

ASME BPVC VIII-1 2021

Example E4.16.1 - E4.16.2 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 E4.16.1 - E4.16.2 PTB-4-2021

Summary

| | | | | | | | | | |
|--|--|-----------------|----------------------------------|--|----------------|---------|---------------|----------|-------|
| Strength Calculation Software | | | Program System ATLAS | | | Version | | 10.0.98 | |
| 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 E4.16.2 - Loose Type | | | | | | | | | |
| | | Required load W | 1,703,878.63 N | | 383,047.25 lbf | | 387702.50 lbf | | 1.20% |



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Example E4.16.1 - E4.16.2 PTB-4-2021

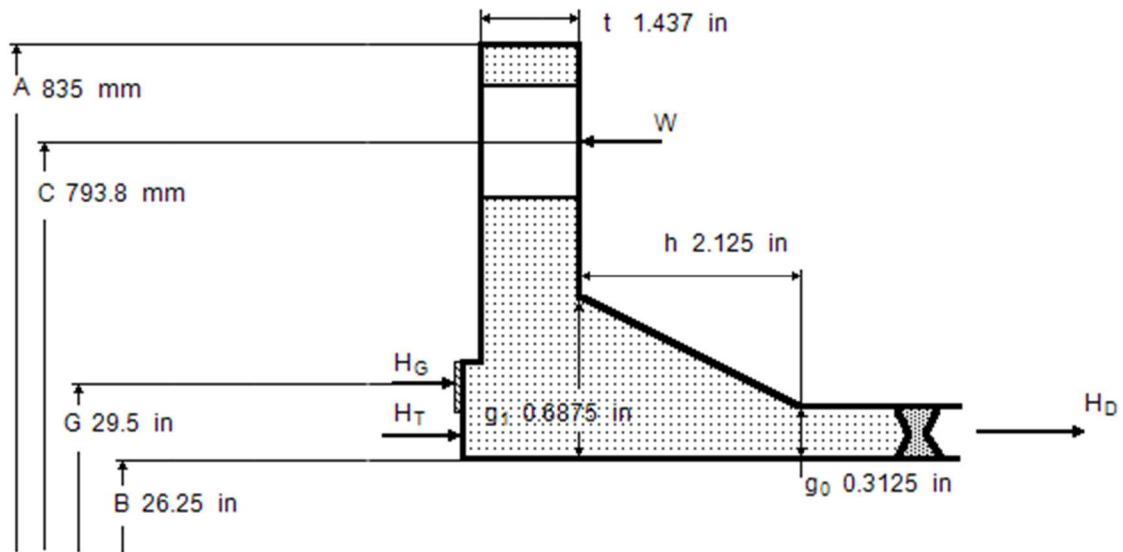
E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2021

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

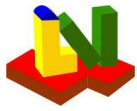


| | | | | | |
|----------------------|-------|-----------|------------------|-------|-----------|
| Outside diameter | A | 835 mm | Inside diameter | B | 26.25 in |
| Bolt circle diameter | C | 793.8 mm | Pipe size | B_n | 26.25 in |
| Hub length | h | 2.125 in | Flange thickness | t | 1.437 in |
| Large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

| | | |
|--------------------------------------|-----------------------------|--------------|
| 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 E4.16.1 - E4.16.2 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} 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 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 |
|----------------------------------|------|-----|

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· 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





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Example E4.16.1 - E4.16.2 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

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



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Example E4.16.1 - E4.16.2 PTB-4-2021

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



ASME BPVC VIII-1 2021 **Example E4.16.1 - E4.16.2 PTB-4-2021**

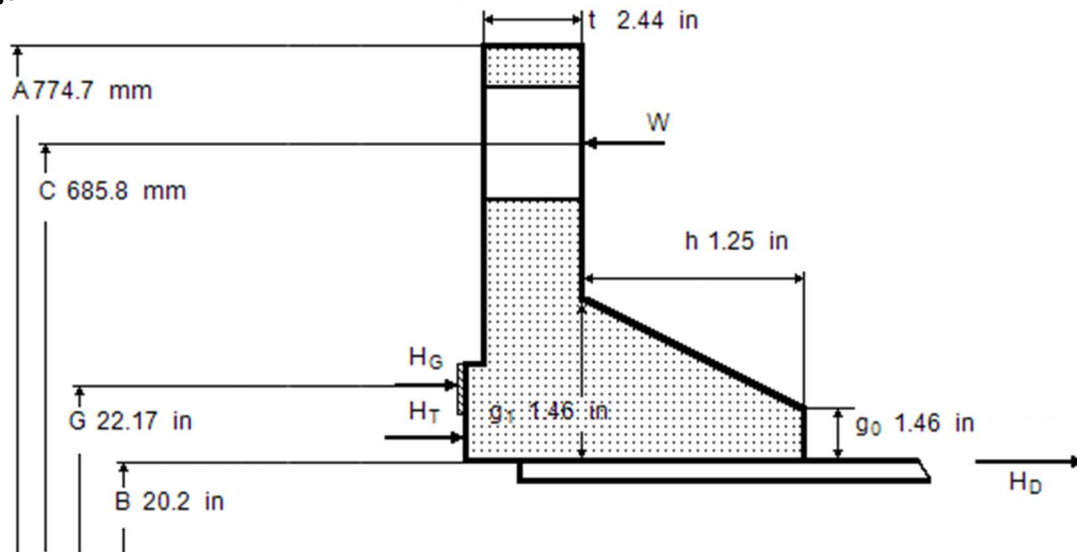
E 4.16.2 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2021

Loose Type Flange With Full Neck

Design data

| | | |
|-------------------------|-------|---------|
| Design pressure | P_D | 450 psi |
| Hydrostatic head | D_P | 0 psi |
| Calculation pressure | P_0 | 450 psi |
| Calculation temperature | T_0 | 650 °F |

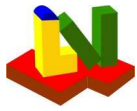
Flange



| | | | | | |
|--------------------------------------|----------|--------------|---------------------|-------|---------|
| 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 |
| 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 | 22.17 in |
| Basic gasket seating width | b_0 | 12.91 mm |
| Effective gasket width | b | 0.3536 in |
| Gasket factor | m | 2 |
| Gasket seating load | y | 2500 psi |



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Example E4.16.1 - E4.16.2 PTB-4-2021

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 in ² |
| Required cross section | W_{m1}/S_b | A_{m1} | 8.735 in ² |
| Required cross section | W_{m2}/S_a | A_{m2} | 2.467 in ² |
| 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 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 |
| $M_D = H_D \cdot h_D$ | = 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 · 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





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Example E4.16.1 - E4.16.2 PTB-4-2021

Auxiliary values

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

$$T = 1.706 \quad (\text{Fig. 2-7.1})$$

$$U = 5.368 \quad (\text{Fig. 2-7.1})$$

$$Y = 4.885 \quad (\text{Fig. 2-7.1})$$

$$Z = 2.563 \quad (\text{Fig. 2-7.1})$$

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

$$F = 3.261 \quad (\text{Fig. 2-7.4})$$

$$V = 11.37 \quad (\text{Fig. 2-7.5})$$

$$f = 1$$

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

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

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

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

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

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

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

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

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

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

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

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

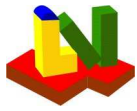
$$h_T = \frac{(h_D + h_G)}{2} = 73.86 \text{ mm}$$

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)



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Example E4.16.1 - E4.16.2 PTB-4-2021

For

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

Eq.(7)

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

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

Rigidity criterion: J **1.979** ≤ 1.0