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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 ATLA Version **8.33.8**
Developed by Lauterbach Verfahrenstechnik GmbH	
Certified per DIN EN ISO 9001:2015	Certificate Number 01 100 044763

	LV Soft		ASME	Diff [%]
Example E4.6.1 - Flat Unstayed Circular heads Attached by Bolts				
Required plate thickness t	41.95 mm	1.65 in	1.65 in	0.05%
Example E4.6.2 - Flat Unstayed Non Circular heads Attached by Welding				
Required plate thickness t	17.88 mm	0.70 in	0.70 in	0.09%

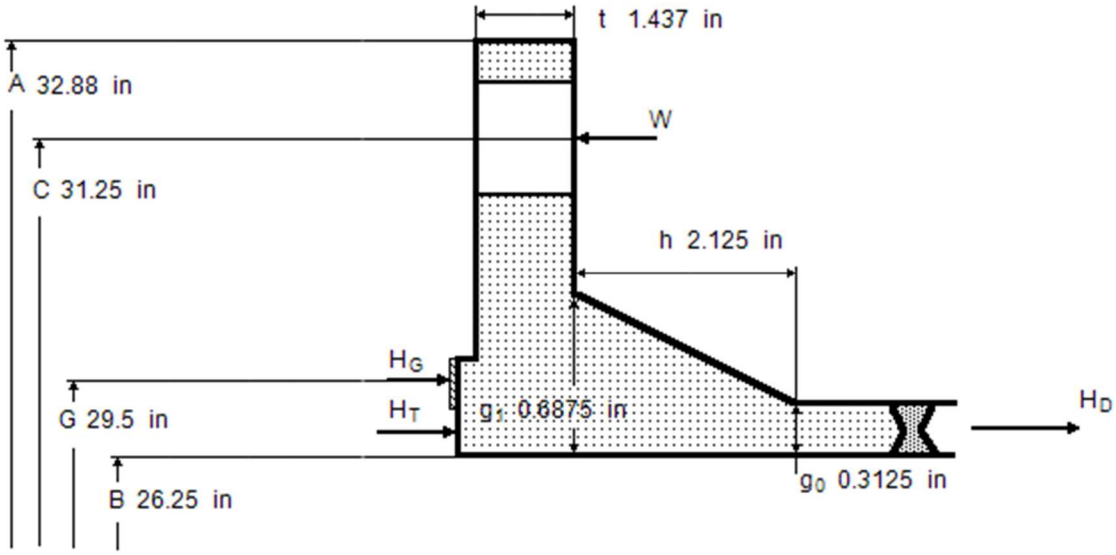
E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2021

Integral Type Flange

Design data

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

Flange



Outside diameter	A	32.88	in	Inside diameter	B	26.25	in
Bolt circle diameter	C	31.25	in	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

Thickness of semi-finished product	t_0		mm
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
Basic gasket seating width		b_0	**5.159**	mm
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 bolt force				1	

External forces and moments

		Operation	
External axial force	W_{ax}		N
External moment	M_b		N·mm
Resulting external force	W'		N

Note: External forces are considered as pseudo static pressure and added to the calculation pressure!

Resulting pseudo static pressure	P'	MPa

Moment

		Force		·	Lever arm		=	Result	
$M_D = H_D \cdot h_D$	=	**73024**	lbf	·	**2.156**	in	=	**13122**	lbf·ft
$M_G = H_G \cdot h_G$	=	**19049**	lbf	·	**0.875**	in	=	**1389**	lbf·ft
$M_T = H_T \cdot h_T$	=	**19202**	lbf	·	**1.688**	in	=	**2700**	lbf·ft

Total operating moment	M_{01}	= $M_D + M_G + M_T$	=	**17211** lbf·ft
Total gasket seating moment, Eq. (6)	M_{02}	= $W \cdot (C-G)/2$	=	**17289** lbf·ft

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	**2.231**	in	≤	**3.529**	in	= 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)

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

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

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

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

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

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

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

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

$W_{m2}=\pi\cdot b\cdot g\cdot y=636011$ 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 4.6.1 - Unstayed flat heads and covers - ASME BPVC VIII-1 UG-34 & UG-39: 2021

Circular flat heads and plates with flange moment

Design data

Design pressure	p_D	135	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	p_0	**135**	psi
Calculation temperature	T_0	650	°F
Design type (Fig. UG-34)	Type	1	

Gasket

Gasket diameter	G	29.5	in
Effective gasket width	b	0.2031	in
Gasket factor	m	3.7	
Gasket seating load	y	7600	psi

Bolt forces

Gasket seating force W acc. 2-5(e) Eq.(5), AFL	W_{E1}	***237101***	lbf
Lever arm	h_g	0.875	in

Flat head or plate

Final wall thickness	t_h	1.437	in
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0.125	in
Wall thickness without allowances	t_0	**1.312**	in
Design diameter	d	29.5	in
Joint efficiency (or Cast Quality Factor)	E	1	

Material data

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

Allowable stress installation	S_E	20015	psi
Allowable stress operation	S_B	17811	psi

Results

Gasket force for min. pressure	W_{m2}	**142982**	lbf
Bolting force for installation MAX(W_{E1}, W_{m2})	W_E	**237101**	lbf
Bolt force for operation	W_{m1}	**111020**	lbf
Design factor	C	0.3	
Required thickness	t	**1.526**	in
Required thickness incl. allowances	$t+c_1+c_{2<7sub>}$	**1.651**	in
Minimum required thickness in a groove	t_m	**0.8171**	in

Remark

Openings according to UG-39

Nozzle material			
Opening diameter, corroded (≤ d/2)	d_i		in
Nozzle wall thickness without allowances	t_n		in
Allowable nozzle stress	S_n		psi
Wall thickness reserve	t'	**-0.2145**	in
Available reinforcement area (plate)	A_1		in²
Required reinforcement area	A		in²
Alternative plate thickness acc. UG-39(d) corroded	t_A		in
Remark			

Allowable unreinforced opening diameter d for welded, brazed, and flued connections acc. UG 36(c)3

d ≤ 89 mm for t ≤10 mm	or	d ≤ 3 1/2 in for t ≤3/8 in
d ≤ 60 mm for t > 10 mm	or	d ≤ 2 3/8 in for t > 3/8 in

Equations

$$t_E = d \cdot \sqrt{1.9 \cdot W_E \cdot \frac{h_g}{\left(S_E \cdot E \cdot d^3\right)}} = 749.3\ \text{mm} \cdot \sqrt{1.9 \cdot 1054673\ \text{N} \cdot \frac{22.23\ \text{mm}}{(138\ \text{N/mm}^2 \cdot 1 \cdot (749.3\ \text{mm})^3)}} = 20.75\ \text{mm}$$

$$t_B = d \cdot \sqrt{C \cdot \frac{P_0}{(S_B \cdot E)} + 1.9 \cdot W_{m1} \cdot \frac{h_g}{\left(S_B \cdot E \cdot d^3\right)}} =$$

UG-34 (c-2) (2)

$$749.3\ \text{mm} \cdot \sqrt{0.3 \cdot \frac{9.308\ \text{bar}}{(122.8\ \text{N/mm}^2 \cdot 1)} + 1.9 \cdot 493841\ \text{N} \cdot \frac{22.23\ \text{mm}}{(122.8\ \text{N/mm}^2 \cdot 1 \cdot (749.3\ \text{mm})^3)}} = 38.77\ \text{mm}$$

$$38.77\ \text{mm} = Max\left\{\begin{matrix} t_E \\ t_B \end{matrix}\right.$$

$$t_m = d \cdot \sqrt{1.9 \cdot max\left(\frac{W_E}{S_E}; \frac{W_{m1}}{S_B}\right) \cdot \frac{h_g}{(E \cdot d^3)}} = 749.3\ \text{mm} \cdot \sqrt{1.9 \cdot 7643\ \text{mm}^2 \cdot \frac{22.23\ \text{mm}}{(1 \cdot (749.3\ \text{mm})^3)}} = 20.75\ \text{mm}$$

$$t' = E_1 \cdot (t_h - c_1 - c_2) - t_{(E=1)} = 1 \cdot (36.5\ \text{mm} - 0\ \text{mm} - 3.175\ \text{mm}) - 38.77\ \text{mm} = -5.448\ \text{mm}$$

Available reinforcement area analogously to Fig. UG-37.1

If

$$d_i > 2 \cdot (t_0 + t_n) \Leftrightarrow d_i > 2 \cdot (33.32\ \text{mm} + t_n)$$

Fig. UG-37.1

then

$$A_1 = \left(d_i - 2 \cdot t_n \cdot \left(1 - \frac{S_n}{S_B}\right)\right) \cdot t' = \left(d_i - 2 \cdot t_n \cdot \left(1 - \frac{S_n}{122.8\ \text{N/mm}^2}\right)\right) \cdot -5.448\ \text{mm} = A_1$$

Fig. UG-37.1

else

$$A_1 = 2 \cdot \left[t_0 + t_n - t_n \cdot \left(1 - \frac{S_n}{S_B}\right)\right] \cdot t' =$$

$$2 \cdot \left[33.32\ \text{mm} + t_n - t_n \cdot \left(1 - \frac{S_n}{122.8\ \text{N/mm}^2}\right)\right] \cdot -5.448\ \text{mm} = A_1$$

Fig. UG-37.1

Required reinforcement area acc. UG-39(b)(1)

$$A = 0.5 \cdot t \cdot d_i + t \cdot t_n \cdot \left(1 - \frac{S_n}{S_B}\right) = 0.5 \cdot 38.77\ \text{mm} \cdot d_i + 38.77\ \text{mm} \cdot t_n \cdot \left(1 - \frac{S_n}{122.8\ \text{N/mm}^2}\right) = A$$

UG-39 (b) (1)

If A1 > A in² > in² is not met, the available reinforcement area can better be calculated acc. UG-37 analogously to openings in cylinders (Longitudinal plane, F=1)

A_{avl} in² acc. UG-37 (≥ A in²)

Alternatively the plate thickness without allowances can be increased

t in acc. UG-39(d) (≤ t_0 **1.312** in)

E.4.6.2 - Unstayed flat heads and covers - ASME BPVC VIII-1 UG-34 & UG-39: 2021

Non-circular flat heads and plates without flange moment

Design data

Design pressure	p_D	400	psi
Hydrostatic head	D_p	0	psi
Calculation pressure	p_0	**400**	psi
Calculation temperature	T_0	500	°F
Design type (Fig. UG-34)	Type	c	

Cylinder

Outside diameter	D_0		in
Final thickness without allowance	t_s		in
Required thickness without allowance	t_r		in
Final thickness for type b1 ($\geq 2 \cdot t_s$)	t_f		in

Flat head or plate

Final wall thickness	t_h	0.8	in
Wall thickness allowance	c_1	0	in
Allowance (corrosion)	c_2	0.125	in
Wall thickness without allowances	t_0	**0.675**	in
Short span	d	7.375	in
Long span	D	9.5	in
Joint efficiency (or Cast Quality Factor)	E	1	

Material data

Material	K02700-SA-516-70-Class:-Size:		
Allowable stress	S	19957	psi

Results

Ratio	m		
Design factor	Z	**1.537**	
Design factor	C	0.2	
Required thickness	t	**0.5789**	in
Allowable excess pressure	P	**543.9**	psi
Required thickness incl. allowances	$t+c_1+c_{2<7sub>}$	**0.7039**	in
Required bend radius	rmin		in

Remark

Openings according to UG-39

Nozzle material				
Opening diameter, corroded	d_i		in	≤ d/2
Nozzle wall thickness without allowances	t_n		in	
Allowable nozzle stress	S_n		psi	
Wall thickness reserve	t'	**0.09614**	in	
Available reinforcement area (plate)	A_1		in²	
Required reinforcement area	A		in²	
Alternative plate thickness acc. UG-39(d) corroded	t_A		in	
Remark				

Allowable unreinforced opening diameter d for welded, brazed, and flued connections acc. UG 36(c)3

d ≤ 89 mm for t ≤10 mm	or	d ≤ 3 1/2 in for t ≤3/8 in
d ≤ 60 mm for t > 10 mm	or	d ≤ 2 3/8 in for t > 3/8 in

Equations

$$m=\frac{t_r}{t_s}$$

$$Z=3.4-2.4\cdot\frac{d}{D}=3.4-2.4\cdot\frac{187.3\text{ mm}}{241.3\text{ mm}}=1.537$$

$1.537\leq 2.5$

$$t=d\cdot\sqrt{Z\cdot C\cdot\frac{P_0}{(S\cdot E)}}=187.3\text{ mm}\cdot\sqrt{1.537\cdot 0.2\cdot\frac{27.58\text{ bar}}{(137.6\text{ N/mm}^2\cdot 1)}}=14.7\text{ mm}$$ UG-34 (b-2) (3)

$$t'=E_1\cdot(t_h-c_1-c_2)-t_{(E=1)}=1\cdot(20.32\text{ mm}-0\text{ mm}-3.175\text{ mm})-14.7\text{ mm}=2.442\text{ mm}$$

Available reinforcement area analogously to Fig. UG-37.1
If

$$d_i>2\cdot(t_0+t_n)\Leftrightarrow d_i>2\cdot(17.15\text{ mm}+t_n)$$ Fig. UG-37.1

then

$$A_1=\left[D_i-2\cdot t_n\cdot\left(1-\frac{S_n}{S_B}\right)\right]\cdot t'=\left[D_i-2\cdot t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)\right]\cdot 2.442\text{ mm}=A_1$$ Fig. UG-37.1

else

$$A_1=2\cdot\left[t_0+t_n-t_n\cdot\left(1-\frac{S_n}{S_B}\right)\right]\cdot t'=$$ Fig. UG-37.1

$$2\cdot\left[17.15\text{ mm}+t_n-t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)\right]\cdot 2.442\text{ mm}=A_1$$

Required reinforcement area acc. UG-39(b)(1)

$$A=0.5\cdot t\cdot d_i+t\cdot t_n\cdot\left(1-\frac{S_n}{S_B}\right)=0.5\cdot 14.7\text{ mm}\cdot d_i+14.7\text{ mm}\cdot t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)=A$$ UG-39 (b) (1)

If A1 > A in² > in² is not met, the available reinforcement area can better be calculated acc. UG-37 analogously to openings in cylinders (Longitudinal plane, F=1)

A_{avl} in² acc. UG-37 (≥ A in²)

Alternatively the plate thickness without allowances can be increased

t in acc. UG-39(d) (≤ t_0 **0.675** in)