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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

Comparison - Form for equations

Equation form

Comment
Results for example E4.7-1 acc. ASME and Lauterbach Verfahrenstechnik GmbH (LV)
The LV-program uses formulas for Spherically Dished Bolted Covers acc. VIII-1, App.1-6.

Equations		Value
Conversion factor	mm2in = 0.03937	**0.03937**
.	N.mm2lbfin = 0.008848	**0.008848**
'Results Ex. E4.7.Step 7 LV and ASME		**0**
Total gasket seating moment acc. LV	Mo = #54(1)*0.00885075	**106001**
Total asket seating moment acc. ASME	MoAsme = 106192.5	**106193**
Difference in %	Diff1 = (Mo-MoAsme)/MoAsme*100	**-0.1804**
'Results Ex. E4.7.a LV and ASME		**0**
Required thickness t acc. LV	t2 = #26(3)*mm2in	**0.1672**
Required thickness t ASME	t2Asme = 0.1674	**0.1674**
Difference in %	Diff2 = (t2-t2Asme)/t2Asme*100	**-0.09636**
'Results Ex. E4.7.a LV and ASME		**0**
.	Corrosion Allowance CAS = 0.125	**0.125**
Required thickness acc. LV	T = #31(5)*mm2in+2*CAS	**2.254**
Required thickness ASME	TAsme = 2.2539	**2.254**
Difference in %	Diff3 = (T-TAsme)/TAsme*100	**0.02125**
'Maximum difference between LV and ASME		**0**
Dmax = Max(|Diff1|;|Diff2|;|Diff3|)		**0.1804**

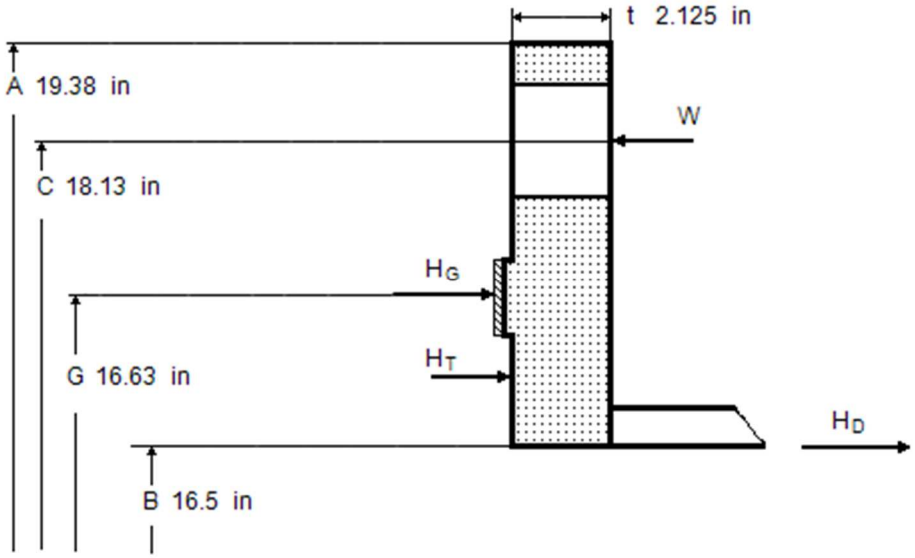
E 4.7. Step 7 - Bolted flanges ASME BPVC VIII DIVISION 1 APP. 2, 2017 Edition

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:

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}	2.915e+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	$(A_m+A_b)\cdot S_a/2$	W	**141335**	lbf	(5)
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			(11)
Radial	S_R	0		0			(11)
Tangential	S_T	**8234**	psi	**17309**	psi	≤ S_f	(11)
Allowable stress	S_f	19989	psi	20015	psi		
Bolt pitch	B_S	**2.847**	in	≤ **3.625**	in	= B_{Smax}	(3)

Remark

Auxiliary values

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

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

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

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

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

$H_T=H-H_D=3080$ N

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

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

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

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

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

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

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

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

For $B_S>2 \cdot a+t$

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

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

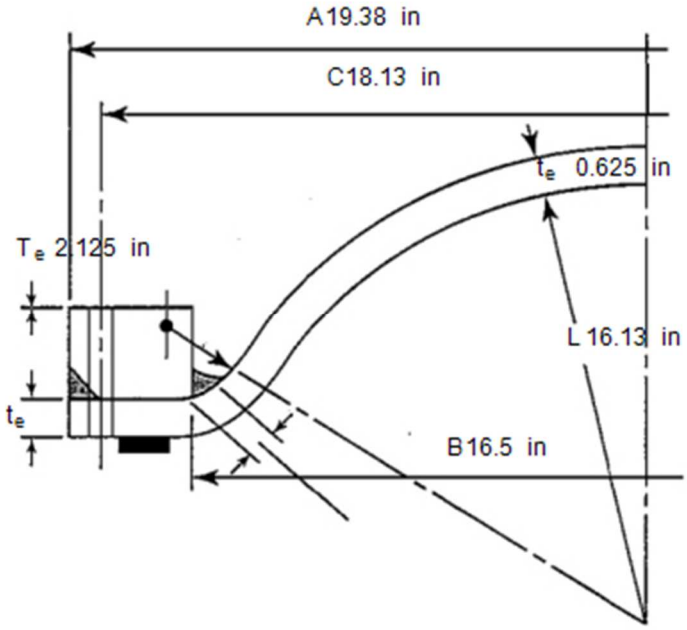
J = 109.4·[M_{01} or M_{02}]/[E or E_{20C}]/t^3 /K_L/Ln(K)
= 109.4·[**5697270** or **1.198e+7**]/[190733 or 201000]/ 53.97^3
/ **0.2**/ Ln(**1.174**) = **1.29** ≤ 1.0

Rigidity criterion: J **1.29** ≤ 1.0

E 4.7.1 a - Spherically dished covers (bolted heads) according to 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_0	213	psi
Design pressure	P_0	**213**	psi
Design temperature	T_0	400	°F



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)

Equations

$$t = \frac{5 \cdot P0 \cdot L}{6 \cdot S} = \frac{5 \cdot 1.469\ \text{N/mm}^2 \cdot 409.6\ \text{mm}}{6 \cdot 118\ \text{N/mm}^2} = 4.248\ \text{mm} \quad (1)$$

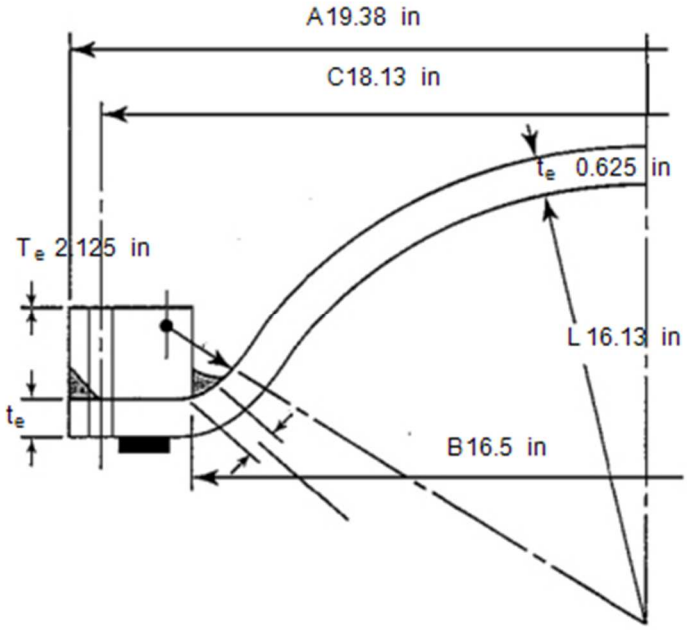
$$T = \sqrt{\frac{|M0|}{S \cdot B} \cdot \left[\frac{A+B}{A-B}\right]} = \sqrt{\frac{|1.2e+7\ \text{Nmm}|}{118\ \text{N/mm}^2 \cdot 419.1\ \text{mm}} \cdot \left[\frac{492.1\ \text{mm}+419.1\ \text{mm}}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 55.02\ \text{mm} \quad (2)$$

$$T = 0.6 \cdot \sqrt{\frac{P}{S} \cdot \left[\frac{B \cdot (A+B) \cdot (C-B)}{A-B}\right]} = 0.6 \cdot \sqrt{\frac{1.469\ \text{N/mm}^2}{118\ \text{N/mm}^2} \cdot \left[\frac{419.1\ \text{mm} \cdot (492.1\ \text{mm}+419.1\ \text{mm}) \cdot (460.4\ \text{mm}-419.1\ \text{mm})}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 31.1\ \text{mm} \quad (3)$$

E.4.7.1 c.Step3 - Spherically dished covers (bolted heads) according to 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_0	213	psi
Design pressure	P_0	**213**	psi
Design temperature	T_0	400	°F



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)

Equations

$$t = \frac{5 \cdot P0 \cdot L}{6 \cdot S} = \frac{5 \cdot 1.469\ \text{N/mm}^2 \cdot 409.6\ \text{mm}}{6 \cdot 137.8\ \text{N/mm}^2} = 3.637\ \text{mm} \quad (1)$$

$$T = \sqrt{\frac{|M0|}{S \cdot B} \cdot \left[\frac{A+B}{A-B}\right]} = \sqrt{\frac{|1.2e+7\ \text{Nmm}|}{137.8\ \text{N/mm}^2 \cdot 419.1\ \text{mm}} \cdot \left[\frac{492.1\ \text{mm}+419.1\ \text{mm}}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 50.91\ \text{mm} \quad (2)$$

$$T = 0.6 \cdot \sqrt{\frac{P}{S} \cdot \left[\frac{B \cdot (A+B) \cdot (C-B)}{A-B}\right]} = 0.6 \cdot \sqrt{\frac{1.469\ \text{N/mm}^2}{137.8\ \text{N/mm}^2} \cdot \left[\frac{419.1\ \text{mm} \cdot (492.1\ \text{mm}+419.1\ \text{mm}) \cdot (460.4\ \text{mm}-419.1\ \text{mm})}{492.1\ \text{mm}-419.1\ \text{mm}}\right]} = 28.78\ \text{mm} \quad (3)$$

Appendix: Material documentation

Section 2: Flansch/AFL
Section 4: Tellerboden/ATB

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]: 2 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:	1,00	1,00
Allowable stress [N/mm²]:	138,00	137,82
Modulus of elasticity [kN/mm²]:	201	190,7333

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. längs %	Rupture elong. quer %

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
	67.0	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 cond. W/Km	Heat capac. J/kgK
7,85	12,1	12,7	13,3	13,8	14,4					

Section 2: Schraube/AFL

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]:	2	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:	1,00	1,00
Allowable stress [N/mm²]:	172,00	172,00
Modulus of elasticity [kN/mm²]:	204	192,7333

Notes:

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Creep rupture strength for 100000 h [MPa]:

Tensile strength and yield stress at ambient temperature:

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

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					

Section 3: Tellerboden/ATB

Material specification:

Regulation: ASMET1A:2017 Spec. 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]: 15,88 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:	1,00	1,00
Allowable stress [N/mm²]:	118,00	118,00
Modulus of elasticity [kN/mm²]:	202	191,7333

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. längs %	Rupture elong quer %

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. <= mm	450°C MPa	500°C MPa	550°C MPa	600°C MPa	650°C MPa	700°C MPa	800°C 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					