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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	**8.29.1**
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%**

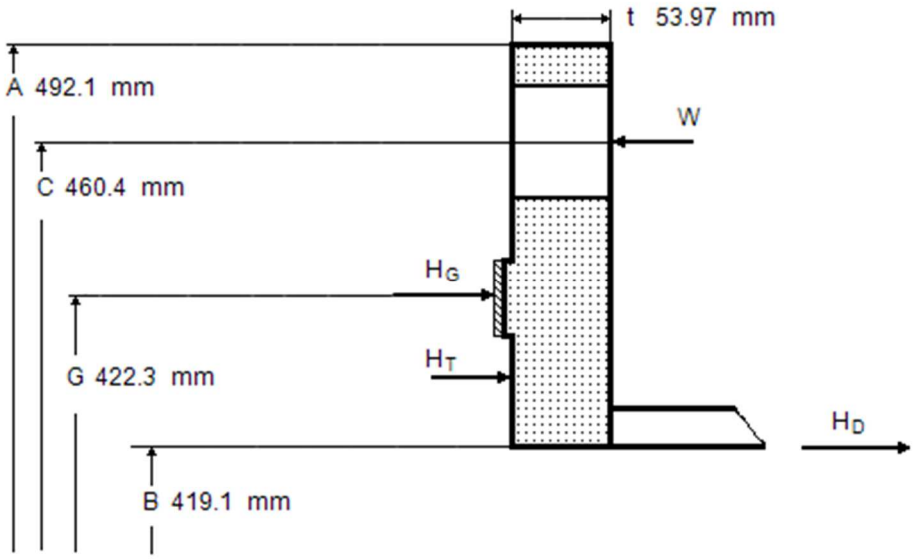
E 4.7. Step 7 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2017

Loose Type Flange without Neck

Design data

Design pressure	P_D	**14.69** bar	$= p_D$	14.69	bar
Hydrostatic head	D_P	**0** bar	$= D_p$	0	bar
Calculation pressure	P_0	**14.69** bar	$= p_0$	**14.69**	bar
Calculation temperature			T_0	204.4	°C

Flange



Outside diameter	A	492.1 mm	Inside diameter	B	419.1 mm
Bolt circle diameter	C	460.4 mm	Pipe size	B_n	**419.1** mm
Flange thickness				t	53.97 mm

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

Allowable operating stress	S_{fb}	137.8 N/mm²
Allowable installation stress	S_{fa}	138 N/mm²
Corrosion allowance	c_2	0 mm
Modulus of elasticity at operation	E_T	190733 N/mm²
Modulus of elasticity at test (20°C)	E_{20}	201300 N/mm²

Gasket

Gasket diameter		G	422.3	mm
Effective gasket width	[Table: 2-5.2]	b	3.571	mm
Gasket factor	[Table: 2-5.1]	m	5.5	
Gasket seating load	[Table: 2-5.1]	y	124.1	N/mm²

Bolts

Number			n	20	
Root diameter			d_K	15.75	mm
Nominal diameter			a	19.05	mm
Material	G41400-SA-193-B7-Class:-Size:<=64				
Allowable operating stress			S_b	172	N/mm²
Allowable installation stress			S_a	172	N/mm²
Consider bolt spacing correction factor B_{SC} 2-6(7)?			(N=No)	Y	(Y/N)
Required operation bolt load	Eq.(1)		W_{m1}	**282067**	N
Minimum initial bolt load	Eq.(2)		W_{m2}	**587676**	N
Available cross section of bolts			A_b	**3894**	mm²
Required cross section		W_{m1}/S_b	A_{m1}	**1640**	mm²
Required cross section		W_{m2}/S_a	A_{m2}	**3417**	mm²
Req. bolt load for gasket seating	Eq.(5)	$(A_m+A_b)\cdot S_a/2$	W	**628687**	N
Allowable bolt load		$A_b\cdot S_a$	W_{all}	**669698**	N
Design (gasket seating =1; max. allowable=2)				1	(1,2)

Moment

	Force			Lever arm		=	Result	
$M_D = H_D \cdot h_D$	=	**202491**	N	·	**20.64**	mm	=	**36987**	lbf·in
$M_G = H_G \cdot h_G$	=	**76496**	N	·	**19.05**	mm	=	**12898**	lbf·in
$M_T = H_T \cdot h_T$	=	**3080**	N	·	**19.84**	mm	=	**540.9**	lbf·in

Total operating moment	$M_{01} = F_M \cdot (M_D + M_G + M_T)$	=	**50425**	lbf·in
Total gasket seating moment, Eq. (6)	$M_{02} = F_M \cdot W \cdot (C-G)/2$	=	**106001**	lbf·in

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	**119.3**	N/mm²	≤ S_f	Eq.(11)
Allowable stress	S_f	137.8	N/mm²	138	N/mm²		
Bolt pitch	B_S	**72.32**	mm ≤	**92.07**	mm	= 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)

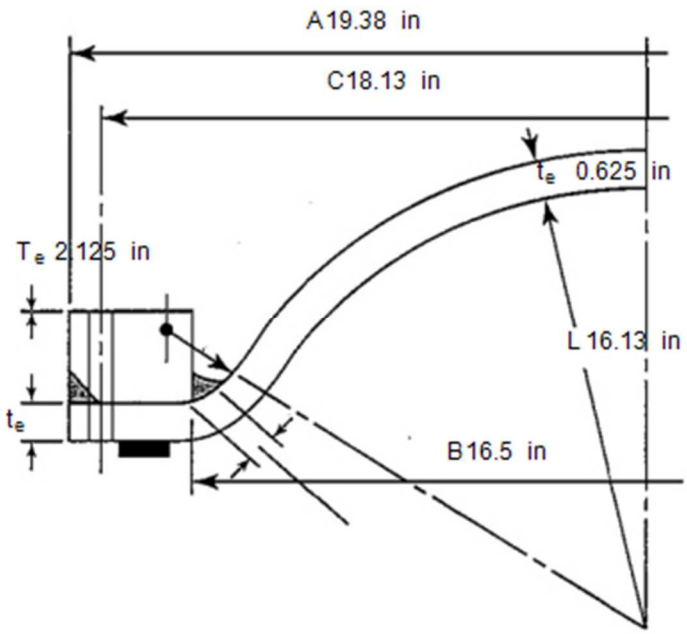
KL (=0.2 acc. Table 2-14) = **0.2**

Rigidity criterion: J **1.289** ≤ 1.0

E 4.7.1 a - Spherically dished covers (bolted heads) - ASME VIII APPENDIX 1, 1-6 2017 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		bar
Hydrostatic head		D_p		bar
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	**55.02**	mm	(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)

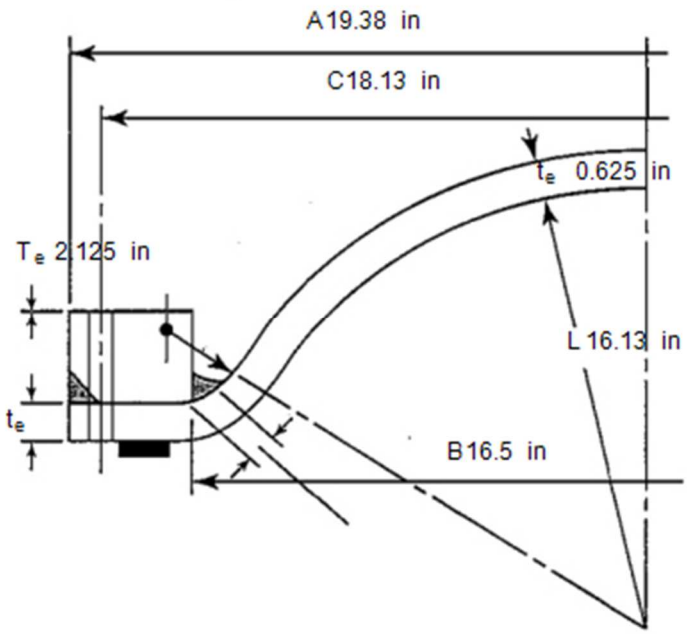
$$T = 0.6 \cdot \sqrt{\frac{P}{S} \cdot \left[\frac{B \cdot (A+B) \cdot (C-B)}{A-B}\right]} =$$

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

E.4.7.1 c.Step3 - Spherically dished covers (bolted heads) - ASME VIII APPENDIX 1, 1-6 2017 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		bar
Hydrostatic head		D_p		bar
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	**50.91**	mm	(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/E 4.7. Step 7
Section 3: Tellerboden/E.4.7.1 c.Step3

Material specification:

Regulation: ASMET1A:2017Spec. No.: SA-105 Product: Forgings
Material code: K03504-SA-105--Class:-Size: Short name: Carbon steel

Design conditions and dimensions:

Temperature [°C]: 204,4444 Pressure [bar]: 14,68592
Thickness [mm]: 3 Outside diameter [mm]: 0

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	138.00	137.82
Safety factor:		
Allowable stress [N/mm²]:	138.00	137.82
Modulus of elasticity [kN/mm²]:	201,3	190,7333

Wall thickness tolerance [mm]: 0.00 acc. to SA-105
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.

--
Creep rupture strength for 100000 h [MPa]:

Tensile strength and yield stress at ambient temperature:

Diam./ Thick. <= mm	Tensile str. Rm min MPa	Rm max MPa	ReH MPa	Rupture elong. lngt. %	Rupture elong. lat. %

K-values as function of the temperature

Diam./ Thickn. <= mm	50°C MPa	100°C MPa	150°C MPa	200°C MPa	250°C MPa	300°C MPa	350°C MPa	400°C MPa
	138	138	138	136	129	122	101	

K-values as function of the temperature

Diam./ Thickn. <= mm	450°C MPa	500°C MPa	550°C MPa	600°C MPa	650°C MPa	700°C MPa	800°C MPa
	67	33.6	12.9				

Modulus of elasticity in dependence of the temperature:

Static modulus of elasticity in [kN/mm²] at the temperature of

-75	-200	-125	25	100	150	200	250	300	350	400	450	500	550	600
207	215	211	201	197	194	191	188	183	178	170	161	149	136	121

Coefficient of linear expansion:

Thermal coefficient of expansion between 20°C and

Density (20 °C) kg/dm³	100°C 10E-6/K	200°C 10E-6/K	300°C 10E-6/K	400°C 10E-6/K	500°C 10E-6/K	600°C 10E-6/K	700°C 10E-6/K	800°C 10E-6/K	Heat W/Km	Heat cond. J/kgK	capac.
7.85	12,1	12,7	13,3	13,8	14,4	14.8	15.1	15.4			

Section 1: Schraube/E 4.7. Step 7

Material specification:

Regulation: ASMET3:2010Spec. No.: SA-193 Product: Bolting
Material code: G41400-SA-193-B7-Class:-Size:<=64 Short name: 1Cr-0.2Mo

Design conditions and dimensions:

Temperature [°C]: 204,4444 Pressure [bar]: 14,68592
Thickness [mm]: 3 Outside diameter [mm]: 0

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	172.00	172.00
Safety factor:		
Allowable stress [N/mm²]:	172.00	172.00
Modulus of elasticity [kN/mm²]:	204,3	192,7333

Wall thickness tolerance [mm]: 0.00 acc. to SA-193
Notes:

--
Creep rupture strength for 100000 h [MPa]:

Tensile strength and yield stress at ambient temperature:

Diam./Thick. <= mm	Tensile str. Rm min MPa	Rm max MPa	ReH MPa	Rupture elong. lngt. %	Rupture elong. lat. %

K-values as function of the temperature

Diam./Thickn. <= mm	50°C MPa	100°C MPa	150°C MPa	200°C MPa	250°C MPa	300°C MPa	350°C MPa	400°C MPa
		172	172	172	172	172	172	162

K-values as function of the temperature

Diam./Thickn. <= mm	450°C MPa	500°C MPa	550°C MPa	600°C MPa	650°C MPa	700°C MPa	800°C MPa
	118	68.8	18.9				

Modulus of elasticity in dependence of the temperature:

Static modulus of elasticity in [kN/mm²] at the temperature of

650	-75	-200	-125	25	100	150	200	250	300	350	400	450	500	550
150	210	218	213	204	200	197	193	190	186	183	179	174	169	164

Static modulus of elasticity in [kN/mm²] at the temperature of

600	700			
157	142			

Coefficient of linear expansion:

Thermal coefficient of expansion between 20°C and

Density (20 °C) kg/dm³	100°C 10E-6/K	200°C 10E-6/K	300°C 10E-6/K	400°C 10E-6/K	500°C 10E-6/K	600°C 10E-6/K	700°C 10E-6/K	800°C 10E-6/K	Heat cond. W/Km	Heat capac. J/kgK
7.85	12,1	12,7	13,3	13,8	14,4	14.8	15.1	15.4		

Section 2: Tellerboden/E 4.7.1 a

Material specification:

Regulation: ASMET1A:2017Spec. No.: SA-515 Product: Plate
Material code: K02401-SA-515-60-Class:-Size: Short name: Carbon steel

Design conditions and dimensions:

Temperature [°C]: 204,4444 Pressure [bar]: 14,68592
Thickness [mm]: 15,875 Outside diameter [mm]: 0

Material values for test and design conditions:

	Test condition	Operating condition
Nominal design strength [N/mm²]:	118.00	118.00
Safety factor:		
Allowable stress [N/mm²]:	118.00	118.00
Modulus of elasticity [kN/mm²]:	202,35	191,7333

Wall thickness tolerance [mm]: 0.00 acc. to SA-515
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
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T2 Time-Dependent Properties
Allowable stresses for temperatures of 400°C and above are values obtained from time–dependent properties.

--
Creep rupture strength for 100000 h [MPa]:

Tensile strength and yield stress at ambient temperature:

Diam./Thick. <= mm	Tensile str. Rm min MPa	Rm max MPa	ReH MPa	Rupture elong. lngt. %	Rupture elong. lat. %

K-values as function of the temperature

Diam./Thickn. <= mm	50°C MPa	100°C MPa	150°C MPa	200°C MPa	250°C MPa	300°C MPa	350°C MPa	400°C MPa
	118	118	118	118	115	108	88.9	

K-values as function of the temperature

Diam./Thickn.	450°C	500°C	550°C	600°C	650°C	700°C	800°C

<= mm	MPa	MPa	MPa	MPa	MPa	MPa	MPa
...	62.7	31.6	12.7	...	...	...	...

Modulus of elasticity in dependence of the temperature:

Static modulus of elasticity in [kN/mm²] at the temperature of

-75	-200	-125	25	100	150	200	250	300	350	400	450	500	550
209	216	212	202	198	195	192	189	185	179	171	162	151	137

Coefficient of linear expansion:

Thermal coefficient of expansion between 20°C and

Density (20 °C) kg/dm³	100°C 10E-6/K	200°C 10E-6/K	300°C 10E-6/K	400°C 10E-6/K	500°C 10E-6/K	600°C 10E-6/K	700°C 10E-6/K	800°C 10E-6/K	Heat cond. W/Km	Heat capac. J/kgK
7.85	12,1	12,7	13,3	13,8	14,4	14.8	15.1	15.4	...	...