

ASME BPVC VIII-1 2023

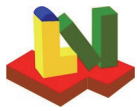
Example E4.6.1 - E4.6.2 PTB-4-2021

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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



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Example E4.6.1 - E4.6.2 PTB-4-2021

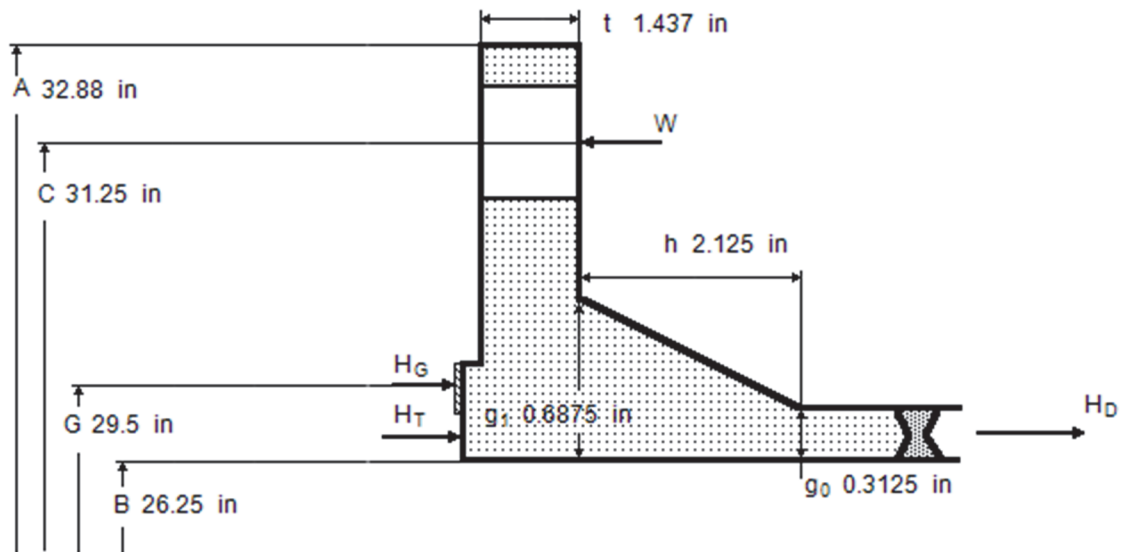
E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2023

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

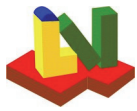


Outside diameter	A	32.88 in	Inside diameter	B	26.25 in
Bolt circle diameter	C	31.25 in	Pipe size	B_n	26.25 in
Hub length	h	2.125 in	Flange thickness	t	1.437 in
Large hub thickness	g_1	0.6875 in	Small hub thick.	g_0	0.3125 in

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	b	0.2031 in
Gasket factor	m	3.75
Gasket seating load	y	7600 psi



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Example E4.6.1 - E4.6.2 PTB-4-2021

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}	(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 in ²
Required cross section	W_{m1}/S_b	A_{m1} 4.46 in ²
Required cross section	W_{m2}/S_a	A_{m2} 5.732 in ²
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
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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

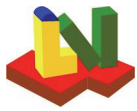
Stress

	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	≤ S_f	Eq.(9)
Radial	S_R 6157 psi	6184 psi	≤ S_f	Eq.(10)
Tangential	S_T 5548 psi	5573 psi	≤ S_f	
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





ASME BPVC VIII-1 2023
Example E4.6.1 - E4.6.2 PTB-4-2021

Auxiliary values

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

$$T = 1.817 \quad (\text{Fig. 2-7.1})$$

$$U = 9.623 \quad (\text{Fig. 2-7.1})$$

$$Y = 8.757 \quad (\text{Fig. 2-7.1})$$

$$Z = 4.518 \quad (\text{Fig. 2-7.1})$$

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

$$F = 0.7677 \quad (\text{Fig. 2-7.2})$$

$$V = 0.1576 \quad (\text{Fig. 2-7.3})$$

$$f = 1 \quad (\text{Fig. 2-7.6})$$

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

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

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

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

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

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

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

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

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

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

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

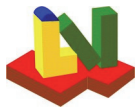
$$h_D = R + 0.5 \cdot g_1 = 54.77 \text{ mm}$$

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

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

Bolt pitch

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



ASME BPVC VIII-1 2023
Example E4.6.1 - E4.6.2 PTB-4-2021

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

Eq.(3)

For

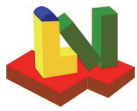
$$B_S > 2 \cdot a + t$$

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

Eq.(7)

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

Rigidity criterion: J **0.8339** ≤ 1.0



ASME BPVC VIII-1 2023
Example E4.6.1 - E4.6.2 PTB-4-2021

E 4.6.1 - Unstayed flat heads and covers - ASME BPVC VIII-1 UG-34 & UG-39: 2023

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

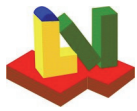
Remark

Openings according to UG-39

Nozzle material		
Opening diameter, corroded ($\leq d/2$)	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	in ²
Required reinforcement area	A	in ²
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

$d \leq 89 \text{ mm for } t \leq 10 \text{ mm}$	or	$d \leq 3 \frac{1}{2} \text{ in for } t \leq \frac{3}{8} \text{ in}$
$d \leq 60 \text{ mm for } t > 10 \text{ mm}$	or	$d \leq 2 \frac{3}{8} \text{ in for } t > \frac{3}{8} \text{ in}$



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Example E4.6.1 - E4.6.2 PTB-4-2021

Equations

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

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

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

$$38.77 \text{ mm} = \text{Max} \begin{cases} t_E \\ t_B \end{cases}$$

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

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

Available reinforcement area analogously to Fig. UG-37.1

If

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

then

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

else

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

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

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

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

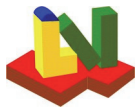
UG-34 (c-2)
(2)

Fig. UG-37.1

Fig. UG-37.1

Fig. UG-37.1

UG-39 (b)
(1)



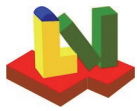
ASME BPVC VIII-1 2023 **Example E4.6.1 - E4.6.2 PTB-4-2021**

If $A_1 > A_2$ in^2 $>$ in^2 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} in^2 acc. UG-37 ($\geq A_2$ in^2)

Alternatively the plate thickness without allowances can be increased

t in acc. UG-39(d) ($\leq t_0$ **1.312** in)



ASME BPVC VIII-1 2023

Example E4.6.1 - E4.6.2 PTB-4-2021

E 4.6.2 - Unstayed flat heads and covers - ASME BPVC VIII-1 UG-34 & UG-39: 2023

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	$t + c_1 + c_{2 < 7 \text{sub} >}$	0.7039	in
Required bend radius	r_{min}		in

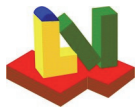
Remark

Openings according to UG-39

Nozzle material			
Opening diameter, corroded	d_i	in	$\leq d/2$
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	in ²	
Required reinforcement area	A	in ²	
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

$d \leq 89 \text{ mm for } t \leq 10 \text{ mm}$	or	$d \leq 3 \frac{1}{2} \text{ in for } t \leq \frac{3}{8} \text{ in}$
$d \leq 60 \text{ mm for } t > 10 \text{ mm}$	or	$d \leq 2 \frac{3}{8} \text{ in for } t > \frac{3}{8} \text{ in}$



ASME BPVC VIII-1 2023

Example E4.6.1 - E4.6.2 PTB-4-2021

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

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

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

Fig. UG-37.1

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

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

UG-39 (b)
(1)

If $A_1 > A$ $\text{in}^2 > \text{in}^2$ is not met, the available reinforcement area can better be calculated acc. UG-37 analogously to openings in cylinders (Longitudinal plane, F=1)

$$A_{\text{avl}} \text{ in}^2 \text{ acc. UG-37 } (\geq A \text{ in}^2)$$

Alternatively the plate thickness without allowances can be increased

$$t \text{ in acc. UG-39(d)} (\leq t_0 \text{ } \mathbf{0.675} \text{ in})$$