400x6000	11	S355J2G3	B
	round 3	2400x6000	11	S355J2G3	B
	round 2	2400x6000	12	S355J2G3	B
	round 1	2400x6000	13	S355J2G3	B
	stiffener	U140		S355J2G3	
bottom	annular ring	870	10	S355J2G3	B
	middle plates		7	S235J2G3	B

13.2. Collection Bassin

Element	Part	Dimensions	Thickness	Material	Grade
shell	round 6	1800x6000	9	S355J2G3	B
	round 5	2000x6000	9	S355J2G3	B
	round 4	2000x6000	9	S355J2G3	B
	round 3	2400x6000	9	S355J2G3	B
	round 2	2400x6000	9	S355J2G3	B
	round 1	2400x6000	10	S355J2G3	B
	end stiffener	welded	multi	S235J2G3	
	stiffener	U140		S355J2G3	

APPENDIX A: Software Print Outs

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 1
order......... Diesel Storage Tank
order number.. 5.7638
commission....

input data

design data and load collection:

axial force	P =	8070.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	41.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	2 rounds	
length of 1st round	l1 =	600.0	mm
length of 2nd round	l2 =	2400.0	mm
wall thickness of 1st round	t1 =	12.0	mm
wall thickness of 2nd round	t2 =	13.0	mm
border conditions	=	transl. fixed - transl. fixed	

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.3	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with modified wall thickness

manufacturing inaccuracies			round 1	round 2	element
measure length (longit.)	lmx	mm	1752.	1824.	(302)
all. longit. buckle depth	tvx	mm	17.5	18.2	(302)
measure length (circumf.)	lmf	mm	1179.	2000.	(302)
all. circumf. buckle depth	tvf	mm	11.8	20.0	(302)
allowed eccentricity	e	mm	0.5	0.5	304/T.4
pseudo wall thickness	teff	mm	10.7	11.7	AD-B0

geometry of 3-round pseudo cylinder				remark
pseudo round length top	lo	mm	1500.0	element (509)
pseudo round length mid	lm	mm	750.0	element (509)
pseudo round length down	lu	mm	750.0	element (509)
pseudo wall thickness top	to	mm	11.30	element (509)
pseudo wall thickness mid	tm	mm	11.70	element (509)
pseudo wall thickness down	tu	mm	11.70	element (509)
parameter for figure 20	lo/l	--	0.50	fig. 20
parameter for figure 20	tm/to	--	1.04	fig. 20
parameter for figure 20	tu/to	--	1.04	fig. 20
coefficient for pseudo cylinder	ß	--	0.50	fig. 20

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	41.4	with yF

customer...... OMV		drawing....... BF 1	
revisor....... Panenka		order......... Diesel Storage Tank	
revision......		order number.. 5.7638	
prod.number...		commission....	

axial load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
cylinder class		--	sh/mdl	sh/mdl	4.2/5.3
coefficient Cx	Cx	--	1.0	1.0	4.2/5.3
id. buckling stress	σxSi	N/mm²	87.5	95.9	4.2/5.3
rel. slenderness	£Sx	--	2.0	1.9	eq.1
reduction factor	æx	--	0.0	0.1	eq.8
reduc. reduction factor	æx	--	0.0	0.1	(305)
real buckling stress	σxSRk	N/mm²	17.5	19.2	eq.4
safety coefficient	yMx	--	1.5	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	12.1	13.4	eq.9
max. membrane stress	σx	N/mm²	7.6	6.9	with yF
ratio	σx/σd	--	0.628	0.518	eq.14

circumferential load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
pseudo class for 3-round cyl.		--	sh/mdl	sh/mdl	4.2/5.3
id. pseudo buckling stress	σfSiE	N/mm²	20.6	18.9	5.3.2
max. ideal buckl. stress	σfSi	N/mm²	20.6	18.9	4.2/5.3
related slenderness	£Sf	--	4.15	4.34	eq.2
reduction factor	æf	--	0.04	0.03	eq.7/8
reduced reduction factor	æf	--	0.04	0.03	(305)
real buckling stress	σfSRk	N/mm²	13.4	12.3	eq.5
safety coefficient	yMf	--	1.1	1.1	eq.12/
limit for buckling stress	σfSRd	N/mm²	12.2	11.1	eq.10
max. membrane stress	σf	--	6.2	5.7	with yF
ratio	σf/σd	--	0.509	0.509	eq.15

combined loads		round 1	round 2	element
ratio	--	0.989	0.869	eq.50

customer...... OMV	drawing....... BF 2
revisor....... Panenka	order......... Diesel Storage Tank
revision......	order number.. 5.7638
prod.number...	commission....

input data

design data and load collection:

axial force		P =	7620.00	kN
safety coefficient (axial load)		yF,P =	1.01	-
external pressure (area load)		q =	46.0	mbar
safety coefficient (external pressure)		yF,q =	1.01	-
external windload	=		no	
wind undertow	=		no	
safety coefficient (wind)		yF,w =	1.01	-
temperature		T =	40	°C

---

geometry and configuration data:

kind of shell	=		cylinder	
radius of shell mean area		r =	16000.0	mm
number of rounds	=		2 rounds	
length of 1st round		l1 =	100.0	mm
length of 2nd round		l2 =	1800.0	mm
wall thickness of 1st round		t1 =	11.0	mm
wall thickness of 2nd round		t2 =	12.0	mm
border conditions	=	transl. fixed - transl. fixed		

---

material data:

material number	=		1.0570	
semi product	=		plate	
mill undertolerance		c1 =	0.3	mm
corrosion allowance		c2 =	1.0	mm
stress value		fy =	355.0	N/mm²
elastic modulus		E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with modified wall thickness

manufacturing inaccuracies			round 1	round 2	element
measure length (longit.)	lmx	mm	1678.	1752.	(302)
all. longit. buckle depth	tvx	mm	16.8	17.5	(302)
measure length (circumf.)	lmf	mm	471.1	2000.	(302)
all. circumf. buckle depth	tvf	mm	4.7	20.0	(302)
allowed eccentricity	e	mm	0.5	0.5	304/T.4
pseudo wall thickness	teff	mm	9.7	10.7	AD-B0

geometry of 3-round pseudo cylinder				remark
pseudo round length top	lo	mm	950.0	element (509)
pseudo round length mid	lm	mm	475.0	element (509)
pseudo round length down	lu	mm	475.0	element (509)
pseudo wall thickness top	to	mm	10.59	element (509)
pseudo wall thickness mid	tm	mm	10.70	element (509)
pseudo wall thickness down	tu	mm	10.70	element (509)
parameter for figure 20	lo/l	--	0.50	fig. 20
parameter for figure 20	tm/to	--	1.01	fig. 20
parameter for figure 20	tu/to	--	1.01	fig. 20
coefficient for pseudo cylinder	ß	--	0.50	fig. 20

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 2
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
cylinder class		--	sh/mdl	sh/mdl	4.2/5.3
coefficient Cx	Cx	--	1.1	1.1	4.2/5.3
id. buckling stress	σxSi	N/mm²	82.1	91.1	4.2/5.3
rel. slenderness	£Sx	--	2.1	2.0	eq.1
reduction factor	æx	--	0.0	0.1	eq.8
reduc. reduction factor	æx	--	0.0	0.1	(305)
real buckling stress	σxSRk	N/mm²	16.4	18.2	eq.4
safety coefficient	yMx	--	1.5	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	11.3	12.6	eq.9
max. membrane stress	σx	N/mm²	7.9	7.2	with yF
ratio	σx/σd	--	0.697	0.567	eq.14

circumferential load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
pseudo class for 3-round cyl.		--	sh/mdl	sh/mdl	4.2/5.3
id. pseudo buckling stress	σfSiE	N/mm²	30.4	27.5	5.3.2
max. ideal buckl. stress	σfSi	N/mm²	30.4	27.5	4.2/5.3
related slenderness	£Sf	--	3.42	3.59	eq.2
reduction factor	æf	--	0.06	0.05	eq.7/8
reduced reduction factor	æf	--	0.06	0.05	(305)
real buckling stress	σfSRk	N/mm²	19.7	17.9	eq.5
safety coefficient	yMf	--	1.1	1.1	eq.12/
limit for buckling stress	σfSRd	N/mm²	18.0	16.3	eq.10
max. membrane stress	σf	--	7.7	6.9	with yF
ratio	σf/σd	--	0.427	0.427	eq.15

combined loads		round 1	round 2	element
ratio	--	0.982	0.837	eq.50

customer......	OMV	drawing.......	BF 3
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	7350.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	2000.0	mm
wall thickness	t =	11.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.3	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1678.	(302)
all. longit. buckle depth	tvx	mm	16.8	(302)
measure length (circumf.)	lmf	mm	2000.	(302)
all. circumf. buckle depth	tvf	mm	20.0	(302)
pseudo wall thickness	teff	mm	9.7	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.1	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	81.6	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.1	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	16.3	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	11.3	eq.9
max. membrane stress	σx	N/mm²	7.6	with yF
ratio	σx/σd	--	0.676	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.3	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	30.8	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	3.39	eq.2
reduction factor	æf	--	0.06	eq.7/8
reduced reduction factor	æf	--	0.06	(305)
real buckling stress	σfSRk	N/mm²	20.0	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	18.2	eq.10
max. membrane stress	σf	--	7.7	with yF
ratio	σf/σd	--	0.421	eq.15

combined loads			element
ratio	--	0.952	eq.50

customer......	OMV	drawing.......	
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force		P =	7090.00	kN
safety coefficient (axial load)		yF,P =	1.01	-
external pressure (area load)		q =	46.0	mbar
safety coefficient (external pressure)		yF,q =	1.01	-
external windload	=		no	
wind undertow	=		no	
safety coefficient (wind)		yF,w =	1.01	-
temperature		T =	40	°C

---

geometry and configuration data:

kind of shell	=		cylinder	
radius of shell mean area		r =	16000.0	mm
number of rounds	=		no rounds	
total length of cylinder		l =	2000.0	mm
wall thickness		t =	11.0	mm
border conditions	=		transl. fixed - transl. fixed	

---

material data:

material number	=		1.0570	
semi product	=		plate	
mill undertolerance		c1 =	0.3	mm
corrosion allowance		c2 =	1.0	mm
stress value		fy =	355.0	N/mm^2
elastic modulus		E =	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1678.	(302)
all. longit. buckle depth	tvx	mm	16.8	(302)
measure length (circumf.)	lmf	mm	2000.	(302)
all. circumf. buckle depth	tvf	mm	20.0	(302)
pseudo wall thickness	teff	mm	9.7	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing.......

order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.1	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	81.6	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.1	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	16.3	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	11.3	eq.9
max. membrane stress	σx	N/mm²	7.3	with yF
ratio	σx/σd	--	0.652	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.3	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	30.8	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	3.39	eq.2
reduction factor	æf	--	0.06	eq.7/8
reduced reduction factor	æf	--	0.06	(305)
real buckling stress	σfSRk	N/mm²	20.0	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	18.2	eq.10
max. membrane stress	σf	--	7.7	with yF
ratio	σf/σd	--	0.421	eq.15

combined loads			element
ratio	--	0.925	eq.50

customer......	OMV	drawing.......	BF 5
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	6845.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	2 rounds	
length of 1st round	l1 =	400.0	mm
length of 2nd round	l2 =	700.0	mm
wall thickness of 1st round	t1 =	10.0	mm
wall thickness of 2nd round	t2 =	11.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with modified wall thickness

manufacturing inaccuracies			round 1	round 2	element
measure length (longit.)	lmx	mm	1600.	1678.	(302)
all. longit. buckle depth	tvx	mm	16.0	16.8	(302)
measure length (circumf.)	lmf	mm	920.0	1246.	(302)
all. circumf. buckle depth	tvf	mm	9.2	12.5	(302)
allowed eccentricity	e	mm	0.5	0.5	304/T.4
pseudo wall thickness	teff	mm	8.5	9.5	AD-B0

geometry of 3-round pseudo cylinder				remark
pseudo round length top	lo	mm	550.0	element (509)
pseudo round length mid	lm	mm	275.0	element (509)
pseudo round length down	lu	mm	275.0	element (509)
pseudo wall thickness top	to	mm	8.77	element (509)
pseudo wall thickness mid	tm	mm	9.50	element (509)
pseudo wall thickness down	tu	mm	9.50	element (509)
parameter for figure 20	lo/l	--	0.50	fig. 20
parameter for figure 20	tm/to	--	1.08	fig. 20
parameter for figure 20	tu/to	--	1.08	fig. 20
coefficient for pseudo cylinder	ß	--	0.51	fig. 20

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 5
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
cylinder class		--	sh/mdl	sh/mdl	4.2/5.3
coefficient Cx	Cx	--	1.2	1.2	4.2/5.3
id. buckling stress	σxSi	N/mm²	79.0	89.8	4.2/5.3
rel. slenderness	£Sx	--	2.1	2.0	eq.1
reduction factor	æx	--	0.0	0.1	eq.8
reduc. reduction factor	æx	--	0.0	0.1	(305)
real buckling stress	σxSRk	N/mm²	15.8	18.0	eq.4
safety coefficient	yMx	--	1.5	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	10.9	12.4	eq.9
max. membrane stress	σx	N/mm²	8.1	7.2	with yF
ratio	σx/σd	--	0.743	0.584	eq.14

circumferential load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
pseudo class for 3-round cyl.		--	sh/mdl	sh/mdl	4.2/5.3
id. pseudo buckling stress	σfSiE	N/mm²	38.0	34.0	5.3.2
max. ideal buckl. stress	σfSi	N/mm²	38.0	34.0	4.2/5.3
related slenderness	£Sf	--	3.06	3.23	eq.2
reduction factor	æf	--	0.07	0.06	eq.7/8
reduced reduction factor	æf	--	0.07	0.06	(305)
real buckling stress	σfSRk	N/mm²	24.7	22.1	eq.5
safety coefficient	yMf	--	1.1	1.1	eq.12/
limit for buckling stress	σfSRd	N/mm²	22.5	20.1	eq.10
max. membrane stress	σf	--	8.7	7.8	with yF
ratio	σf/σd	--	0.389	0.389	eq.15

combined loads		round 1	round 2	element
ratio	--	0.997	0.818	eq.50

customer......	OMV	drawing.......	BF 6
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	6700.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	1500.0	mm
wall thickness	t =	10.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.3	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm^2
elastic modulus	E =	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1600.	(302)
all. longit. buckle depth	tvx	mm	16.0	(302)
measure length (circumf.)	lmf	mm	1781.	(302)
all. circumf. buckle depth	tvf	mm	17.8	(302)
pseudo wall thickness	teff	mm	8.7	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 6
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.1	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm^2	75.6	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.2	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm^2	15.1	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm^2	10.4	eq.9
max. membrane stress	σx	N/mm^2	7.7	with yF
ratio	σx/σd	--	0.742	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.5	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm^2	38.2	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	3.05	eq.2
reduction factor	æf	--	0.07	eq.7/8
reduced reduction factor	æf	--	0.07	(305)
real buckling stress	σfSRk	N/mm^2	24.8	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm^2	22.5	eq.10
max. membrane stress	σf	--	8.5	with yF
ratio	σf/σd	--	0.379	eq.15

combined loads			element
ratio	--	0.986	eq.50

customer......	OMV	drawing.......	BF 7
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	6535.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	2 rounds	
length of 1st round	l1 =	100.0	mm
length of 2nd round	l2 =	600.0	mm
wall thickness of 1st round	t1 =	9.0	mm
wall thickness of 2nd round	t2 =	10.0	mm
border conditions	=	transl. fixed - transl. fixed	

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with modified wall thickness

manufacturing inaccuracies			round 1	round 2	element
measure length (longit.)	lmx	mm	1517.	1600.	(302)
all. longit. buckle depth	tvx	mm	15.2	16.0	(302)
measure length (circumf.)	lmf	mm	448.0	1126.	(302)
all. circumf. buckle depth	tvf	mm	4.5	11.3	(302)
allowed eccentricity	e	mm	0.5	0.5	304/T.4
pseudo wall thickness	teff	mm	7.5	8.5	AD-B0

geometry of 3-round pseudo cylinder				remark
pseudo round length top	lo	mm	350.0	element (509)
pseudo round length mid	lm	mm	175.0	element (509)
pseudo round length down	lu	mm	175.0	element (509)
pseudo wall thickness top	to	mm	8.21	element (509)
pseudo wall thickness mid	tm	mm	8.50	element (509)
pseudo wall thickness down	tu	mm	8.50	element (509)
parameter for figure 20	lo/l	--	0.50	fig. 20
parameter for figure 20	tm/to	--	1.03	fig. 20
parameter for figure 20	tu/to	--	1.03	fig. 20
coefficient for pseudo cylinder	ß	--	0.50	fig. 20

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 7
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
cylinder class		--	sh/mdl	sh/mdl	4.2/5.3
coefficient Cx	Cx	--	1.4	1.4	4.2/5.3
id. buckling stress	σxSi	N/mm²	81.5	95.7	4.2/5.3
rel. slenderness	£Sx	--	2.1	1.9	eq.1
reduction factor	æx	--	0.0	0.1	eq.8
reduc. reduction factor	æx	--	0.0	0.1	(305)
real buckling stress	σxSRk	N/mm²	16.3	19.1	eq.4
safety coefficient	yMx	--	1.5	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	11.2	13.3	eq.9
max. membrane stress	σx	N/mm²	8.8	7.7	with yF
ratio	σx/σd	--	0.778	0.579	eq.14

circumferential load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
pseudo class for 3-round cyl.		--	sh/mdl	sh/mdl	4.2/5.3
id. pseudo buckling stress	σfSiE	N/mm²	56.8	50.1	5.3.2
max. ideal buckl. stress	σfSi	N/mm²	56.8	50.1	4.2/5.3
related slenderness	£Sf	--	2.50	2.66	eq.2
reduction factor	æf	--	0.10	0.09	eq.7/8
reduced reduction factor	æf	--	0.10	0.09	(305)
real buckling stress	σfSRk	N/mm²	36.9	32.6	eq.5
safety coefficient	yMf	--	1.1	1.1	eq.12/
limit for buckling stress	σfSRd	N/mm²	33.6	29.6	eq.10
max. membrane stress	σf	--	9.9	8.7	with yF
ratio	σf/σd	--	0.295	0.295	eq.15

combined loads		round 1	round 2	element
ratio	--	0.949	0.723	eq.50

input data

design data and load collection:

axial force	P =	6465.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	700.0	mm
wall thickness	t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1517.	(302)
all. longit. buckle depth	tvx	mm	15.2	(302)
measure length (circumf.)	lmf	mm	1185.	(302)
all. circumf. buckle depth	tvf	mm	11.9	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV	drawing....... BF 8
revisor....... Panenka	order......... Diesel Storage Tank
revision......	order number.. 5.7638
prod.number...	commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.4	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	81.5	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.1	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	16.3	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	11.2	eq.9
max. membrane stress	σx	N/mm²	8.7	with yF
ratio	σx/σd	--	0.770	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	2.2	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	96.9	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	1.91	eq.2
reduction factor	æf	--	0.18	eq.7/8
reduced reduction factor	æf	--	0.18	(305)
real buckling stress	σfSRk	N/mm²	63.0	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	57.3	eq.10
max. membrane stress	σf	--	4.0	with yF
ratio	σf/σd	--	0.069	eq.15

combined loads			element
ratio	--	0.757	eq.50

customer......	OMV	drawing.......	BF 9
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	6400.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	900.0	mm
wall thickness	t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0144	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	275.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1517.	(302)
all. longit. buckle depth	tvx	mm	15.2	(302)
measure length (circumf.)	lmf	mm	1344.	(302)
all. circumf. buckle depth	tvf	mm	13.4	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 9
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.2	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	72.9	4.2/5.3/6.2
rel. slenderness	£Sx	--	1.9	eq.1
reduction factor	æx	--	0.1	eq.8
reduc. reduction factor	æx	--	0.1	(305)
real buckling stress	σxSRk	N/mm²	14.6	eq.4
safety coefficient	yMx	--	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	10.1	eq.9
max. membrane stress	σx	N/mm²	8.6	with yF
ratio	σx/σd	--	0.846	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.8	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	63.7	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	2.08	eq.2
reduction factor	æf	--	0.15	eq.7/8
reduced reduction factor	æf	--	0.15	(305)
real buckling stress	σfSRk	N/mm²	41.4	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	37.7	eq.10
max. membrane stress	σf	--	7.1	with yF
ratio	σf/σd	--	0.188	eq.15

combined loads			element
ratio	--	0.935	eq.50

customer......	OMV	drawing.......	BF 10
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	6265.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	960.0	mm
wall thickness	t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed	

material data:

material number	=	1.0144	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	275.0	N/mm^2
elastic modulus	E =	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1517.	(302)
all. longit. buckle depth	tvx	mm	15.2	(302)
measure length (circumf.)	lmf	mm	1388.	(302)
all. circumf. buckle depth	tvf	mm	13.9	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.2	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	71.3	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.0	eq.1
reduction factor	æx	--	0.1	eq.8
reduc. reduction factor	æx	--	0.1	(305)
real buckling stress	σxSRk	N/mm²	14.3	eq.4
safety coefficient	yMx	--	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	9.9	eq.9
max. membrane stress	σx	N/mm²	8.4	with yF
ratio	σx/σd	--	0.849	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.8	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	57.5	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	2.19	eq.2
reduction factor	æf	--	0.14	eq.7/8
reduced reduction factor	æf	--	0.14	(305)
real buckling stress	σfSRk	N/mm²	37.4	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	34.0	eq.10
max. membrane stress	σf	--	8.0	with yF
ratio	σf/σd	--	0.236	eq.15

combined loads				element
ratio		--	0.980	eq.50

customer...... OMV	drawing....... BF 11
revisor....... Panenka	order......... Diesel Storage Tank
revision......	order number.. 5.7638
prod.number...	commission....

__input data__

design data and load collection:

axial force		P =	6147.00	kN
safety coefficient (axial load)		yF,P =	1.01	-
external pressure (area load)		q =	46.0	mbar
safety coefficient (external pressure)		yF,q =	1.01	-
external windload	=		no	
wind undertow	=		no	
safety coefficient (wind)		yF,w =	1.01	-
temperature		T =	40	°C

geometry and configuration data:

kind of shell	=		cylinder	
radius of shell mean area		r =	16000.0	mm
number of rounds	=		no rounds	
total length of cylinder		l =	1000.0	mm
wall thickness		t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed		

material data:

material number	=		1.0144	
semi product	=		plate	
mill undertolerance		c1 =	0.5	mm
corrosion allowance		c2 =	1.0	mm
stress value		fy =	275.0	N/mm²
elastic modulus		E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1517.	(302)
all. longit. buckle depth	tvx	mm	15.2	(302)
measure length (circumf.)	lmf	mm	1416.	(302)
all. circumf. buckle depth	tvf	mm	14.2	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.2	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	70.4	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.0	eq.1
reduction factor	æx	--	0.1	eq.8
reduc. reduction factor	æx	--	0.1	(305)
real buckling stress	σxSRk	N/mm²	14.1	eq.4
safety coefficient	yMx	--	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	9.7	eq.9
max. membrane stress	σx	N/mm²	8.2	with yF
ratio	σx/σd	--	0.846	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.7	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	53.9	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	2.26	eq.2
reduction factor	æf	--	0.13	eq.7/8
reduced reduction factor	æf	--	0.13	(305)
real buckling stress	σfSRk	N/mm²	35.1	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	31.9	eq.10
max. membrane stress	σf	--	8.7	with yF
ratio	σf/σd	--	0.271	eq.15

combined loads			element
ratio	--	1.007	eq.50

customer...... OMV	drawing....... BF 12
revisor....... Panenka	order......... Diesel Storage Tank
revision......	order number.. 5.7638
prod.number...	commission....

input data

design data and load collection:

axial force	P =	6045.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	46.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

---

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	16000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	1000.0	mm
wall thickness	t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed	

---

material data:

material number	=	1.0144	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	275.0	N/mm²
elastic modulus	E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1517.	(302)
all. longit. buckle depth	tvx	mm	15.2	(302)
measure length (circumf.)	lmf	mm	1416.	(302)
all. circumf. buckle depth	tvf	mm	14.2	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	46.4	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... BF 12
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.2	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	70.4	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.0	eq.1
reduction factor	æx	--	0.1	eq.8
reduc. reduction factor	æx	--	0.1	(305)
real buckling stress	σxSRk	N/mm²	14.1	eq.4
safety coefficient	yMx	--	1.4	eq.13
limit for buckling stress	σxSRd	N/mm²	9.7	eq.9
max. membrane stress	σx	N/mm²	8.1	with yF
ratio	σx/σd	--	0.832	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.7	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	53.9	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	2.26	eq.2
reduction factor	æf	--	0.13	eq.7/8
reduced reduction factor	æf	--	0.13	(305)
real buckling stress	σfSRk	N/mm²	35.1	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	31.9	eq.10
max. membrane stress	σf	--	8.7	with yF
ratio	σf/σd	--	0.271	eq.15

combined loads			element
ratio	--	0.990	eq.50

customer...... OMV	drawing....... Bassin BF1
revisor....... Panenka	order......... Diesel Storage Tank
revision......	order number.. 5.7638
prod.number...	commission....

input data

design data and load collection:

axial force	P =	2265.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	19.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	18000.0	mm
number of rounds	=	2 rounds	
length of 1st round	l1 =	800.0	mm
length of 2nd round	l2 =	2400.0	mm
wall thickness of 1st round	t1 =	9.0	mm
wall thickness of 2nd round	t2 =	10.0	mm
border conditions	=	transl. fixed - transl. fixed	

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm^2
elastic modulus	E =	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with modified wall thickness

manufacturing inaccuracies			round 1	round 2	element
measure length (longit.)	lmx	mm	1610.	1697.	(302)
all. longit. buckle depth	tvx	mm	16.1	17.0	(302)
measure length (circumf.)	lmf	mm	1305.	2000.	(302)
all. circumf. buckle depth	tvf	mm	13.1	20.0	(302)
allowed eccentricity	e	mm	0.5	0.5	304/T.4
pseudo wall thickness	teff	mm	7.5	8.5	AD-B0

geometry of 3-round pseudo cylinder				remark
pseudo round length top	lo	mm	1600.0	element (509)
pseudo round length mid	lm	mm	800.0	element (509)
pseudo round length down	lu	mm	800.0	element (509)
pseudo wall thickness top	to	mm	8.00	element (509)
pseudo wall thickness mid	tm	mm	8.50	element (509)
pseudo wall thickness down	tu	mm	8.50	element (509)
parameter for figure 20	lo/l	--	0.50	fig. 20
parameter for figure 20	tm/to	--	1.06	fig. 20
parameter for figure 20	tu/to	--	1.06	fig. 20
coefficient for pseudo cylinder	ß	--	0.51	fig. 20

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	19.1	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... Bassin BF1
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
cylinder class		--	sh/mdl	sh/mdl	4.2/5.3
coefficient Cx	Cx	--	1.0	1.0	4.2/5.3
id. buckling stress	σxSi	N/mm²	54.0	61.4	4.2/5.3
rel. slenderness	£Sx	--	2.6	2.4	eq.1
reduction factor	æx	--	0.0	0.0	eq.8
reduc. reduction factor	æx	--	0.0	0.0	(305)
real buckling stress	σxSRk	N/mm²	10.8	12.3	eq.4
safety coefficient	yMx	--	1.5	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	7.5	8.5	eq.9
max. membrane stress	σx	N/mm²	2.7	2.4	with yF
ratio	σx/σd	--	0.362	0.281	eq.14

circumferential load			round 1	round 2	element
report necessary ?		--	yes	yes	4.2/5.3
report possible ?		--	yes	yes	
pseudo class for 3-round cyl.		--	sh/mdl	sh/mdl	4.2/5.3
id. pseudo buckling stress	σfSiE	N/mm²	11.0	9.7	5.3.2
max. ideal buckl. stress	σfSi	N/mm²	11.0	9.7	4.2/5.3
related slenderness	£Sf	--	5.67	6.04	eq.2
reduction factor	æf	--	0.02	0.02	eq.7/8
reduced reduction factor	æf	--	0.02	0.02	(305)
real buckling stress	σfSRk	N/mm²	7.2	6.3	eq.5
safety coefficient	yMf	--	1.1	1.1	eq.12/
limit for buckling stress	σfSRd	N/mm²	6.5	5.8	eq.10
max. membrane stress	σf	--	4.6	4.1	with yF
ratio	σf/σd	--	0.706	0.706	eq.15

combined loads		round 1	round 2	element
ratio	--	0.928	0.852	eq.50

input data

design data and load collection:

axial force	P	=	1635.00	kN
safety coefficient (axial load)	yF,P	=	1.01	-
external pressure (area load)	q	=	19.0	mbar
safety coefficient (external pressure)	yF,q	=	1.01	-
external windload		=	no	
wind undertow		=	no	
safety coefficient (wind)	yF,w	=	1.01	-
temperature	T	=	40	°C

geometry and configuration data:

kind of shell		=	cylinder	
radius of shell mean area	r	=	18000.0	mm
number of rounds		=	no rounds	
total length of cylinder	l	=	3500.0	mm
wall thickness	t	=	9.0	mm
border conditions		=	transl. fixed - transl. fixed	

material data:

material number		=	1.0570	
semi product		=	plate	
mill undertolerance	c1	=	0.5	mm
corrosion allowance	c2	=	1.0	mm
stress value	fy	=	355.0	N/mm^2
elastic modulus	E	=	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1610.	(302)
all. longit. buckle depth	tvx	mm	16.1	(302)
measure length (circumf.)	lmf	mm	2000.	(302)
all. circumf. buckle depth	tvf	mm	20.0	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	19.1	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... Bassin BF2
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.0	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	53.9	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.6	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	10.8	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	7.4	eq.9
max. membrane stress	σx	N/mm²	1.9	with yF
ratio	σx/σd	--	0.262	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.1	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	9.7	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	6.06	eq.2
reduction factor	æf	--	0.02	eq.7/8
reduced reduction factor	æf	--	0.02	(305)
real buckling stress	σfSRk	N/mm²	6.3	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	5.7	eq.10
max. membrane stress	σf	--	4.6	with yF
ratio	σf/σd	--	0.806	eq.15

combined loads			element
ratio	--	0.951	eq.50

customer......	OMV	drawing.......	Bassin BF3
revisor.......	Panenka	order.........	Diesel Storage Tank
revision......		order number..	5.7638
prod.number...		commission....	

input data

design data and load collection:

axial force	P =	1065.00	kN
safety coefficient (axial load)	yF,P =	1.01	-
external pressure (area load)	q =	19.0	mbar
safety coefficient (external pressure)	yF,q =	1.01	-
external windload	=	no	
wind undertow	=	no	
safety coefficient (wind)	yF,w =	1.01	-
temperature	T =	40	°C

geometry and configuration data:

kind of shell	=	cylinder	
radius of shell mean area	r =	18000.0	mm
number of rounds	=	no rounds	
total length of cylinder	l =	3500.0	mm
wall thickness	t =	9.0	mm
border conditions	=	transl. fixed - transl. fixed	

material data:

material number	=	1.0570	
semi product	=	plate	
mill undertolerance	c1 =	0.5	mm
corrosion allowance	c2 =	1.0	mm
stress value	fy =	355.0	N/mm^2
elastic modulus	E =	210250	N/mm^2

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1610.	(302)
all. longit. buckle depth	tvx	mm	16.1	(302)
measure length (circumf.)	lmf	mm	2000.	(302)
all. circumf. buckle depth	tvf	mm	20.0	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	19.1	with yF

customer...... OMV
revisor....... Panenka
revision......
prod.number...

drawing....... Bassin BF3
order......... Diesel Storage Tank
order number.. 5.7638
commission....

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.0	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	53.9	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.6	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	10.8	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	7.4	eq.9
max. membrane stress	σx	N/mm²	1.3	with yF
ratio	σx/σd	--	0.171	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.1	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	9.7	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	6.06	eq.2
reduction factor	æf	--	0.02	eq.7/8
reduced reduction factor	æf	--	0.02	(305)
real buckling stress	σfSRk	N/mm²	6.3	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	5.7	eq.10
max. membrane stress	σf	--	4.6	with yF
ratio	σf/σd	--	0.806	eq.15

combined loads				element
ratio		--	0.873	eq.50

input data

design data and load collection:

axial force		P =	645.00	kN
safety coefficient (axial load)		yF,P =	1.01	-
external pressure (area load)		q =	19.0	mbar
safety coefficient (external pressure)		yF,q =	1.01	-
external windload	=		no	
wind undertow	=		no	
safety coefficient (wind)		yF,w =	1.01	-
temperature		T =	40	°C

geometry and configuration data:

kind of shell	=		cylinder	
radius of shell mean area		r =	18000.0	mm
number of rounds	=		no rounds	
total length of cylinder		l =	2800.0	mm
wall thickness		t =	9.0	mm
border conditions	=		transl. fixed - transl. fixed	

material data:

material number	=		1.0570	
semi product	=		plate	
mill undertolerance		c1 =	0.5	mm
corrosion allowance		c2 =	1.0	mm
stress value		fy =	355.0	N/mm²
elastic modulus		E =	210250	N/mm²

results

declaration to the abbrevations

x	index for axial direction	f	index for circumf. direction
σx	axial stress	σf	circumferential stress
æ	reduction factor	σi	ideal buckling stress
yF	safety coefficient loading	yM	safety coefficient material
£S	related grade of slenderness	long	long cylinder class
sh	short cylinder class	mdl	midlong cylinder class

cylindrical shells with not modified wall thickness

manufacturing inaccuracies				element
measure length (longit.)	lmx	mm	1610.	(302)
all. longit. buckle depth	tvx	mm	16.1	(302)
measure length (circumf.)	lmf	mm	2000.	(302)
all. circumf. buckle depth	tvf	mm	20.0	(302)
pseudo wall thickness	teff	mm	7.5	AD-B0

results for pseudo wind load				remark
summation of pseudo wind loads	qwind	mbar	0.0	accord. (424)
superposition with external pressure	qG	mbar	19.1	with yF

axial load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
cylinder class		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient Cx	Cx	--	1.0	4.2/5.3/6.2/7.2
id. buckling stress	σxSi	N/mm²	54.4	4.2/5.3/6.2
rel. slenderness	£Sx	--	2.6	eq.1
reduction factor	æx	--	0.0	eq.8
reduc. reduction factor	æx	--	0.0	(305)
real buckling stress	σxSRk	N/mm²	10.9	eq.4
safety coefficient	yMx	--	1.5	eq.13
limit for buckling stress	σxSRd	N/mm²	7.5	eq.9
max. membrane stress	σx	N/mm²	0.8	with yF
ratio	σx/σd	--	0.102	eq.14

circumferential load				element
report necessary ?		--	yes	4.2/5.3/6.2/7.2
report possible ?		--	yes	
pseudo class for 3-round cyl.		--	sh/mdl	4.2/5.3/6.2/7.2
coefficient	Cf	--	1.2	4.2/5.3/6.2/7.2
max. ideal buckl. stress	σfSi	N/mm²	12.6	4.2/5.3/6.2/7.2
related slenderness	£Sf	--	5.30	eq.2
reduction factor	æf	--	0.02	eq.7/8
reduced reduction factor	æf	--	0.02	(305)
real buckling stress	σfSRk	N/mm²	8.2	eq.5
safety coefficient	yMf	--	1.1	eq.12/13
limit for buckling stress	σfSRd	N/mm²	7.5	eq.10
max. membrane stress	σf	--	4.6	with yF
ratio	σf/σd	--	0.618	eq.15

combined loads			element
ratio	--	0.605	eq.50