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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 E4.16.1 - Integral Type								
Required load W	1.054.672,88	N	237.099,95	lbf		237626,30	lbf	**0,22%**
Example E4.16.1 - Loose Type								
Required load W	1.703.878,63	N	383.047,25	lbf		387702,50	lbf	**1,20%**

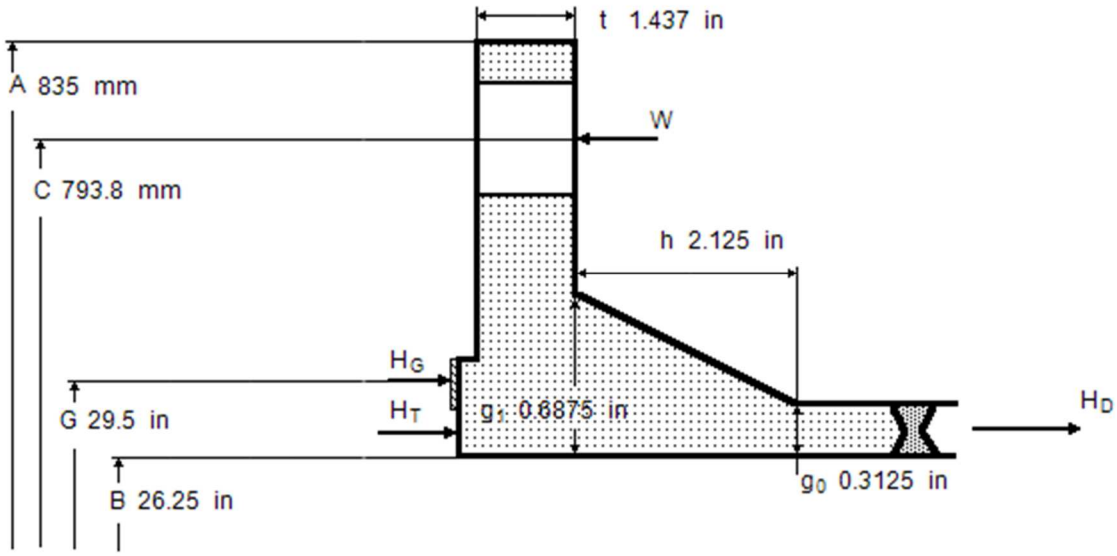
E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2019

Integral Type Flange

Design data

Design pressure	P_D	**135** psi	= p_D	135	psi
Hydrostatic head	D_P	**0** psi	= D_p	0	psi
Calculation pressure	P_0	**135** psi	= p_0	**135**	psi
Calculation temperature			T_0	650	°F

Flange



Outside diameter	A	835	mm	Inside diameter	B	26.25	in
Bolt circle diameter	C	793.8	mm	Pipe size	B_n	**26.25**	in
Hub length	h	2.125	in	Flange thickness	t	1.437	in
Large hub thickness	g_1	0.6875	in	Small hub thick.	g_0	0.3125	in

Material	K03504-SA-105--Class:-Size:		
Cast Quality Factor	f	1	
Design strength operation	S_{do}	17811	psi
Design strength installation	S_{da}	20015	psi
Allowable operating stress	S_{fb}	**17811**	psi
Allowable installation stress	S_{fa}	**20015**	psi
Corrosion allowance	c_2	0	in
Modulus of elasticity at operation	E_T	2.591e+7	psi
Modulus of elasticity at test (20°C)	E_{20}	2.92e+7	psi

Gasket

Gasket diameter		G	29.5	in
Effective gasket width	[Table: 2-5.2]	b	0.2031	in
Gasket factor	[Table: 2-5.1]	m	3.75	
Gasket seating load	[Table: 2-5.1]	y	7600	psi

Bolts

Number			n	44	
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}	**111274**	lbf
Minimum initial bolt load	Eq.(2)		W_{m2}	**142982**	lbf
Available cross section of bolts			A_b	**13.28**	in²
Required cross section		W_{m1}/S_b	A_{m1}	**4.46**	in²
Required cross section		W_{m2}/S_a	A_{m2}	**5.732**	in²
Req. bolt load for gasket seating	Eq.(5)	$(A_m+A_b)\cdot S_a/2$	W	**237101**	lbf
Allowable bolt load		$A_b\cdot S_a$	W_{all}	**331221**	lbf
Design (gasket seating =1; max. allowable=2)				1	(1,2)

Moment

	Force		Lever arm		Result	
$M_D = H_D \cdot h_D$	= **324826**	N	· **54.77**	mm	= **157458**	lbf·in
$M_G = H_G \cdot h_G$	= **84732**	N	· **22.23**	mm	= **16667**	lbf·in
$M_T = H_T \cdot h_T$	= **85412**	N	· **42.86**	mm	= **32403**	lbf·in

Total operating moment	$M_{01} = M_D + M_G + M_T$	=	**206529** lbf·in
Total gasket seating moment, Eq. (6)	$M_{02} = W \cdot (C-G)/2$	=	**207464** lbf·in

Stress

		Operation		Installation		≤ Allowable	
Longitudinal	S_H	**17786**	psi	**17866**	psi	≤ $1.5\cdot S_f$	Eq.(8)
Ratio	S_H/S_f	**0.9986**		**0.8926**		≤ 1.5	
Allowable stress	S_f	**17811**	psi	**20015**	psi		
Radial	S_R	**6157**	psi	**6184**	psi	≤ S_f	Eq.(9)
Tangential	S_T	**5548**	psi	**5573**	psi	≤ S_f	Eq.(10)
Combination	$(S_H+S_R)/2$ =	**11971**	psi	**12025**	psi	≤ S_f	
Combination	$(S_H+S_T)/2$ =	**11667**	psi	**11719**	psi	≤ S_f	

Bolt pitch	B_S	**56.67**	mm	≤	**89.63**	mm = B_{Smax}	Eq.(3)

Remark

Cross-sectional area of bolts	☑
Strength condition flange	☑

Auxiliary values

$K = \frac{A}{B} = 1.252$

$T = 1.817$ (Fig. 2-7.1)

$U = 9.623$ (Fig. 2-7.1)

$Y = 8.757$ (Fig. 2-7.1)

$Z = 4.518$ (Fig. 2-7.1)

$h_0 = \sqrt{B \cdot g_0} = 72.75 \text{ mm}$

$F = 0.7677$ (Fig. 2-7.2)

$V = 0.1576$ (Fig. 2-7.3)

$f = 1$ (Fig. 2-7.6)

$d = \left(\frac{U}{V}\right) \cdot h_0 \cdot g_0^2 = 279869 \text{ mm}^3$

$e = \frac{F}{h_0} = 0.01055 \text{ 1/mm}$

$L = \frac{(t \cdot e + 1)}{T} + \frac{t^3}{d} = 0.9359$

$H = 0.785 \cdot G^2 \cdot P \cdot 0.1 = 410239 \text{ N}$

$H_D = 0.785 \cdot B^2 \cdot P \cdot 0.1 = 324826 \text{ N}$

$H_P = 2 \cdot b \cdot \pi \cdot G \cdot m \cdot P \cdot 0.1 = 84732 \text{ N}$

$H_T = H - H_D = 85412 \text{ N}$

$W_{m1} = H + H_P = 494970 \text{ N}$ Eq.(1)

$W_{m2} = \pi \cdot b \cdot g \cdot y = 636011 \text{ N}$ Eq.(2)

$H_G = W_{m1} - H = 84732 \text{ N}$

$R = \frac{(C - B)}{2} - g_1 = 46.04 \text{ mm}$

$h_D = R + 0.5 \cdot g_1 = 54.77 \text{ mm}$

$h_G = \frac{(C - G)}{2} = 22.23 \text{ mm}$

$h_T = \frac{(R + g_1 + h_G)}{2} = 42.86 \text{ mm}$

Bolt pitch

$$B_S = \pi \cdot \frac{C}{n} = 56.67 \text{ mm}$$

Eq.(3)

$$B_{Smax} = 2 \cdot a + 6 \cdot \frac{t}{(m + 0.5)} = 89.63 \text{ mm}$$

For $B_S > 2 \cdot a + t$

Eq.(7)

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

KI (=0.3 acc. Table 2-14) = **0.3**

Rigidity criterion: J **0.8339** ≤ 1.0

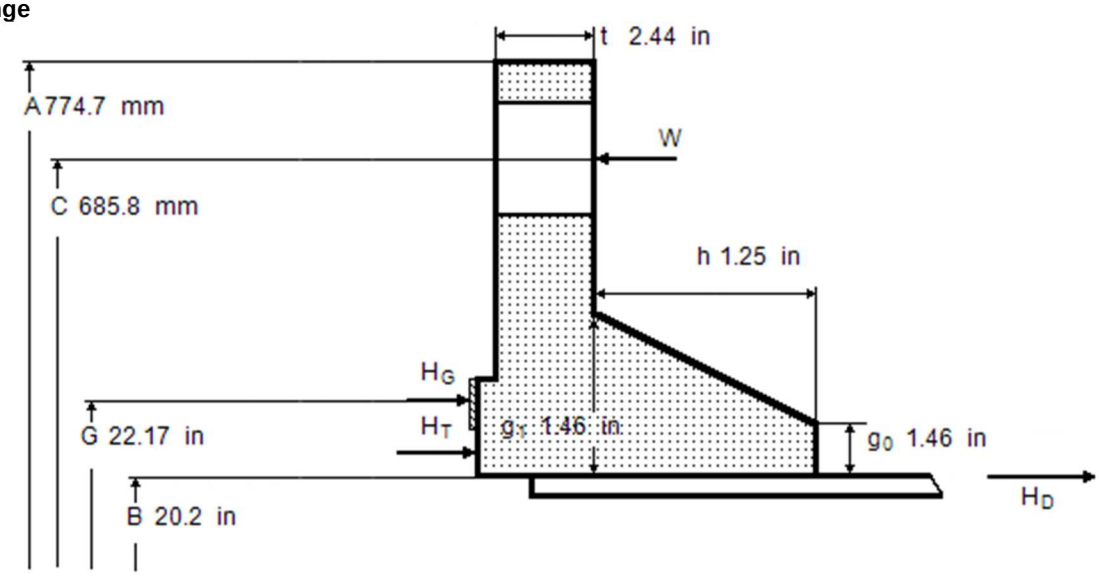
E 4.16.2 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2019

Loose Type Flange With Full Neck

Design data

Design pressure	P_D	**450** psi	= p_D	450	psi
Hydrostatic head	D_P	0 psi	= D_p	**0**	psi
Calculation pressure	P_0	**450** psi	= p_0	**450**	psi
Calculation temperature			T_0	650	°F

Flange



Outside diameter	A	774.7	mm	Inside diameter	B	20.2	in
Bolt circle diameter	C	685.8	mm	Pipe size	B_n	**20.2**	in
Hub length	h	1.25	in	Flange thickness	t	2.44	in
Large hub thickness	g_1	1.46	in	Small hub thickness	g_0	1.46	in

Material	K03504-SA-105--Class:-Size:		
Cast Quality Factor	f	1	
Design strength operation	S_{do}	17811	psi
Design strength installation	S_{da}	20015	psi
Allowable operating stress	S_{fb}	**17811**	psi
Allowable installation stress	S_{fa}	**20015**	psi
Corrosion allowance	c_2	0	in
Modulus of elasticity at operation	E_T	2.591e+7	psi
Modulus of elasticity at test (20°C)	E_{20}	2.92e+7	psi

Gasket

Gasket diameter		G	22.17	in
Effective gasket width	[Table: 2-5.2]	b	0.3536	in
Gasket factor	[Table: 2-5.1]	m	2	
Gasket seating load	[Table: 2-5.1]	y	2500	psi

Bolts

Number			n	24	
Root diameter			d_K	1.08	in
Nominal diameter			a	1.25	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}	**217897**	lbf
Minimum initial bolt load	Eq.(2)		W_{m2}	**61533**	lbf
Available cross section of bolts			A_b	**21.97**	in²
Required cross section		W_{m1}/S_b	A_{m1}	**8.735**	in²
Required cross section		W_{m2}/S_a	A_{m2}	**2.467**	in²
Req. bolt load for gasket seating	Eq.(5)	$(A_m+A_b)\cdot S_a/2$	W	**383049**	lbf
Allowable bolt load		$A_b\cdot S_a$	W_{all}	**548201**	lbf
Design (gasket seating =1; max. allowable=2)				1 (1,2)	

Moment

	Force		Lever arm		Result	
$M_D = H_D \cdot h_D$ =	**641171**	N ·	**86.36**	mm =	**490082**	lbf·in
$M_G = H_G \cdot h_G$ =	**197073**	N ·	**61.37**	mm =	**107043**	lbf·in
$M_T = H_T \cdot h_T$ =	**131005**	N ·	**73.86**	mm =	**85646**	lbf·in

Total operating moment	$M_{01} = M_D + M_G + M_T$ =	**682770**	lbf·in
Total gasket seating moment, Eq. (6)	$M_{02} = W \cdot (C-G)/2$ =	**925485**	lbf·in

Stress

		Operation		Installation		≤ Allowable	
Longitudinal	S_H	**3864**	psi	**5238**	psi	≤ $1.5\cdot S_f$	Eq.(8)
Ratio	S_H/S_f	**0.217**		**0.2617**		≤ 1.5	
Allowable stress	S_f	**17811**	psi	**20015**	psi		
Radial	S_R	**4080**	psi	**5530**	psi	≤ S_f	Eq.(9)
Tangential	S_T	**17278**	psi	**23420**	psi	≤ S_f	Eq.(10)
Combination	$(S_H+S_R)/2$ =	**3972**	psi	**5384**	psi	≤ S_f	
Combination	$(S_H+S_T)/2$ =	**10571**	psi	**14329**	psi	≤ S_f	

Bolt pitch	B_S	**89.77**	mm	≤	**212.2**	mm = B_{Smax}	Eq.(3)

Remark

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

Auxiliary values

$K = \frac{A}{B} = 1.51$

$T = 1.706$ (Fig. 2-7.1)

$U = 5.368$ (Fig. 2-7.1)

$Y = 4.885$ (Fig. 2-7.1)

$Z = 2.563$ (Fig. 2-7.1)

$h_0 = \sqrt{B \cdot g_0} = 137.9 \text{ mm}$

$F = 3.261$ (Fig. 2-7.4)

$V = 11.37$ (Fig. 2-7.5)

$f = 1$

$d = \left(\frac{U}{V}\right) \cdot h_0 \cdot g_0^2 = 89541 \text{ mm}^3$

$e = \frac{F}{h_0} = 0.02364 \text{ 1/mm}$

$L = \frac{(t \cdot e + 1)}{T} + \frac{t^3}{d} = 4.103$

$H = 0.785 \cdot G^2 \cdot P \cdot 0.1 = 772176 \text{ N}$

$H_D = 0.785 \cdot B^2 \cdot P \cdot 0.1 = 641171 \text{ N}$

$H_P = 2 \cdot b \cdot \pi \cdot G \cdot m \cdot P \cdot 0.1 = 197073 \text{ N}$

$H_T = H - H_D = 131005 \text{ N}$

$W_{m1} = H + H_P = 969249 \text{ N}$ Eq.(1)

$W_{m2} = \pi \cdot b \cdot g \cdot y = 273712 \text{ N}$ Eq.(2)

$H_G = W_{m1} - H = 197073 \text{ N}$

$h_D = \frac{(C - B)}{2} = 86.36 \text{ mm}$

$h_G = \frac{(C - G)}{2} = 61.37 \text{ mm}$

$h_T = \frac{(h_D + h_G)}{2} = 73.86 \text{ mm}$

Bolt pitch

$B_S = \pi \cdot \frac{C}{n} = 89.77 \text{ mm}$

$B_{Smax} = 2 \cdot a + 6 \cdot \frac{t}{(m + 0.5)} = 212.2 \text{ mm}$ 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 **1.979** ≤ 1.0

Appendix: Material documentation

Section 1: Flansch/E 4.16.1
Section 2: Flansch/E 4.16.2

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]: 343.33	Thickness [mm]:
Pressure [bar]: 9.31	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	138	122.8
Safety factor:	1	1
Allowable stress [N/mm²]:	138	122.8
Modulus of elasticity [kN/mm²]:	201.3	178.7

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]: 343.33	Thickness [mm]:
Pressure [bar]: 31.03	Outside diameter [mm]:

Section 1: Schraube/E 4.16.1
Section 2: Schraube/E 4.16.2

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]: 343.33	Thickness [mm]:
Pressure [bar]: 9.31	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	183.4

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

Design conditions and dimensions:	
Temperature [°C]: 343.33	Thickness [mm]:
Pressure [bar]: 31.03	Outside diameter [mm]: