CALCULATION OF A CYLINDRICAL SHELL ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Plast 1
Order n° : <undef>
Description : <undef>

Material
Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Hot rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d	=	173.333 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Dimensions

External diameter	$D_{e,nom}$	=	1600.000 mm	**Base diameter**
Internal diameter	$D_{i,nom}$	=	1584.000 mm	
Thickness	e_n	=	8.000 mm	
Length	L_{cyl}	=	1750.000 mm	
Panel length	L	=	1750.000 mm	
Welded joint coefficient	z	=	0.850 -	Test group 3 (z = 0.85)
Unsupported length left side of shell	h_1	=	0.000 mm	
Unsupported length right side of shell	h_2	=	0.000 mm	
Allowance (e_n)				
Tolerance	Tol	=	0.300 mm	EN 10029 Class B
Fabrication	Tol_{fab}	=	0.300 mm	EN 10029 Class B
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)	
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)	
Mass cylinder	M	=	553.157 kg	
Volume cylinder (content)	V	=	3448.564 dm³	

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Hot rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	8.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal calculation (EN 13445 Part 3 Section 7.4.2)

Condition

Description	: Internal Case 1			
Design condition	: Operating			
Design pressure	P	=	0.600 MPa	
Design temperature	T	=	20.000 °C	

Calculation in **corroded** condition.

Minimum calculation

Mean diameter	D_m	=	1596.150 mm	D_e - e
Design stress (T,$e_{n,req}$)	$f_{en,req}$	=	173.333 N/mm²	
Minimum required thickness	e	=	3.250 mm	
Nominal minimum required thickness	$e_{n,req}$	=	3.850 mm	$P \cdot D_e/(2 \cdot f_{en,req} \cdot z + P)$

OK: $e_n \geq e_{n,req}$

Nominal calculation (e_n = 8.000 mm)

External diameter	D_e	=	1599.400 mm	$D_{e,nom} - 2 \cdot (CA_{ext} + Tol_{fab})$
Internal diameter	D_i	=	1584.600 mm	$D_{i,nom} + 2 \cdot (CA_{int} + Tol)$
Mean diameter	D_m	=	1592.000 mm	$D_i + D_e/2$
Outside radius	R_e	=	799.700 mm	$D_{e,nom}/2 - (CA_{ext} + Tol_{fab})$
Inside radius	R_i	=	792.300 mm	$D_{i,nom}/2 + (CA_{int} + Tol)$
Thickness	e_a	=	7.400 mm	$e_n - (CA_{int} + CA_{ext} + Tol + Tol_{fab})$
Maximum pressure	P_{max}	=	1.370 MPa	$2 \cdot f \cdot z \cdot e_a/D_m$
Design stress (T,e_n)	f	=	173.333 N/mm²	

OK: $P \leq P_{max}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	173.333 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

Internal calculation (EN 13445 Part 3 Section 7.4.2)

Condition

Description	: Internal Case 2			
Design condition	: Testing			
Design pressure	P	=	0.860 MPa	
Design temperature	T	=	20.000 °C	
Testing always in **uncorroded** condition				

Minimum calculation

Mean diameter	D_m	=	1597.358 mm	$D_e - e$
Design stress ($T,e_{n,req}$)	$f_{en,req}$	=	260.000 N/mm²	
Minimum required thickness	e	=	2.642 mm	
Nominal minimum required thickness	$e_{n,req}$	=	2.642 mm	$P \cdot D_e/(2 \cdot f_{en,req} \cdot z + P)$

OK: $e_n \geq e_{n,req}$

Nominal calculation (e_n = 8.000 mm)

External diameter	D_e	=	1599.400 mm	$D_{e,nom} - 2 \cdot Tol_{fab}$
Internal diameter	D_i	=	1584.600 mm	$D_{i,nom} + 2 \cdot Tol$
Mean diameter	D_m	=	1592.000 mm	$D_i + D_e/2$
Outside radius	R_e	=	799.700 mm	$D_{e,nom}/2 - Tol_{fab}$
Inside radius	R_i	=	792.300 mm	$D_{i,nom}/2 + Tol$
Thickness	e_a	=	7.400 mm	$e_n - (Tol + Tol_{fab})$
Maximum pressure	P_{max}	=	2.417 MPa	$2 \cdot f \cdot z \cdot e_a/D_m$
Design stress (T,e_n)	f	=	260.000 N/mm²	

OK: $P \leq P_{max}$

Internal calculation (EN 13445 Part 3 Section 7.4.2)

Condition

Description	: Internal Case 3			
Design condition	: Operating			
Design pressure	P	=	0.200 MPa	
Design temperature	T	=	85.000 °C	

Calculation in **corroded** condition.

Minimum calculation

Mean diameter	D_m	=	1598.782 mm	$D_e - e$
Design stress ($T, e_{n,req}$)	$f_{en,req}$	=	154.400 N/mm²	
Minimum required thickness	e	=	1.218 mm	
Nominal minimum required thickness	$e_{n,req}$	=	1.218 mm	$P \cdot D_e/(2 \cdot f_{en,req} \cdot z + P)$

OK: $e_n \geq e_{n,req}$

Nominal calculation (e_n = 8.000 mm)

External diameter	D_e	=	1599.400 mm	$D_{e,nom} - 2 \cdot (CA_{ext} + Tol_{fab})$
Internal diameter	D_i	=	1584.600 mm	$D_{i,nom} + 2 \cdot (CA_{int} + Tol)$
Mean diameter	D_m	=	1592.000 mm	$D_i + D_e/2$
Outside radius	R_e	=	799.700 mm	$D_{e,nom}/2 - (CA_{ext} + Tol_{fab})$
Inside radius	R_i	=	792.300 mm	$D_{i,nom}/2 + (CA_{int} + Tol)$
Thickness	e_a	=	7.400 mm	$e_n - (CA_{int} + CA_{ext} + Tol + Tol_{fab})$
Maximum pressure	P_{max}	=	1.220 MPa	$2 \cdot f \cdot z \cdot e_a/D_m$
Design stress (T, e_n)	f	=	154.400 N/mm²	

OK: $P \leq P_{max}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	154.400 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	2.860 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

SIMPLIFIED ASSESSMENT OF FATIGUE LIFE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Simplified fatigue 4
Order n° : <undef>
Description : <undef>

Shell type : EuroCylinder

Material

Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Hot rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	N/mm²
20.00	210.000	250.000	520.000	0.000	N/mm²

f_d	=	173.333 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Shell Dimensions

Thickness	e_n	=	8.000 mm
Welded joint coefficient	z	=	0.850 - Test group 3 (z = 0.85)
Allowance (<none>)			
Tolerance	Tol	=	0.300 mm EN 10029 Class B
Fabrication	Tol_{fab}	=	0.300 mm EN 10029 Class B
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)
Design temperature	t_d	=	85.000 °C
Maximum pressure	P_{max}	=	1.220 MPa

Pressure Ranges

Name	ΔP (MPa)	t_{min} (°C)	t_{max} (°C)	n
Range1	0.600	0.000	20.000	100000

Conditions of applicability (C17.4)

As regards weld defects: For application of this clause, the following conditions (as required by EN 13445-5:2009 Annex G) shall be met in addition to the general acceptance criteria for weld imperfections given in EN 13445-5:2009
- no undercut,
- no root concavity,
- no lack of penetration for full penetration welds.

As regards tolerances:
- manufacturing tolerances shall not exceed those given in EN 13445-4:2009;
- for seam welds, the Manufacturer shall assume certain tolerances and derive the corresponding stress factors to be used for fatigue assessment (see Table 17-1, cases S1.2 to S1.5, S2.2 to S2.4 and S5.2 to S5.4). Then the assumed tolerances shall be checked and guarenteed after manufacturing.

The data on which these requirements are based are valid for fatigue in dry air. It is presupposed that there are that there are no environmental effects which can reduce the fatigue life further. For designs involving such effects, see 18.4.5.

NOTE For vessel parts made from non-austenitic steels and operating in contact with water at temperatures exceeding 200.000 °C, the stress change due to pressure variations above and below operating pressure where the magnetite protective layer forms, may result in cracking of the layer. For assessment of this risk, reference may be made to EN 12952-3:2001, 13.4.3.

For application of this clause, instructions for appropriate maintenance shall be included in the operating instructions.

NOTE Recommendations on appropriate maintenance are given in Annex M.

Conclusion: OK: Dimensions are valid

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Hot rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	8.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
C	0	0.0700
Cr	17.5000	19.5000
Mn	0	2.0000
N	0	0.1000
Ni	8.0000	10.5000
P	0	0.0450
S	0	0.0150
Si	0	1.0000

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Fatigue assessment (C17)

Description : Case 1
Section is **welded**.

Component stress factor (Table 17-1)	h	=	0.850
Fatigue class (Table 17-4)	C	=	71 MPa

Fatigue assessment

Range	f (N/mm²)	Ds (N/mm²)	C_e	t* (°C)	C_t
Range1	154.40	64.54	1.00	15.00	1.00

Range	D_{SD} (N/mm²)	$D_{S,cut}$ (N/mm²)	D_S* (N/mm²)	D_{SR} (N/mm²)	$D_{SR,constant}$ (N/mm²)	
Range1	52.33	28.76	64.54	64.54	N.A.	OK

Range	n_{eq}	N	D	N_{eq}
Range1	11894	2664708	0.03753	1287

Equivalent full pressure cycles	n_{eq}	=	11894
Maximum total fatigue index	D_{max}	=	0.30000
Total fatigue index	D	=	0.03753
Allowable number full pressure cycles	N_{eq}	=	1287

Conclusion: **OK: Calculation is valid (D <= 1)**

CALCULATION OF A CONICAL SHELL ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Kuzel 1a
Order n° : <undefined>
Description : <undefined>

Cone type : Concentric
Junction large end : With knuckle
Junction small end : None

Cone

Material EN 10028-7 X5CrNi18-10 (+AT (Hot rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d	=	173.333 N/mm²	Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]
f_{test}	=	260.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]
f_{exc}	=	260.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]

Angle	α	=	45.00 °	
Length	L_{con}	=	553.00 mm	
Unsupported length	L	=	553.00 mm	
Minimum length	L_{min}	=	156.44 mm	
MeanThickness	$e_{m,n}$	=	8.00 mm	
Welded joint coefficient	z	=	0.850 -	Test group 3 (z = 0.85)
Allowance ($e_{con,l,n}$, $e_{con,s,n}$)				
Tolerance	Tol	=	0.300 mm	
Fabrication	Tol_{fab}	=	0.000 mm	
Internal corrosion	CA_{int}	=	0.000 mm	
External corrosion	CA_{ext}	=	0.000 mm	

At large end of cone

External diameter	$D_{e,l,nom}$	=	1600.00 mm	Base Diameter
Internal diameter	$D_{i,l,nom}$	=	1588.69 mm	
Mean diameter	$D_{m,l,nom}$	=	1594.34 mm	
Thickness	$e_{con,l,n}$	=	8.00 mm	

At small end of cone

External diameter	$D_{e,s,nom}$	=	494.00 mm	Base Diameter
Internal diameter	$D_{i,s,nom}$	=	482.69 mm	
Mean diameter	$D_{m,s,nom}$	=	488.34 mm	
Thickness	$e_{con,s,n}$	=	8.00 mm	

Mass cone	M	=	0.000 kg
Volume cone (content)	V	=	0.000 dm³

Junction at large end

Cylinder material at large junction EN 10028-7 X5CrNi18-10 (+AT (Hot rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d	=	173.333 N/mm²	Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]
f_{test}	=	260.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]
f_{exc}	=	260.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]

External diameter	$D_{e,l,j,nom}$	=	1600.00 mm
Internal diameter	$D_{i,l,j,nom}$	=	1584.00 mm
Reduced mean cylinder diameter	$D_{c,l}$	=	1592.30 mm
Knuckle radius	r_l	=	70.00 mm
Reduced Knuckle radius	$r_{l,a}$	=	70.30 mm
Reinforcing thickness in cylinder	$e_{1,l,n}$	=	8.00 mm
Reinforcement length along cylinder	$l_{1,l}$	=	130.23 mm
Reinforcing thickness in cone	$e_{2,l,n}$	=	8.00 mm
Reinforcement length along cone	$l_{2,l}$	=	154.87 mm
Allowance ($e_{1,l,n}$)			
Tolerance	Tol	=	0.300 mm
Fabrication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm
External corrosion	CA_{ext}	=	0.000 mm

NOTE!!! Minimum distances from large junction to the next major discontinuity (C7.6.5)

Along large cylinder	$L_{disc.,cyl,l}$	=	**186.04 mm**
Along cone	$L_{disc.,con,l}$	=	**221.24 mm**

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Hot rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	8.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000

Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Hot rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	0.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150

P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab : Plate and sheet
Alloy : Austenitic corrosion resistant
Code : EN 10028-7 (12-2007)

Material name : X5CrNi18-10
Material number : 1.4301
Suffix : +AT (Hot rolled strip)

Material Group according EN13445-2 : **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	8.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 173.333 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 1			
Design condition	: Operating			
Design pressure	P	=	0.6 MPa	
Design temperature	T	=	20 °C	

Calculation in **corroded** condition.

Large side of conical shell	**($e_{con,l,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	173.333 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	173.333 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	4.598 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	4.898 mm	
Reduced thickness	$e_{con,l,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	1.006 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	173.333 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	173.333 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	1.420 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	1.420 mm	
Reduced thickness	$e_{con,s,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	3.284 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell				
Design stress (t_d,$e_{cyl,min,l}$)	$f_{cyl,l}$	=	173.333 N/mm²	
Reduced minimum thickness	$e_{cyl,l}$	=	3.251 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	3.551 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction

Reduced min. cyl. thickness	$e_{1,l}$	=	5.435 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	5.735 mm	
Reduced min. cone thickness	$e_{2,l}$	=	5.435 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	5.735 mm	
Required thickness	e_j	=	7.700 mm	(7.6-12/20)
Factor b	b	=	2.040	(7.6-11/17)
Factor r	r	=	0.3654	(7.6-18)
Factor g	g	=	1.1968	(7.6-19)
Reduced knuckle radius	r	=	70.300 mm	
Pressure 7.6.7.3 c	P_1	=	1.425 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	1.006 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	0.984 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	0.984 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_{con,l,n})$
Nominal design stress at T	f_{Td}	=	173.333 N/mm²	$f(T, e_{con,l,n})$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 2			
Design condition	: Testing			
Design pressure	P	=	0.86 MPa	
Design temperature	T	=	20 °C	
Testing always in **uncorroded** condition				

Large side of conical shell	**($e_{con,l,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	260.000 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	260.000 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	3.736 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	4.036 mm	
Reduced thickness	$e_{con,l,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	1.776 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	260.000 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	260.000 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	1.154 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	1.154 mm	
Reduced thickness	$e_{con,s,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	5.795 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell

Design stress (t_d,$e_{cyl,min,l}$)	$f_{cyl,l}$	=	260.000 N/mm²	
Reduced minimum thickness	$e_{cyl,l}$	=	2.642 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	2.642 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction

Reduced min. cyl. thickness	$e_{1,l}$	=	5.262 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	5.562 mm	
Reduced min. cone thickness	$e_{2,l}$	=	5.262 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	5.562 mm	
Required thickness	e_j	=	7.700 mm	(7.6-12/20)
Factor b	b	=	2.040	(7.6-11/17)
Factor r	r	=	0.3654	(7.6-18)
Factor g	g	=	1.1968	(7.6-19)
Reduced knuckle radius	r	=	70.300 mm	
Pressure 7.6.7.3 c	P_1	=	2.137 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	1.509 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	1.476 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	1.476 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 3			
Design condition	: Operating			
Design pressure	P	=	0.2 MPa	
Design temperature	T	=	85 °C	
Calculation in **corroded** condition.				

Large side of conical shell	**($e_{con,l,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	154.400 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	154.400 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	1.723 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	1.723 mm	
Reduced thickness	$e_{con,l,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	0.896 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**8.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	154.400 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	154.400 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	0.532 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	0.532 mm	
Reduced thickness	$e_{con,s,a}$	=	7.700 mm	
Maximum pressure	P_{max}	=	2.925 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell				
Design stress (t_d,$e_{cyl,min,l}$)	$f_{cyl,l}$	=	154.400 N/mm²	
Reduced minimum thickness	$e_{cyl,l}$	=	1.218 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	1.218 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction				
Reduced min. cyl. thickness	$e_{1,l}$	=	2.665 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	2.665 mm	
Reduced min. cone thickness	$e_{2,l}$	=	2.665 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	2.665 mm	
Required thickness	e_j	=	7.700 mm	(7.6-12/20)
Factor b	b	=	2.040	(7.6-11/17)
Factor r	r	=	0.3654	(7.6-18)
Factor g	g	=	1.1968	(7.6-19)
Reduced knuckle radius	r	=	70.300 mm	
Pressure 7.6.7.3 c	P_1	=	1.269 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	0.896 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	0.876 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	0.876 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_{con,l,n})$
Nominal design stress at T	f_{Td}	=	154.400 N/mm²	$f(T, e_{con,l,n})$
Test pressure	P_t	=	2.860 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

SIMPLIFIED ASSESSMENT OF FATIGUE LIFE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Simplified fatigue 3
Order n° : <undef>
Description : <undef>

Shell type : EuroCone

Material

Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Hot rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	N/mm²
20.00	210.000	250.000	520.000	0.000	N/mm²

f_d = 173.333 N/mm² $Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test} = 260.000 N/mm² $Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc} = 260.000 N/mm² $Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Shell Dimensions

Thickness e_n = 8.000 mm
Welded joint coefficient z = 0.850 - Test group 3 (z = 0.85)
Allowance (<none>)
Tolerance Tol = 0.300 mm EN 10029 Class B
Fabrication Tol_{fab} = 0.000 mm
Internal corrosion CA_{int} = 0.000 mm (= 0.00 when Testing)
External corrosion CA_{ext} = 0.000 mm (= 0.00 when Testing)

Design temperature t_d = 85.000 °C
Maximum pressure P_{max} = 0.876 MPa

Pressure Ranges

Name	ΔP (MPa)	t_{min} (°C)	t_{max} (°C)	n
Range1	0.600	0.000	20.000	100000

Conditions of applicability (C17.4)

As regards weld defects: For application of this clause, the following conditions (as required by EN 13445-5:2009 Annex G) shall be met in addition to the general acceptance criteria for weld imperfections given in EN 13445-5:2009
- no undercut,
- no root concavity,
- no lack of penetration for full penetration welds.

As regards tolerances:
- manufacturing tolerances shall not exceed those given in EN 13445-4:2009;
- for seam welds, the Manufacturer shall assume certain tolerances and derive the corresponding stress factors to be used for fatigue assessment (see Table 17-1, cases S1.2 to S1.5, S2.2 to S2.4 and S5.2 to S5.4). Then the assumed tolerances shall be checked and guarenteed after manufacturing.

The data on which these requirements are based are valid for fatigue in dry air. It is presupposed that there are that there are no environmental effects which can reduce the fatigue life further. For designs involving such effects, see 18.4.5.

NOTE For vessel parts made from non-austenitic steels and operating in contact with water at temperatures exceeding 200.000 °C, the stress change due to pressure variations above and below operating pressure where the magnetite protective layer forms, may result in cracking of the layer. For assessment of this risk, reference may be made to EN 12952-3:2001, 13.4.3.

For application of this clause, instructions for appropriate maintenance shall be included in the operating instructions.

NOTE Recommendations on appropriate maintenance are given in Annex M.

Conclusion: OK: Dimensions are valid

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Hot rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	8.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	12.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 173.333 N/mm²
$\text{Max}[R_{p1,0/T}/1.5, \text{Min}[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)

f_{test} = 260.000 N/mm²
$\text{Max}[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

f_{exc} = 260.000 N/mm²
$\text{Max}[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
C	0	0.0700
Cr	17.5000	19.5000
Mn	0	2.0000
N	0	0.1000
Ni	8.0000	10.5000
P	0	0.0450
S	0	0.0150
Si	0	1.0000

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Fatigue assessment (C17)

Description : Case 1
Section is **welded**.

Component stress factor (Table 17-1)	h	=	0.850
Fatigue class (Table 17-4)	C	=	71 MPa

Fatigue assessment

Range	f (N/mm²)	Ds (N/mm²)	C_e	t* (°C)	C_t
Range1	154.40	89.87	1.00	15.00	1.00

Range	D_{SD} (N/mm²)	$D_{S,cut}$ (N/mm²)	D_S* (N/mm²)	D_{SR} (N/mm²)	$D_{SR,constant}$ (N/mm²)	
Range1	52.33	28.76	89.87	89.87	N.A.	OK

Range	n_{eq}	N	D	N_{eq}
Range1	32106	987117	0.10131	1287

Equivalent full pressure cycles	n_{eq}	=	32106
Maximum total fatigue index	D_{max}	=	0.30000
Total fatigue index	D	=	0.10131
Allowable number full pressure cycles	N_{eq}	=	1287

Conclusion: **OK: Calculation is valid (D <= 1)**

CALCULATION OF A CONICAL SHELL ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Kuzel 1b
Order n° : <undefined>
Description : <undefined>

Cone type : Concentric
Junction large end : With knuckle
Junction small end : None

Cone

Material EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d	=	153.333 N/mm²	$Min[R_{p0,2/T}/1.5, R_m/2.4]$
f_{test}	=	219.048 N/mm²	$R_{p0,2/T}/1.05$
f_{exc}	=	219.048 N/mm²	$R_{p0,2/T}/1.05$

Angle	α	=	45.00 °	
Length	L_{con}	=	164.50 mm	
Unsupported length	L	=	164.50 mm	
Minimum length	L_{min}	=	44.09 mm	
MeanThickness	$e_{m,n}$	=	4.00 mm	
Welded joint coefficient	z	=	0.850 -	Test group 3 (z = 0.85)
Allowance ($e_{con,l,n}$, $e_{con,s,n}$)				
Tolerance	Tol	=	0.300 mm	
Fabrication	Tol_{fab}	=	0.000 mm	
Internal corrosion	CA_{int}	=	0.000 mm	
External corrosion	CA_{ext}	=	0.000 mm	

At large end of cone

External diameter	$D_{e,l,nom}$	=	434.00 mm	Base Diameter
Internal diameter	$D_{i,l,nom}$	=	428.34 mm	
Mean diameter	$D_{m,l,nom}$	=	431.17 mm	
Thickness	$e_{con,l,n}$	=	4.00 mm	

At small end of cone

External diameter	$D_{e,s,nom}$	=	105.00 mm	Base Diameter
Internal diameter	$D_{i,s,nom}$	=	99.34 mm	
Mean diameter	$D_{m,s,nom}$	=	102.17 mm	
Thickness	$e_{con,s,n}$	=	4.00 mm	

Mass cone	M	=	0.000 kg
Volume cone (content)	V	=	0.000 dm³

Junction at large end

Cylinder material at large junction EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d	=	180.000 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

External diameter	$D_{e,l,j,nom}$	=	434.00 mm
Internal diameter	$D_{i,l,j,nom}$	=	426.00 mm
Reduced mean cylinder diameter	$D_{c,l}$	=	430.30 mm
Knuckle radius	r_l	=	20.00 mm
Reduced Knuckle radius	$r_{l,a}$	=	20.30 mm
Reinforcing thickness in cylinder	$e_{1,l,n}$	=	4.00 mm
Reinforcement length along cylinder	$l_{1,l}$	=	36.70 mm
Reinforcing thickness in cone	$e_{2,l,n}$	=	4.00 mm
Reinforcement length along cone	$l_{2,l}$	=	43.65 mm
Allowance ($e_{1,l,n}$)			
Tolerance	Tol	=	0.300 mm
Fabrication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm
External corrosion	CA_{ext}	=	0.000 mm

NOTE!!! Minimum distances from large junction to the next major discontinuity (C7.6.5)

Along large cylinder	$L_{disc.,cyl,l}$	=	**52.43 mm**
Along cone	$L_{disc.,con,l}$	=	**62.35 mm**

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Cold rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	4.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000

Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Cold rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	0.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 180.000 N/mm²
Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 270.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 270.000 N/mm²
Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150

P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Cold rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	4.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d Min[$R_{p0,2/T}$/1.5, R_m/2.4]	= 153.333 N/mm²	Non austenitic (A < 30%) (per 6.2)
f_{test} $R_{p0,2/T}$/1.05	= 219.048 N/mm²	Non austenitic (A < 30%) (per 6.2)

f_{exc} = 219.048 N/mm²
$R_{p0,2/T}/1.05$ Non austenitic (A < 30%) (per 6.2)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 1			
Design condition	: Operating			
Design pressure	P	=	0.6 MPa	
Design temperature	T	=	20 °C	
Calculation in **corroded** condition.				
Large side of conical shell	**($e_{con,l,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	153.333 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	153.333 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	1.410 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	1.410 mm	
Reduced thickness	$e_{con,l,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	1.581 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	153.333 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	153.333 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	0.341 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	0.341 mm	
Reduced thickness	$e_{con,s,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	6.661 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell
Design stress (t_d,$e_{cyl,min,l}$) $f_{cyl,l}$ = 180.000 N/mm²

Reduced minimum thickness	$e_{cyl,l}$	=	0.849 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	0.849 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction

Reduced min. cyl. thickness	$e_{1,l}$	=	1.594 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	1.594 mm	
Reduced min. cone thickness	$e_{2,l}$	=	1.594 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	1.594 mm	

Required thickness	e_j	=	3.700 mm	(7.6-12/20)
Factor b	b	=	1.492	(7.6-11/17)
Factor r	r	=	0.2928	(7.6-18)
Factor g	g	=	1.1450	(7.6-19)
Reduced knuckle radius	r	=	20.300 mm	
Pressure 7.6.7.3 c	P_1	=	2.631 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	1.581 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	2.024 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	1.581 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Test pressure

Nominal design stress at T_t	f_a	=	153.333 N/mm²	$f(T_t, e_{con,l,n})$
Nominal design stress at T	f_{Td}	=	153.333 N/mm²	$f(T, e_{con,l,n})$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 2			
Design condition	: Testing			
Design pressure	P	=	0.86 MPa	
Design temperature	T	=	20 °C	
Testing always in **uncorroded** condition				

Large side of conical shell	**($e_{con,l,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	219.048 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	219.048 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	1.202 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	1.202 mm	
Reduced thickness	$e_{con,l,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	2.657 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	219.048 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	219.048 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	0.291 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	0.291 mm	
Reduced thickness	$e_{con,s,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	11.195 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell

Design stress (t_d,$e_{cyl,min,l}$)	$f_{cyl,l}$	=	270.000 N/mm²	
Reduced minimum thickness	$e_{cyl,l}$	=	0.690 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	0.690 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction

Reduced min. cyl. thickness	$e_{1,l}$	=	1.598 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	1.598 mm	
Reduced min. cone thickness	$e_{2,l}$	=	1.598 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	1.598 mm	
Required thickness	e_j	=	3.700 mm	(7.6-12/20)
Factor b	b	=	1.492	(7.6-11/17)
Factor r	r	=	0.2928	(7.6-18)
Factor g	g	=	1.1450	(7.6-19)
Reduced knuckle radius	r	=	20.300 mm	
Pressure 7.6.7.3 c	P_1	=	3.947 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	2.258 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	2.891 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	2.258 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Internal pressure (EN 13445 Part 3 Paragraph 7.6)

Condition

Description	: Internal Case 3			
Design condition	: Operating			
Design pressure	P	=	0.2 MPa	
Design temperature	T	=	85 °C	
Calculation in **corroded** condition.				

Large side of conical shell	**($e_{con,l,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,l,n}$)	f_{min}	=	111.267 N/mm²	
Design stress (t_d,$e_{con,l,n}$)	f	=	111.267 N/mm²	
Reduced minimum thickness	$e_{con,l}$	=	0.648 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,l,n}$	=	0.648 mm	
Reduced thickness	$e_{con,l,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	1.147 MPa	(7.6-4)

OK: $e_{con,l,n}$ >= $e_{con,min,l,n}$

Small side of conical shell	**($e_{con,s,n}$**	**=**	**4.000 mm)**	
Design stress (t_d,$e_{con,min,s,n}$)	f_{min}	=	111.267 N/mm²	
Design stress (t_d,$e_{con,s,n}$)	f	=	111.267 N/mm²	
Reduced minimum thickness	$e_{con,s}$	=	0.157 mm	(7.6-2/3)
Minimum thickness	$e_{con,min,s,n}$	=	0.157 mm	
Reduced thickness	$e_{con,s,a}$	=	3.700 mm	
Maximum pressure	P_{max}	=	4.834 MPa	(7.6-4)

OK: $e_{con,s,n}$ >= $e_{con,min,s,n}$

JUNCTION AT LARGE END

Cylindrical shell				
Design stress (t_d,$e_{cyl,min,l}$)	$f_{cyl,l}$	=	154.400 N/mm²	
Reduced minimum thickness	$e_{cyl,l}$	=	0.330 mm	(7.4-1/2)
Minimum thickness	$e_{cyl,min,l,n}$	=	0.330 mm	

OK: $e_{1,l,n}$ >= $e_{cyl,min,l,n}$

Junction

Reduced min. cyl. thickness	$e_{1,l}$	=	0.909 mm	
Minimum cylinder thickness	$e_{1,min,l,n}$	=	0.909 mm	
Reduced min. cone thickness	$e_{2,l}$	=	0.909 mm	
Minimum cone thickness	$e_{2,min,l,n}$	=	0.909 mm	
Required thickness	e_j	=	3.700 mm	(7.6-12/20)
Factor b	b	=	1.492	(7.6-11/17)
Factor r	r	=	0.2928	(7.6-18)
Factor g	g	=	1.1450	(7.6-19)
Reduced knuckle radius	r	=	20.300 mm	
Pressure 7.6.7.3 c	P_1	=	2.257 MPa	(7.4-3)
Pressure 7.6.7.3 d	P_2	=	1.147 MPa	(7.6-4)
Pressure 7.6.7.3 f	P_3	=	1.468 MPa	(7.6-21)
Maximum pressure	$P_{max,l}$	=	1.147 -	

OK: $e_{1,l,n}$ >= $e_{1,min,l,n}$
OK: $e_{2,l,n}$ >= $e_{2,min,l,n}$

Test pressure

Nominal design stress at T_t	f_a	=	153.333 N/mm²	$f(T_t, e_{con,l,n})$
Nominal design stress at T	f_{Td}	=	111.267 N/mm²	$f(T, e_{con,l,n})$
Test pressure	P_t	=	3.445 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

SIMPLIFIED ASSESSMENT OF FATIGUE LIFE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Simplified fatigue 4
Order n° : <undef>
Description : <undef>

Shell type : EuroCone

Material

Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	N/mm²
20.00	230.000	260.000	540.000	0.000	N/mm²

f_d	=	153.333 N/mm²	$Min[R_{p0,2/T}/1.5, R_m/2.4]$
f_{test}	=	219.048 N/mm²	$R_{p0,2/T}/1.05$
f_{exc}	=	219.048 N/mm²	$R_{p0,2/T}/1.05$

Shell Dimensions

Thickness	e_n	=	4.000 mm	
Welded joint coefficient	z	=	0.850 - Test group 3 (z = 0.85)	
Allowance (<none>)				
Tolerance	Tol	=	0.300 mm	EN 10029 Class B
Fabrication	Tol_{fab}	=	0.000 mm	
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)	
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)	
Design temperature	t_d	=	85.000 °C	
Maximum pressure	P_{max}	=	1.147 MPa	

Pressure Ranges

Name	ΔP (MPa)	t_{min} (°C)	t_{max} (°C)	n
Range1	0.600	0.000	20.000	100000

Conditions of applicability (C17.4)

As regards weld defects: For application of this clause, the following conditions (as required by EN 13445-5:2009 Annex G) shall be met in addition to the general acceptance criteria for weld imperfections given in EN 13445-5:2009
- no undercut,
- no root concavity,
- no lack of penetration for full penetration welds.

As regards tolerances:
- manufacturing tolerances shall not exceed those given in EN 13445-4:2009;
- for seam welds, the Manufacturer shall assume certain tolerances and derive the corresponding stress factors to be used for fatigue assessment (see Table 17-1, cases S1.2 to S1.5, S2.2 to S2.4 and S5.2 to S5.4). Then the assumed tolerances shall be checked and guarenteed after manufacturing.

The data on which these requirements are based are valid for fatigue in dry air. It is presupposed that there are that there are no environmental effects which can reduce the fatigue life further. For designs involving such effects, see 18.4.5.

NOTE For vessel parts made from non-austenitic steels and operating in contact with water at temperatures exceeding 200.000 °C, the stress change due to pressure variations above and below operating pressure where the magnetite protective layer forms, may result in cracking of the layer. For assessment of this risk, reference may be made to EN 12952-3:2001, 13.4.3.

For application of this clause, instructions for appropriate maintenance shall be included in the operating instructions.

NOTE Recommendations on appropriate maintenance are given in Annex M.

Conclusion: OK: Dimensions are valid

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Cold rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	4.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 153.333 N/mm²
Min[$R_{p0,2/T}$/1.5, R_m/2.4] Non austenitic (A < 30%) (per 6.2)

f_{test} = 219.048 N/mm²
$R_{p0,2/T}$/1.05 Non austenitic (A < 30%) (per 6.2)

f_{exc} = 219.048 N/mm²
$R_{p0,2/T}$/1.05 Non austenitic (A < 30%) (per 6.2)

Chemical composition

Name	Min (%)	Max (%)
C	0	0.0700
Cr	17.5000	19.5000
Mn	0	2.0000
N	0	0.1000
Ni	8.0000	10.5000
P	0	0.0450

S	0	0.0150
Si	0	1.0000

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Fatigue assessment (C17)

Description : Case 1
Section is **welded**.

Component stress factor (Table 17-1) h = 0.850
Fatigue class (Table 17-4) C = 71 MPa

Fatigue assessment

Range	f (N/mm²)	Ds (N/mm²)	C_e	t* (°C)	C_t
Range1	111.27	49.47	1.00	15.00	1.00

Range	D_{SD} (N/mm²)	$D_{S,cut}$ (N/mm²)	D_S* (N/mm²)	D_{SR} (N/mm²)	$D_{SR,constant}$ (N/mm²)	
Range1	52.33	28.76	49.47	49.47	114.42	OK

Range	n_{eq}	N	D	N_{eq}
Range1	14307	6623809	0.01510	3441

Equivalent full pressure cycles n_{eq} = 14307
Maximum total fatigue index D_{max} = 0.30000
Total fatigue index D = 0.01510
Allowable number full pressure cycles N_{eq} = 3441

Conclusion: **OK: Calculation is valid (D <= 1)**

CALCULATION OF A DISHED END ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Dno 1
Order n° : <undef>
Description : <undef>

Type : Korbbogen

Material EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d = 180.000 N/mm² Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]
f_{test} = 270.000 N/mm² Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]
f_{exc} = 270.000 N/mm² Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]

Cold spun seamless austenic stainless steel = **No**

Dimensions

Outside diameter	$D_{e,nom}$	=	1600.000 mm	**Base diameter**
Inside diameter	$D_{i,nom}$	=	1588.000 mm	
Thickness	e_n	=	6.000 mm	
Inside dish radius	r_{nom}	=	1280.000 mm	
Inside knuckle radius	R_{nom}	=	246.400 mm	
Inside height	$h_{i,nom}$	=	403.380 mm	
Outside height	$h_{e,nom}$	=	409.380 mm	
Welded joint coefficient	z	=	0.850 -	Test group 3 (z = 0.85)
Allowance (e_n)				
Tolerance	Tol	=	0.300 mm	EN 10029 Class B
Fabrication	Tol_{fab}	=	0.300 mm	EN 10029 Class B
Internal corrosion	CA_{int}	=	0.000 mm	
External corrosion	CA_{ext}	=	0.000 mm	
Mass	M	=	131.348 kg	
Volume (content)	V	=	524.125 dm³	

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Cold rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	6.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000

C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal Calculation (EN 13445-3 Chapter 7.4.3)

Type : Korbbogen

Condition

Description : Internal Case 1
Design condition : Operating
Design pressure P = 0.600 MPa
Design temperature T = 20.000 °C
Calculation in **corroded** condition.

Minimum calculation ($e_{min,nom}$ = 4.433 mm)

Design stress (t_d,$e_{min,nom}$) f =
180.000 N/mm²

Factors

Y = min(e/R;0.04) =
0.00257 - (7.5-9)
Z = log10(1/Y) =
2.590 - (7.5-10)
X = r/D_i =
0.155 - (7.5-11)
N = 1.006-1/{6.2+(90·Y)^4} =
0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) =
1.06889 - (7.5-15)
$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2); 0.5} =
0.52675 - (7.5-17)
β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} =
0.77135 - (7.5-16)

Design stress for buckling equation
f_b = $R_{p0.2/t}$/1.5 =
153.333 N/mm² (7.5-4/5)

Minimum required thickness
at spherical part to limit membrane stress
e_s = (P·R)/(2·f·z-0.5·P) =
2.512 mm (7.5-1)

at knuckle to avoid axisymmetric yielding
e_y = (β·P·(0.75·R+0.2·Di))/f =
3.288 mm (7.5-2)

at knuckle to avoid plastic buckling
e_b = (0.75·R+0.2·Di)·((P/(111·fb))·(Di/r)^0.825)^(1/1.5) =
3.833 mm (7.5-3)

Minimum required thickness e = max(e_s,e_y,e_b) =
3.833 mm
Nominal minimum required thickness $e_{min,nom}$ = e+Tol+Fab+CAInt+CAExt =

4.433 mm

OK: $e_a \geq e$

Nominal calculation (e_n = 6.000 mm)

Thickness e_a = e_n-Tol-Fab-CAInt-CAExt = 5.400 mm

Internal diameter D_i = $D_{i,nom}$+2·(Tol+CAInt) = 1588.600 mm

External diameter D_e = $D_{e,nom}$-2·(Fab+CAExt) = 1599.400 mm

Internal dish radius R = R_{nom}+Tol+CAInt = 1280.300 mm

Internal knuckle radius r = r_{nom}+Tol+CAInt = 246.700 mm

Design stress (t_d,e_n) f = 180.000 N/mm²

Factors

Y = min(e_a/R;0.04) = 0.00422 - (7.5-9)

Z = log10(1/Y) = 2.375 - (7.5-10)

X = r/D_i = 0.155 - (7.5-11)

N = 1.006-1/{6.2+(90·Y)^4} = 0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) = 0.98394 - (7.5-15)

$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2);0.5} = 0.52283 - (7.5-17)

β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} = 0.72897 - (7.5-16)

Design stress for buckling equation

f_b = $R_{p0.2/t}$/1.5 = 153.333 N/mm² (7.5-4/5)

Maximum pressure

at spherical part to limit membrane stress

P_s = (2·f·z·e_a)/(R+0.5·e_a) = 1.288 MPa (7.5-6)

at knuckle to avoid axisymmetric yielding

P_y = f·e_a/(β·(0.75·R+0.2·D_i)) = 1.043 MPa (7.5-7)

at knuckle to avoid plastic buckling

P_b = 111·f_b·(e_a/(0.75·R+0.2·D_i))^1.5·(r/D_i)^0.825 = 1.006 MPa (7.5-8)

Maximum pressure (MAWP)

P_{max} = min(P_s,P_y,P_b) = 1.006 MPa

OK: $P_d \leq P_{max}$

Miscellaneous results

Maximum diameter opening in knuckle	$d_{i,max}$	=	282.761 mm
Minimum distance knuckle to reduced dish	√(R·e)	=	83.148 mm
Maximum length straight cylindrical flange	l_{flange}	=	18.524 mm

Test pressure

Nominal design stress at T_t	f_a	=	180.000 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	180.000 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

Internal Calculation (EN 13445-3 Chapter 7.4.3)

Type : Korbbogen

Condition

Description : Internal Case 2
Design condition : Testing
Design pressure P = 0.860 MPa
Design temperature T = 20.000 °C
Testing always in **uncorroded** condition

Minimum calculation ($e_{min,nom}$ = 4.441 mm)

Design stress (t_d,$e_{min,nom}$) f = 270.000 N/mm²

Factors

Y = min(e/R;0.04) = 0.00246 - (7.5-9)
Z = log10(1/Y) = 2.608 - (7.5-10)
X = r/D_i = 0.155 - (7.5-11)
N = 1.006-1/{6.2+(90·Y)^4} = 0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) = 1.07480 - (7.5-15)
$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2); 0.5} = 0.52698 - (7.5-17)
β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} = 0.77429 - (7.5-16)

Design stress for buckling equation
f_b = $R_{p0.2/t}$/1.05 = 219.048 N/mm² (7.5-4/5)

Minimum required thickness
at spherical part to limit membrane stress
e_s = (P·R)/(2·f·z-0.5·P) = 2.040 mm (7.5-1)

at knuckle to avoid axisymmetric yielding
e_y = (β·P·(0.75·R+0.2·Di))/f = 3.154 mm (7.5-2)

at knuckle to avoid plastic buckling
e_b = (0.75·R+0.2·Di)·((P/(111·fb))·(Di/r)^0.825)^(1/1.5) = 3.841 mm (7.5-3)

Minimum required thickness e = max(e_s,e_y,e_b) = 3.841 mm
Nominal minimum required thickness $e_{min,nom}$ = e+Tol+Fab+CAInt+CAExt = 4.441 mm

OK: $e_a \geq e$

Nominal calculation (e_n = 6.000 mm)

Thickness e_a = e_n-Tol-Fab-CAInt-CAExt =
5.400 mm
Internal diameter D_i = $D_{i,nom}$+2·(Tol+CAInt) =
1588.600 mm
External diameter D_e = $D_{e,nom}$-2·(Fab+CAExt) =
1599.400 mm
Internal dish radius R = R_{nom}+Tol+CAInt =
1280.300 mm
Internal knuckle radius r = r_{nom}+Tol+CAInt =
246.700 mm
Design stress (t_d,e_n) f =
270.000 N/mm²

Factors

Y = min(e_a/R;0.04) =
0.00422 - (7.5-9)
Z = log10(1/Y) =
2.375 - (7.5-10)
X = r/D_i =
0.155 - (7.5-11)
N = 1.006-1/{6.2+(90·Y)^4} =
0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) =
0.98394 - (7.5-15)
$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2);0.5} =
0.52283 - (7.5-17)
β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} =
0.72897 - (7.5-16)

Design stress for buckling equation
f_b = $R_{p0.2/t}$/1.05 =
219.048 N/mm² (7.5-4/5)

Maximum pressure

at spherical part to limit membrane stress
P_s = (2·f·z·e_a)/(R+0.5·e_a) =
2.273 MPa (7.5-6)

at knuckle to avoid axisymmetric yielding
P_y = f·e_a/(β·(0.75·R+0.2·D_i)) =
1.565 MPa (7.5-7)

at knuckle to avoid plastic buckling
P_b = 111·f_b·(e_a/(0.75·R+0.2·D_i))^1.5·(r/D_i)^0.825 =
1.437 MPa (7.5-8)

Maximum pressure (MAWP)
P_{max} = min(P_s,P_y,P_b) =
1.437 MPa

OK: $P_d \leq P_{max}$

Miscellaneous results

Maximum diameter opening in knuckle	$d_{i,max}$	=	303.923 mm
Minimum distance knuckle to reduced dish	√(R·e)	=	83.148 mm
Maximum length straight cylindrical flange	l_{flange}	=	18.524 mm

Internal Calculation (EN 13445-3 Chapter 7.4.3)

Type : Korbbogen

Condition

Description	: Internal Case 3		
Design condition	: Operating		
Design pressure	P	=	0.200 MPa
Design temperature	T	=	85.000 °C

Calculation in **corroded** condition.

Minimum calculation ($e_{min,nom}$ = 2.287 mm)

Design stress (t_d,$e_{min,nom}$) f = 154.400 N/mm²

Factors

Y = min(e/R;0.04) = 0.00125 - (7.5-9)

Z = log10(1/Y) = 2.903 - (7.5-10)

X = r/D_i = 0.154 - (7.5-11)

N = 1.006-1/{6.2+(90·Y)^4} = 0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) = 1.13651 - (7.5-15)

$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2); 0.5} = 0.52957 - (7.5-17)

β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} = 0.80689 - (7.5-16)

Design stress for buckling equation

f_b = $R_{p0.2/t}$/1.5 = 111.267 N/mm² (7.5-4/5)

Minimum required thickness

at spherical part to limit membrane stress

e_s = (P·R)/(2·f·z-0.5·P) = 0.976 mm (7.5-1)

at knuckle to avoid axisymmetric yielding

e_y = (β·P·(0.75·R+0.2·Di))/f = 1.600 mm (7.5-2)

at knuckle to avoid plastic buckling

e_b = (0.75·R+0.2·Di)·((P/(111·fb))·(Di/r)^0.825)^(1/1.5) = 2.287 mm (7.5-3)

Minimum required thickness e = max(e_s,e_y,e_b) = 2.287 mm

Nominal minimum required thickness $e_{min,nom}$ = e+Tol+Fab+CAInt+CAExt = 2.287 mm

OK: $e_a \geq e$

Nominal calculation (e_n = 6.000 mm)

Thickness e_a = e_n-Tol-Fab-CAInt-CAExt =
5.400 mm
Internal diameter D_i = $D_{i,nom}$+2·(Tol+CAInt) =
1588.600 mm
External diameter D_e = $D_{e,nom}$-2·(Fab+CAExt) =
1599.400 mm
Internal dish radius R = R_{nom}+Tol+CAInt =
1280.300 mm
Internal knuckle radius r = r_{nom}+Tol+CAInt =
246.700 mm
Design stress (t_d,e_n) f =
154.400 N/mm²

Factors

Y = min(e_a/R;0.04) =
0.00422 - (7.5-9)
Z = log10(1/Y) =
2.375 - (7.5-10)
X = r/D_i =
0.155 - (7.5-11)
N = 1.006-1/{6.2+(90·Y)^4} =
0.845 - (7.5-12)

$\beta_{0.1}$ = N·(-0.1833·Z^3+1.0383·Z^2-1.2943·Z+0.837) =
0.98394 - (7.5-15)
$\beta_{0.2}$ = max{0.95·(0.56-1.94·Y-82.5·Y^2);0.5} =
0.52283 - (7.5-17)
β = 10·{(0.2-X)·$\beta_{0.1}$+(X-0.1)·$\beta_{0.2}$} =
0.72897 - (7.5-16)

Design stress for buckling equation
f_b = $R_{p0.2/t}$/1.5 =
111.267 N/mm² (7.5-4/5)

Maximum pressure

at spherical part to limit membrane stress
P_s = (2·f·z·e_a)/(R+0.5·e_a) =
1.105 MPa (7.5-6)

at knuckle to avoid axisymmetric yielding
P_y = f·e_a/(β·(0.75·R+0.2·D_i)) =
0.895 MPa (7.5-7)

at knuckle to avoid plastic buckling
P_b = 111·f_b·(e_a/(0.75·R+0.2·D_i))^1.5·(r/D_i)^0.825 =
0.730 MPa (7.5-8)

Maximum pressure (MAWP)
P_{max} = min(P_s,P_y,P_b) =
0.730 MPa

OK: $P_d \leq P_{max}$

Miscellaneous results

Maximum diameter opening in knuckle	$d_{i,max}$	=	622.659 mm
Minimum distance knuckle to reduced dish	√(R·e)	=	83.148 mm
Maximum length straight cylindrical flange	l_{flange}	=	18.524 mm

Test pressure

Nominal design stress at T_t	f_a	=	180.000 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	154.400 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	2.915 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

SIMPLIFIED ASSESSMENT OF FATIGUE LIFE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Simplified fatigue 4
Order n° : <undef>
Description : <undef>

Shell type : EuroFront

Material

Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	N/mm²
20.00	230.000	260.000	540.000	0.000	N/mm²

f_d = 180.000 N/mm² $Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test} = 270.000 N/mm² $Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc} = 270.000 N/mm² $Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Shell Dimensions

Thickness e_n = 6.000 mm
Welded joint coefficient z = 1.000 - Not applicable
Allowance (<none>)
Tolerance Tol = 0.300 mm EN 10029 Class B
Fabrication Tol_{fab} = 0.300 mm EN 10029 Class B
Internal corrosion CA_{int} = 0.000 mm (= 0.00 when Testing)
External corrosion CA_{ext} = 0.000 mm (= 0.00 when Testing)

Design temperature t_d = 85.000 °C
Maximum pressure P_{max} = 0.730 MPa

Pressure Ranges

Name	ΔP (MPa)	t_{min} (°C)	t_{max} (°C)	n
Range1	0.600	0.000	20.000	100000

Conditions of applicability (C17.4)

As regards weld defects: For application of this clause, the following conditions (as required by EN 13445-5:2009 Annex G) shall be met in addition to the general acceptance criteria for weld imperfections given in EN 13445-5:2009
- no undercut,
- no root concavity,
- no lack of penetration for full penetration welds.

As regards tolerances:
- manufacturing tolerances shall not exceed those given in EN 13445-4:2009;
- for seam welds, the Manufacturer shall assume certain tolerances and derive the corresponding stress factors to be used for fatigue assessment (see Table 17-1, cases S1.2 to S1.5, S2.2 to S2.4 and S5.2 to S5.4). Then the assumed tolerances shall be checked and guarenteed after manufacturing.

The data on which these requirements are based are valid for fatigue in dry air. It is presupposed that there are that there are no environmental effects which can reduce the fatigue life further. For designs involving such effects, see 18.4.5.

NOTE For vessel parts made from non-austenitic steels and operating in contact with water at temperatures exceeding 200.000 °C, the stress change due to pressure variations above and below operating pressure where the magnetite protective layer forms, may result in cracking of the layer. For assessment of this risk, reference may be made to EN 12952-3:2001, 13.4.3.

For application of this clause, instructions for appropriate maintenance shall be included in the operating instructions.

NOTE Recommendations on appropriate maintenance are given in Annex M.

Conclusion: OK: Dimensions are valid

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Cold rolled strip)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	6.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
C	0	0.0700
Cr	17.5000	19.5000
Mn	0	2.0000
N	0	0.1000
Ni	8.0000	10.5000
P	0	0.0450
S	0	0.0150
Si	0	1.0000

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Fatigue assessment (C17)

Description : Case 1
Section is **welded**.

Component stress factor (Table 17-1)	h	=	0.850
Fatigue class (Table 17-4)	C	=	71 MPa

Fatigue assessment

Range	f (N/mm²)	Ds (N/mm²)	C_e	t* (°C)	C_t
Range1	154.40	107.90	1.00	15.00	1.00

Range	D_{SD} (N/mm²)	$D_{S,cut}$ (N/mm²)	D_S* (N/mm²)	D_{SR} (N/mm²)	$D_{SR,constant}$ (N/mm²)	
Range1	52.33	28.76	107.90	107.90	N.A.	OK

Range	n_{eq}	N	D	N_{eq}
Range1	55567	570340	0.17533	1287

Equivalent full pressure cycles	n_{eq}	=	55567
Maximum total fatigue index	D_{max}	=	0.30000
Total fatigue index	D	=	0.17533
Allowable number full pressure cycles	N_{eq}	=	1287

Conclusion: **OK: Calculation is valid (D <= 1)**

CALCULATION OF A FLAT END ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Trubkovnice
Order n° : <undefined>
Description : <undef>

Flat end shape : **Circular**
Flat end type : **Bolted, with a narrow face gasket**

Flat end

Outside diameter	$D_{f,o,nom}$	=	1790.000 mm	
Thickness	e_n	=	60.000 mm	
Thickness at extension	$e_{1,nom}$	=	52.000 mm	

Allowance (e_n)

Tolerance	Tol	=	0.300 mm	EN 10029 Class B
Fabrication	Tol_{fab}	=	0.300 mm	EN 10029 Class B
Internal corrosion	CA_{int}	=	0.000 mm	
External corrosion	CA_{ext}	=	0.000 mm	

Allowance at flange extension thickness ($e_{1,nom}$)

Tolerance	Tol	=	0.000 mm
Fabication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm
External corrosion	CA_{ext}	=	0.000 mm

Allowance at outside diameter of extension ($D_{f,o,nom}$)

Tolerance	Tol	=	0.300 mm	EN 10029 Class B
Corrosion	CA_{ext}	=	0.000 mm	

Flat end material
Code : EN 10028-7
Name : X5CrNi18-10 (+AT (Hot rolled plate)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d	=	173.333 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	260.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Bolt

Pitch circle diameter	C	=	1700.000 mm	
Nominal diameter	d_b	=	30.000 mm	
Root diameter	d_r	=	26.717 mm	
Hole diameter in flat end	d_h	=	33.000 mm	
Number	n	=	24	
Pitch circle perimeter	L	=	5340.708 mm	$\pi \cdot C$
Mean pitch	t_B	=	222.529 mm	L/n

Loads

Minimum operating load	$W_{op,min}$	=	1258139.999 N	
Design operating load	W_{op}	=	1258139.999 N	
Minimum seating load	$W_{A,min}$	=	0.000 N	$\pi \cdot G \cdot b \cdot y$
Initial seating load	W_A	=	0.000 N	
Minimum design seating load	W_{min}	=	1258139.999 N	
Design seating load	W	=	1258139.999 N	

Calculation of tightening torque (Annex G.8)

Coating type : Average conditions

Bolting-up method and measuring method : Wrench. Operator feel, uncontrolled

Waisted diameter of bolt	d_{Bs}	=	<undef> mm	
Friction coefficient on thread	μ_t	=	0.200	
Friction coefficient under nut or bolt	μ_n	=	0.200	
Thread pitch	p_t	=	3.500 mm	
Thread angle	α	=	30.000 °	
Nut width across flats	a	=	46.000 mm	
Mean contact diameter on thread	d_t	=	27.727 mm	
Mean contact diameter under nut or bolt	d_n	=	38.000 mm	
Tightening factor	k_B	=	7.559	(G.8-9)
Scatter value of bolt load for 1 bolt below nominal value	ε_{1-}	=	0.400	(T.G.8-2)
Scatter value of bolt load for n bolts below nominal value	ε_{n-}	=	0.161	(G.6-16)
Total required bolt force of all bolts	$F_{B0,req}$	=	1258139.999 N	
Total bolt force of all bolts	$F_{B0,nom}$	=	1499995.070 N	
Minimum tightening torque	$M_{t,nom,min}$	=	472413.692 N·mm	(G.8-4)
Tightening torque	$M_{t,nom}$	=	472413.692 N·mm	

Bolt material

Code : EN 10272

Name : X5CrNi18-10 (+AT) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	190.000	225.000	500.000	0.000	N/mm²
20.00	190.000	225.000	500.000	0.000	N/mm²

f_d	=	166.667 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Gasket

Ring joint		=	NO	
Gasket factor	m	=	0.500 -	
Seating pressure	y	=	0.000 MPa	
Inside diameter	A_1	=	1614.000 mm	
Outside diameter	G_o	=	1634.000 mm	
Diameter of reaction load	G	=	1624.000 mm	$G_o - 2 \cdot w$
Thickness	T	=	4.000 mm	
Contact width	w	=	10.000 mm	
Reaction point perimeter	L_g	=	5101.946 mm	$\pi \cdot G$

Miscellaneous

Test pressure	P_{test}	=	8.600 bar
Maximum pressure	P_{max}	=	0.599 MPa
Mass flat end	M	=	1163.080 kg
Volume flat end (content)	V	=	0.000 dm^3

Conclusion: The flatend is valid according to EN13445-3.

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Hot rolled plate)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	0.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	75.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000

C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Bar
Alloy	: Austenitic corrosion resistant
Code	: EN 10272 (10-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	30.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	250.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	190.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	190.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	225.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	225.00 N/mm²
Tensile strength	R_m	=	500.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	500.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	199964.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7930.00 kg/m³

Allowables

f_d	= 166.667 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0.0000	1.0000
S	0.0000	0.0150
P	0.0000	0.0450

Ni	8.0000	10.5000
N	0.0000	0.1000
Mn	0.0000	2.0000
Cr	17.5000	19.5000
C	0.0000	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Elasticity: Elasticity according EN13445-3 Annex O.4.2
Density: Density according EN13445-3 Annex O.3.1
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab : Plate and sheet
Alloy : Austenitic corrosion resistant
Code : EN 10028-7 (12-2007)

Material name : X5CrNi18-10
Material number : 1.4301
Suffix : +AT (Hot rolled plate)

Material Group according EN13445-2 : **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	60.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	75.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 173.333 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 260.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
C	0	0.0700
Cr	17.5000	19.5000
Mn	0	2.0000
N	0	0.1000
Ni	8.0000	10.5000
P	0	0.0450
S	0	0.0150
Si	0	1.0000

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Calculation (EN 13445-3 Chapter 10)

Condition

Description			: Internal Case 1	
Design condition			: Operating	
Design pressure	P	=	0.600 MPa	
Design temperature	T	=	20.000 °C	
Bolt design temperature	T_{bolts}	=	20.000 °C	
External force	F_E	=	0.000 N	
External moment	M_E	=	0.000 N·mm	
Equivalent calculation pressure	P_{eq}	=	0.600 MPa	$P + 4 \cdot F_E/(\pi \cdot G^2) + 16 \cdot \lvert M_E \rvert/(\pi \cdot G^3)$

Calculation in **uncorroded** condition.

Flat end

Outside diameter	$D_{f,o}$	=	1789.700 mm	$D_{f,o,nom} - 2 \cdot (Tol + Tol_{fab})$
Thickness	e_a	=	59.400 mm	$e_n - (Tol + Tol_{fab})$
Thickness at extension	$e_{1,a}$	=	52.000 mm	$e_{1,nom} - (Tol + Tol_{fab})$

Gasket

Basic seating width	b_0	=	5.000 mm	$w/2$
Effective seating width	b	=	5.000 mm	b_0
Diameter at location of load reaction	G	=	1624.000 mm	$G_o - 2 \cdot w$

Bolts

Bolt design stress seating	$f_{b,A}$	=	166.667 N/mm²	(20°C, d_b)
Bolt design stress operating	f_b	=	166.667 N/mm²	(T_{bolts}, d_b)
Minimum total bolt surface operating	$A_{B,min,op}$	=	7548.840 mm²	W_{op}/f_b
Minimum total bolt surface seating	$A_{B,min,A}$	=	0.000 mm²	$W_A/f_{b,A}$
Minimum total bolt surface	$A_{B,min}$	=	7548.840 mm²	$Max[A_{B,min,op}, A_{B,min,A}]$
Section area	a_B	=	560.595 mm²	$0.25 \cdot \pi \cdot d_r^2$
Minimum number of bolts	$n_{bolts,min}$	=	14	$A_{B,min}/a_B$
Number of bolts	n	=	24	
Total bolt surface	A_B	=	13454.273 mm²	$n \cdot a_B$

OK: $n \geq n_{bolts,min}$

Loads on bolts

Design operating load	W_{op}	= 1258139.999 N	
Minimum bolt operating load	$W_{op,min}$	= 1258139.999 N	$H + H_{G,min}$
Initial seating load	W_A	= 0.000 N	
Minimum bolt seating load	$W_{A,min}$	= 0.000 N	$\pi \cdot G \cdot b \cdot y$
Design load (controlled)	W	= 1258139.999 N	

Tightening torque according G.8.4

Bolt load ratio	φ_B	= <undef>	

φ_B <= 1.0 : Bolt load ratio for tightening torque OK !

Loads on flange extension

Hydrostatic end force	H	= 1242834.160 N	$(\pi/4) \cdot G^2 \cdot P_{eq}$
Minimum contact compression load	$H_{G,min}$	= 15305.839 N	$2b'' \cdot \pi \cdot G \cdot m \cdot P_{eq}$
Gasket compression load	H_G	= 15305.839 N	W_{op} - H
Distance gasket compression load	h_G	= 38.000 mm	(C - G)/2

Minimum calculation

Nominal design stress seating	$f_{A,[e]}$	=	173.333 N/mm²	(20°C, $e_{req,nom}$)
Nominal design stress operating	$f_{[e]}$	=	173.333 N/mm²	(T, $e_{req,nom}$)
Bolt pitch correction factor	C_F	=	1.000 -	$Max[\sqrt{(t_B/(2 \cdot d_b + (6 \cdot e_{1,a}/(m + 0.5))))}, 1]$

Minimum required thickness

At center

Poisson ratio	ν	=	0.300 -	
Minimum thickness seating	e_A	=	18.010 mm	$\sqrt{(C_F \cdot 3 \cdot (C - G) \cdot W/(\pi \cdot G \cdot f_A))}$
Minimum thickness operating	e_{op}	=	56.114 mm	$\sqrt{([3 \cdot (3 + \nu) \cdot G^2/32 + 3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G)] \cdot P/f)}$
Minimum required thickness	e	=	56.114 mm	$Max[e_A, e_{op}]$
Nominal minimum required thickness	$e_{req,nom}$	=	56.714 mm	$e + (Tol + Tol_{fab})$

OK: $e_n \geq e_{req,nom}$

At extension

Minimum thickness seating	$e_{1,A}$	=	18.010 mm	$\sqrt{(C_F \cdot 3 \cdot (C - G) \cdot W/(\pi \cdot G \cdot f_A))}$
Minimum thickness operating	$e_{1,op}$	=	18.010 mm	$\sqrt{(3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G) \cdot P_{eq}/f)}$
Minimum required thickness	e_1	=	18.010 mm	$Max[e_{1,A}, e_{1,op}]$
Nominal minimum required thickness	$e_{1,req,nom}$	=	18.010 mm	$e_1 + (Tol + Tol_{fab})$

OK: $e_{1,nom} \geq e_{1,req,nom}$

Nominal calculation (e_n = 60.000 mm)

Nominal design stress operating	f	=	173.333 N/mm²	(T, e_n)
Bolt pitch correction factor	C_F	=	1.000 -	$Max[\sqrt{(t_B/(2 \cdot d_b + (6 \cdot e_{1,a}/(m + 0.5))))}, 1]$

Maximum pressure

Maximum pressure	P_{max}	=	0.672 MPa	$e_a^2 \cdot f/(3 \cdot (3 + \nu) \cdot G^2/32 + (3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G)))$
Maximum pressure at extension	$P_{1,max}$	=	4.887 MPa	$e_{1,a}^2 \cdot f/(3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G))$

OK: $P \leq P_{max}$
OK: $P \leq P_{1,max}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	173.333 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

Calculation (EN 13445-3 Chapter 10)

Condition

Description		: Internal Case 2		
Design condition		: Testing		
Design pressure	P	=	0.860 MPa	
Design temperature	T	=	20.000 °C	
Bolt design temperature	T_{bolts}	=	20.000 °C	
External force	F_E	=	0.000 N	
External moment	M_E	=	0.000 N·mm	
Equivalent calculation pressure	P_{eq}	=	0.860 MPa	$P + 4 \cdot F_E/(\pi \cdot G^2) + 16 \cdot \lvert M_E \rvert/(\pi \cdot G^3)$

Testing always in **uncorroded** condition

Flat end

Outside diameter	$D_{f,o}$	=	1789.700 mm	$D_{f,o,nom} - 2 \cdot (Tol + Tol_{fab})$
Thickness	e_a	=	59.400 mm	$e_n - (Tol + Tol_{fab})$
Thickness at extension	$e_{1,a}$	=	52.000 mm	$e_{1,nom} - (Tol + Tol_{fab})$

Gasket

Basic seating width	b_0	=	5.000 mm	$w/2$
Effective seating width	b	=	5.000 mm	b_0
Diameter at location of load reaction	G	=	1624.000 mm	$G_o - 2 \cdot w$

Bolts

Bolt design stress seating	$f_{b,A}$	=	166.667 N/mm²	(20°C, d_b)
Bolt design stress operating	f_b	=	250.000 N/mm²	(T_{bolts}, d_b)
Minimum total bolt surface operating	$A_{B,min,op}$	=	7213.336 mm²	W_{op}/f_b
Minimum total bolt surface seating	$A_{B,min,A}$	=	0.000 mm²	$W_A/f_{b,A}$
Minimum total bolt surface	$A_{B,min}$	=	7213.336 mm²	$Max[A_{B,min,op}, A_{B,min,A}]$
Section area	a_B	=	560.595 mm²	$0.25 \cdot \pi \cdot d_r^2$
Minimum number of bolts	$n_{bolts,min}$	=	14	$A_{B,min}/a_B$
Number of bolts	n	=	24	
Total bolt surface	A_B	=	13454.273 mm²	$n \cdot a_B$

OK: $n \geq n_{bolts,min}$

Loads on bolts

Design operating load	W_{op}	=	1258139.999 N	
Minimum bolt operating load	$W_{op,min}$	=	1803333.999 N	$H + H_{G,min}$
Initial seating load	W_A	=	0.000 N	
Minimum bolt seating load	$W_{A,min}$	=	0.000 N	$\pi \cdot G \cdot b \cdot y$
Design load (controlled)	W	=	1258139.999 N	

Tightening torque according G.8.4

Bolt load ratio	φ_B	=	<undef>

φ_B <= 1.0 : Bolt load ratio for tightening torque OK !

Loads on flange extension

Hydrostatic end force	H	=	1781395.629 N	$(\pi/4) \cdot G^2 \cdot P_{eq}$
Minimum contact compression load	$H_{G,min}$	=	21938.370 N	$2b'' \cdot \pi \cdot G \cdot m \cdot P_{eq}$
Gasket compression load	H_G	=	21938.370 N	$W_{op} - H$
Distance gasket compression load	h_G	=	38.000 mm	$(C - G)/2$

Minimum calculation

Nominal design stress seating	$f_{A,[e]}$	=	173.333 N/mm²	(20°C, $e_{req,nom}$)
Nominal design stress operating	$f_{[e]}$	=	260.000 N/mm²	(T, $e_{req,nom}$)
Bolt pitch correction factor	C_F	=	1.000 -	$\mathrm{Max}[\sqrt{(t_B/(2\cdot d_b + (6\cdot e_{1,a}/(m + 0.5))))}, 1]$

Minimum required thickness

At center

Poisson ratio	ν	=	0.300 -	
Minimum thickness seating	e_A	=	18.010 mm	$\sqrt{(C_F\cdot 3\cdot(C - G)\cdot W/(\pi\cdot G\cdot f_A))}$
Minimum thickness operating	e_{op}	=	54.853 mm	$\sqrt{([3\cdot(3 + \nu)\cdot G^2/32 + 3\cdot C_F\cdot(G/4 + 2\cdot b\cdot m)\cdot(C - G)]\cdot P/f)}$
Minimum required thickness	e	=	54.853 mm	$\mathrm{Max}[e_A, e_{op}]$
Nominal minimum required thickness	$e_{req,nom}$	=	55.453 mm	$e + (Tol + Tol_{fab})$

OK: $e_n \geq e_{req,nom}$

At extension

Minimum thickness seating	$e_{1,A}$	=	18.010 mm	$\sqrt{(C_F\cdot 3\cdot(C - G)\cdot W/(\pi\cdot G\cdot f_A))}$
Minimum thickness operating	$e_{1,op}$	=	17.606 mm	$\sqrt{(3\cdot C_F\cdot(G/4 + 2\cdot b\cdot m)\cdot(C - G)\cdot P_{eq}/f)}$
Minimum required thickness	e_1	=	18.010 mm	$\mathrm{Max}[e_{1,A}, e_{1,op}]$
Nominal minimum required thickness	$e_{1,req,nom}$	=	18.010 mm	$e_1 + (Tol + Tol_{fab})$

OK: $e_{1,nom} \geq e_{1,req,nom}$

Nominal calculation (e_n = 60.000 mm)

Nominal design stress operating	f	=	260.000 N/mm²	(T, e_n)
Bolt pitch correction factor	C_F	=	1.000 -	$\mathrm{Max}[\sqrt{(t_B/(2\cdot d_b + (6\cdot e_{1,a}/(m + 0.5))))}, 1]$

Maximum pressure

Maximum pressure	P_{max}	=	1.008 MPa	$e_a^2\cdot f/(3\cdot(3 + \nu)\cdot G^2/32 + (3\cdot C_F\cdot(G/4 + 2\cdot b\cdot m)\cdot(C - G)))$
Maximum pressure at extension	$P_{1,max}$	=	7.330 MPa	$e_{1,a}^2\cdot f/(3\cdot C_F\cdot(G/4 + 2\cdot b\cdot m)\cdot(C - G))$

OK: $P \leq P_{max}$
OK: $P \leq P_{1,max}$

Calculation (EN 13445-3 Chapter 10)

Condition

Description		: Internal Case 3		
Design condition		: Operating		
Design pressure	P	=	0.200 MPa	
Design temperature	T	=	85.000 °C	
Bolt design temperature	T_{bolts}	=	85.000 °C	
External force	F_E	=	0.000 N	
External moment	M_E	=	0.000 N·mm	
Equivalent calculation pressure	P_{eq}	=	0.200 MPa	$P + 4 \cdot F_E/(\pi \cdot G^2) + 16 \cdot \lvert M_E \rvert/(\pi \cdot G^3)$

Calculation in **uncorroded** condition.

Flat end

Outside diameter	$D_{f,o}$	=	1789.700 mm	$D_{f,o,nom} - 2 \cdot (Tol + Tol_{fab})$
Thickness	e_a	=	59.400 mm	$e_n - (Tol + Tol_{fab})$
Thickness at extension	$e_{1,a}$	=	52.000 mm	$e_{1,nom} - (Tol + Tol_{fab})$

Gasket

Basic seating width	b_0	=	5.000 mm	$w/2$
Effective seating width	b	=	5.000 mm	b_0
Diameter at location of load reaction	G	=	1624.000 mm	$G_o - 2 \cdot w$

Bolts

Bolt design stress seating	$f_{b,A}$	=	166.667 N/mm²	(20°C, d_b)
Bolt design stress operating	f_b	=	153.125 N/mm²	(T_{bolts}, d_b)
Minimum total bolt surface operating	$A_{B,min,op}$	=	8216.424 mm²	W_{op}/f_b
Minimum total bolt surface seating	$A_{B,min,A}$	=	0.000 mm²	$W_A/f_{b,A}$
Minimum total bolt surface	$A_{B,min}$	=	8216.424 mm²	$Max[A_{B,min,op}, A_{B,min,A}]$
Section area	a_B	=	560.595 mm²	$0.25 \cdot \pi \cdot d_r^2$
Minimum number of bolts	$n_{bolts,min}$	=	16	$A_{B,min}/a_B$
Number of bolts	n	=	24	
Total bolt surface	A_B	=	13454.273 mm²	$n \cdot a_B$

OK: $n \geq n_{bolts,min}$

Loads on bolts

Design operating load	W_{op}	=	1258139.999 N	
Minimum bolt operating load	$W_{op,min}$	=	419380.000 N	$H + H_{G,min}$
Initial seating load	W_A	=	0.000 N	
Minimum bolt seating load	$W_{A,min}$	=	0.000 N	$\pi \cdot G \cdot b \cdot y$
Design load (controlled)	W	=	1258139.999 N	

Tightening torque according G.8.4

Bolt load ratio	φ_B	=	<undef>	

φ_B <= 1.0 : Bolt load ratio for tightening torque OK !

Loads on flange extension

Hydrostatic end force	H	=	414278.053 N	$(\pi/4) \cdot G^2 \cdot P_{eq}$
Minimum contact compression load	$H_{G,min}$	=	5101.946 N	$2b'' \cdot \pi \cdot G \cdot m \cdot P_{eq}$
Gasket compression load	H_G	=	843861.946 N	$W_{op} - H$
Distance gasket compression load	h_G	=	38.000 mm	$(C - G)/2$

Minimum calculation

Nominal design stress seating	$f_{A,[e]}$	=	173.333 N/mm²	(20°C, $e_{req,nom}$)
Nominal design stress operating	$f_{[e]}$	=	154.400 N/mm²	(T, $e_{req,nom}$)
Bolt pitch correction factor	C_F	=	1.000 -	$Max[\sqrt{(t_B/(2 \cdot d_b + (6 \cdot e_{1,a}/(m + 0.5))))}, 1]$

Minimum required thickness

At center

Poisson ratio	ν	=	0.300 -	
Minimum thickness seating	e_A	=	18.010 mm	$\sqrt{(C_F \cdot 3 \cdot (C - G) \cdot W/(\pi \cdot G \cdot f_A))}$
Minimum thickness operating	e_{op}	=	34.326 mm	$\sqrt{([3 \cdot (3 + \nu) \cdot G^2/32 + 3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G)] \cdot P/f)}$
Minimum required thickness	e	=	34.326 mm	$Max[e_A, e_{op}]$
Nominal minimum required thickness	$e_{req,nom}$	=	34.926 mm	$e + (Tol + Tol_{fab})$

OK: $e_n \geq e_{req,nom}$

At extension

Minimum thickness seating	$e_{1,A}$	=	18.010 mm	$\sqrt{(C_F \cdot 3 \cdot (C - G) \cdot W/(\pi \cdot G \cdot f_A))}$
Minimum thickness operating	$e_{1,op}$	=	11.017 mm	$\sqrt{(3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G) \cdot P_{eq}/f)}$
Minimum required thickness	e_1	=	18.010 mm	$Max[e_{1,A}, e_{1,op}]$
Nominal minimum required thickness	$e_{1,req,nom}$	=	18.010 mm	$e_1 + (Tol + Tol_{fab})$

OK: $e_{1,nom} \geq e_{1,req,nom}$

Nominal calculation (e_n = 60.000 mm)

Nominal design stress operating	f	=	154.400 N/mm²	(T, e_n)
Bolt pitch correction factor	C_F	=	1.000 -	$Max[\sqrt{(t_B/(2 \cdot d_b + (6 \cdot e_{1,a}/(m + 0.5))))}, 1]$

Maximum pressure

Maximum pressure	P_{max}	=	0.599 MPa	$e_a^2 \cdot f/(3 \cdot (3 + \nu) \cdot G^2/32 + (3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G)))$
Maximum pressure at extension	$P_{1,max}$	=	4.353 MPa	$e_{1,a}^2 \cdot f/(3 \cdot C_F \cdot (G/4 + 2 \cdot b \cdot m) \cdot (C - G))$

OK: $P \leq P_{max}$
OK: $P \leq P_{1,max}$

Test pressure

Nominal design stress at T_t	f_a	=	173.333 N/mm²	$f(T_t, e_n)$
Nominal design stress at T	f_{Td}	=	154.400 N/mm²	$f(T, e_n)$
Test pressure	P_t	=	2.860 bar	$Max[1.43 \cdot P, 1.25 \cdot P \cdot f_a/f_{Td}]$

CALCULATION OF A FLANGE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Priruba 1
Order n° : <undef>
Description : <undef>

Flange type : **Loose** **Weld**

Method of calculation: Integral method

Flange Material EN 10028-7 X5CrNi18-10 (+AT (Hot rolled plate)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d	=	166.667 N/mm²	$R_{p1,0/T}/1.5$
f_{test}	=	238.095 N/mm²	$R_{p1,0/T}/1.05$
f_{exc}	=	238.095 N/mm²	$R_{p1,0/T}/1.05$

Dimensions of the flange

Outside diameter	A_{nom}	=	1790.000 mm
Inside diameter	B_{nom}	=	1600.000 mm
Thickness	e_n	=	85.000 mm
Thickness of hub at small end	$g_{0,nom}$	=	6.000 mm
Thickness of hub at flange side	$g_{1,nom}$	=	6.000 mm
Length of hub	h	=	6.000 mm
Minimum radius of fillet	$r_{min,nom}$	=	5.000 mm
Length of cylindrical part	l	=	<undef> mm
Allowance (e_n)			
Tolerance	Tol	=	0.000 mm
Fabrication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)
Allowance at inside diameter and hub ($B_{nom}/g_{1,nom}/g_{0,nom}$)			
Tolerance	$Tol_{,i}$	=	0.000 mm
Internal corrosion	$CA_{int,i}$	=	0.000 mm (= 0.00 when Testing)
External corrosion	$CA_{ext,i}$	=	0.000 mm (= 0.00 when Testing)
Allowance at outside diameter of flange (A_{nom})			
Tolerance	$Tol_{,o}$	=	0.000 mm
Corrosion	$CA_{ext,o}$	=	0.000 mm (= 0.00 when Testing)

Gasket data

Group	: Flat, non metallic gaskets		
Nature	: Rubber without fabric or high % of asbestos fiber		
Fabrication	: Below 75° IRH		
Seating/Facing	: Both raised		
Gasket factor	m	=	0.500 -
Minimum seating pressure	y	=	0.000 N/mm²
Contact width	w	=	10.000 mm
Basic seating width	b_0	=	5.000 mm
Effective seating width	b	=	5.000 mm
Outside diameter	G_o	=	1634.000 mm
Diameter at location of load reaction	G	=	1624.000 mm

Bolt Material EN 10272 X5CrNi18-10 (+AT) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	190.000	225.000	500.000	0.000	**N/mm²**
20.00	190.000	225.000	500.000	0.000	**N/mm²**

f_d	=	166.667 N/mm²	Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]
f_{test}	=	250.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]
f_{exc}	=	250.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]

Bolt data

Pitch circle diameter	C	=	1700.000 mm
Nominal diameter	d_b	=	30.000 mm
Root diameter	d_r	=	26.717 mm
Hole diameter	d_h	=	33.000 mm
Number	n	=	24
Bolt surface	a_B	=	560.595 mm²
Total bolt surface (n·a_B)	A_B	=	13454.273 mm²

Loads

Minimum operating load	W_{op}	=	1258139.999 N
Design operating load	W_{op}	=	1258139.999 N
Minimum seating load	W_A	=	0.000 N
Initial seating load	W_A	=	0.000 N
Minimum design seating load	W	=	1258139.999 N
Design seating load	W	=	1258139.999 N

Calculation of tightening torque (Annex G.8)

Coating type	: Average conditions			
Bolting-up method and measuring method	: Wrench. Operator feel, uncontrolled			
Waisted diameter of bolt	d_{BS}	=	<undef> mm	
Friction coefficient on thread	μ_t	=	0.200	
Friction coefficient under nut or bolt	μ_n	=	0.200	
Thread pitch	p_t	=	3.500 mm	
Thread angle	α	=	30.000 °	
Nut width across flats	a	=	46.000 mm	
Mean contact diameter on thread	d_t	=	27.727 mm	
Mean contact diameter under nut or bolt	d_n	=	38.000 mm	
Tightening factor	k_B	=	7.559	(G.8-9)
Scatter value of bolt load for 1 bolt below nominal value	ε_{1-}	=	0.400	(T.G.8-2)
Scatter value of bolt load for n bolts below nominal value	ε_{n-}	=	0.161	(G.6-16)
Total required bolt force of all bolts	$F_{B0,req}$	=	1258139.999 N	
Total bolt force of all bolts	$F_{B0,nom}$	=	1499995.070 N	
Minimum tightening torque	$M_{t,nom,min}$	=	472413.692 N·mm	(G.8-4)
Tightening torque	$M_{t,nom}$	=	472413.692 N·mm	

Attached Shell Material EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d	=	180.000 N/mm²	Max[$R_{p1,0/T}$/1.5, Min[$R_{p1,0/T}$/1.2, $R_{m/T}$/3]]
f_{test}	=	270.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]
f_{exc}	=	270.000 N/mm²	Max[$R_{p1,0/T}$/1.05, $R_{m/T}$/2]

Attached shell data

Outside diameter	$D_{e,nom}$	=	1600.000 mm	**Base diameter**
Inside diameter	D_{nom}	=	1588.000 mm	
Thickness	$e_{s,n}$	=	6.000 mm	

Allowance at shell ($e_{s,n}$)

Tolerance	Tol	=	0.000 mm
Fabication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)

Prefab	: Bar		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10272 (10-2007)		

Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT		

Material Group according EN13445-2 : **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	30.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	250.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	190.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	190.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	225.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	225.00 N/mm²
Tensile strength	R_m	=	500.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	500.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	199964.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7930.00 kg/m³

Allowables

f_d = 166.667 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0.0000	1.0000
S	0.0000	0.0150
P	0.0000	0.0450
Ni	8.0000	10.5000
N	0.0000	0.1000
Mn	0.0000	2.0000
Cr	17.5000	19.5000
C	0.0000	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Elasticity: Elasticity according EN13445-3 Annex O.4.2
Density: Density according EN13445-3 Annex O.3.1
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Cold rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	6.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d = 180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450

Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab : Plate and sheet
Alloy : Austenitic corrosion resistant
Code : EN 10028-7 (12-2007)

Material name : X5CrNi18-10
Material number : 1.4301
Suffix : +AT (Hot rolled plate)

Material Group according EN13445-2 : **8.1**

Temperature T = 20.00 °C
Thickness e_n = 85.00 mm

Minimum allowed thickness e_{MIN} = 0.00 mm
Maximum allowed thickness e_{MAX} = 75.00 mm Thickness exceeds maximum material thickness!

Properties

0.2% Proof strength $R_{p0,2}$ = 210.00 N/mm²
0.2% Proof strength at temperature $R_{p0,2/T}$ = 210.00 N/mm²
1.0% Proof strength $R_{p1,0}$ = 250.00 N/mm²
1.0% Proof strength at temperature $R_{p1,0/T}$ = 250.00 N/mm²

Tensile strength R_m = 520.00 N/mm²
Tensile strength at temperature $R_{m/T}$ = 520.00 N/mm²

Creep rupture at 100.000 hrs $R_{m/T/100k}$ = 0.00 N/mm²
1% Creep strain at 100.000 hrs $R_{p1,0/T/100k}$ = 0.00 N/mm²

Modulus of Elasticity E = 200000.00 N/mm²
Lineair expansion α = 1.53E-005 m/(m·°C)
Elongation after Rupture A = 45.00 %
Poisson's ratio ν = 0.30
Density ρ = 7900.00 kg/m³

Allowables

f_d = 166.667 N/mm²
$R_{p1,0/T}/1.5$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 238.095 N/mm²
$R_{p1,0/T}/1.05$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 238.095 N/mm²
$R_{p1,0/T}/1.05$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal pressure (EN 13445-3 Section 11)

Condition

Description		: Internal 1	
Design condition		: Operating	
Design pressure	P_d	=	0.600 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	1790.000 mm
Inside diameter	B	=	1600.000 mm
Ratio flange diameters	K	=	1.119
Inside diameter of shell	D	=	1588.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	6.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	97.980 mm
Minimum thickness seating	$e_{min,A}$	=	65.054 mm
Minimum thickness operating	$e_{min,P}$	=	80.126 mm
Minimum thickness	e_{min}	=	80.126 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	166.667 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	7548.840 mm²
Minimum number of bolts	n_{min}	=	14
Number of bolts	n	=	24
Total bolt surface ($n \cdot a_B$)	A_B	=	13454.273 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	0.000 N

Minimum operating load	$W_{op,min}$	=	1258139.999 N
Minimum design seating load	W_{min}	=	1750259.449 N
Initial seating load	W_A	=	0.000 N
Design operating load	W_{op}	=	1258139.999 N
Design seating load (controlled)	$W_{contr.}$	=	1258139.999 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	15305.839 N	h_G	=	38.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	36462.581 N	h_T	=	44.000 mm
Force by pressure on flange face (at B)	H_D	=	1206371.579 N	h_D	=	47.000 mm

Bending moments on flange

Momentum gasket seating	M_A	=	47809319.976 N·mm
Momentum operating	M_{op}	=	58885439.672 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	58.884 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	1.415 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	138.471 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,A}|$ (70.661 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,A}|$ (1.698 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,A}|$ (166.165 N/mm²) <= $1.5\cdot\min(f_A, f_{H,A})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (118.413 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (83.931 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	72.526 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	1.743 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	170.550 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_P	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	180.000 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,P}|$ (87.031 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,P}|$ (2.092 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,P}|$ (204.661 N/mm²) <= $1.5\cdot\min(f_P, f_{H,P})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (145.846 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (103.376 N/mm²) <= f_P (166.667 N/mm²)

Factors

β_T	=	1.870449	β_U	=	19.010908	β_Y	=	17.299927
β_F	=	0.908920	β_V	=	0.550103	λ	=	5.994217
Hub stress correction factor for "Integral" flanges						φ	=	1.000000

Test pressure

Nominal design stress at T_t	f_a	=	166.667 N/mm²	$f(T_t, e_n)$
Nominal design stress at T_{flange}	f_{Td}	=	166.667 N/mm²	$f(T_{flange}, e_n)$
Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P_d, 1.25 \cdot P_d \cdot f_a/f_{Td}]$

Internal pressure (EN 13445-3 Section 11)

Condition

Description		: Internal 2	
Design condition		: Testing	
Design pressure	P_d	=	0.860 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	1790.000 mm
Inside diameter	B	=	1600.000 mm
Ratio flange diameters	K	=	1.119
Inside diameter of shell	D	=	1588.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	6.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	97.980 mm
Minimum thickness seating	$e_{min,A}$	=	64.935 mm
Minimum thickness operating	$e_{min,P}$	=	80.245 mm
Minimum thickness	e_{min}	=	80.245 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	250.000 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	7213.336 mm²
Minimum number of bolts	n_{min}	=	14
Number of bolts	n	=	24
Total bolt surface ($n \cdot a_B$)	A_B	=	13454.273 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	0.000 N
Minimum operating load	$W_{op,min}$	=	1803333.999 N
Minimum design seating load	W_{min}	=	1722300.783 N
Initial seating load	W_A	=	0.000 N
Design operating load	W_{op}	=	1803333.999 N
Design seating load (controlled)	$W_{contr.}$	=	1258139.999 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	21938.370 N	h_G	=	38.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	52263.033 N	h_T	=	44.000 mm
Force by pressure on flange face (at B)	H_D	=	1729132.597 N	h_D	=	47.000 mm

Bending moments on flange

Momentum gasket seating	M_A	=	47809319.976 N·mm
Momentum operating	M_{op}	=	84402463.530 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	58.884 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	1.415 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	138.471 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,A}|$ (70.661 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,A}|$ (1.698 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,A}|$ (166.165 N/mm²) <= $1.5\cdot\min(f_A, f_{H,A})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (118.413 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (83.931 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	103.953 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	2.498 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	244.456 N/mm²
Allowable longitudinal hub stress		=	357.143 N/mm²
Flange allowable stress	f_P	=	238.095 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	270.000 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,P}|$ (124.744 N/mm²) <= f_P (238.095 N/mm²)
OK: $k\cdot|\sigma_{r,P}|$ (2.998 N/mm²) <= f_P (238.095 N/mm²)
OK: $k\cdot|\sigma_{H,P}|$ (293.347 N/mm²) <= $1.5\cdot\min(f_P, f_{H,P})$ (357.143 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (209.045 N/mm²) <= f_P (238.095 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (148.172 N/mm²) <= f_P (238.095 N/mm²)

Factors

β_T	=	1.870449	β_U	=	19.010908	β_Y	=	17.299927
β_F	=	0.908920	β_V	=	0.550103	λ	=	5.994217
Hub stress correction factor for "Integral" flanges						φ	=	1.000000

Internal pressure (EN 13445-3 Section 11)

Condition

Description		: Internal 3	
Design condition		: Operating	
Design pressure	P_d	=	0.200 MPa
Design temperature	T_{flange}	=	85.000 °C
Shell design temperature	T_{shell}	=	85.000 °C
Bolt design temperature	T_{bolts}	=	85.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	1790.000 mm
Inside diameter	B	=	1600.000 mm
Ratio flange diameters	K	=	1.119
Inside diameter of shell	D	=	1588.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	6.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	97.980 mm
Minimum thickness seating	$e_{min,A}$	=	62.270 mm
Minimum thickness operating	$e_{min,P}$	=	82.978 mm
Minimum thickness	e_{min}	=	82.978 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	153.125 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	8216.424 mm²
Minimum number of bolts	n_{min}	=	16
Number of bolts	n	=	24
Total bolt surface ($n \cdot a_B$)	A_B	=	13454.273 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	0.000 N
Minimum operating load	$W_{op,min}$	=	419380.000 N
Minimum design seating load	W_{min}	=	1805891.490 N
Initial seating load	W_A	=	0.000 N
Design operating load	W_{op}	=	1258139.999 N
Design seating load (controlled)	$W_{contr.}$	=	1258139.999 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	843861.946 N	h_G	=	38.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	12154.194 N	h_T	=	44.000 mm
Force by pressure on flange face (at B)	H_D	=	402123.860 N	h_D	=	47.000 mm

Bending moments on flange

Momentum gasket seating	M_A	=	47809319.976 N·mm
Momentum operating	M_{op}	=	51501359.875 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	58.884 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	1.415 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	138.471 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,A}|$ (70.661 N/mm²) <= f_A (166.667 N/mm²)

OK: $k\cdot|\sigma_{r,A}|$ (1.698 N/mm²) <= f_A (166.667 N/mm²)

OK: $k\cdot|\sigma_{H,A}|$ (166.165 N/mm²) <= $1.5\cdot\min(f_A, f_{H,A})$ (250.000 N/mm²)

OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (118.413 N/mm²) <= f_A (166.667 N/mm²)

OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (83.931 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	63.431 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	1.524 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	149.164 N/mm²
Allowable longitudinal hub stress		=	202.100 N/mm²
Flange allowable stress	f_P	=	134.733 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	154.400 N/mm²
Stress factor	k	=	1.200

OK: $k\cdot|\sigma_{\theta,P}|$ (76.117 N/mm²) <= f_P (134.733 N/mm²)

OK: $k\cdot|\sigma_{r,P}|$ (1.829 N/mm²) <= f_P (134.733 N/mm²)

OK: $k\cdot|\sigma_{H,P}|$ (178.997 N/mm²) <= $1.5\cdot\min(f_P, f_{H,P})$ (202.100 N/mm²)

OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (127.557 N/mm²) <= f_P (134.733 N/mm²)

OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (90.413 N/mm²) <= f_P (134.733 N/mm²)

Factors

β_T	=	1.870449	β_U	=	19.010908	β_Y	=	17.299927
β_F	=	0.908920	β_V	=	0.550103	λ	=	5.994217
Hub stress correction factor for "Integral" flanges						φ	=	1.000000

Test pressure

Nominal design stress at T_t	f_a	=	166.667 N/mm²	$f(T_t, e_n)$
Nominal design stress at T_{flange}	f_{Td}	=	134.733 N/mm²	$f(T_{flange}, e_n)$
Test pressure	P_t	=	3.093 bar	$\text{Max}[1.43\cdot P_d, 1.25\cdot P_d\cdot f_a/f_{Td}]$

CALCULATION OF A FLANGE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Priruba 2a
Order n° : <undef>
Description : <undef>

Flange type : **Loose** **Weld**

Method of calculation: Loose method

Flange Material EN 10028-7 X5CrNi18-10 (+AT (Hot rolled plate)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d = 166.667 N/mm² $R_{p1,0/T}/1.5$
f_{test} = 238.095 N/mm² $R_{p1,0/T}/1.05$
f_{exc} = 238.095 N/mm² $R_{p1,0/T}/1.05$

Dimensions of the flange

Outside diameter	A_{nom}	=	595.000 mm
Inside diameter	B_{nom}	=	437.000 mm
Thickness	e_n	=	27.000 mm
Thickness of hub at small end	$g_{0,nom}$	=	6.000 mm
Thickness of hub at flange side	$g_{1,nom}$	=	7.500 mm
Length of hub	h	=	1.500 mm
Minimum radius of fillet	$r_{min,nom}$	=	1.875 mm
Length of cylindrical part	l	=	<undef> mm
Allowance (e_n)			
Tolerance	Tol	=	0.000 mm
Fabrication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)
Allowance at inside diameter and hub ($B_{nom}/g_{1,nom}/g_{0,nom}$)			
Tolerance	$Tol_{,i}$	=	0.000 mm
Internal corrosion	$CA_{int,i}$	=	0.000 mm (= 0.00 when Testing)
External corrosion	$CA_{ext,i}$	=	0.000 mm (= 0.00 when Testing)
Allowance at outside diameter of flange (A_{nom})			
Tolerance	$Tol_{,o}$	=	0.000 mm
Corrosion	$CA_{ext,o}$	=	0.000 mm (= 0.00 when Testing)

Gasket data

Group	: Ring gaskets		
Nature	: Rubber O-ring		
Fabrication	: Below 75° IRH		
Seating/Facing	: Groove for O-ring		
Gasket factor	m	=	0.000 -
Minimum seating pressure	y	=	0.700 N/mm²
Contact width	w	=	6.000 mm
Effective seating width	b	=	0.750 mm
Outside diameter	G_o	=	480.000 mm
Diameter at location of load reaction	G	=	474.000 mm

Bolt Material EN 10272 X5CrNi18-10 (+AT) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	190.000	225.000	500.000	0.000	**N/mm²**
20.00	190.000	225.000	500.000	0.000	**N/mm²**

f_d	=	166.667 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Bolt data

Pitch circle diameter	C	=	560.000 mm
Nominal diameter	d_b	=	16.000 mm
Root diameter	d_r	=	14.124 mm
Hole diameter	d_h	=	20.000 mm
Number	n	=	16
Bolt surface	a_B	=	156.666 mm²
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²

Loads

Minimum operating load	W_{op}	=	105876.071 N
Design operating load	W_{op}	=	105876.071 N
Minimum seating load	W_A	=	1042.380 N
Initial seating load	W_A	=	1042.380 N
Minimum design seating load	W	=	105876.071 N
Design seating load	W	=	105876.071 N

Calculation of tightening torque (Annex G.8)

Coating type : Average conditions

Bolting-up method and measuring method : Wrench. Operator feel, uncontrolled

Waisted diameter of bolt	d_{BS}	=	<undef> mm	
Friction coefficient on thread	μ_t	=	0.200	
Friction coefficient under nut or bolt	μ_n	=	0.200	
Thread pitch	p_t	=	2.000 mm	
Thread angle	α	=	30.000 °	
Nut width across flats	a	=	24.000 mm	
Mean contact diameter on thread	d_t	=	14.701 mm	
Mean contact diameter under nut or bolt	d_n	=	20.000 mm	
Tightening factor	k_B	=	4.016	(G.8-9)
Scatter value of bolt load for 1 bolt below nominal value	ε_{1-}	=	0.400	(T.G.8-2)
Scatter value of bolt load for n bolts below nominal value	ε_{n-}	=	0.175	(G.6-16)
Total required bolt force of all bolts	$F_{B0,req}$	=	105876.071 N	
Total bolt force of all bolts	$F_{B0,nom}$	=	128334.631 N	
Minimum tightening torque	$M_{t,nom,min}$	=	32210.635 N·mm	(G.8-4)
Tightening torque	$M_{t,nom}$	=	32210.635 N·mm	

Attached Shell Material EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d	=	180.000 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Attached shell data

Outside diameter	$D_{e,nom}$	=	494.000 mm	**Base diameter**
Inside diameter	D_{nom}	=	482.000 mm	
Thickness	$e_{s,n}$	=	6.000 mm	

Allowance at shell ($e_{s,n}$)

Tolerance	Tol	=	0.000 mm
Fabication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab : Bar
Alloy : Austenitic corrosion resistant
Code : EN 10272 (10-2007)

Material name : X5CrNi18-10
Material number : 1.4301
Suffix : +AT

Material Group according EN13445-2 : **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	16.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	250.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	190.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	190.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	225.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	225.00 N/mm²
Tensile strength	R_m	=	500.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	500.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	199964.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7930.00 kg/m³

Allowables

f_d = 166.667 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)
f_{test} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)
f_{exc} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0.0000	1.0000
S	0.0000	0.0150
P	0.0000	0.0450
Ni	8.0000	10.5000
N	0.0000	0.1000
Mn	0.0000	2.0000
Cr	17.5000	19.5000
C	0.0000	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Elasticity: Elasticity according EN13445-3 Annex O.4.2
Density: Density according EN13445-3 Annex O.3.1
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Cold rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	6.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	=	180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$		Austenitic (A >= 35%) (per 6.5)
f_{test}	=	270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$		Austenitic (A >= 35%) (per 6.5)
f_{exc}	=	270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$		Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000

N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Hot rolled plate)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	27.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	75.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 166.667 N/mm²
$R_{p1,0/T}/1.5$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 238.095 N/mm²
$R_{p1,0/T}/1.05$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 238.095 N/mm²
$R_{p1,0/T}/1.05$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)

Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal pressure (EN 13445-3 Section 11)

Condition

Description			: Internal 1
Design condition			: Operating
Design pressure	P_d	=	0.600 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	482.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	7.500 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	51.205 mm
Minimum thickness seating	$e_{min,A}$	=	17.436 mm
Minimum thickness operating	$e_{min,P}$	=	23.083 mm
Minimum thickness	e_{min}	=	23.083 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	166.667 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	635.256 mm²
Minimum number of bolts	n_{min}	=	6
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	105876.071 N
Minimum design seating load	W_{min}	=	261825.937 N
Initial seating load	W_A	=	1042.380 N

Design operating load W_{op} = 105876.071 N
Design seating load (controlled) $W_{contr.}$ = 105876.071 N

Tightening torque according G.8.4

Bolt load ratio ϕ_B = <undef> (G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	0.000 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	15884.050 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	89992.021 N	h_D	=	57.750 mm

Bending moments on flange

Momentum gasket seating M_A = 4552671.038 N·mm
Momentum operating M_{op} = 6026980.808 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	92.062 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.036 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.024 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k\cdot|\sigma_{\theta,A}|$ (92.062 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,A}|$ (0.036 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,A}|$ (0.024 N/mm²) <= $1.5\cdot\min(f_A, f_{H,A})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (46.043 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.030 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	121.874 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.047 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.032 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_P	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k\cdot|\sigma_{\theta,P}|$ (121.874 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,P}|$ (0.047 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,P}|$ (0.032 N/mm²) <= $1.5\cdot\min(f_P, f_{H,P})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (60.953 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.039 N/mm²) <= f_P (166.667 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	26.104752	β_{VL}	=	5142.989025	λ	=	7755.571720

Test pressure

Nominal design stress at T_t f_a = 166.667 N/mm² $f(T_t, e_n)$
Nominal design stress at T_{flange} f_{Td} = 166.667 N/mm² $f(T_{flange}, e_n)$

Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P_d, 1.25 \cdot P_d \cdot f_a / f_{Td}]$

Internal pressure (EN 13445-3 Section 11)

Condition

Description		: Internal 2	
Design condition		: Testing	
Design pressure	P_d	=	0.860 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	482.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	7.500 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	51.205 mm
Minimum thickness seating	$e_{min,A}$	=	17.407 mm
Minimum thickness operating	$e_{min,P}$	=	23.121 mm
Minimum thickness	e_{min}	=	23.121 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	250.000 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	607.023 mm²
Minimum number of bolts	n_{min}	=	4
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	151755.701 N
Minimum design seating load	W_{min}	=	259473.135 N
Initial seating load	W_A	=	1042.380 N
Design operating load	W_{op}	=	151755.701 N
Design seating load (controlled)	$W_{contr.}$	=	105876.071 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	0.000 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	22767.138 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	128988.564 N	h_D	=	57.750 mm

Bending moments on flange

Momentum gasket seating	M_A	= 4552671.038 N·mm
Momentum operating	M_{op}	= 8638672.491 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	92.062 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.036 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.024 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,A}|$ (92.062 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{r,A}|$ (0.036 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{H,A}|$ (0.024 N/mm²) <= $1.5 \cdot \min(f_A, f_{H,A})$ (250.000 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (46.043 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.030 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	174.686 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.068 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.045 N/mm²
Allowable longitudinal hub stress		=	357.143 N/mm²
Flange allowable stress	f_P	=	238.095 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	270.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,P}|$ (174.686 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot |\sigma_{r,P}|$ (0.068 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot |\sigma_{H,P}|$ (0.045 N/mm²) <= $1.5 \cdot \min(f_P, f_{H,P})$ (357.143 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (87.366 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.056 N/mm²) <= f_P (238.095 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	26.104752	β_{VL}	=	5142.989025	λ	=	7755.571720

Internal pressure (EN 13445-3 Section 11)

Condition

Description			: Internal 3
Design condition			: Operating
Design pressure	P_d	=	0.200 MPa
Design temperature	T_{flange}	=	85.000 °C
Shell design temperature	T_{shell}	=	85.000 °C
Bolt design temperature	T_{bolts}	=	85.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	482.000 mm
Hub thickness at small end	g_0	=	6.000 mm
Hub thickness at flange face	g_1	=	7.500 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	51.205 mm
Minimum thickness seating	$e_{min,A}$	=	17.137 mm
Minimum thickness operating	$e_{min,P}$	=	23.487 mm
Minimum thickness	e_{min}	=	23.487 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	153.125 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	691.436 mm²
Minimum number of bolts	n_{min}	=	6
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	35292.024 N
Minimum design seating load	W_{min}	=	266507.532 N
Initial seating load	W_A	=	1042.380 N
Design operating load	W_{op}	=	105876.071 N
Design seating load (controlled)	$W_{contr.}$	=	105876.071 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	70584.047 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	5294.683 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	29997.340 N	h_D	=	57.750 mm

Bending moments on flange

Momentum gasket seating	M_A	= 4552671.038 N·mm
Momentum operating	M_{op}	= 5044107.628 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	92.062 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.036 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.024 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,A}|$ (92.062 N/mm²) <= f_A (166.667 N/mm²)
OK: $k \cdot |\sigma_{r,A}|$ (0.036 N/mm²) <= f_A (166.667 N/mm²)
OK: $k \cdot |\sigma_{H,A}|$ (0.024 N/mm²) <= $1.5 \cdot \min(f_A, f_{H,A})$ (250.000 N/mm²)
OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (46.043 N/mm²) <= f_A (166.667 N/mm²)
OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.030 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	101.999 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.040 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.026 N/mm²
Allowable longitudinal hub stress		=	202.100 N/mm²
Flange allowable stress	f_P	=	134.733 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	154.400 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,P}|$ (101.999 N/mm²) <= f_P (134.733 N/mm²)
OK: $k \cdot |\sigma_{r,P}|$ (0.040 N/mm²) <= f_P (134.733 N/mm²)
OK: $k \cdot |\sigma_{H,P}|$ (0.026 N/mm²) <= $1.5 \cdot \min(f_P, f_{H,P})$ (202.100 N/mm²)
OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (51.013 N/mm²) <= f_P (134.733 N/mm²)
OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.033 N/mm²) <= f_P (134.733 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	26.104752	β_{VL}	=	5142.989025	λ	=	7755.571720

Test pressure

Nominal design stress at T_t	f_a	=	166.667 N/mm²	$f(T_t, e_n)$
Nominal design stress at T_{flange}	f_{Td}	=	134.733 N/mm²	$f(T_{flange}, e_n)$
Test pressure	P_t	=	3.093 bar	$Max[1.43 \cdot P_d, 1.25 \cdot P_d \cdot f_a/f_{Td}]$

CALCULATION OF A FLANGE ACCORDING TO EN 13445 Part 3

Calculation made with CodeX
EN 13445-3:2014 Issue 5 (2018-07)

Object name : Priruba 2b
Order n° : <undef>
Description : <undef>

Flange type : **Loose** **Weld**

Method of calculation: Loose method

Flange Material EN 10028-7 X5CrNi18-10 (+AT (Hot rolled plate)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	210.000	250.000	520.000	0.000	**N/mm²**
20.00	210.000	250.000	520.000	0.000	**N/mm²**

f_d = 166.667 N/mm² $R_{p1,0/T}/1.5$
f_{test} = 238.095 N/mm² $R_{p1,0/T}/1.05$
f_{exc} = 238.095 N/mm² $R_{p1,0/T}/1.05$

Dimensions of the flange

Outside diameter	A_{nom}	=	595.000 mm
Inside diameter	B_{nom}	=	437.000 mm
Thickness	e_n	=	28.000 mm
Thickness of hub at small end	$g_{0,nom}$	=	4.000 mm
Thickness of hub at flange side	$g_{1,nom}$	=	5.000 mm
Length of hub	h	=	1.000 mm
Minimum radius of fillet	$r_{min,nom}$	=	1.250 mm
Length of cylindrical part	l	=	<undef> mm
Allowance (e_n)			
Tolerance	Tol	=	0.000 mm
Fabrication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)
Allowance at inside diameter and hub ($B_{nom}/g_{1,nom}/g_{0,nom}$)			
Tolerance	$Tol_{,i}$	=	0.000 mm
Internal corrosion	$CA_{int,i}$	=	0.000 mm (= 0.00 when Testing)
External corrosion	$CA_{ext,i}$	=	0.000 mm (= 0.00 when Testing)
Allowance at outside diameter of flange (A_{nom})			
Tolerance	$Tol_{,o}$	=	0.000 mm
Corrosion	$CA_{ext,o}$	=	0.000 mm (= 0.00 when Testing)

Gasket data

Group	: Ring gaskets		
Nature	: Rubber O-ring		
Fabrication	: Below 75° IRH		
Seating/Facing	: Groove for O-ring		
Gasket factor	m	=	0.000 -
Minimum seating pressure	y	=	0.700 N/mm²
Contact width	w	=	6.000 mm
Effective seating width	b	=	0.750 mm
Outside diameter	G_o	=	480.000 mm
Diameter at location of load reaction	G	=	474.000 mm

Bolt Material EN 10272 X5CrNi18-10 (+AT) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	190.000	225.000	500.000	0.000	**N/mm²**
20.00	190.000	225.000	500.000	0.000	**N/mm²**

f_d	=	166.667 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	250.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Bolt data

Pitch circle diameter	C	=	560.000 mm
Nominal diameter	d_b	=	16.000 mm
Root diameter	d_r	=	14.124 mm
Hole diameter	d_h	=	20.000 mm
Number	n	=	16
Bolt surface	a_B	=	156.666 mm²
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²

Loads

Minimum operating load	W_{op}	=	105876.071 N
Design operating load	W_{op}	=	105876.071 N
Minimum seating load	W_A	=	1042.380 N
Initial seating load	W_A	=	1042.380 N
Minimum design seating load	W	=	105876.071 N
Design seating load	W	=	105876.071 N

Calculation of tightening torque (Annex G.8)

Coating type : Average conditions

Bolting-up method and measuring method : Wrench. Operator feel, uncontrolled

Waisted diameter of bolt	d_{BS}	=	<undef> mm	
Friction coefficient on thread	μ_t	=	0.200	
Friction coefficient under nut or bolt	μ_n	=	0.200	
Thread pitch	p_t	=	2.000 mm	
Thread angle	α	=	30.000 °	
Nut width across flats	a	=	24.000 mm	
Mean contact diameter on thread	d_t	=	14.701 mm	
Mean contact diameter under nut or bolt	d_n	=	20.000 mm	
Tightening factor	k_B	=	4.016	(G.8-9)
Scatter value of bolt load for 1 bolt below nominal value	ε_{1-}	=	0.400	(T.G.8-2)
Scatter value of bolt load for n bolts below nominal value	ε_{n-}	=	0.175	(G.6-16)
Total required bolt force of all bolts	$F_{B0,req}$	=	105876.071 N	
Total bolt force of all bolts	$F_{B0,nom}$	=	128334.631 N	
Minimum tightening torque	$M_{t,nom,min}$	=	32210.635 N·mm	(G.8-4)
Tightening torque	$M_{t,nom}$	=	32210.635 N·mm	

Attached Shell Material EN 10028-7 X5CrNi18-10 (+AT (Cold rolled strip)) (1.4301)

T(°C)	$R_{p0,2/T}$	$R_{p1,0/T}$	$R_{m/T}$	$R_{m/T/100k}$	
20.00	230.000	260.000	540.000	0.000	**N/mm²**
20.00	230.000	260.000	540.000	0.000	**N/mm²**

f_d	=	180.000 N/mm²	$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$
f_{test}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$
f_{exc}	=	270.000 N/mm²	$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$

Attached shell data

Outside diameter	$D_{e,nom}$	=	437.000 mm	**Base diameter**
Inside diameter	D_{nom}	=	429.000 mm	
Thickness	$e_{s,n}$	=	4.000 mm	

Allowance at shell ($e_{s,n}$)

Tolerance	Tol	=	0.000 mm
Fabication	Tol_{fab}	=	0.000 mm
Internal corrosion	CA_{int}	=	0.000 mm (= 0.00 when Testing)
External corrosion	CA_{ext}	=	0.000 mm (= 0.00 when Testing)

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Bar		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10272 (10-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	16.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	250.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	190.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	190.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	225.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	225.00 N/mm²
Tensile strength	R_m	=	500.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	500.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	199964.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7930.00 kg/m³

Allowables

f_d = 166.667 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$ Austenitic (A >= 35%) (per 6.5)

f_{test} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

f_{exc} = 250.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$ Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0.0000	1.0000
S	0.0000	0.0150
P	0.0000	0.0450
Ni	8.0000	10.5000
N	0.0000	0.1000
Mn	0.0000	2.0000
Cr	17.5000	19.5000
C	0.0000	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Elasticity: Elasticity according EN13445-3 Annex O.4.2
Density: Density according EN13445-3 Annex O.3.1
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet		
Alloy	: Austenitic corrosion resistant		
Code	: EN 10028-7 (12-2007)		
Material name	: X5CrNi18-10		
Material number	: 1.4301		
Suffix	: +AT (Cold rolled strip)		
Material Group according EN13445-2	: **8.1**		
Temperature	T	=	20.00 °C
Thickness	e_n	=	4.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	6.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	230.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	230.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	260.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	260.00 N/mm²
Tensile strength	R_m	=	540.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	540.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 180.000 N/mm²
$Max[R_{p1,0/T}/1.5, Min[R_{p1,0/T}/1.2, R_{m/T}/3]]$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 270.000 N/mm²
$Max[R_{p1,0/T}/1.05, R_{m/T}/2]$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)
Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000

N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Material Specification sheet for EN 13445-3:2014 Issue 5 (2018-07)

Prefab	: Plate and sheet
Alloy	: Austenitic corrosion resistant
Code	: EN 10028-7 (12-2007)
Material name	: X5CrNi18-10
Material number	: 1.4301
Suffix	: +AT (Hot rolled plate)
Material Group according EN13445-2	: **8.1**

Temperature	T	=	20.00 °C
Thickness	e_n	=	28.00 mm
Minimum allowed thickness	e_{MIN}	=	0.00 mm
Maximum allowed thickness	e_{MAX}	=	75.00 mm

Properties

0.2% Proof strength	$R_{p0,2}$	=	210.00 N/mm²
0.2% Proof strength at temperature	$R_{p0,2/T}$	=	210.00 N/mm²
1.0% Proof strength	$R_{p1,0}$	=	250.00 N/mm²
1.0% Proof strength at temperature	$R_{p1,0/T}$	=	250.00 N/mm²
Tensile strength	R_m	=	520.00 N/mm²
Tensile strength at temperature	$R_{m/T}$	=	520.00 N/mm²
Creep rupture at 100.000 hrs	$R_{m/T/100k}$	=	0.00 N/mm²
1% Creep strain at 100.000 hrs	$R_{p1,0/T/100k}$	=	0.00 N/mm²
Modulus of Elasticity	E	=	200000.00 N/mm²
Lineair expansion	α	=	1.53E-005 m/(m·°C)
Elongation after Rupture	A	=	45.00 %
Poisson's ratio	ν	=	0.30
Density	ρ	=	7900.00 kg/m³

Allowables

f_d	= 166.667 N/mm²
$R_{p1,0/T}/1.5$	Austenitic (A >= 35%) (per 6.5)
f_{test}	= 238.095 N/mm²
$R_{p1,0/T}/1.05$	Austenitic (A >= 35%) (per 6.5)
f_{exc}	= 238.095 N/mm²
$R_{p1,0/T}/1.05$	Austenitic (A >= 35%) (per 6.5)

Chemical composition

Name	Min (%)	Max (%)

Si	0	1.0000
S	0	0.0150
P	0	0.0450
Ni	8.0000	10.5000
N	0	0.1000
Mn	0	2.0000
Cr	17.5000	19.5000
C	0	0.0700

Additional Information

Expansion: Expansion according EN13445-3 Annex O.4.2
Poisson: Poisson according EN13445-3 Annex O.3.5

Internal pressure (EN 13445-3 Section 11)

Condition

Description			: Internal 1
Design condition			: Operating
Design pressure	P_d	=	0.600 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	429.000 mm
Hub thickness at small end	g_0	=	4.000 mm
Hub thickness at flange face	g_1	=	5.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	41.809 mm
Minimum thickness seating	$e_{min,A}$	=	17.287 mm
Minimum thickness operating	$e_{min,P}$	=	23.312 mm
Minimum thickness	e_{min}	=	23.312 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	166.667 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	635.256 mm²
Minimum number of bolts	n_{min}	=	6
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	105876.071 N
Minimum design seating load	W_{min}	=	261825.937 N
Initial seating load	W_A	=	1042.380 N

Design operating load	W_{op}	=	105876.071 N
Design seating load (controlled)	$W_{contr.}$	=	105876.071 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	0.000 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	15884.050 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	89992.021 N	h_D	=	59.000 mm

Bending moments on flange

Momentum gasket seating	M_A	= 4552671.038 N·mm
Momentum operating	M_{op}	= 6139470.834 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	85.684 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.009 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.010 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k\cdot|\sigma_{\theta,A}|$ (85.684 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,A}|$ (0.009 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,A}|$ (0.010 N/mm²) <= $1.5\cdot\min(f_A, f_{H,A})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (42.847 N/mm²) <= f_A (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.009 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	115.548 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.012 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.013 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_P	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k\cdot|\sigma_{\theta,P}|$ (115.548 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{r,P}|$ (0.012 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot|\sigma_{H,P}|$ (0.013 N/mm²) <= $1.5\cdot\min(f_P, f_{H,P})$ (250.000 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (57.781 N/mm²) <= f_P (166.667 N/mm²)
OK: $k\cdot(|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.012 N/mm²) <= f_P (166.667 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	31.971659	β_{VL}	=	9448.266150	λ	=	43754.205236

Test pressure

Nominal design stress at T_t	f_a	=	166.667 N/mm²	$f(T_t, e_n)$
Nominal design stress at T_{flange}	f_{Td}	=	166.667 N/mm²	$f(T_{flange}, e_n)$

Test pressure	P_t	=	8.580 bar	$Max[1.43 \cdot P_d, 1.25 \cdot P_d \cdot f_a / f_{Td}]$

Internal pressure (EN 13445-3 Section 11)

Condition

Description			: Internal 2
Design condition			: Testing
Design pressure	P_d	=	0.860 MPa
Design temperature	T_{flange}	=	20.000 °C
Shell design temperature	T_{shell}	=	20.000 °C
Bolt design temperature	T_{bolts}	=	20.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	429.000 mm
Hub thickness at small end	g_0	=	4.000 mm
Hub thickness at flange face	g_1	=	5.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	41.809 mm
Minimum thickness seating	$e_{min,A}$	=	17.258 mm
Minimum thickness operating	$e_{min,P}$	=	23.351 mm
Minimum thickness	e_{min}	=	23.351 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	250.000 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	607.023 mm²
Minimum number of bolts	n_{min}	=	4
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	151755.701 N
Minimum design seating load	W_{min}	=	259473.135 N
Initial seating load	W_A	=	1042.380 N
Design operating load	W_{op}	=	151755.701 N
Design seating load (controlled)	$W_{contr.}$	=	105876.071 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	0.000 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	22767.138 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	128988.564 N	h_D	=	59.000 mm

Bending moments on flange

Momentum gasket seating	M_A	= 4552671.038 N·mm
Momentum operating	M_{op}	= 8799908.196 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	85.684 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.009 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.010 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,A}|$ (85.684 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{r,A}|$ (0.009 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{H,A}|$ (0.010 N/mm²) <= $1.5 \cdot \min(f_A, f_{H,A})$ (250.000 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (42.847 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.009 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	165.619 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.017 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.018 N/mm²
Allowable longitudinal hub stress		=	357.143 N/mm²
Flange allowable stress	f_P	=	238.095 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	270.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,P}|$ (165.619 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot |\sigma_{r,P}|$ (0.017 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot |\sigma_{H,P}|$ (0.018 N/mm²) <= $1.5 \cdot \min(f_P, f_{H,P})$ (357.143 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (82.819 N/mm²) <= f_P (238.095 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.018 N/mm²) <= f_P (238.095 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	31.971659	β_{VL}	=	9448.266150	λ	=	43754.205236

Internal pressure (EN 13445-3 Section 11)

Condition

Description			: Internal 3
Design condition			: Operating
Design pressure	P_d	=	0.200 MPa
Design temperature	T_{flange}	=	85.000 °C
Shell design temperature	T_{shell}	=	85.000 °C
Bolt design temperature	T_{bolts}	=	85.000 °C

Calculation with **uncorroded** condition.

Flange

Outside diameter	A	=	595.000 mm
Inside diameter	B	=	437.000 mm
Ratio flange diameters	K	=	1.362
Inside diameter of shell	D	=	429.000 mm
Hub thickness at small end	g_0	=	4.000 mm
Hub thickness at flange face	g_1	=	5.000 mm
$\sqrt{(B \cdot g_0)}$	l_0	=	41.809 mm
Minimum thickness seating	$e_{min,A}$	=	17.084 mm
Minimum thickness operating	$e_{min,P}$	=	23.589 mm
Minimum thickness	e_{min}	=	23.589 mm

Bolts

Bolt design stress seating	$f_{B,A}$	=	166.667 N/mm²
Bolt design stress operating	f_B	=	153.125 N/mm²
Minimum total bolt surface	$A_{B,min}$	=	691.436 mm²
Minimum number of bolts	n_{min}	=	6
Number of bolts	n	=	16
Total bolt surface ($n \cdot a_B$)	A_B	=	2506.655 mm²
Bolt pitch correction factor	C_F	=	1.000 -

OK: Sufficient number of bolts !

Loads on bolts

Minimum bolt seating load	$W_{A,min}$	=	1042.380 N
Minimum operating load	$W_{op,min}$	=	35292.024 N
Minimum design seating load	W_{min}	=	266507.532 N
Initial seating load	W_A	=	1042.380 N
Design operating load	W_{op}	=	105876.071 N
Design seating load (controlled)	$W_{contr.}$	=	105876.071 N

Tightening torque according G.8.4

Bolt load ratio	ϕ_B	=	<undef>	(G.8-15)

OK: ϕ_B <= 1.0

Loads on flange

				Distance		
Gasket compressionload	H_G	=	70584.047 N	h_G	=	43.000 mm
Force by pressure across gasket (at (B+G)/2)	H_T	=	5294.683 N	h_T	=	52.250 mm
Force by pressure on flange face (at B)	H_D	=	29997.340 N	h_D	=	59.000 mm

Bending moments on flange

Momentum gasket seating	M_A	= 4552671.038 N·mm
Momentum operating	M_{op}	= 5081604.304 N·mm

Stress(es) in gasket seating condition

Tangential flange stress	$\sigma_{\theta,A}$	=	85.684 N/mm²
Radial flange stress	$\sigma_{r,A}$	=	0.009 N/mm²
Longitudinal hub stress	$\sigma_{H,A}$	=	0.010 N/mm²
Allowable longitudinal hub stress		=	250.000 N/mm²
Flange allowable stress	f_A	=	166.667 N/mm²
Shell/flange allowable stress	$f_{H,A}$	=	180.000 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,A}|$ (85.684 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{r,A}|$ (0.009 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot |\sigma_{H,A}|$ (0.010 N/mm²) <= $1.5 \cdot \min(f_A, f_{H,A})$ (250.000 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{\theta,A}|)/2$ (42.847 N/mm²) <= f_A (166.667 N/mm²)

OK: $k \cdot (|\sigma_{H,A}|+|\sigma_{r,A}|)/2$ (0.009 N/mm²) <= f_A (166.667 N/mm²)

Stress(es) in operating condition

Tangential flange stress	$\sigma_{\theta,P}$	=	95.639 N/mm²
Radial flange stress	$\sigma_{r,P}$	=	0.010 N/mm²
Longitudinal hub stress	$\sigma_{H,P}$	=	0.011 N/mm²
Allowable longitudinal hub stress		=	202.100 N/mm²
Flange allowable stress	f_P	=	134.733 N/mm²
Shell/flange allowable stress	$f_{H,p}$	=	154.400 N/mm²
Stress factor	k	=	1.000

OK: $k \cdot |\sigma_{\theta,P}|$ (95.639 N/mm²) <= f_P (134.733 N/mm²)

OK: $k \cdot |\sigma_{r,P}|$ (0.010 N/mm²) <= f_P (134.733 N/mm²)

OK: $k \cdot |\sigma_{H,P}|$ (0.011 N/mm²) <= $1.5 \cdot \min(f_P, f_{H,P})$ (202.100 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{\theta,P}|)/2$ (47.825 N/mm²) <= f_P (134.733 N/mm²)

OK: $k \cdot (|\sigma_{H,P}|+|\sigma_{r,P}|)/2$ (0.010 N/mm²) <= f_P (134.733 N/mm²)

Factors

β_T	=	1.770917	β_U	=	7.088288	β_Y	=	6.450342
β_{FL}	=	31.971659	β_{VL}	=	9448.266150	λ	=	43754.205236

Test pressure

Nominal design stress at T_t	f_a	=	166.667 N/mm²	$f(T_t, e_n)$
Nominal design stress at T_{flange}	f_{Td}	=	134.733 N/mm²	$f(T_{flange}, e_n)$
Test pressure	P_t	=	3.093 bar	$\text{Max}[1.43 \cdot P_d, 1.25 \cdot P_d \cdot f_a/f_{Td}]$