



Wolf GmbH & Co.KG
57234 Wilnsdorf

Air Liquide Purchase-no.:
4500023998

Project: ASU Kosice No.9

Kom.Nr. 37106

Dokument No. :

Document: Design Calculation

Description: Molsieve Adsorber

Tag No.: W15001 / W15002

Drawing No.: 11437 - 0

0	first issue	07.12.2004		Strake	TB		
Status	Ausgabe	Datum	geänd.Seiten	erstellt	Abtlg.	geprüft	genehmigt

Table of contents

1.	Test pressure calculation	Page	3
2.	heads (left and right)	Page	4
3.	shell	Page	5 - 8
4.	Manway flange N6 DN1000	Page	9 - 11
5.	Manway cover DN 1000	Page	15
6.	Manway flange N5 DN500	Page	16 - 18
7.	Manway cover DN 500	Page	19
8.	table with additional Nozzle loads	Page	20
9.	additional Nozzle loads N1 WRC 107 calculation case I	Page	21 - 23
10.	additional Nozzle loads N1 WRC 107 calculation case II	Page	24 - 26
11.	additional Nozzle loads N3,N4 WRC 107 calculation case I	Page	27 - 29
12.	additional Nozzle loads N3,N4 WRC 107 calculation case II	Page	30 - 32
13.	statical calculation	Page	35 - 51

Test Pressure Calculation
acc to AD 2000-Merkblatt HP30:2003-01

drawing no: 11437-0
name/ item: Molsieve Adsorber W15001 / W15002

input data

Operating Data

maximum allowable pressure	p =	6 bar
relative density of the test fluid	GammaP =	1 dN/dm ³
relative density of the working fluid	GammaF =	1 dN/dm ³
design temperature	T =	250 °C
temperature for test condition	T' =	20 °C
operating mode horizontal = 1	vertical = 2 =	2
pressure test horizontal = 1	vertical = 2 =	1
length (height) of vessel	L / H =	4020 mm
test pressure calculation under consideration of		
maximum ratio K'/K:	1	
or preferably minimum ratio K'/K:	2 =	2

Material Data

name/item: Mantel
material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strenght value K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
design strength value at T' K' = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]

results

scope:

Only for a liquid pressure test according to AD 2000 Hp 30, section 4.

Attention!

The condition is that the pressure gauge is placed on the highest level of the vertical or horizontal vessel during testing procedure.

additional pressure from static liquid column pstat = 0.402 bar

intermediate results			thickness	factor		req test
no	name / item	material	* mm	K' / K	Fp	press bar
1	Mantel	P 265 GH	D >16=<40	1.457	1.821	11.330

required test pressure pT = 11.331 bar, for component with no. 1
the lowest ratio of K'/K was taken into account

* D = data from DIMy database resp. F = individual input data

Fp= test pressure factor

Attention: it have to be checked whether all components of the pressure equipment will withstand this calculated test pressure!

For Information

For the calculation of testing condition of the vessel the additional static column from medium (=Di) have to be considered.

Formed Heads with Opening
under internal and external pressure
acc to AD 2000-Merkblatt B3/B9:2000-10

drawing no: 11437-0
name/ item: Heads left and right

input data - dished end

design data

design pressure p = 6 bar
design temperature T = 250 °C

material data, dished end

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
design strength value at room temperature K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor S = 1.5
joint efficiency v = .85

geometry data, dished end

head type: 2- Korbboogen type
outer diameter Da = 4040 mm
wall thickness se = 20 mm
manufacturing tolerance c1 = 6- DIN 28011-13
corrosion allowance c2 = 3 mm

results - dished end

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

req wall thickness without opening [15] sreq = 17.79 mm
» act wall thickness is adequate! res = +12 %
with $\beta = 2.34$ and $(sreq-c)/Da = .0035$
and manuf. tolerance/corrosion allowance c1/c2 = 0.50/3.00 mm
allowances, head (act wall thickness) c1/c2 = 0.50/3.00 mm
max. unreinforced opening crown da max ca 640 mm
knuckle da max ca 324 mm
influence of multiple openings / AD-B9 [8] from l <= 654.4 mm

max all working pressure pmax = 7.13 bar
- with decisive component: dished end
max all test pressure pTmax = 14.84 bar

Cylindrical Shells with Opening
under Internal Pressure
acc to AD 2000-Merkblatt B1/B9:2000-10

drawing no: 11437-0
name/ item: Shell Molsieve Adsorber W15001 / W15002

input data - shell

design data

design pressure p = 6 bar
design temperature T = 250 °C

material data, shell

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
design strength value at room temperature K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor S = 1.5
joint efficiency v = .85

geometry data, shell

outer diameter Da = 4040 mm
actual wall thickness se = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

results - shell

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

req wall thickness without opening [2] sreq = 15.78 mm
» act wall thickness is adequate! res = +27 %
manufacturing tolerance / corrosion allowance c1/c2 = 0.60/3.00 mm
allowances, shell (act wall thickness) c1/c2 = 0.60/3.00 mm
max unreinforced opening da max ca 299 mm
influence of multiple nozzles / AD-B9 [8] from l <= 513.8 mm

max all working pressure pmax = 6.58 bar
- with decisive component: opening no. 1
max all test pressure pTmax = 13.69 bar

input data - opening 1

opening - name/item: Manway N6, DN1000

type of opening: 1- nozzle, set-through without reinf. pad

material data

nozzle: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, nozzle K = 175 N/mm²
yield strength Rp 0.2 [250°C, 25mm]
design strength value, nozzle at room temp. K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 25mm]
joint efficiency, nozzle v = .85

geometry data

outer diameter da = 1000 mm
actual wall thickness ss = 25 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
actual length of nozzle ls = 200 mm
protruding length ls' = 50 mm
distance nozzle outside diameter - discontinuity x = 190 mm

results - opening 1

opening-name/item: Manway N6, DN1000

req wall thickness of nozzle acc to AD-B1 [2] sserf = 6.42 mm
» act wall thickness is adequate! res = +290 %
with manufact. tolerance/corrosion allowance c1/c2 = 0.40/3.00 mm
area comparison acc to AD-B9 with act wall thicknesses:
actual stress [2] σ_v = 106.4 N/mm²
allowable stress K/S = 116.7 N/mm²
» actual opening is adequately reinforced! res = +10 %
with allowances, nozzle (act wall thickness) c1/c2 = 0.80/3.00 mm
calculated wall thickness of nozzle ss = 21.2 mm
calculated outer nozzle length [6] ls mit = 180.1 mm
inner nozzle length ls' mit = 50.0 mm
calculated shell length [3] b mit = 190.0 mm
load-bearing cross sectional area A_σ = 8341 mm²
pressure load area A_p = 1475491 mm²

input data - opening 2

opening - name/item: Nozzle N1 / N2, DN 700

type of opening: 1- nozzle, set-through without reinf. pad

material data

nozzle: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, nozzle K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
design strength value, nozzle at room temp. K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
joint efficiency, nozzle v = .85

geometry data

outer diameter da = 711 mm
actual wall thickness ss = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
actual length of nozzle ls = 150 mm
protruding length ls' = 50 mm
distance nozzle outside diameter - discontinuity x = 0 mm

results - opening 2

opening-name/item: Nozzle N1 / N2, DN 700

req wall thickness of nozzle acc to AD-B1 [2] sserf = 5.54 mm
» act wall thickness is adequate! res = +261 %
with manufact. tolerance/corrosion allowance c1/c2 = 0.40/3.00 mm
area comparison acc to AD-B9 with act wall thicknesses:
actual stress [2] σ_v = 102.6 N/mm²
allowable stress K/S = 116.7 N/mm²
» actual opening is adequately reinforced! res = +14 %
with allowances, nozzle (act wall thickness) c1/c2 = 0.60/3.00 mm
calculated wall thickness of nozzle ss = 16.4 mm
calculated outer nozzle length [6] ls mit = 133.4 mm
inner nozzle length ls' mit = 50.0 mm
calculated shell length [3] b mit = 256.9 mm
load-bearing cross sectional area A_σ = 7490 mm²
pressure load area A_p = 1276945 mm²

input data - opening 3

opening - name/item: Nozzle N8, N9 DN500

type of opening: 1- nozzle, set-through without reinf. pad

material data

nozzle: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, nozzle K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]

continuation material data

design strength value, nozzle at room temp. K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
joint efficiency, nozzle v = .85

geometry data

outer diameter da = 508 mm
actual wall thickness ss = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
actual length of nozzle ls = 150 mm
protruding length ls' = 0 mm
distance nozzle outside diameter - discontinuity x = 0 mm

results - opening 3

opening-name/item: Nozzle N8, N9 DN500

req wall thickness of nozzle acc to AD-B1 [2] sserf = 4.93 mm
» act wall thickness is adequate! res = +306 %
with manufact. tolerance/corrosion allowance c1/c2 = 0.40/3.00 mm
area comparison acc to AD-B9 with act wall thicknesses:
actual stress [2] σ_v = 100.3 N/mm²
allowable stress K/S = 116.7 N/mm²
» actual opening is adequately reinforced! res = +16 %
with allowances, nozzle (act wall thickness) c1/c2 = 0.60/3.00 mm
calculated wall thickness of nozzle ss = 16.4 mm
calculated outer nozzle length [6] ls mit = 112.2 mm
inner nozzle length ls' mit = 0.0 mm
calculated shell length [3] b mit = 256.9 mm
load-bearing cross sectional area A σ = 6322 mm²
pressure load area Ap = 1054162 mm²

input data - opening 4

opening - name/item: Manway N5, DN500

type of opening: 1- nozzle, set-through without reinf. pad

material data

nozzle: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, nozzle K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
design strength value, nozzle at room temp. K20 = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
joint efficiency, nozzle v = .85

geometry data

outer diameter da = 508 mm
actual wall thickness ss = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
actual length of nozzle ls = 150 mm
protruding length ls' = 0 mm
distance nozzle outside diameter - discontinuity x = 0 mm

results - opening 4

opening-name/item: Manway N5, DN500

req wall thickness of nozzle acc to AD-B1 [2] sserf = 4.93 mm
 » act wall thickness is adequate! res = +306 %
 with manufact. tolerance/corrosion allowance c1/c2 = 0.40/3.00 mm
 area comparison acc to AD-B9 with act wall thicknesses:
 actual stress [2] σ_v = 100.3 N/mm²
 allowable stress K/S = 116.7 N/mm²
 » actual opening is adequately reinforced! res = +16 %
 with allowances, nozzle (act wall thickness) c1/c2 = 0.60/3.00 mm
 calculated wall thickness of nozzle ss = 16.4 mm
 calculated outer nozzle length [6] ls mit = 112.2 mm
 inner nozzle length ls' mit = 0.0 mm
 calculated shell length [3] b mit = 256.9 mm
 load-bearing cross sectional area A_σ = 6322 mm²
 pressure load area A_p = 1054162 mm²

input data - opening 5

opening - name/item: Nozzle N4, N5 DN50

type of opening: 1- nozzle, set-through without reinf. pad

material data

nozzle: 0090-St 35.8 (1.0305) DIN 17175 AD-W4/W12
 design strength value, nozzle K = 165 N/mm²
 yield strength Rp 0.2 [250°C, 5.6mm]
 design strength value, nozzle at room temp. K20 = 235 N/mm²
 yield strength Rp 0.2 [20°C, 5.6mm]
 joint efficiency, nozzle v = 1

geometry data

outer diameter da = 60.3 mm
 actual wall thickness ss = 5.6 mm
 manufacturing tolerance c1 = 3- DIN 17175
 corrosion allowance c2 = 3 mm
 actual length of nozzle ls = 100 mm
 protruding length ls' = 0 mm
 distance nozzle outside diameter - discontinuity x = 0 mm

results - opening 5

opening-name/item: Nozzle N4, N5 DN50

req wall thickness of nozzle acc to AD-B1 [2] sserf = 3.52 mm
 » act wall thickness is adequate! res = +59 %
 with manufact. tolerance/corrosion allowance c1/c2 = 0.35/3.00 mm
 area comparison acc to AD-B9 with act wall thicknesses:
 actual stress [2] σ_v = 81.2 N/mm²
 allowable stress K/S = 116.7 N/mm²
 » actual opening is adequately reinforced! res = +44 %
 with allowances, nozzle (act wall thickness) c1/c2 = 0.56/3.00 mm
 calculated wall thickness of nozzle ss = 2.0 mm
 calculated outer nozzle length [6] ls mit = 13.6 mm
 inner nozzle length ls' mit = 0.0 mm
 calculated shell length [3] b mit = 256.9 mm
 load-bearing cross sectional area A_σ = 4271 mm²
 pressure load area A_p = 575936 mm²

Integral Type Flanges
under Internal Pressure and Additional Forces
acc to AD 2000-B7:2000-10 B8:2000-10 DINV 2505:1986-01

drawing no: 11437-0
name/ item: manway flange N6, DN1000

input data

Type Declaration

flange type: 1- welding neck flange (inside gasket)
bolt type: 3- bolts, S=1.8 / S'=1.26 / phi=1.0 (AD-B7)
calculation of bolting torque = 1- yes

Design Data

design pressure p = 6 bar
test pressure p' = 11.6 bar
design temperature T = 50 °C
code no. of external loads: 1- without external loads

Geometry Data, Flange

outside diameter flange da = 1130 mm
outside diameter hub dr = 1000 mm
bolt-circle diameter dt = 1080 mm
outer dia of tapered neck at trans to flange d3 = 1024 mm
flange thickness hF = 45 mm
total length of flange ha = 70 mm
bolt hole diameter dL = 27 mm
number of bolts or bolt holes n = 40 Stck
act wall thickness of hub respectively tube s1 = 12 mm
manufacturing tolerance of hub respect. tube c1 = 0 mm
corrosion allowance of hub respect. tube c2 = 3 mm

Material Data, Flange

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
strength value, design K = 215 N/mm²
yield strength Rp 0.2 [50°C, 70mm]
safety factor, design S = 1.5
strength value, test/bolting-up K = 215 N/mm²
yield strength Rp 0.2 [20°C, 70mm]
safety factor, test/bolting-up S = 1.05
modulus of elasticity, design [50°C] E = 210125 N/mm²
modulus of elasticity, bolting-up [20°C] E = 212000 N/mm²

Gasket Data

gasket type: 4- asbestos - only for Information
calculation without reduction of setting load = 1- yes
retighten the bolts after setting of gasket = 0- No
code no. of medium: 1- design: gases and vapours; test: liquids
outside diameter, gasket dDa = 1050 mm
inside diameter, gasket dDi = 1000 mm
thickness of gasket hD = 3 mm

Bolt Data

material: 0171-5.6 DIN 267 Teil 13:1993-08 AD-W7:1999-12
strength value, design K = 300 N/mm²
yield strength Rp 0.2 [50°C, 20mm]
strength value, test/bolting-up K' = 300 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
root diameter of screw thread dk = 20.11 mm
effective diameter thread d2 = 22.051 mm
outer diameter of bearing surface (bolting) daS = 36 mm
thread angle, bolts α = 60 °
thread pitch, bolts P = 3 mm
min coefficient of friction, thread μG_min = .12
min coefficient of friction, bearing surface μA_min = .12

continuation Bolt Data

max coefficient of friction, thread $\mu G_{\max} = .12$
max coefficient of friction, bearing surface $\mu A_{\max} = .12$

results

summary of results

flange		bolting-up	design	testing	FS0 max
act. stresses and reserve					
section A-A	N/mm ²	95 116%	44 224%	84 144%	194
section B-B	N/mm ²	155 32%	72 99%	137 49%	317
section C-C	N/mm ²	29 603%	9 999%	17 999%	60
act. flange deflection	°	0.579	0.273	0.512	1.19
bolts					
req root diameter	dk mm	15.81 62%	13.41 170%	11.99 181%	20.11

geometry data

calc. wall thickness of hub respectively tube $s1 = 9.00$ mm
with manufacturing tolerance $c1 = 0.00$ mm
corosion allowance $c2 = 3.00$ mm
moment arms
- of hub load $aR = 44.50$ mm
- of ring area load $aF = 38.25$ mm
- of gasket load $aD = 27.50$ mm
- of bolt load (for section C-C) $a1 = 28.00$ mm
reduced bolt hole diameter $dL' = 13.50$ mm
mean gasket diameter $dD = 1025.00$ mm
effective width of gasket $bD = 25.00$ mm
bolt pitch / dL $= 3.14$

		bolt-up (0)	design (B)	testing (P)
gasket data				
medium		gases/vap.	gases/vap.	liquids
characteristic k1	mm	--	32.50	25.00
characteristic k0*KD	N/mm	577.35	--	--
loads	N			
hub load - int.press.	FI..	--	454427	878559
ring area load	FF..	--	40668	78626
gasket load - design	FD..	--	75351	112061
setting load	FDV	1859145	--	--
min req bolt load	FS..	1859145	570447	1069245
flange (DIN 2505)				
bending moments	Nmm			
section A-A,B-B		51126476	23849724	45184968
section C-C		51126476	15972502	29938864
section modulus	mm ³			
section A-A		539842	539479	538485
section B-B		330709	330350	329368
section C-C		1754246	1754246	1754246
act stresses	N/mm ²			
section A-A		94.71	44.21	83.91
section B-B		154.60	72.20	137.19
section C-C		29.14	9.11	17.07
design stress	N/mm ²	204.76	143.33	204.76
eff. stress reserve				
section A-A	%	116	224	144
section B-B	%	32	99	49
section C-C	%	603	999	999
act flange deflection	°	0.5792	0.2726	0.5119

			bolt-up (0)	design (B)	testing (P)
bolts					
req root diameter	dk	mm	15.81	13.41	11.99
auxiliary factor	Z		1.27	1.51	1.27
design allowance	c5	mm	0.00	3.00	0.00
stress reserve	%		62	170	181

max allow operating pressure
 max allow test pressure

pmax = 11.87 bar
 pTmax = 17.23 bar

results for bolting up condition (for information)

basic bolt load FS0 max = 3811495 N
 acc. to stress value of 100% of strength value
 of bolts (testing/ bolting-up)

actual stress section A-A = 194.2 N/mm²
 actual stress section B-B = 316.9 N/mm²
 actual stress section C-C = 59.7 N/mm²
 actual flange deflection = 1.187 °
 actual seating stress of gaske = 47.3 N/mm²

bolting torques acc. to VDI-Richtlinie 2230

req bolting torque (with μ_{max}) MAmin = 182 Nm
 with FVM = FS0 = 1859145 N / 40 bolts = 46479 N

act seating stress of gasket with MAmin = 23.1 N/mm²

max bolting torque (bolting-up/with μ_{min}) MAmax = 241 Nm
 with FVM = FS0maxT = 2462421 N / 40 bolts = 61561 N
 FS0maxT = cause of usage factor of flange reduced force FS0max.

act seating stress of gasket with MAmax = 30.6 N/mm²

$$\begin{aligned} MA &= FVM * (d2/2 * \tan(\phi + \rho') + \mu_A * r_A) \\ \phi &= \arctan(P / (d2 * \pi)) \\ \rho' &= \arctan(\mu_G / \cos(\alpha / 2)) \\ r_A &= (dL + daS) / 4 \end{aligned}$$

the seating stress of gasket was not checked with MAmax !

Unstayed and Stayed Flat Ends and Plates
acc to AD 2000-Merkblatt B5:2004-05

drawing no: 11437-0
name/ item: cover manway flange N6, DN1000

input data

Type Declaration

shape of plate = 1- circular
bound cond: 13- supplementary marginal moment (chapt 6.3)
calculation of deflection of plate without opening = 0- no

Design Data/ Type of Plate

design pressure p = 6 bar
design temperature T = 250 °C

Material Data

plate: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, plate K = 175 N/mm²
yield strength Rp 0.2 [250°C, 45mm]
design strength value at room temperature K20 = 245 N/mm²
yield strength Rp 0.2 [20°C, 45mm]
modulus of elasticity [250°C] E = 195500 N/mm²
safety factor, plate S = 1.5

Geometry Data

actual wall thickness, plate se = 45 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
bolt circle diameter (plate width) dt;f = 1080 mm
mean gasket diameter (plate width) dD;f = 1025 mm
residual plate thickness sR = 42 mm
gasket type: 4- asbestos - only for Information
width of gasket b = 25 mm
code no. of medium: 1- gases and vapours

Openings in Plates

opening: 0- none

results

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

required plate thickness sreq = 38.14 mm
res = +18 %
manufacturing tolerance c1 = 0.0 mm
corrosion allowance c2 = 3.0 mm
manuf. toler., act. plate thickness, for Info only c1 = 1.0 mm
design diameter (width) D1;f = 1025.0 mm
design factor (fig 5) C1 = 0.478
with diameter ratio dt/dD = 1.054
with gasket characteristic k1 = 32.500 mm
with value delta = 1.152

max allow operating pressure pmax = 8.57 bar
max allow test pressure pTmax = 17.14 bar

conditions for flat end design
req resid thickness sRmin = 26.70 mm
res = +57 %

Integral Type Flanges

under Internal Pressure and Additional Forces
acc to AD 2000-B7:2000-10 B8:2000-10 DINV 2505:1986-01

drawing no: 11437-0
name/ item: manway flange N5, DN500

input data

Type Declaration

flange type: 1- welding neck flange (inside gasket)
bolt type: 3- bolts, S=1.8 / S'=1.26 / phi=1.0 (AD-B7)
calculation of bolting torque = 1- yes

Design Data

design pressure p = 6 bar
test pressure p' = 11.6 bar
design temperature T = 250 °C
code no. of external loads: 1- without external loads

Geometry Data, Flange

outside diameter flange da = 615 mm
outside diameter hub dr = 528 mm
bolt-circle diameter dt = 570 mm
outer dia of tapered neck at trans to flange d3 = 544 mm
flange thickness hF = 30 mm
total length of flange ha = 50 mm
bolt hole diameter dL = 23 mm
number of bolts or bolt holes n = 20 Stck
act wall thickness of hub respectively tube s1 = 10 mm
manufacturing tolerance of hub respect. tube c1 = 0 mm
corrosion allowance of hub respect. tube c2 = 3 mm

Material Data, Flange

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
strength value, design K = 175 N/mm²
yield strength Rp 0.2 [250°C, 50mm]
safety factor, design S = 1.5
strength value, test/bolting-up K = 245 N/mm²
yield strength Rp 0.2 [20°C, 50mm]
safety factor, test/bolting-up S = 1.05
modulus of elasticity, design [250°C] E = 195500 N/mm²
modulus of elasticity, bolting-up [20°C] E = 212000 N/mm²

Gasket Data

gasket type: 4- asbestos - only for Information
calculation without reduction of setting load = 1- yes
retighten the bolts after setting of gasket = 0- No
code no. of medium: 1- design: gases and vapours; test: liquids
outside diameter, gasket dDa = 544 mm
inside diameter, gasket dDi = 508 mm
thickness of gasket hD = 3 mm

Bolt Data

material: 0171-5.6 DIN 267 Teil 13:1993-08 AD-W7:1999-12
strength value, design K = 215 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
strength value, test/bolting-up K' = 300 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
root diameter of screw thread dk = 16.76 mm
effective diameter thread d2 = 18.376 mm
outer diameter of bearing surface (bolting) daS = 30 mm
thread angle, bolts α = 60 °
thread pitch, bolts P = 3 mm
min coefficient of friction, thread μG_min = .12
min coefficient of friction, bearing surface μA_min = .12

continuation Bolt Data

max coefficient of friction, thread $\mu G_{\max} = .12$
max coefficient of friction, bearing surface $\mu A_{\max} = .12$

results

summary of results

flange		bolting-up	design	testing	FS0 max
act. stresses and reserve					
section A-A	N/mm ²	120 95%	26 355%	48 388%	196
section B-B	N/mm ²	167 39%	36 225%	67 249%	274
section C-C	N/mm ²	25 828%	5 999%	9 999%	41
act. flange deflection	°	0.548	0.127	0.218	0.90
bolts					
req root diameter	dk mm	14.75 29%	12.16 126%	8.88 256%	16.76

geometry data

calc. wall thickness of hub respectively tube $s1 = 7.00$ mm
with manufacturing tolerance $c1 = 0.00$ mm
corrosion allowance $c2 = 3.00$ mm
moment arms
- of hub load $aR = 24.50$ mm
- of ring area load $aF = 25.00$ mm
- of gasket load $aD = 22.00$ mm
- of bolt load (for section C-C) $a1 = 13.00$ mm
reduced bolt hole diameter $dL' = 11.50$ mm
mean gasket diameter $dD = 526.00$ mm
effective width of gasket $bD = 18.00$ mm
bolt pitch / dL $= 3.89$

		bolt-up (0)	design (B)	testing (P)
gasket data				
medium		gases/vap.	gases/vap.	liquids
characteristic k1	mm	--	23.40	18.00
characteristic k0*KD	N/mm	489.90	--	--
loads	N			
hub load - int.press.	FI..	--	124499	240699
ring area load	FF..	--	5881	11370
gasket load - design	FD..	--	27841	41404
setting load	FDV	809546	--	--
min req bolt load	FS..	809546	158221	293473
flange (DIN 2505)				
bending moments	Nmm			
section A-A,B-B		17810002	3809764	7092274
section C-C		10524092	2056879	3815155
section modulus	mm ³			
section A-A		148617	148538	148467
section B-B		106337	106259	106189
section C-C		418460	418460	418460
act stresses	N/mm ²			
section A-A		119.84	25.65	47.77
section B-B		167.49	35.85	66.79
section C-C		25.15	4.92	9.12
design stress	N/mm ²	233.33	116.67	233.33
eff. stress reserve				
section A-A	%	95	355	388
section B-B	%	39	225	249
section C-C	%	828	999	999
act flange deflection	°	0.5485	0.1272	0.2184

			bolt-up (0)	design (B)	testing (P)
bolts					
req root diameter	dk	mm	14.75	12.16	8.88
auxiliary factor	Z		1.27	1.51	1.27
design allowance	c5	mm	0.00	3.00	0.00
stress reserve		%	29	126	256

max allow operating pressure
 max allow test pressure

pmax = 13.54 bar
 pTmax = 39.90 bar

results for bolting up condition (for information)

basic bolt load FS0 max = 1323699 N
 acc. to stress value of 100% of strength value
 of bolts (testing/ bolting-up)

actual stress section A-A = 195.9 N/mm²
 actual stress section B-B = 273.9 N/mm²
 actual stress section C-C = 41.1 N/mm²
 actual flange deflection = 0.897 °
 actual seating stress of gaske = 44.5 N/mm²

bolting torques acc. to VDI-Richtlinie 2230

req bolting torque (with μ_{max}) MAmin = 136 Nm
 with FVM = FS0 = 809546 N / 20 bolts = 40477 N

act seating stress of gasket with MAmin = 27.2 N/mm²

max bolting torque (bolting-up/with μ_{min}) MAmax = 179 Nm
 with FVM = FS0maxT = 1069693 N / 20 bolts = 53485 N
 FS0maxT = cause of torsional strain reduced force FS0max

act seating stress of gasket with MAmax = 36.0 N/mm²

$$MA = FVM * (d2/2 * \tan(\phi + \rho') + \mu_A * r_A)$$

$$\phi = \arctan(P / (d2 * \pi))$$

$$\rho' = \arctan(\mu_G / \cos(\alpha / 2))$$

$$r_A = (dL + daS) / 4$$

the seating stress of gasket was not checked with MAmax !

Unstayed and Stayed Flat Ends and Plates
acc to AD 2000-Merkblatt B5:2004-05

drawing no: 11437-0
name/ item: cover manway flange N5, DN500

input data

Type Declaration

shape of plate = 1- circular
bound cond: 13- supplementary marginal moment (chapt 6.3)
calculation of deflection of plate without opening = 0- no

Design Data/ Type of Plate

design pressure p = 6 bar
design temperature T = 250 °C

Material Data

plate: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value, plate K = 175 N/mm²
yield strength Rp 0.2 [250°C, 45mm]
design strength value at room temperature K20 = 245 N/mm²
yield strength Rp 0.2 [20°C, 45mm]
modulus of elasticity [250°C] E = 195500 N/mm²
safety factor, plate S = 1.5

Geometry Data

actual wall thickness, plate se = 30 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
bolt circle diameter (plate width) dt;f = 570 mm
mean gasket diameter (plate width) dD;f = 526 mm
residual plate thickness sR = 27 mm
gasket type: 4- asbestos - only for Information
width of gasket b = 18 mm
code no. of medium: 1- gases and vapours

Openings in Plates

opening: 0- none

results

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

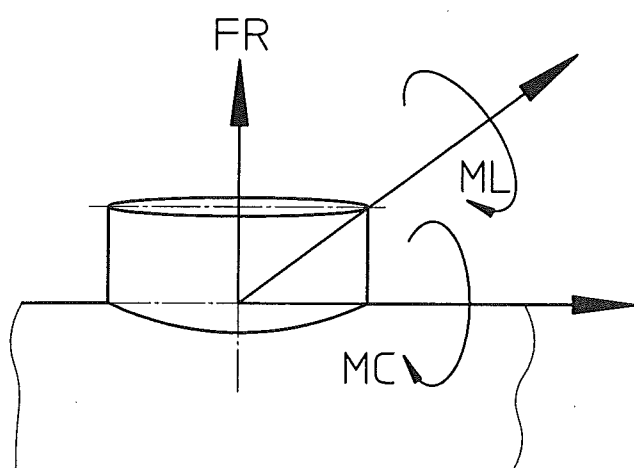
required plate thickness sreq = 22.27 mm
res = +35 %
manufacturing tolerance c1 = 0.6 mm
corrosion allowance c2 = 3.0 mm
manuf. toler., act. plate thickness, for Info only c1 = 0.8 mm
design diameter (width) D1;f = 526.0 mm
design factor (fig 5) C1 = 0.495
with diameter ratio dt/dD = 1.084
with gasket characteristic k1 = 23.400 mm
with value delta = 1.214

max allow operating pressure pmax = 12.54 bar
max allow test pressure pTmax = 25.08 bar

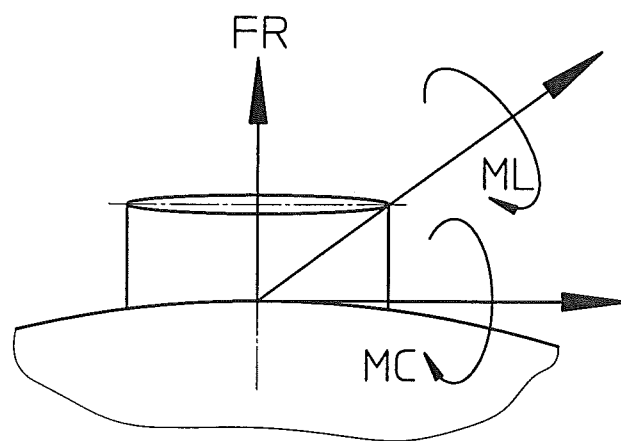
conditions for flat end design
req resid thickness sRmin = 15.59 mm
res = +73 %

Stutzen-Zusatzlasten Additional Nozzle loads

Stutzen Nr.	DN	FR [N]	ML [Nm]	MC [Nm]
N1,N2	700	31500	27400	22500
N3,N4	50	1125	900	800



Mantel



Boden

Cylindrical shell

subject to internal pressure and add. loads
WRC 107:1979-03, KTA 3211.2, AD S4:2000-10

drawing no: 11437-0
name/ item: flange N1, DN700

input data

Type Declaration

superposition of int. pressure: 2- AD-S4/KTA 3211

Design Data

design pressure p = 1 bar
design temperature T = 250 °C

Additional Loads

lever arm of loading point Please note INFO F1! a = 0 mm
radial force (in direction of vessel - positive) P = -31500 N
shearing force - circumferential direction Vc = 0 N
shearing force - longitudinal direction Vl = 0 N
moment - circumferential direction Mc = 22500 Nm
moment - longitudinal direction Ml = 27400 Nm
torsional moment Mt = 0 Nm

Material Data

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
safety factor S = 1.5
shear stress theory= 1 / deformation energy theory= 2 = 2

Geometry Data Cylindrical Shell

outer diameter DA = 4040 mm
wall thickness T = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

Geometry Data Nozzle

code-no: 1- nozzle, round
outer diameter da = 711 mm
wall thickness t = 25 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

attention

errors WRC 107:

 $dm/Dm \cdot \sqrt{(Dm/T)} = 2.685$ out of scope
diagram range for WRC App.3.3.4: $dm/Dm \cdot \sqrt{(Dm/T)} < 2$

errors KTA 3211:

 $Dm/T = 245.34$ out of scope.
range for KTA: $30 \leq Dm/T \leq 200$

calculation may be unconservative.

results FOR INFORMATION ONLY

actual shell thickness	T= sH= Te-c1-c2 =	16.40 mm
tollerance cylindrical shell	c1/c2 =	0.60/3.00 mm
actual shell thickness	t= sA= te-c1-c2 =	21.20 mm
tollerance nozzle	c1/c2 =	0.80/3.00 mm

geometrical values

WRC: Gamma = 122.671

 $\beta = 0.155$ KTA: $t/T = 1.292$ $dm/\sqrt{(Dm \cdot T)} = 2.685$

	factors resulting WRC-diagrams			
	A-B		C-D	
N ϕ - P	14.933	(4C)	7.848	(3C)
M ϕ - P	0.024	(2C-1)	0.052	(1C)
N ϕ - Mc			4.513	(3A)
M ϕ - Mc			0.065	(1A)
N ϕ - Ml	10.534	(3B)		
M ϕ - Ml	0.017	(1B-1)		
Nx - P	7.848	(3C)	14.933	(4C)
Mx - P	0.052	(1C-1)	0.024	(2C)
Nx - Mc			10.437	(4A)
Mx - Mc			0.029	(2A)
Nx - Ml	4.553	(4B)		
Mx - Ml	0.022	(2B-1)		

	factors resulting KTA-Diagrams							
	A-B				C-D			
	ϕ -up	ϕ -lo	x-up	x-lo	ϕ -up	ϕ -lo	x-up	x-lo
Pl	2.76	2.76	0.32	0.32	0.03	0.03	0.36	0.36
PlQ	2.45	2.93	0.63	0.01	0.52	-0.50	0.64	0.05

N / M = bending- / membran stress component () = diagram
 Mc / Ml = circumferential / longitudinal moment P = radial load
 ϕ / x = circumferential / longitudinal component up/lo = upper/lower
 Pl / PlQ = membr. / membr.+bend. stress acc. to internal Pressure

single stresses

σ	N/mm ²		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
N ϕ - P	14.3	14.3	14.3	14.3	14.3	14.3	7.5	7.5	7.5	7.5
M ϕ - P	17.1	-17.1	17.1	-17.1	17.1	-17.1	36.4	-36.4	36.4	-36.4
N ϕ - Mc							-9.9	-9.9	9.9	9.9
M ϕ - Mc							-105.1	105.1	105.1	-105.1
N ϕ - Ml	-28.1	-28.1	28.1	28.1	28.1	28.1				
M ϕ - Ml	-34.0	34.0	34.0	-34.0	34.0	-34.0				
total - ϕ	-30.8	3.1	93.5	-8.8	93.5	-8.8	-71.1	66.3	158.9	-124.1
Nx - P	7.5	7.5	7.5	7.5	7.5	7.5	14.3	14.3	14.3	14.3
Mx - P	36.4	-36.4	36.4	-36.4	36.4	-36.4	17.1	-17.1	17.1	-17.1
Nx - Mc							-22.9	-22.9	22.9	22.9
Mx - Mc							-47.2	47.2	47.2	-47.2
Nx - Ml	-12.2	-12.2	12.2	12.2	12.2	12.2				
Mx - Ml	-43.4	43.4	43.4	-43.4	43.4	-43.4				
total - x	-11.7	2.4	99.4	-60.1	99.4	-60.1	-38.7	21.4	101.4	-27.2
τ - Mt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
τ - Fc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
τ - Fl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
total - τ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Au= Location A upper, Al= Location A lower, Bu= Loc B upper, etc.
 N = membran stress, M = bending stress, τ =Tau= shear stress
 P = radial force, Mc/Ml= moment of load, Vc/Vl= shear force
 Mt= torsional moment, ϕ = circumf. direction x= longit. direction

combines stress according to AD-Merkblatt S4

GEH: distortion energy theory

m stress		A		B		C		D	
N/mm ²									
WRC- ϕ	$\sigma_m \phi$	-13.9		42.4		-2.4		17.4	
WRC-x	$\sigma_m x$	-4.7		19.6		-8.6		37.1	
WRC- τ	$\sigma_m \tau$	0.0		0.0		0.0		0.0	
KTA- ϕ	$\sigma_m P \phi$	33.9		33.9		0.4		0.4	
KTA-x	$\sigma_m P x$	4.0		4.0		4.4		4.4	
total- ϕ	$\sigma_m T \phi$	20.0		76.3		-2.0		17.8	
total-x	$\sigma_m T x$	-0.7		23.6		-4.2		41.5	
comb.str.	$\sigma_m C$	20.4	758%	67.6	159%	3.7	999%	36.1	385%
allowable	1.5*f	175.0		175.0		175.0		175.0	

m+b stress		Au		Bu		Cu		Du	
N/mm ²									
WRC- ϕ	$\sigma_{mb} \phi$	-30.8	3.1	93.5	-8.8	-71.1	66.3	158.9	-124.1
WRC-x	$\sigma_{mb} x$	-11.7	2.4	99.4	-60.1	-38.7	21.4	101.4	-27.2
WRC- τ	$\sigma_{mb} \tau$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KTA- ϕ	$\sigma_{mb} P \phi$	30.0	36.0	30.0	36.0	6.4	-6.1	6.4	-6.1
KTA-x	$\sigma_{mb} P x$	7.8	0.1	7.8	0.1	7.9	0.6	7.9	0.6
total- ϕ	$\sigma_{mb} T \phi$	-0.8	39.1	123.6	27.2	-64.8	60.2	165.2	-130.2
total-x	$\sigma_{mb} T x$	-3.9	2.5	107.2	-60.0	-30.8	22.0	109.3	-26.6
comb.str.	$\sigma_{mb} C$	3.6	37.9	116.3	77.3	56.1	52.8	145.6	119.2
		999%	825%	201%	353%	524%	563%	140%	194%
allowed	3*f	350.0		350.0		350.0		350.0	

m= membrane stress b= bending stress C= combined stress
 ϕ = circumf. direction x= tangential direction T= total stress

reference: - Welding Research Council Bulletin No.107, edition 3.79
 - KTA 3211.2
 - stress rating according to AD-Merkblatt S4

Cylindrical shell

subject to internal pressure and add. loads
WRC 107:1979-03, KTA 3211.2, AD S4:2000-10

drawing no: 11437-0
name/ item: flange N1, DN700

input data

Type Declaration

superposition of int. pressure: 2- AD-S4/KTA 3211

Design Data

design pressure p = 6 bar
design temperature T = 50 °C

Additional Loads

lever arm of loading point Please note INFO F1! a = 0 mm
radial force (in direction of vessel - positive) P = -31500 N
shearing force - circumferential direction Vc = 0 N
shearing force - longitudinal direction Vl = 0 N
moment - circumferential direction Mc = 22500 Nm
moment - longitudinal direction Ml = 27400 Nm
torsional moment Mt = 0 Nm

Material Data

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 255 N/mm²
yield strength Rp 0.2 [50°C, 20mm]
safety factor S = 1.5
shear stress theory= 1 / deformation energy theory= 2 = 2

Geometry Data Cylindrical Shell

outer diameter DA = 4040 mm
wall thickness T = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

Geometry Data Nozzle

code-no: 1- nozzle, round
outer diameter da = 711 mm
wall thickness t = 25 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

attention

errors WRC 107:

 $dm/Dm \cdot \sqrt{(Dm/T)} = 2.685$ out of scope
diagramrange for WRC App.3.3.4: $dm/Dm \cdot \sqrt{(Dm/T)} < 2$

errors KTA 3211:

 $Dm/T = 245.34$ out of scope.
range for KTA: $30 \leq Dm/T \leq 200$

calculation may be unconservative.

results FOR INFORMATION ONLY

actual shell thickness	$T = s_H = T_e - c1 - c2 =$	16.40 mm
tollerance cylindrical shell	$c1/c2 =$	0.60/3.00 mm
actual shell thickness	$t = s_A = t_e - c1 - c2 =$	21.20 mm
tollerance nozzle	$c1/c2 =$	0.80/3.00 mm

geometrical values

WRC: Gamma = 122.671

B = 0.155

KTA: t/T = 1.292

dm/ $\sqrt{(Dm \cdot T)}$ = 2.685

	factors resulting WRC-diagrams			
	A-B		C-D	
N ϕ - P	14.933	(4C)	7.848	(3C)
M ϕ - P	0.024	(2C-1)	0.052	(1C)
N ϕ - Mc			4.513	(3A)
M ϕ - Mc			0.065	(1A)
N ϕ - Ml	10.534	(3B)		
M ϕ - Ml	0.017	(1B-1)		
Nx - P	7.848	(3C)	14.933	(4C)
Mx - P	0.052	(1C-1)	0.024	(2C)
Nx - Mc			10.437	(4A)
Mx - Mc			0.029	(2A)
Nx - Ml	4.553	(4B)		
Mx - Ml	0.022	(2B-1)		

	factors resulting KTA-Diagrams							
	A-B				C-D			
	ϕ -up	ϕ -lo	x-up	x-lo	ϕ -up	ϕ -lo	x-up	x-lo
Pl	2.76	2.76	0.32	0.32	0.03	0.03	0.36	0.36
PlQ	2.45	2.93	0.63	0.01	0.52	-0.50	0.64	0.05

N / M = bending- / membran stress component () = diagram
 Mc / Ml = circumferential / longitudinal moment P = radial load
 ϕ / x = circumferential / longitudinal component up/lo = upper/lower
 Pl / PlQ = membr. / membr.+bend. stress acc. to internal Pressure

single stresses

σ	N/mm ²	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
N ϕ - P		14.3	14.3	14.3	14.3	7.5	7.5	7.5	7.5
M ϕ - P		17.1	-17.1	17.1	-17.1	36.4	-36.4	36.4	-36.4
N ϕ - Mc						-9.9	-9.9	9.9	9.9
M ϕ - Mc						-105.1	105.1	105.1	-105.1
N ϕ - Ml		-28.1	-28.1	28.1	28.1				
M ϕ - Ml		-34.0	34.0	34.0	-34.0				
total - ϕ		-30.8	3.1	93.5	-8.8	-71.1	66.3	158.9	-124.1
Nx - P		7.5	7.5	7.5	7.5	14.3	14.3	14.3	14.3
Mx - P		36.4	-36.4	36.4	-36.4	17.1	-17.1	17.1	-17.1
Nx - Mc						-22.9	-22.9	22.9	22.9
Mx - Mc						-47.2	47.2	47.2	-47.2
Nx - Ml		-12.2	-12.2	12.2	12.2				
Mx - Ml		-43.4	43.4	43.4	-43.4				
total - x		-11.7	2.4	99.4	-60.1	-38.7	21.4	101.4	-27.2
τ - Mt		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
τ - Fc		0.0	0.0	0.0	0.0				
τ - Fl						0.0	0.0	0.0	0.0
total - τ		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Au= Location A upper, Al= Location A lower, Bu= Loc B upper, etc.
 N = membran stress, M = bending stress, τ =Tau= shear stress
 P = radial force, Mc/Ml= moment of load, Vc/Vl= shear force
 Mt= torsional moment, ϕ = circumf. direction x= longit. direction

combines stress according to AD-Merkblatt S4

GEH: distortion energy theory

m stress		A		B		C		D	
N/mm ²									
WRC- ϕ	$\sigma_m \phi$	-13.9		42.4		-2.4		17.4	
WRC-x	$\sigma_m x$	-4.7		19.6		-8.6		37.1	
WRC- τ	$\sigma_m \tau$	0.0		0.0		0.0		0.0	
KTA- ϕ	$\sigma_m P \phi$	203.4		203.4		2.2		2.2	
KTA-x	$\sigma_m P x$	23.8		23.8		26.4		26.4	
total- ϕ	$\sigma_m T \phi$	189.6		245.8		-0.2		19.6	
total-x	$\sigma_m T x$	19.1		43.4		17.7		63.5	
comb.str.	$\sigma_m C$	180.8	41%	227.2	12%	17.8	999%	56.3	353%
allowable	1.5*f	255.0		255.0		255.0		255.0	

m+b stress		Au		Bu		Cu		Du	
N/mm ²									
WRC- ϕ	$\sigma_{mb} \phi$	-30.8	3.1	93.5	-8.8	-71.1	66.3	158.9	-124.1
WRC-x	$\sigma_{mb} x$	-11.7	2.4	99.4	-60.1	-38.7	21.4	101.4	-27.2
WRC- τ	$\sigma_{mb} \tau$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KTA- ϕ	$\sigma_{mb} P \phi$	180.2	216.0	180.2	216.0	38.3	-36.8	38.3	-36.8
KTA-x	$\sigma_{mb} P x$	46.7	0.8	46.7	0.8	47.4	3.3	47.4	3.3
total- ϕ	$\sigma_{mb} T \phi$	149.4	219.1	273.7	207.2	-32.8	29.5	197.2	-160.9
total-x	$\sigma_{mb} T x$	35.0	3.2	146.2	-59.4	8.8	24.8	148.9	-23.8
comb.str.	$\sigma_{mb} C$	135.3	217.5	237.2	242.4	38.0	27.4	178.0	150.4
		277%	134%	115%	110%	999%	999%	186%	239%
allowed	3*f	510.0		510.0		510.0		510.0	

m= membrane stress b= bending stress C= combined stress
 ϕ = circumf. direction x= tangential direction T= total stress

reference: - Welding Research Council Bulletin No.107, edition 3.79
 - KTA 3211.2
 - stress rating according to AD-Merkblatt S4

Cylindrical shell

subject to internal pressure and add. loads
WRC 107:1979-03, AD S3/6 sec. 5.3, AD S4:2000-10

drawing no: 1
name/ item: Nozzle N3,N4, DN50

input data

Type Declaration

superposition of int. pressure: 3- AD S3/6 sec. 5.3

Design Data

utilisation factor rho = .6
design temperature T = 250 °C

Additional Loads

lever arm of loading point Please note INFO F1! a = 0 mm
radial force (in direction of vessel - positive) P = -1125 N
shearing force - circumferential direction Vc = 0 N
shearing force - longitudinal direction Vl = 0 N
moment - circumferential direction Mc = 900 Nm
moment - longitudinal direction Ml = 800 Nm
torsional moment Mt = 0 Nm

Material Data

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 175 N/mm²
yield strength Rp 0.2 [250°C, 20mm]
safety factor S = 1.5

Geometry Data Cylindrical Shell

outer diameter DA = 4040 mm
wall thickness T = 15 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

Geometry Data Nozzle

code-no: 1- nozzle, round
outer diameter da = 60.3 mm
wall thickness t = 8.8 mm
manufacturing tolerance c1 = 0 mm
corrosion allowance c2 = 3 mm

attention

errors WRC 107:

B = 0.013 is out of scope
range for WRC Fig 1A-4C page 38-53: $0.03 \leq B \leq 0.22$
values taken for B = .03

results FOR INFORMATION ONLY

actual shell thickness T= sH= Te-c1-c2 = 11.40 mm
tolerance cylindrical shell c1/c2 = 0.60/3.00 mm
actual shell thickness t= sA= te-c1-c2 = 5.80 mm
tolerance nozzle c1/c2 = 0.00/3.00 mm

geometrical values

WRC: Gamma = 176.693

B = 0.030

	factors resulting WRC-diagrams			
	A-B		C-D	
N ϕ - P	31.898	(4C)	31.545	(3C)
M ϕ - P	0.138	(2C-1)	0.182	(1C)
N ϕ - Mc			2.962	(3A)
M ϕ - Mc			0.100	(1A)
N ϕ - Ml	12.309	(3B)		
M ϕ - Ml	0.058	(1B-1)		
Nx - P	31.545	(3C)	31.898	(4C)
Mx - P	0.182	(1C-1)	0.138	(2C)
Nx - Mc			4.121	(4A)
Mx - Mc			0.059	(2A)
Nx - Ml	3.094	(4B)		
Mx - Ml	0.089	(2B-1)		

N / M = bending- / membran stress component () = diagram
 Mc / Ml = circumferential / longitudinal moment P = radial load
 ϕ / x = circumferential / longitudinal component

single stresses

σ	N/mm ²	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
N ϕ - P		1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.5
M ϕ - P		7.2	-7.2	7.2	-7.2	9.5	-9.5	9.5	-9.5
N ϕ - Mc						-1.9	-1.9	1.9	1.9
M ϕ - Mc						-68.8	68.8	68.8	-68.8
N ϕ - Ml		-7.1	-7.1	7.1	7.1				
M ϕ - Ml		-35.7	35.7	35.7	-35.7				
total - ϕ		-34.1	23.0	51.5	-34.2	-59.7	58.9	81.7	-74.7
Nx - P		1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6
Mx - P		9.5	-9.5	9.5	-9.5	7.2	-7.2	7.2	-7.2
Nx - Mc						-2.7	-2.7	2.7	2.7
Mx - Mc						-40.9	40.9	40.9	-40.9
Nx - Ml		-1.8	-1.8	1.8	1.8				
Mx - Ml		-54.3	54.3	54.3	-54.3				
total - x		-45.1	44.6	67.1	-60.4	-34.8	32.6	52.3	-43.8
τ - Mt		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
τ - Fc		0.0	0.0	0.0	0.0				
τ - Fl						0.0	0.0	0.0	0.0
total - τ		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Au= Location A upper, Al= Location A lower, Bu= Loc B upper, etc.
 N = membran stress, M= bending stress, τ =Tau= shear stress
 P = radial force, Mc/Ml= moment of load, Vc/Vl= shear force
 Mt= torsional moment, ϕ = circumf. direction x= longit. direction

combines stress according to AD-Merkblatt S4

SSH: shear stress theory

hypothetical strength

$$K_{\text{quer}} = K \cdot (1 - \rho) = 70.0 \text{ N/mm}^2$$

m stress		A	B	C	D
	N/mm ²				
WRC- ϕ	$\sigma_m \phi$	-5.5	8.7	-0.4	3.5
WRC-x	$\sigma_m x$	-0.2	3.3	-1.1	4.2
WRC- τ	$\sigma_m \tau$	0.0	0.0	0.0	0.0
comb.str.	$\sigma_m C$	5.5 999%	8.7 708%	1.1 999%	4.2 999%

$$\text{allowable membran stress } \sigma_{mVzul} = 1.5 \cdot K_{\text{quer}} / S = 70.0$$

m+b stress		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	N/mm ²								
WRC- ϕ	$\sigma_{mb} \phi$	-34.1	23.0	51.5	-34.2	-59.7	58.9	81.7	-74.7
WRC-x	$\sigma_{mb} x$	-45.1	44.6	67.1	-60.4	-34.8	32.6	52.3	-43.8
WRC- τ	$\sigma_{mb} \tau$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
comb.str.	$\sigma_{mb} C$	45.1	44.6	67.1	60.4	59.7	58.9	81.7	74.7
		211%	214%	109%	132%	135%	138%	71%	87%

$$\text{allowable membran+bending stress } \sigma_{mbVzul} = 3 \cdot K_{\text{quer}} / S = 140.0$$

m= membrane stress b= bending stress C= combined stress
 ϕ = circumf. direction x= tangential direction T= total stress

reference: - Welding Research Council Bulletin No.107, edition 3.79
 - AD-S3/6 section 5.3
 - stress rating according to AD-Merkblatt S4

According to AD-S3/6 sec. 5.3 this calculation is only valid for pre-dominatly static loads, stiffness limits acc. BS 5500. are kept and the reinforcement of opening does not take place exclusively in the nozzle.

Cylindrical shell

subject to internal pressure and add. loads
WRC 107:1979-03, AD S3/6 sec. 5.3, AD S4:2000-10

drawing no: 1
name/ item: Nozzle N3,N4, DN50

input data

Type Declaration

superposition of int. pressure: 3- AD S3/6 sec. 5.3

Design Data

utilisation factor rho = .6
design temperature T = 50 °C

Additional Loads

lever arm of loading point Please note INFO F1! a = 0 mm
radial force (in direction of vessel - positive) P = -1125 N
shearing force - circumferential direction Vc = 0 N
shearing force - longitudinal direction Vl = 0 N
moment - circumferential direction Mc = 900 Nm
moment - longitudinal direction Ml = 800 Nm
torsional moment Mt = 0 Nm

Material Data

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 255 N/mm²
yield strength Rp 0.2 [50°C,20mm]
safety factor S = 1.5

Geometry Data Cylindrical Shell

outer diameter DA = 4040 mm
wall thickness T = 15 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm

Geometry Data Nozzle

code-no: 1- nozzle, round
outer diameter da = 60.3 mm
wall thickness t = 8.8 mm
manufacturing tolerance c1 = 0 mm
corrosion allowance c2 = 3 mm

attention

errors WRC 107:

 $\beta = 0.013$ is out of scope
pange for WRC Fig 1A-4C page 38-53: $0.03 \leq \beta \leq 0.22$
values taken for $\beta = .03$

results FOR INFORMATION ONLY

actual shell thickness	T= sH= Te-c1-c2 =	11.40 mm
tollerance cylindrical shell	c1/c2 =	0.60/3.00 mm
actual shell thickness	t= sA= te-c1-c2 =	5.80 mm
tollerance nozzle	c1/c2 =	0.00/3.00 mm

geometrical values

WRC: Gamma = 176.693

$\beta = 0.030$

	factors resulting WRC-diagrams			
	A-B		C-D	
N ϕ - P	31.898	(4C)	31.545	(3C)
M ϕ - P	0.138	(2C-1)	0.182	(1C)
N ϕ - Mc			2.962	(3A)
M ϕ - Mc			0.100	(1A)
N ϕ - Ml	12.309	(3B)		
M ϕ - Ml	0.058	(1B-1)		
Nx - P	31.545	(3C)	31.898	(4C)
Mx - P	0.182	(1C-1)	0.138	(2C)
Nx - Mc			4.121	(4A)
Mx - Mc			0.059	(2A)
Nx - Ml	3.094	(4B)		
Mx - Ml	0.089	(2B-1)		

N / M = bending- / membran stress component () = diagram
 Mc / Ml = circumferential / longitudinal moment P = radial load
 ϕ / x = circumferential / longitudinal component

single stresses

σ	N/mm ²	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
N ϕ - P		1.6	1.6	1.6	1.6	1.5	1.5	1.5	1.5
M ϕ - P		7.2	-7.2	7.2	-7.2	9.5	-9.5	9.5	-9.5
N ϕ - Mc						-1.9	-1.9	1.9	1.9
M ϕ - Mc						-68.8	68.8	68.8	-68.8
N ϕ - Ml		-7.1	-7.1	7.1	7.1				
M ϕ - Ml		-35.7	35.7	35.7	-35.7				
total - ϕ		-34.1	23.0	51.5	-34.2	-59.7	58.9	81.7	-74.7
Nx - P		1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6
Mx - P		9.5	-9.5	9.5	-9.5	7.2	-7.2	7.2	-7.2
Nx - Mc						-2.7	-2.7	2.7	2.7
Mx - Mc						-40.9	40.9	40.9	-40.9
Nx - Ml		-1.8	-1.8	1.8	1.8				
Mx - Ml		-54.3	54.3	54.3	-54.3				
total - x		-45.1	44.6	67.1	-60.4	-34.8	32.6	52.3	-43.8
τ - Mt		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
τ - Fc		0.0	0.0	0.0	0.0				
τ - Fl						0.0	0.0	0.0	0.0
total - τ		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Au= Location A upper, Al= Location A lower, Bu= Loc B upper, etc.
 N = membran stress, M= bending stress, τ =Tau= shear stress
 P = radial force, Mc/Ml= moment of load, Vc/Vl= shear force
 Mt= torsional moment, ϕ = circumf. direction x= longit. direction

combines stress according to AD-Merkblatt S4

SSH: shear stress theory

hypothetical strength

$$K_{\text{quer}} = K \cdot (1 - \rho) = 102.0 \text{ N/mm}^2$$

m stress		A	B	C	D
	N/mm ²				
WRC- ϕ	$\sigma m \phi$	-5.5	8.7	-0.4	3.5
WRC-x	$\sigma m x$	-0.2	3.3	-1.1	4.2
WRC- τ	$\sigma m \tau$	0.0	0.0	0.0	0.0
comb.str.	$\sigma m C$	5.5 999%	8.7 999%	1.1 999%	4.2 999%

allowable membran stress $\sigma m V_{\text{zul}} = 1.5 \cdot K_{\text{quer}} / S = 102.0$

m+b stress		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	N/mm ²								
WRC- ϕ	$\sigma m b \phi$	-34.1	23.0	51.5	-34.2	-59.7	58.9	81.7	-74.7
WRC-x	$\sigma m b x$	-45.1	44.6	67.1	-60.4	-34.8	32.6	52.3	-43.8
WRC- τ	$\sigma m b \tau$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
comb.str.	$\sigma m b C$	45.1	44.6	67.1	60.4	59.7	58.9	81.7	74.7
		353%	358%	204%	238%	242%	246%	150%	173%

allowable membran+bending stress $\sigma m b V_{\text{zul}} = 3 \cdot K_{\text{quer}} / S = 204.0$

m= membrane stress b= bending stress C= combined stress
 ϕ = circumf. direction x= tangential direction T= total stress

reference: - Welding Research Council Bulletin No.107, edition 3.79
 - AD-S3/6 section 5.3
 - stress rating according to AD-Merkblatt S4

According to AD-S3/6 sec. 5.3 this calculation is only valid for pre-dominantly static loads, stiffness limits acc. BS 5500. are kept and the reinforcement of opening does not take place exclusively in the nozzle.

Static Calculation

saddle of Molsieve Adsorber W15001 / W15002

In consideration of wind-, snow, earthquake- and nozzle loads

Description : **Molsieve Adsorber**

Item Nr.: **W15001 / W15002**

accompanying drawing: **11437-0**

Client **Kosice No.9**

 Slovakia

calculate: **Strake**

approved: **Str.**

date: **25.11.2004**

issue: **0**

date of revision

1. General

Operation data: acc. drawing No.: 11437 - 0
Windloads: acc. DIN 1055
Snowloads: acc. DIN 1055
earthquake: acc. Assessment of Seismic Hazard of
Construction Edifice 730036

2. reference of calculation

- drawing No.: 11437-0
- acc. DIN 1055
- AD-S3/2
- WRC 107

3. Materials and allowable stresses

zul. Betriebstemperatur: 250 °C

Vessel and reinforcing pad

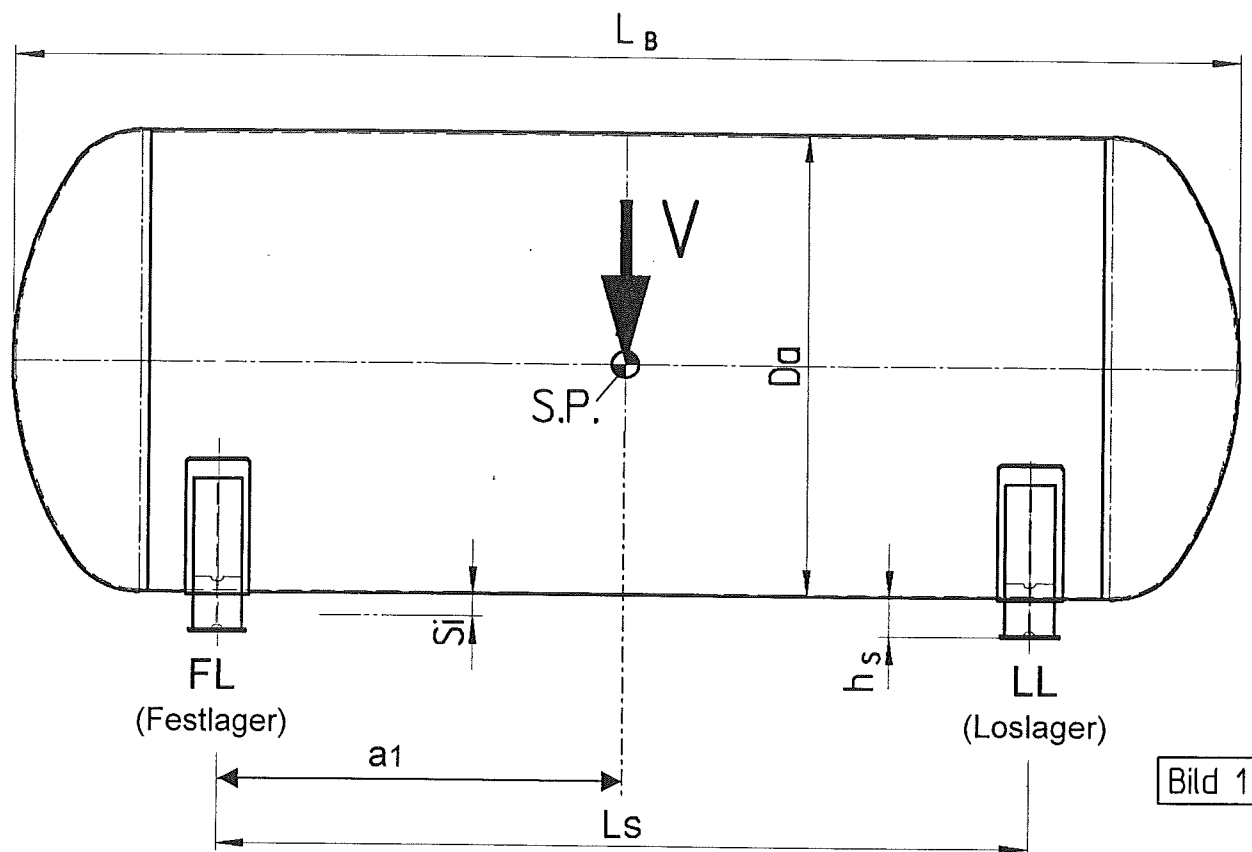
Material: **P265 GH**
design strenght value at 250 °C = **175** N/mm²
allowable stress 1,5 - safety factor $\sigma =$ **116,6** N/mm²

saddle (without reinforcing pad)

material: **P265GH**
design strenght value at 250 °C = **175** N/mm²
allowable stress 1,5 - safety factor $\sigma =$ **116,6** N/mm²

anchorbolts **M 24** ; n= **4** bolts per saddle

Material **4.6**
design strenght value at **20** °C = **240** N/mm²
allowable tensile stress **2,2** - safety factor $\sigma =$ **109,1** N/mm²
allowable Shear stress **2,2** - safety factor $\sigma =$ **87,3** N/mm²
2,2 - safety factor $\sigma_{LD} =$ **127,3** N/mm²
rel. bolt cross sectional area **380,5** mm²



4. Vessel dimension

Erection weight

$$V_M = 285000 \text{ N}$$

total operation weight
(with water filling)

$$V_B = 1317500 \text{ N}$$

vessel diameter

$$D_o = 4040 \text{ mm}$$

Insulation thickness

$$S_i = 300 \text{ mm}$$

length of vessel

$$L_B = 8327 \text{ mm}$$

saddle height

$$h_s = 430 \text{ mm}$$

distance between saddles

$$L_s = 5100 \text{ mm}$$

distance in longitudinal direction to fixed saddle

$$a_1 = 3000 \text{ mm}$$

number of saddles

$$n_s = 2$$

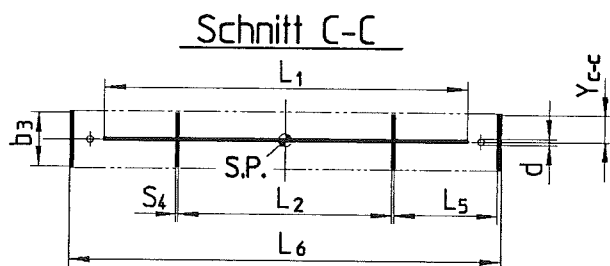
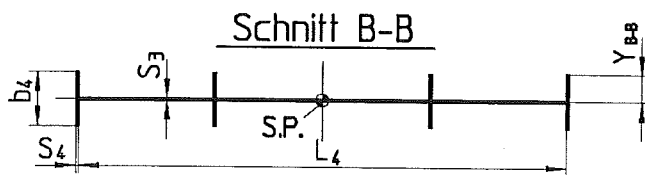
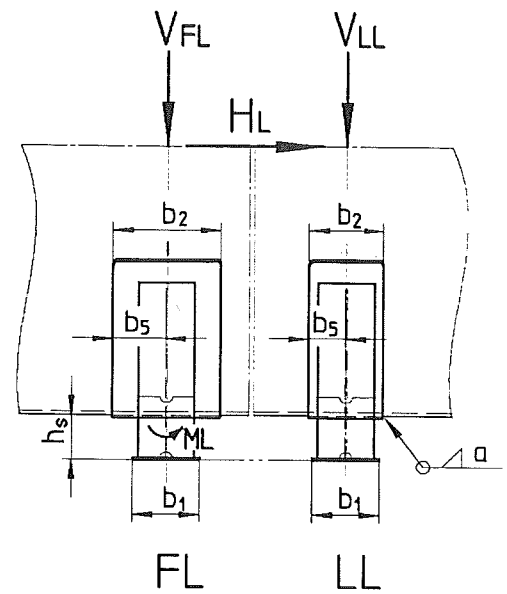
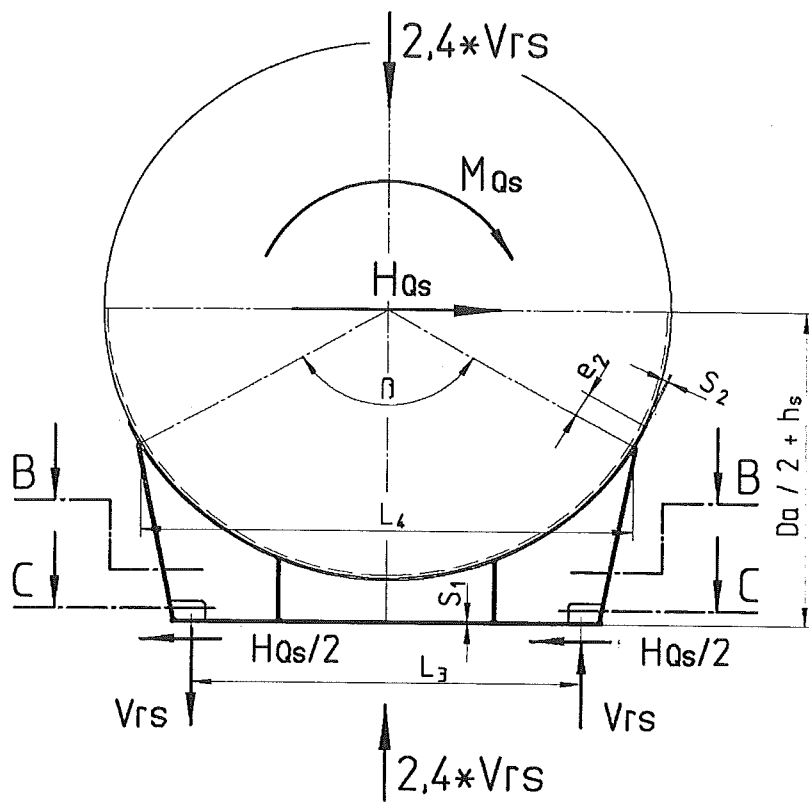


Bild 2

5. saddle dimensions

L1 = 2700 mm	b1 FL = 450 mm	b1 LL = 450 mm	S1 = 18 mm
L2 = 1600 mm	b2 FL = 500 mm	b2 LL = 500 mm	S2 = 18 mm
L3 = 2900 mm	b3 FL = 420 mm	b3 LL = 420 mm	S3 = 18 mm
L4 = 3560 mm	b4 FL = 420 mm	b4 LL = 420 mm	S4 = 18 mm
L5 = 754 mm	b5 FL = 250 mm	b5 LL = 250 mm	a = 10 mm
L6 = 3180 mm	e2 FL = 350 mm	e2 LL = 350 mm	d = 35 mm
β = 120 °			

$$A_{B-B} = 93014 \text{ mm}^2 \quad *) \quad Y_{B-B} = 210 \text{ mm} \quad *) D_u$$

$$A_{C-C} = 63072 \text{ mm}^2 \quad *) \quad Y_{C-C} = 210 \text{ mm} \quad *) D_u$$

$$W_{B-B} = 2124871 \text{ mm}^3 \quad *) Z_{cu}$$

$$W_{C-C} = 1064565 \text{ mm}^3 \quad *) Z_{cu}$$

*) (data from ME10) Schnitt A-A = Schnitt B-B

7. calculation of vertical loads for testing condition

- vertical load sliding point $V_{LL} =$ **625000** N } Wert aus der DIMY Berechnung data from dimy calculation AD2000-S3/2. See page: bis
- vertical load fixed point $V_{FL} =$ **625000** N } Wert aus der DIMY Berechnung data from Dimy calculation AD2000-S3/2. (conservatively)

8. saddle loads resulting from wind - longitudinal direction testing condition

- ZONE: acc DIN1055
- const. Pressure at $h < 8$ m $q_0 =$ **0,70** kN/m²
- Form factor / Formbeiwert $C_f =$ **1,2**
- horizontal load : $HL = q_0 \cdot c_f \cdot ((Da+2 \cdot Si)^2 \cdot \pi/4 + L_4 \cdot h_s) =$ **15489,7** N
- horizontal load sliding point $H_{LLL} =$ **0** N
- horizontal load Fix point $H_{LFL} =$ **HL** = **15489,7** N
- longitud.moment slid. point $M_{LLL} =$ **0** N
- longitud.moment fix. point $M_{LFL} =$ **HL \cdot h_s** = **6.660.567** Nmm

calculation of saddles for section B-B,

This calculation shows the stability of the shell and the saddle with vertical loads for testing condition. (results conservatively)

Load in anchorbolt / Schubbelastung Ankerschrauben - Längsrichtung/longitudinal

$$\tau_{ASL} = \frac{H_{LFL}}{n \cdot A_{sp}} = \underline{\underline{10,18}} \text{ N/mm}^2 < \tau_{zul.} \text{ (758 \% -Reserve) } < >$$

$$\sigma_{LD} = \frac{H_{LFL}}{n \cdot 24 \cdot S_1} = \underline{\underline{8,96}} \text{ N/mm}^2 < \sigma_{zul.} \text{ (1320 \% -Reserve) }$$

9. saddle loads from Wind - Querrichtung im Montagezustand

- **ZONE:** acc DIN1055
- const. Pressure at height $h=10$ m $q_0 = 0,70$ kN/m²
- Form factor / Formbeiwert $C_f = 1,2$
- Horizontalload: $H_Q = q_0 \cdot c_f \cdot (L_B \cdot (D_a + 2 \cdot S_i) + n_s \cdot b_3 \cdot h_s) = \underline{32758,7}$ N
- Horizontal load per Saddle $H_{Qs} = H_Q / 2 = \underline{16379,4}$ N
- Moment per Saddle $M_{Qs} = H_{Qs} \cdot (D_a / 2 + h_s) = \underline{40.129.436}$ Nmm
- **Vertikallast** V_{rs} as result of M_{Qs} (see Bild 2) :

$$V_{rs} = \frac{M_{Qs}}{L/3} = \underline{13837,7} \text{ N}$$

calculation of Saddles for section B-B,

This calculation shows the stability of the shell and saddle with vertical loads for operating conditions. (results conservatively)

Zugbelastung je Ankerschraube im Sattel - Querrichtung

$$F_{LLZUG} = 0,5 \cdot n \cdot (V_{rs} - V_{LL} / 2) = \underline{-597325} \text{ N}$$

Ein Nachweis der Ankerschrauben und der Grundplatte im Bereich der Ankerschrauben auf Zugbelastung erübrigt sich, da die Zugkraft negativ ist.

$$F_{FLZUG} = 0,5 \cdot n \cdot (V_{rs} - V_{FL} / 2) = \underline{-597325} \text{ N}$$

Ein Nachweis der Ankerschrauben und der Grundplatte im Bereich der Ankerschrauben auf Zugbelastung erübrigt sich, da die Zugkraft negativ ist.

10. Operating Condition

calculation of total vertical load

from dead load of the vessel and additional Nozzle loads

dead load of the vessel:

$$V_B = 1317500 \text{ N}$$

additional Nozzle loads (Definition - WRC 107, Revision 03.79, see accomp. drawing) :

$$P_{St} = 65250 \text{ N}$$

$$V_{LSt} = 0 \text{ N}$$

$$V_{CSt} = 0 \text{ N}$$

$$M_{LSt} = 56600 \text{ Nm}$$

$$M_{CSt} = 46600 \text{ Nm}$$

resulting vertical loads :

$$V_1 \text{ (aus } V_{LSt}) = \frac{V_{LSt} * (D_a + h_s)}{L_s / 2} = 0 \text{ N}$$

$$V_2 \text{ (aus } V_{CSt}) = \frac{V_{CSt} * (D_a + h_s)}{L_3} = 0 \text{ N}$$

$$V_3 \text{ (aus } M_{LSt}) = \frac{M_{LSt}}{L_s / 2} = 22196 \text{ N}$$

$$V_4 \text{ (aus } M_{CSt}) = \frac{M_{CSt}}{L_3} = 16069 \text{ N}$$

Result / Ergebnis :

$$G = V_B + V_1 + V_2 + V_3 + V_4 = 1355765 \text{ N} \quad (\text{Werte für Berechnung nach AD2000-S3/2})$$

(P)**	- Vertikalload slid. Point	$V_{LL} =$	<div style="border: 1px solid black; padding: 2px; display: inline-block;">677890</div>	N	} Wert aus der DIMY Berechnung AD2000-S3/2. Siehe Seiten: 1 bis 4
(P)**	- Vertikalload Fix. Point	$V_{FL} =$	<div style="border: 1px solid black; padding: 2px; display: inline-block;">677890</div>	N	

()** - Werte für Berechnung nach WRC 107.
siehe Seite: und 0

Sattellasten aus Wind und zul. Stutzenzusatzlasten - Längsrichtung im Betriebszustand

- **ZONE:** acc DIN1055
- const. Pressure at height $h = 10$ m $q_0 = 0,70$ kN/m²
- Formfactor / Formbeiwert $C_f = 1,2$
- Horizontalload: $H_L = q_0 \cdot c_f \cdot ((D_a + 2 \cdot S_i)^2 \cdot \pi / 4 + L_4 \cdot h_s) = 15489,7$ N
- Horizontalload slid. Point $H_{LL} = 0$ N
- Horizontalload fix. Point $H_{FL} = H_L + V_{Lst} = 15489,7$ N (VI)**
- long. Moment slid. Point $M_{LL} = 0$ N
- long. Moment fix. Point $M_{FL} = H_{FL} \cdot h_s + M_{Lst} = 63.260.567$ Nmm (MI)**

fixed point Section B-B:

$$\sigma_{B-B} = \frac{V_{FL}}{A_{B-B}} + \frac{M_{LFL}}{W_{B-B}} = 7,3 + 29,8 = 37,06 \text{ N/mm}^2 < \sigma_{zul.} \text{ (215 \% -Reserve)}$$

$$F_{Z \text{ naht}} = \frac{M_{LFL}}{b_{2FL}} = 126521,1 \text{ N}$$

$$\sigma_{naht} = \frac{F_{Z \text{ naht}}}{a \cdot ((D_a + S_2) \cdot \pi \cdot \beta / 360^\circ + 2 \cdot e_{2FL})} = 2,56 \text{ N/mm}^2 < \sigma_{zul.} \text{ (3549 \% -Reserve)}$$

plate

$$M_{eUBI} = F_{Z \text{ naht}} \cdot b_5 = 31630284 \text{ Nmm}$$

$$W_{UBI} = \frac{((D_a + S_2) \cdot \pi \cdot \beta / 360^\circ + 2 \cdot e_{2FL}) \cdot S_2^2}{6} = 267274 \text{ mm}^3$$

$$\sigma_{UBI} = \frac{M_{eUBI}}{W_{UBI}} = 118,34 \text{ N/mm}^2 > \sigma_{zul.} \text{ (-1 \% -Reserve)}$$

Schubbelastung Ankerschrauben - Längsrichtung (nur im Festlager)

$$\tau_{ASL} = \frac{H_{LFL}}{n \cdot A_{sp}} = 10,18 \text{ N/mm}^2 < \tau_{zul.} \text{ (758 \% -Reserve)}$$

$$\sigma_{LD} = \frac{H_{LFL}}{n \cdot 24 \cdot S_1} = 8,96 \text{ N/mm}^2 < \sigma_{zul.} \text{ (1320 \% -Reserve)}$$

Nachweis des Mantels unter den Schnittlasten im Sattel:

Der Nachweis erfolgt für das Los- und Festlager, (Bei gleicher Ausführung des LL und FL wird nur der Festlager berechnet.)

Zur Berechnung mit WRC 107 wird eine Belastungsfläche

für Loslager von $2 \cdot c_1 = 3360$ mm ; $2 \cdot c_2 = 500$ mm unterstellt, siehe Seiten: 1 bis 6

für Festlager von $2 \cdot c_1 = 3360$ mm ; $2 \cdot c_2 = 500$ mm unterstellt, siehe Seiten: 1 bis 6

obwohl die Fläche von $2 \cdot c_1 = 4931$ mm ; $2 \cdot c_2 = 500$ mm vorhanden ist.

Dieses geschieht um im Bereich der β -Werte entsprechend WRC 107 zu bleiben.

()** - Werte für Berechnung nach WRC 107.

12. saddle loads from Wind and add. nozzle loads - transverse to longitudinal axis, operatio

- ZONE:

acc DIN1055

- const. Pressure at height $h = 10$ m

$$q_0 = 0,70 \text{ kN/m}^2$$

- Form factor /Formfaktor

$$C_f = 1,2$$

- Horizontalload: $HQ = q_0 \cdot c_f \cdot (L_B \cdot (Da + 2 \cdot Si) + n_s \cdot b_3 \cdot h_s) = \underline{32758,7} \text{ N}$

- horizontalload per Saddle $H_{Qs} = (HQ + V_{Cst}) / 2 = \underline{16379,4} \text{ N}$

- Moment per saddle $M_{Qs} = H_{Qs} \cdot (Da / 2 + h_s) + M_{Cst} = \underline{86.729.436} \text{ Nmm}$

- verticalload V_{rs} (see Picture 2)

$$V_{rs} = \frac{M_{Qs}}{L_3} = \underline{29906,7} \text{ N}$$

- **Total load saddles** (for FLLGES-sliding point und FFLGES-fix point)

(if dimensions at fix and sliding point equal only data for fix point calculated.)

$$F_{LLGES} = 2,4 \cdot V_{rs} + V_{LL} = \underline{749666,1} \text{ N} < \text{zul Fi (siehe Berechnung AD2000-S3/2 Seite: 4 (P)**}$$

$$F_{FLGES} = 2,4 \cdot V_{rs} + V_{FL} = \underline{749666,1} \text{ N} < \text{zul Fi (siehe Berechnung AD2000-S3/2 Seite: 4 (P)**}$$

$$\sigma_{LLC-C} = \frac{F_{LLGES}}{A_{C-C}} = \underline{11,89} \text{ N/mm}^2 < \sigma_{zul.} \left(\begin{array}{l} 881 \\ \% \end{array} \text{ -Reserve} \right) < >$$

$$\sigma_{FLC-C} = \frac{F_{FLGES}}{A_{C-C}} = \underline{11,89} \text{ N/mm}^2 < \sigma_{zul.} \left(\begin{array}{l} 881 \\ \% \end{array} \text{ -Reserve} \right) < >$$

Nachweis des Mantels unter den Schnittlasten im Sattel / verifying of shell as result of loads to saddle :

Der Nachweis erfolgt für das Los- und Festlager, (Bei gleicher Ausführung des LL und FL wird nur der Festlager berechnet.)

Zur Berechnung mit WRC 107 wird eine Belastungsfläche

für Loslager von $2 \cdot c_1 = 3360$ mm ; $2 \cdot c_2 = 500$ mm unterstellt, siehe Seiten: 1 bis 6

für Festlager von $2 \cdot c_1 = 3360$ mm ; $2 \cdot c_2 = 500$ mm unterstellt, siehe Seiten: 1 bis 6

obwohl die Fläche von $2 \cdot c_1 = 4931$ mm ; $2 \cdot c_2 = 500$ mm vorhanden ist.

Dieses geschieht um im Bereich der β -Werte entsprechend WRC 107 zu bleiben.

(**) - Werte für Berechnung nach WRC 107. siehe Seite: und

load per anchorbolt / Zugbelastung je Ankerschraube - Querrichtung

$$F_{LLZUG} = 0,5 \cdot n \cdot (V_{rs} - V_{LL} / 2) = \underline{-618077} \text{ N}$$

$$F_{FLZUG} = 0,5 \cdot n \cdot (V_{rs} - V_{FL} / 2) = \underline{-618077} \text{ N}$$

Ein Nachweis der Ankerschrauben und der Grundplatte im Bereich der Ankerschrauben auf Zugbelastung erübrigt sich, da die Zugkraft negativ ist.

Verifying of anchor bolts and ground plate not necessary, because the resulting anchor load is negative.

additional Nozzle loads

description:

Molsieve Adsorber

Item No.:

W15001 / W15002

drawing No.:

11437-0

additional Nozzle loads

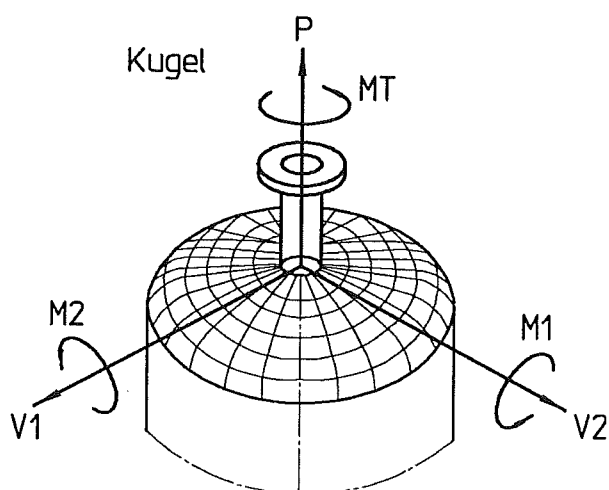
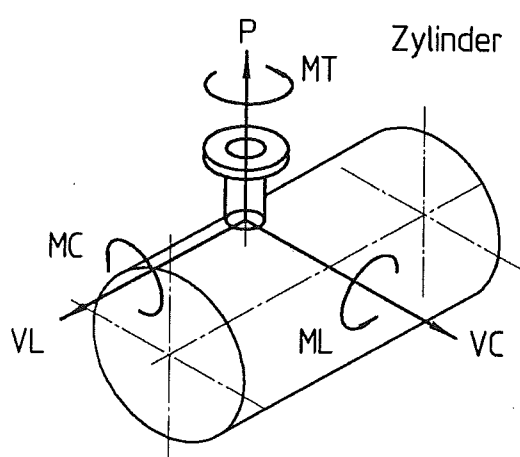
vessel shell (cylinder)

description	no.	Nozzle	P	VC	VL	MC	ML	MT
			N	N	N	Nm	Nm	Nm
N01	1	DN700	31500	0	0	22500	27400	0
N02	1	DN700	31500	0	0	22500	27400	0
N03	1	DN50	1125	0	0	800	900	0
N04	1	DN50	1125	0	0	800	900	0

additional Nozzle loads

heads

description	no	nozzle	P	V1	V2	M1	M2	MT
			N	N	N	Nm	Nm	Nm



Horizontal Cylindrical Shells on Saddles
acc to AD 2000-Merkblatt S3/2:2001-09

drawing no: 11437-0, Molsieb, Probezust.-Wind Querrichtung, *Dish ends Shell*
name/ item: Lasteinleitung in den Mantel u. Nachweis d. Sattelbleches

input data

Type Declaration

types of support: 1- Type A - two saddles, symmetrical
saddle type with stiffener = 0- no
reinforcing plate existent = 0- no
forms of saddle support: 2- form A II - inclined with reinforcing ribs

Design Data

design pressure p = 6 bar
design temperature T = 20 °C
total weight force G = 1355765 N
load case acc to AD-S3/0 sect 4.2: 1- load case BF1
internal pressure, temperature, dead/ external/ live/ wind/ snow load

Material Data, Shell

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor S = 1.5
load case aux value for bending stress, formula 2 K2 = 1.2
modulus of elasticity [20°C] E = 212000 N/mm²
joint efficiency vB = .85

Material Data, Saddle Support

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value Ks = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor Ss = 1.5
allow design stress acc to AD-S3/0, table 1 fv = 170 N/mm²
modulus of elasticity [20°C] Es = 212000 N/mm²

Geometry Data, Shell

outer diameter Da = 4040 mm
wall thickness cylinder se = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
length of cylinder (incl. cylindrical skirt) L = 6300 mm
mean depth of dished end h2 = 1035 mm
weakening factor Nue = .85
largest unsupported length l_DAST = 6300 mm

Geometry Data, Saddle

angle of saddle support, figure 2a and table 2 δ1 = 120 °
angle of support plate, figure 2a δ2 = 140 °
distance of saddle supports l1 = 5100 mm
width of saddle support b1 = 500 mm
thickness of bottom flange plate t5 = 18 mm
width of bottom flange plate b = 450 mm
wall thickness of saddle web plate es = 18 mm
effective plate width of web plate, fig 6 be = 1139.6 mm
wall thickness of support plate, sec A-A, fig 8 e2 = 18 mm
height of web plate, sec A-A, fig 8 hA = 860.5 mm
length of web plate, fig 6 l2 = 3164.4 mm
dist. saddle to center of gravity of dished end a3 = 1435.5 mm

results

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

actual wall thickness $se - c1 - c2 = e = 16.40 \text{ mm}$
 with $c1 = 0.60$ and $c2 = 3.00$
 inner diameter of shell $Da - 2 * e = D = 4007.2 \text{ mm}$
 distance saddle - end of cyl. part $(L-11)/2 = a1 = 600.0 \text{ mm}$

4.2 actual stress resultants

spec. transverse force $G / (L + 4/3 * h2) = q = 176.53 \text{ N/mm}$
 support moment $q * D^2 / 16 = M0 = 177168 \text{ Nm}$

4.2.1 reaction support forces

saddle no. 1 ; 2 $\Omega_1 = 1.0000$
 reaction support force $\Omega_1 * G / n = F1 = 677883 \text{ N}$

4.2.2 moments and transverse shear forces

support moment $q * a3^2 / 2 - M0 = M1 = M2 = 4718 \text{ Nm}$
 trans. force $(L-2*a1) / (L+4/3*h2) * F1 = Q1 = Q2 = 450156 \text{ N}$
 mid-span $M0 + F1 * (L/2-a1) - q/2 * (L/2+2/3*h2)^2 = M = 604234 \text{ Nm}$

4.3 verification at mid-span between supports

4.3.1 vessels subject or not subject to internal pressure

acc. to section 8 (diagrams): $K14 = 1.5437$

$$\frac{p * D}{40 * e * Nue} + \frac{4 * ABS(M) * K14}{\pi * D^2 * e * Nue} \leq f = K/S$$

$$48.42 \leq 170.0 \quad 251 \%$$

verification of stability acc to DAST 013

$4 * ABS(M) / (\pi * (D + e)^2 * e) = \sigma_{x43} = 2.9 \text{ N/mm}^2$
 $\sigma_{x,u} \geq \sigma_{x43} * \tau_{DAST}$ with $\tau_{DAST} = 1.50$
 $185 \geq 4 \quad 4146 \%$

5 verification of cylinder load-carrying capacity in the saddle region

5.2.1.1 proof of strength (no reinf plate, no stiffening ring)

aux values

angle of saddle support $\delta 1B = 2.094 \text{ rad}$
 $2.83 * a1 / D * \text{SQRT}(e/D) = \tau = 0.0271$
 $0.91 * b1 / \text{SQRT}(D*e) = \beta = 1.7749$
 $K2 \text{ see input part}$
 $\max(2.718282^{(-\beta)} * \sin(\beta) / \beta; 0.25) = K3 = 0.250$
 $1 - 2.718282^{(-\beta)} * \cos(\beta) / \beta = K4 = 0.583$
 $1.15 - 0.1432 * \delta 1B / \sin(0.5 * \delta 1) = K5 = 0.982$
 $\max(1.7 - 2.1 * \delta 1B / \pi; 0) / \sin(0.5 * \delta 1) = K6 = 0.346$
 $1.45 - 0.43 * \delta 1B / \sin(0.5 * \delta 1) = K7 = 0.634$
 $\min(1.0; 0.8 * \text{SQRT}(\tau) + 6 * \tau / \delta 1B) = K8 = 0.141$
 $1 - 0.65 / (1 + (6 * \tau)^2) * \text{SQRT}(\pi / (3 * \delta 1B)) = K9 = 0.552$
 $1 / (1 + 0.6 * (D/e)^{(1/3)} * b1 / D * \delta 1B) = K10 = 0.505$

$ABS(4 * M1 / (\pi * D^2 * e)) = \sigma_{mx} = 0.02 \text{ N/mm}^2$

Theta-values at location 2

$-0.23 * K6 * K8 / (K5 * K3) = \text{Theta1, 2} = -0.04563$

$-\sigma_{mx} * K2 / (S * f) = \text{Theta21, 2} = -0.00011$

$(p * D / (40 * e) - \sigma_{mx}) * K2 / (S * f) = \text{Theta22, 2} = 0.17237$

For Theta2-values lesser than 0 the absolute value of Theta2 has been used and the sign of Theta1 has been inverted.

applied: Theta22,2

 $K1, 2 = 1.4836$

Theta-values at location 3

$$\begin{aligned} -0.53 * K4 / (K7 * K9 * K10 * \sin(0.5 * \delta_1)) &= \text{Theta1}, 3 = -2.01596 \\ (\text{const}) &\text{Theta21}, 3 = 0 \\ p * D / (20 * e) * K2 / (S * f) &= \text{Theta22}, 3 = 0.34495 \\ \text{applied: Theta21}, 3 &K1, 3 = 0.4208 \end{aligned}$$

allowable bending stress (5.1)

$$\begin{aligned} \text{with allowable stress} &K / S = f = 170.00 \text{ N/mm}^2 \\ K1, 2 * f * S / K2 &\sigma_{gr}, 2 = 315.26 \text{ N/mm}^2 \\ K1, 3 * f * S / K2 &\sigma_{gr}, 3 = 89.41 \text{ N/mm}^2 \\ 0.7 * \sigma_{gr}, 2 * \text{SQRT}(D * e) * e / (K3 * K5) &= \text{allF2} = 3780768 \text{ N} \\ 0.9 * \sigma_{gr}, 3 * \text{SQRT}(D * e) * e / (K7 * K9 * K10) &= \text{allF3} = 1912302 \text{ N} \\ \text{saddle 1 ; 2} &F1 \leq \min(\text{allF2}; \text{allF3}) \quad 182 \% \end{aligned}$$

5.2.1.2 proof of stability acc to DAST 013

$$\begin{aligned} \text{mean radius of shell} &(D_a - e) / 2 = r = 2011.80 \text{ mm} \\ \text{yield stress} &K = \sigma_F = 255.0 \text{ N/mm}^2 \\ \text{safety factor dependent on load case} &\tau_{DAST} = 1.50 \end{aligned}$$

longitudinal stresses for non-benched cylinders of intermed length

$$\begin{aligned} 0.605 * E * e / r &= \sigma_{x, Ki} = 1045.6 \text{ N/mm}^2 \\ 0.52 / \text{SQRT}(1 + r / (100 * e)) &= \alpha_x = 0.35 \\ \alpha_x * \sigma_{x, Ki} &= \sigma_{x, e} = 364.4 \text{ N/mm}^2 \\ \sigma_F * [1 + 0.434 * (0.2 - \text{SQRT}(\sigma_F / \sigma_{x, e}))] &= \sigma_{x, u} = 184.5 \text{ N/mm}^2 \end{aligned}$$

shear stresses for non-benched cylinders

$$\begin{aligned} 0.74 * E * (e/r)^{5/4} * (r/l_{DAST}/2)^{0.5} &= \sigma_{T, Ki} = 153.5 \text{ N/mm}^2 \\ \text{Linear course of transverse force was assumed!} & \\ (\text{const}) &= \alpha_T = 0.65 \\ \alpha_T * \sigma_{T, Ki} &= \sigma_{T, e} = 99.8 \text{ N/mm}^2 \\ \text{with } \sigma_{T, e} \leq 0.4 * \sigma_F / \text{SQRT}(3) &\sigma_{T, e} = \sigma_{T, u} = 88.8 \text{ N/mm}^2 \\ \text{saddle no. 1 ; 2} & \\ \text{lowest point of the cross section} & \\ F1 * \pi / 4 * \text{SQRT}(D / e) * K6 * K8 &= F_e = 405191.4 \text{ N} \\ 4 * \text{ABS}(M1) / (\pi * (D+e)^2 * e) + F_e / (\pi * (D+e) * e) &= \sigma_x = 2.0 \text{ N/mm}^2 \\ \sigma_{x, u} \geq \sigma_x * \tau_{DAST} &6123 \% \\ \text{side point of the cross section} & \\ 2 * Q1 / [\pi * (D + e) * e] &= \sigma_T = 4.3 \text{ N/mm}^2 \\ \sigma_{T, u} \geq \sigma_T * \tau_{DAST} &1264 \% \end{aligned}$$

6 verification of the load-carrying capacity of the saddle

6.1 allowable forces on the saddle (acc to 6.1.1 - 6.1.3)

$$\begin{aligned} \min(\text{allF4}; \text{allF5}; \text{allF6}) &= \text{allFi} = 2875460 \text{ N} \\ \text{saddle 1 ; 2} &F1 \leq \text{allFi} \quad 324 \% \end{aligned}$$

6.1.1 stability of web plate

not required for saddle support form A II and B II

6.1.2 bending of saddle support

$$\begin{aligned} \text{section modulus in section A-A} &W_A = 9233010 \text{ mm}^3 \\ \text{partially included angle in section A-A} &\Psi = 37.1^\circ \\ 4 * f_s * W_A * \sin(0.5 * \delta_1) / (D * (1 - \cos(\Psi))) &= \text{allF5} = 6687402 \text{ N} \end{aligned}$$

6.1.3 bending of web plate

$$\begin{aligned} 1.4 * f_s * D * e^2 * \sin(0.5 * \delta_2) / b1 &= \text{allF6}_1 = 580736 \text{ N} \\ 2 * f_s * b1 * e^2 * \sin(0.5 * \delta_2) &= \text{allF6}_2 = 2875460 \text{ N} \\ \max(\text{allF6}_1 ; \text{allF6}_2) &= \text{allF6} = 2875460 \text{ N} \end{aligned}$$

Horizontal Cylindrical Shells on Saddles
acc to AD 2000-Merkblatt S3/2:2001-09

drawing no: 11437-0, Molsieb, Probezust.-Wind Querrichtung, *Probe Druck*
name/ item: Lasteinleitung in den Mantel u. Nachweis d. Sattelbleches

input data

Type Declaration

types of support: 1- Type A - two saddles, symmetrical
saddle type with stiffener = 0- no
reinforcing plate existent = 0- no
forms of saddle support: 2- form A II - inclined with reinforcing ribs

Design Data

design pressure p = 11.6 bar
design temperature T = 20 °C
total weight force G = 1250000 N
load case acc to AD-S3/0 sect 4.2: 1- load case BF1
internal pressure, temperature, dead/ external/ live/ wind/ snow load

Material Data, Shell

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value K = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor S = 1.5
load case aux value for bending stress, formula 2 K2 = 1.2
modulus of elasticity [20°C] E = 212000 N/mm²
joint efficiency vB = .85

Material Data, Saddle Support

material: 0741-P 265 GH (1.0425) DIN EN 10028-2:1992 AD-W1:1998-02
design strength value Ks = 255 N/mm²
yield strength Rp 0.2 [20°C, 20mm]
safety factor Ss = 1.5
allow design stress acc to AD-S3/0, table 1 fv = 170 N/mm²
modulus of elasticity [20°C] Es = 212000 N/mm²

Geometry Data, Shell

outer diameter Da = 4040 mm
wall thickness cylinder se = 20 mm
manufacturing tolerance c1 = 7- DIN EN 10029A
corrosion allowance c2 = 3 mm
length of cylinder (incl. cylindrical skirt) L = 6300 mm
mean depth of dished end h2 = 1035 mm
weakening factor Nue = .85
largest unsupported length l_DASt = 6300 mm

Geometry Data, Saddle

angle of saddle support, figure 2a and table 2 δ1 = 120 °
angle of support plate, figure 2a δ2 = 140 °
distance of saddle supports l1 = 5100 mm
width of saddle support b1 = 500 mm
thickness of bottom flange plate t5 = 18 mm
width of bottom flange plate b = 450 mm
wall thickness of saddle web plate es = 18 mm
effective plate width of web plate, fig 6 be = 1139.6 mm
wall thickness of support plate, sec A-A, fig 8 e2 = 18 mm
height of web plate, sec A-A, fig 8 hA = 860.5 mm
length of web plate, fig 6 l2 = 3164.4 mm
dist. saddle to center of gravity of dished end a3 = 1435.5 mm

results

results shown in percentages signify over-/underdimensioning
for dimensions: (act-req) / req, with other data: (allow-act) / act

actual wall thickness $se - c1 - c2 = e = 16.40 \text{ mm}$
 with $c1 = 0.60$ and $c2 = 3.00$
 inner diameter of shell $Da - 2 * e = D = 4007.2 \text{ mm}$
 distance saddle - end of cyl. part $(L-l1)/2 = a1 = 600.0 \text{ mm}$

4.2 actual stress resultants

spec. transverse force $G / (L + 4/3 * h2) = q = 162.76 \text{ N/mm}$
 support moment $q * D^2 / 16 = M0 = 163347 \text{ Nm}$

4.2.1 reaction support forces

saddle no. 1 ; 2 $\Omega_1 = 1.0000$
 reaction support force $\Omega_1 * G / n = F1 = 625000 \text{ N}$

4.2.2 moments and transverse shear forces

support moment $q * a3^2 / 2 - M0 = M1 = M2 = 4350 \text{ Nm}$
 trans. force $(L-2*a1) / (L+4/3*h2) * F1 = Q1 = Q2 = 415039 \text{ N}$
 mid-span $M0 + F1 * (L/2-a1) - q/2 * (L/2+2/3*h2)^2 = M = 557097 \text{ Nm}$

4.3 verification at mid-span between supports

4.3.1 vessels subject or not subject to internal pressure

acc. to section 8 (diagrams): $K14 = 1.5437$

$$\frac{p * D}{40 * e * Nue} + \frac{4 * ABS(M) * K14}{\pi * D^2 * e * Nue} \leq f = K/S$$

$$88.26 \leq 170.0 \quad 93 \%$$

verification of stability acc to DAST 013

$4 * ABS(M) / (\pi * (D + e)^2 * e) = \sigma_{x43} = 2.7 \text{ N/mm}^2$
 $\sigma_{x,u} \geq \sigma_{x43} * \tau_{DAST} \quad \text{with } \tau_{DAST} = 1.50$
 $185 \geq 4 \quad 4505 \%$

5 verification of cylinder load-carrying capacity in the saddle region

5.2.1.1 proof of strength (no reinf plate, no stiffening ring)

aux values

angle of saddle support $\delta 1B = 2.094 \text{ rad}$
 $2.83 * a1 / D * \text{SQRT}(e/D) = \tau = 0.0271$
 $0.91 * b1 / \text{SQRT}(D*e) = \beta = 1.7749$
 $K2 \text{ see input part}$
 $\max(2.718282^{(-\beta)} * \sin(\beta) / \beta; 0.25) = K3 = 0.250$
 $1 - 2.718282^{(-\beta)} * \cos(\beta) / \beta = K4 = 0.583$
 $1.15 - 0.1432 * \delta 1B / \sin(0.5 * \delta 1) = K5 = 0.982$
 $\max(1.7 - 2.1 * \delta 1B / \pi; 0) / \sin(0.5 * \delta 1) = K6 = 0.346$
 $1.45 - 0.43 * \delta 1B / \sin(0.5 * \delta 1) = K7 = 0.634$
 $\min(1.0; 0.8 * \text{SQRT}(\tau) + 6 * \tau / \delta 1B) = K8 = 0.141$
 $1 - 0.65 / (1 + (6 * \tau)^2) * \text{SQRT}(\pi / (3 * \delta 1B)) = K9 = 0.552$
 $1 / (1 + 0.6 * (D/e)^{(1/3)} * b1 / D * \delta 1B) = K10 = 0.505$
 $ABS(4 * M1 / (\pi * D^2 * e)) = \sigma_{mx} = 0.02 \text{ N/mm}^2$

Theta-values at location 2

$-0.23 * K6 * K8 / (K5 * K3) = \text{Theta1, 2} = -0.04563$
 $-\sigma_{mx} * K2 / (S * f) = \text{Theta21, 2} = -0.00010$
 $(p * D / (40 * e) - \sigma_{mx}) * K2 / (S * f) = \text{Theta22, 2} = 0.33336$
 For Theta2-values lesser than 0 the absolute value of Theta2 has been used and the sign of Theta1 has been inverted.
 applied: $\text{Theta22, 2} \quad K1, 2 = 1.3907$

Theta-values at location 3

$$\begin{aligned}
 -0.53 * K4 / (K7 * K9 * K10 * \sin(0.5 * \delta_1)) &= \text{Theta1}_{,3} = -2.01596 \\
 (\text{const}) &\text{Theta21}_{,3} = 0 \\
 p * D / (20 * e) * K2 / (S * f) &= \text{Theta22}_{,3} = 0.66691 \\
 \text{applied: Theta21}_{,3} &K1_{,3} = 0.4208
 \end{aligned}$$

allowable bending stress (5.1)

$$\begin{aligned}
 \text{with allowable stress} &K / S = f = 170.00 \text{ N/mm}^2 \\
 K1_{,2} * f * S / K2 &= \sigma_{gr,2} = 295.53 \text{ N/mm}^2 \\
 K1_{,3} * f * S / K2 &= \sigma_{gr,3} = 89.41 \text{ N/mm}^2
 \end{aligned}$$

$$\begin{aligned}
 0.7 * \sigma_{gr,2} * \text{SQRT}(D * e) * e / (K3 * K5) &= \text{allF2} = 3544176 \text{ N} \\
 0.9 * \sigma_{gr,3} * \text{SQRT}(D * e) * e / (K7 * K9 * K10) &= \text{allF3} = 1912302 \text{ N} \\
 \text{saddle 1 ; 2} &F1 \leq \min(\text{allF2}; \text{allF3}) \quad 206 \%
 \end{aligned}$$

5.2.1.2 proof of stability acc to DAST 013

$$\begin{aligned}
 \text{mean radius of shell} &(D_a - e) / 2 = r = 2011.80 \text{ mm} \\
 \text{yield stress} &K = \sigma_F = 255.0 \text{ N/mm}^2 \\
 \text{safety factor dependent on load case} &\tau_{DAST} = 1.50
 \end{aligned}$$

longitudinal stresses for non-benched cylinders of intermed length

$$\begin{aligned}
 0.605 * E * e / r &= \sigma_{x,Ki} = 1045.6 \text{ N/mm}^2 \\
 0.52 / \text{SQRT}(1 + r / (100 * e)) &= \alpha_x = 0.35 \\
 \alpha_x * \sigma_{x,Ki} &= \sigma_{x,e} = 364.4 \text{ N/mm}^2 \\
 \sigma_F * [1 + 0.434 * (0.2 - \text{SQRT}(\sigma_F / \sigma_{x,e}))] &= \sigma_{x,u} = 184.5 \text{ N/mm}^2
 \end{aligned}$$

shear stresses for non-benched cylinders

$$\begin{aligned}
 0.74 * E * (e/r)^{5/4} * (r/l_{DAST}/2)^{0.5} &= \sigma_{T,Ki} = 153.5 \text{ N/mm}^2 \\
 \text{Linear course of transverse force was assumed!} \\
 (\text{const}) &= \alpha_T = 0.65 \\
 \alpha_T * \sigma_{T,Ki} &= \sigma_{T,e} = 99.8 \text{ N/mm}^2 \\
 \text{with } \sigma_{T,e} \leq 0.4 * \sigma_F / \text{SQRT}(3) &\sigma_{T,e} = \sigma_{T,u} = 88.8 \text{ N/mm}^2 \\
 \text{saddle no. 1 ; 2}
 \end{aligned}$$

lowest point of the cross section

$$\begin{aligned}
 F1 * \pi / 4 * \text{SQRT}(D / e) * K6 * K8 &= F_e = 373581.9 \text{ N} \\
 4 * \text{ABS}(M1) / (\pi * (D+e)^2 * e) + F_e / (\pi * (D+e) * e) &= \sigma_x = 1.8 \text{ N/mm}^2 \\
 \sigma_{x,u} &\geq \sigma_x * \tau_{DAST} \quad 6649 \%
 \end{aligned}$$

side point of the cross section

$$\begin{aligned}
 2 * Q1 / [\pi * (D + e) * e] &= \sigma_T = 4.0 \text{ N/mm}^2 \\
 \sigma_{T,u} &\geq \sigma_T * \tau_{DAST} \quad 1379 \%
 \end{aligned}$$

6 verification of the load-carrying capacity of the saddle

6.1 allowable forces on the saddle (acc to 6.1.1 - 6.1.3)

$$\begin{aligned}
 \min(\text{allF4}; \text{allF5}; \text{allF6}) &= \text{allFi} = 2875460 \text{ N} \\
 \text{saddle 1 ; 2} &F1 \leq \text{allFi} \quad 360 \%
 \end{aligned}$$

6.1.1 stability of web plate

not required for saddle support form A II and B II

6.1.2 bending of saddle support

$$\begin{aligned}
 \text{section modulus in section A-A} &W_A = 9233010 \text{ mm}^3 \\
 \text{partially included angle in section A-A} &\Psi = 37.1^\circ \\
 4 * f_s * W_A * \sin(0.5 * \delta_1) / (D * (1 - \cos(\Psi))) &= \text{allF5} = 6687402 \text{ N}
 \end{aligned}$$

6.1.3 bending of web plate

$$\begin{aligned}
 1.4 * f_s * D * e^2 * \sin(0.5 * \delta_2) / b1 &= \text{allF6}_1 = 580736 \text{ N} \\
 2 * f_s * b1 * e^2 * \sin(0.5 * \delta_2) &= \text{allF6}_2 = 2875460 \text{ N} \\
 \max(\text{allF6}_1 ; \text{allF6}_2) &= \text{allF6} = 2875460 \text{ N}
 \end{aligned}$$

12. Load table Foundation loads

(following loads are taken into account: deadload of vessel, snow- and wind loads and additional Nozzle loads)

Description	Molsieve Adsorber
1. Adsorbent	Zeolite
2. Adsorbate	Water
3. Adsorption process	Physical
4. Adsorption capacity	High
5. Adsorption rate	Fast
6. Adsorption selectivity	High
7. Adsorption stability	High
8. Adsorption regeneration	Easy
9. Adsorption cost	Low
10. Adsorption application	Water treatment

Item No.: **W15001 / W15002**

Drawing No.: **11437-0**

maximal foundation loads per saddle:

fixed saddle	vertical load V / kN	horizontal load ax. HL/kN	horizontal load tr. HQ/kN	Moment axial ML / kN/m	Moment transverse MQ / kN/m
operating	677,89	15,5	16,4	63,3	86,7
testing	625,00	15,5	16,4	6,7	40,1

sliding saddle	vertical load V / kN	horizontal load transverse HQ / kN	Moment transverse MQ / kN/m
operating	677,89	16,4	86,7
testing	625,00	16,4	40,1

Number of anchorbolts per saddle 4

dimension: M 24 bolt crosssectional area = 20,1 mm

material: 4.6

Ebene Böden und Platten
nach AD 2000-Merkblatt B5:2004-05

Zeichnungs-nr: 11420-0
Bez./ Pos-Nr: W-1300A, W1301A Rohrplatte

Eingabedaten

Bauteilbeschreibung

Plattenform = 1- rund
Einspanntyp: 13- zusätzliches Randmoment (Abschnitt 6.3)
Berechnung der Durchbiegung für Platte ohne Ausschnitt = 0- Nein

Betriebsdaten

Berechnungsüberdruck p = 30 bar
Berechnungstemperatur T = 300 °C

Werkstoffdaten

Platte: 0751-P 355 NH (1.0565) DIN EN 10028-3 VdTÜV 354/1 AD-W1
Festigkeitskennwert, Platte K = 177 N/mm²
Streckgrenze Rp 0.2 [300°C, 135mm]
Festigkeitskennwert bei RT K20 = 295 N/mm²
Streckgrenze Rp 0.2 [20°C, 135mm]
Elastizitätsmodul, Platte [300°C] E = 192000 N/mm²
Sicherheitsbeiwert, Platte S = 1.5

Geometriedaten

vorh Plattendicke se = 135 mm
Herstellungstoleranz c1 = 0 mm
Abnutzungszuschlag c2 = 2 mm
Teilkreisdurchmesser (Plattenbreite) dt;f = 1205 mm
mittlerer Dichtungsdurchmesser (Plattenbreite) dD;f = 1118 mm
Restwanddicke sR = 122 mm
Dichtungstyp: 26- Freie Eing., (Metall-) Weichstoff
Dichtungskennwert k1 = 28 mm

Platten-Ausschnitt

Ausschnitt: 0- keiner

Ergebnisse

Prozentangaben im Ergebnis bedeuten Über-/Unterdimensionierungen:
bei Abmessungen: (vorh-erf)/erf, bei sonst Angaben: (zul-vorh)/vorh

erforderliche Plattendicke serf = 89.14 mm
Res = +51 %
Herstellungstoleranz c1 = 0.0 mm
Abnutzungszuschlag c2 = 2.0 mm
Herstellungstol. für ausgef. Wandd. nur zur Info c1 = 0.0 mm
Berechnungsdurchmesser (-breite) D1;f = 1118.0 mm
Berechnungsbeiwert (Bild 5) C1 = 0.489
mit Verhältnis dt/dD = 1.078
mit Dichtungsbeiwert k1 = 28.000 mm
mit Wert delta = 1.120

max zul Betriebsüberdruck pmax = 69.88 bar
max zul Prüfüberdruck pTmax = 166.38 bar

Randbedingung für Einspannung

erforderliche Restwanddicke sRmin = 62.40 mm
Res = +96 %

48 52