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Layout

Input values:	*1.234*	or	1.234
Calculated values:	***1.234***	or	**1.234**
Critical values:	*1.234*	or	1.234
Estimated values:	*1.234*	or	1.234

Summary

Strength Calculation Software			Program System ATLAS			Version	**8.32.1**			
Developed by Lauterbach Verfahrenstechnik GmbH										
Certified per DIN EN ISO 9001:2015			Certificate Number 01 100 044763							
				LV Soft				**ASME**		**Diff [%]**
Example E4.7.1 - Thickness calculation for a type D Head										
		(a)	Required plate thickness t	4,25	mm	0,17	in	0,17	in	**0,10%**
		Step3	Required flange thickness t	50,91	mm	2,25	in	2,25	in	**0,02%**
		Step7	Total gasket seating moment Mo	11.976.492,00	N.mm	106.000,89	lbf.in	106192,50	lbf.in	**0,18%**

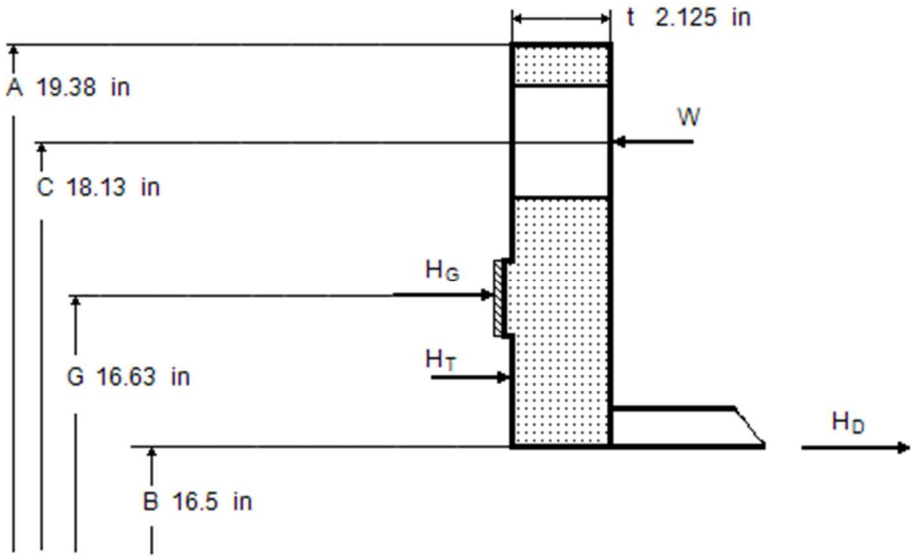
E 4.7. Step 7 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2019

Loose Type Flange without Neck

Design data

Design pressure	P_D	**213** psi	= p_D	213	psi
Hydrostatic head	D_P	**0** psi	= D_p	0	psi
Calculation pressure	P_0	**213** psi	= p_0	**213**	psi
Calculation temperature			T_0	400	°F

Flange



Outside diameter	A	19.38 in	Inside diameter	B	16.5	in
Bolt circle diameter	C	18.13 in	Pipe size	B_n	**16.5**	in
Flange thickness				t	2.125	in

Material K03504-SA-105--Class:-Size:

Cast Quality Factor	f	1	
Design strength operation	S_{do}	19989	psi
Design strength installation	S_{da}	20015	psi
Allowable operating stress	S_{fb}	**19989**	psi
Allowable installation stress	S_{fa}	**20015**	psi
Corrosion allowance	c_2	0	in
Modulus of elasticity at operation	E_T	2.766e+7	psi
Modulus of elasticity at test (20°C)	E_{20}	2.92e+7	psi

Gasket

Gasket diameter		G	16.63	in
Effective gasket width	[Table: 2-5.2]	b	0.1406	in
Gasket factor	[Table: 2-5.1]	m	5.5	
Gasket seating load	[Table: 2-5.1]	y	18000	psi

Bolts

Number		n	20	
Root diameter		d_K	0.62	in
Nominal diameter		a	0.75	in
Material	G41400-SA-193-B7-Class:-Size:<=64			
Allowable operating stress		S_b	24946	psi
Allowable installation stress		S_a	24946	psi
Consider bolt spacing correction factor B_{SC} 2-6(7)?		(N=No)	Y	(Y/N)

Required operation bolt load	Eq.(1)		W_{m1}	**63411**	lbf
Minimum initial bolt load	Eq.(2)		W_{m2}	**132116**	lbf
Available cross section of bolts			A_b	**6.035**	in²
Required cross section		W_{m1}/S_b	A_{m1}	**2.542**	in²
Required cross section		W_{m2}/S_a	A_{m2}	**5.296**	in²
Req. bolt load for gasket seating	Eq.(5)	$(A_m+A_b)\cdot S_a/2$	W	**141335**	lbf
Allowable bolt load		$A_b\cdot S_a$	W_{all}	**150555**	lbf
Design (gasket seating =1; max. allowable=2)				1	(1,2)

Moment

	Force		Lever arm		Result	
$M_D = H_D \cdot h_D$ =	**45522**	lbf ·	**0.8125**	in =	**3082**	lbf·ft
$M_G = H_G \cdot h_G$ =	**17197**	lbf ·	**0.75**	in =	**1075**	lbf·ft
$M_T = H_T \cdot h_T$ =	**692.3**	lbf ·	**0.7813**	in =	**45.07**	lbf·ft

Total operating moment	$M_{01} = F_M \cdot (M_D + M_G + M_T)$ =	**4202**	lbf·ft
Total gasket seating moment, Eq. (6)	$M_{02} = F_M \cdot W \cdot (C-G)/2$ =	**8833**	lbf·ft
Factor App.2-9 for split flange (1=full ring, 2=single split ring, 0.75=double split ring)	F_M	1	(1,2,.75)

Stress

		Operation		Installation		≤ Allowable	
Longitudinal	S_H	0		0			Eq.(11)
Radial	S_R	0		0			Eq.(11)
Tangential	S_T	**8234**	psi	**17309**	psi	≤ S_f	Eq.(11)
Allowable stress	S_f	**19989**	psi	**20015**	psi		
Bolt pitch	B_S	**2.847**	in ≤	**3.625**	in	= B_{Smax}	Eq.(3)

Remark

Cross-sectional area of bolts	✓
Strength condition flange	✗
Flange rigidity	✗

Auxiliary values

$$K=\frac{A}{B}=1.174$$

$Y=12.17$ (Fig. 2-7.1)

$$H=0.785\cdot G^{2}\cdot P\cdot 0.1=205571\ \text{N}$$

$$H_D=0.785\cdot B^{2}\cdot P\cdot 0.1=202491\ \text{N}$$

$$H_P=2\cdot b\cdot \pi\cdot G\cdot m\cdot P\cdot 0.1=76496\ \text{N}$$

$$H_T=H-H_D=3080\ \text{N}$$

$$W_{m1}=H+H_P=282067\ \text{N}$$ Eq.(1)

$$W_{m2}=\pi\cdot b\cdot g\cdot y=587676\ \text{N}$$ Eq.(2)

$$H_G=W_{m1}-H=76496\ \text{N}$$

$$h_D=\frac{(C-B)}{2}=20.64\ \text{mm}$$

$$h_G=\frac{(C-G)}{2}=19.05\ \text{mm}$$

$$h_T=\frac{(h_D+h_G)}{2}=19.84\ \text{mm}$$

Bolt pitch

$$B_S=\pi\cdot\frac{C}{n}=72.32\ \text{mm}$$

$$B_{Smax}=2\cdot a+6\cdot\frac{t}{(m+0.5)}=92.07\ \text{mm}$$ Eq.(3)

For $B_S>2\cdot a+t$

$$B_{SC}=\sqrt{\frac{B_S}{(2\cdot a+t)}}=1$$ Eq.(7)

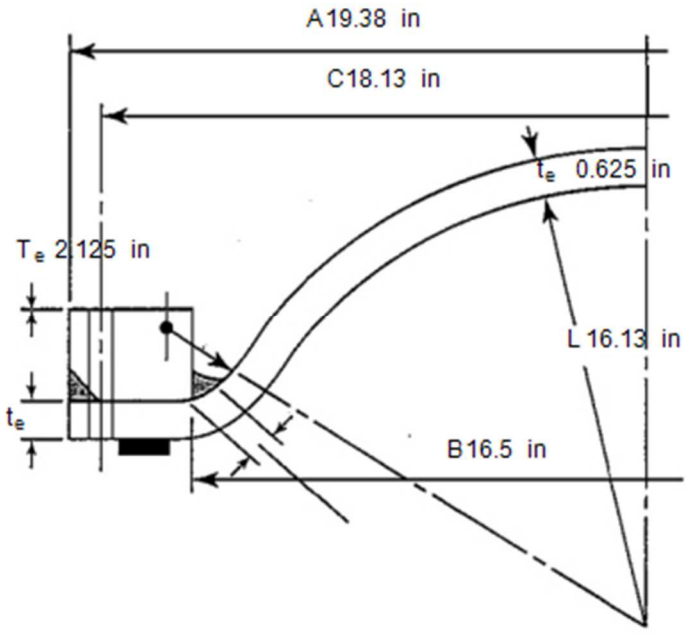
KL (=0.2 acc. Table 2-14) = **0.2**

Rigidity criterion: J **1.289** ≤ 1.0

E 4.7.1 a - Spherically dished covers (bolted heads) - ASME VIII APPENDIX 1, 1-6 2019 Edition

Spherically dished covers as shown in Fig.: 1-6 (b)
Input

Flange moment from 2-6 or 2-11		M_0	8849	lbf·ft
Design pressure		p_D		psi
Hydrostatic head		D_p		psi
Calculation pressure		p_0	213	psi
Design temperature		T_0	400	°F
Gasket	Ring gasket			



Outside diameter	A	19.38	in	
Inside diameter	B	16.5	in	
Bolt circle diameter	C	18.13	in	
Final flange thickness	T_e	2.125	in	
Crown radius	L	16.13	in	
Final head thickness	t_e	0.625	in	
Wall thickness allowance	c_1	0	in	
Corrosion allowance	c_2	0.125	in	
Material	K02401-SA-515-60-Class:-Size:			
Allowable stress	S	17114	psi	

Calculation

Required head thickness		t	**0.1672**	in	(1)
Required thickness incl. allowances		$t+c_1+c_2$	**0.2922**	in	
Required flange thickness	(ring gasket)	T(2)	**2.166**	in	(2)
Required flange thickness	(full face)	T(3)	**1.224**	in	(3)
Required flange thickness		T	**2.166**	in	(6)

Equations

(1)

$$t = \frac{5 \cdot P0 \cdot L}{6 \cdot S} = \frac{5 \cdot 1.469\ \text{N/mm}^2 \cdot 409.6\ \text{mm}}{6 \cdot 118\ \text{N/mm}^2} = 4.248\ \text{mm}$$

(2)

$$T = \sqrt{\frac{|M0|}{S \cdot B} \cdot \left[\frac{A+B}{A-B}\right]} =$$

$$\sqrt{\frac{|1.2\text{e+}7\ \text{Nmm}|}{118\ \text{N/mm}^2 \cdot 419.1\ \text{mm}} \cdot \left[\frac{492.1\ \text{mm}+419.1\ \text{mm}}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 55.02\ \text{mm}$$

(3)

$$T = 0.6 \cdot \sqrt{\frac{P}{S} \cdot \left[\frac{B \cdot (A+B) \cdot (C-B)}{A-B}\right]} =$$

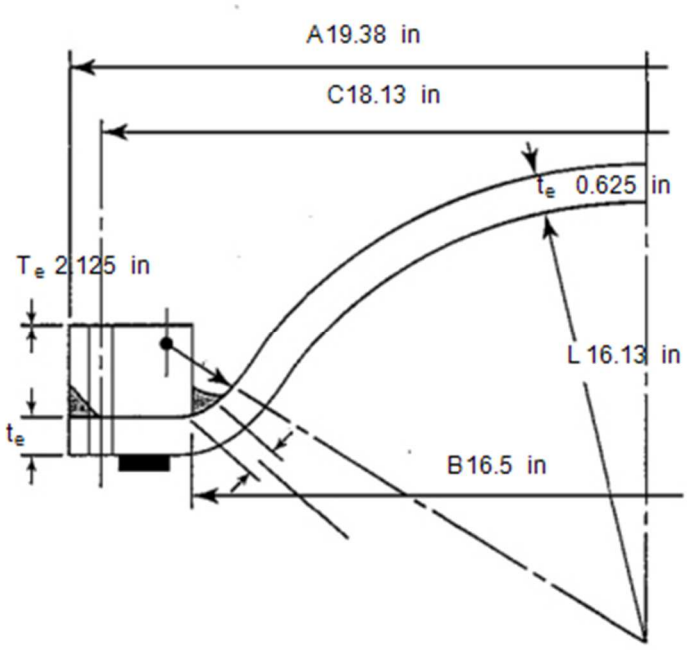
$$0.6 \cdot \sqrt{\frac{1.469\ \text{N/mm}^2}{118\ \text{N/mm}^2} \cdot \left[\frac{419.1\ \text{mm} \cdot (492.1\ \text{mm}+419.1\ \text{mm}) \cdot (460.4\ \text{mm}-419.1\ \text{mm})}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 31.1\ \text{mm}$$

E.4.7.1 c.Step3 - Spherically dished covers (bolted heads) - ASME VIII APPENDIX 1, 1-6 2019 Edition

Spherically dished covers as shown in Fig.: 1-6 (b)

Input

Flange moment from 2-6 or 2-11		M_0	8849	lbf·ft
Design pressure		p_D		psi
Hydrostatic head		D_p		psi
Calculation pressure		p_0	213	psi
Design temperature		T_0	400	°F
Gasket	Ring gasket			



Outside diameter	A	19.38	in	
Inside diameter	B	16.5	in	
Bolt circle diameter	C	18.13	in	
Final flange thickness	T_e	2.125	in	
Crown radius	L	16.13	in	
Final head thickness	t_e	0.625	in	
Wall thickness allowance	c_1	0	in	
Corrosion allowance	c_2	0.125	in	
Material	K03504-SA-105--Class:-Size:			
Allowable stress	S	19989	psi	

Calculation

Required head thickness		t	**0.1432**	in	(1)
Required thickness incl. allowances		$t+c_1+c_2$	**0.2682**	in	
Required flange thickness	(ring gasket)	T(2)	**2.004**	in	(2)
Required flange thickness	(full face)	T(3)	**1.133**	in	(3)
Required flange thickness		T	**2.004**	in	(6)

Equations

(1)

$$t = \frac{5 \cdot P0 \cdot L}{6 \cdot S} = \frac{5 \cdot 1.469\ \text{N/mm}^2 \cdot 409.6\ \text{mm}}{6 \cdot 137.8\ \text{N/mm}^2} = 3.637\ \text{mm}$$

(2)

$$T = \sqrt{\frac{|M0|}{S \cdot B} \cdot \left[\frac{A+B}{A-B}\right]} =$$

$$\sqrt{\frac{|1.2\text{e+}7\ \text{Nmm}|}{137.8\ \text{N/mm}^2 \cdot 419.1\ \text{mm}} \cdot \left[\frac{492.1\ \text{mm}+419.1\ \text{mm}}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 50.91\ \text{mm}$$

(3)

$$T = 0.6 \cdot \sqrt{\frac{P}{S} \cdot \left[\frac{B \cdot (A+B) \cdot (C-B)}{A-B}\right]} =$$

$$0.6 \cdot \sqrt{\frac{1.469\ \text{N/mm}^2}{137.8\ \text{N/mm}^2} \cdot \left[\frac{419.1\ \text{mm} \cdot (492.1\ \text{mm}+419.1\ \text{mm}) \cdot (460.4\ \text{mm}-419.1\ \text{mm})}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 28.78\ \text{mm}$$

Appendix: Material documentation

Section 1: FLANSCH/E4.7.STEP7
Section 5: Tellerboden/E.4.7.1 c.Step3

Material specification:		
Material code: K03504-SA-105--Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-105
Short name: Carbon steel	Product: Forgings	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]:
Pressure [bar]: 14.69	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	138	137.82
Safety factor:	1	1
Allowable stress [N/mm²]:	138	137.8
Modulus of elasticity [kN/mm²]:	201.3	190.7

Notes:
G10: General Requirements
Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A–201 and A–202.
S1: Size Requirements
For Section I applications, stress values at temperatures of 450°C and above are permissible but, except for tubular products 75 mm O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.
T2: Time-Dependent Properties
Allowable stresses for temperatures of 400°C and above are values obtained from time–dependent properties.

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
250	7.85	485

Strength values as a function of temperature										
T	°C	40	100	150	250	325	375	425	475	525
K	N/mm²	138	138	138	136	125	117	83.9	51.1	21.3

Young's modulus-values in dependence of the temperature													
T	°C	25	100	150	200	250	300	350	400	450	500	550	600
E	kN/mm²	201	197	194	191	188	183	178	170	161	149	136	121

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	11.5	12.1	12.7	13.3	13.8	14.4	14.8	15.1	15.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	11.5	12.7	13.8	14.9	15.9	16.7	17.0	17.1	17.7

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]: 15.88
Pressure [bar]: 14.69	Outside diameter [mm]:

Section 1: Schraube/E 4.7. Step 7

Material specification:		
Material code: G41400-SA-193-B7-Class:-Size:<=64	Regulation: ASME II.D Table 3:2010	Spec. No.: SA-193
Short name: 1Cr-0.2Mo	Product: Bolting	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]:
Pressure [bar]: 14.69	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	172	172
Safety factor:	1	1
Allowable stress [N/mm²]:	172	172
Modulus of elasticity [kN/mm²]:	204.3	192.7

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
725	7.85	860

Strength values as a function of temperature												
T	°C	40	100	150	200	250	300	350	400	450	500	550
K	N/mm²	172	172	172	172	172	172	172	162	118	68.8	18.9

Young's modulus-values in dependence of the temperature															
T	°C	25	100	150	200	250	300	350	400	450	500	550	600	650	700
E	kN/mm²	204	200	197	193	190	186	183	179	174	169	164	157	150	142

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	11.5	12.1	12.7	13.3	13.8	14.4	14.8	15.1	15.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	11.5	12.7	13.8	14.9	15.9	16.7	17.0	17.1	17.7

Section 3: Tellerboden/E 4.7.1 a	

Material specification:		
Material code: K02401-SA-515-60-Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-515
Short name: Carbon steel	Product: Plate	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 204.44	Thickness [mm]: 15.88
Pressure [bar]: 14.69	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	118	118
Safety factor:	1	1
Allowable stress [N/mm²]:	118	118
Modulus of elasticity [kN/mm²]:	202.4	191.7

Notes:
G10: General Requirements
Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A–201 and A–202.
S1: Size Requirements
For Section I applications, stress values at temperatures of 450°C and above are permissible but, except for tubular products 75 mm O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.
T2: Time-Dependent Properties
Allowable stresses for temperatures of 400°C and above are values obtained from time–dependent properties.

Strength values at 20°C		
R_{eH}	density	Tensile strength
.	.	$R_{m,\ min}$
N/mm²	kg/dm³	N/mm²
220	7.85	415

Strength values as a function of temperature										
T	°C	40	100	150	250	325	375	425	475	525
K	N/mm²	118	118	118	118	112	104	75.3	45.5	21.9

Young's modulus-values in dependence of the temperature															
T	°C	-200	-125	-75	25	100	150	200	250	300	350	400	450	500	550
E	kN/mm²	216	212	209	202	198	195	192	189	185	179	171	162	151	137

Mean coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_m	1e-6/K	11.5	12.1	12.7	13.3	13.8	14.4	14.8	15.1	15.4

Differential coefficient of thermal expansion-values in dependence of the temperature										
T	°C	20	100	200	300	400	500	600	700	800
α_{diff}	1e-6/K	11.5	12.7	13.8	14.9	15.9	16.7	17.0	17.1	17.7