## Table of contents



## 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 **8.29.1** |
| 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% |

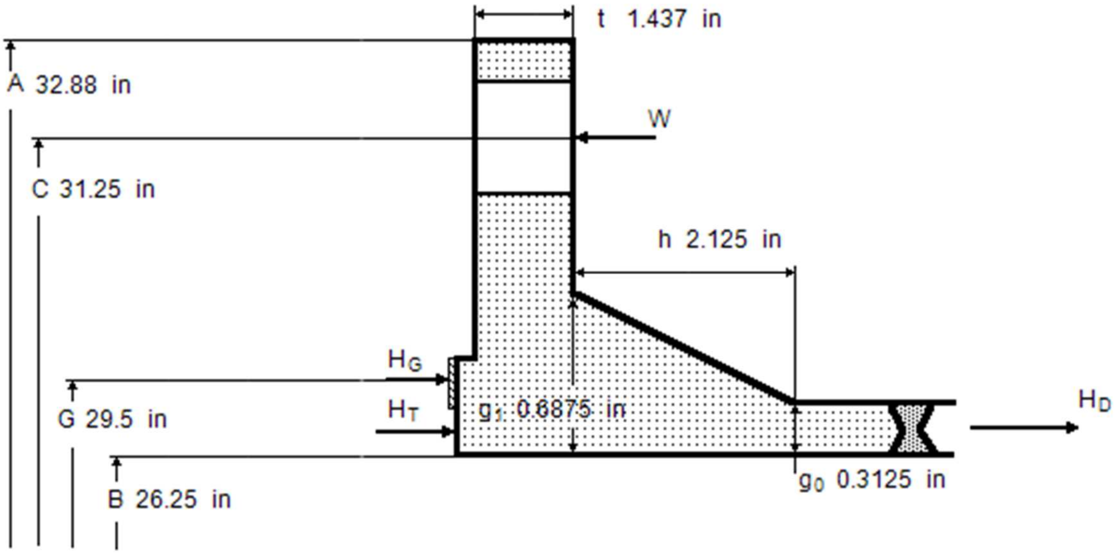
## E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2017

**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 | 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 |

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

| | | |
|---|---|---|
| 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 | |
|---|---|---|---|---|---|---|---|---|---|
| $M_D = H_D \cdot h_D$ | = | **73024** | lbf | · | **2.156** | in | = | **13122** | lbf·ft |
| $M_G = H_G \cdot h_G$ | = | **19049** | lbf | · | **0.875** | in | = | **16667** | lbf·in |
| $M_T = H_T \cdot h_T$ | = | **19202** | lbf | · | **1.688** | in | = | **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 | $B_S$ | **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)

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

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

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

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

$d=\left(\frac{U}{V}\right) \cdot h_0 \cdot g_0^2=279869$ mm³

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

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

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

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

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

$H_T=H-H_D=85412$ N

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

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

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

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

$h_D=R+0.5 \cdot g_1=54.77$ mm

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

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

Bolt pitch

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

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

## E 4.6.1 - Unstayed flat heads and covers - ASME BPVC VIII-1 UG-34 & UG-39: 2017

### 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 | 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**

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

UG-34 (c-2) (2)

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

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

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

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

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

Available reinforcement area analogously to Fig. UG-37.1

If

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

Fig. UG-37.1

then

Fig. UG-37.1

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

else

Fig. UG-37.1

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

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

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

UG-39 (b) (1)

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

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: 2017

**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 | 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**

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

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

$1.537\leq2.5$

UG-34 (b-2)(3)

$$t=d\cdot\sqrt{Z\cdot C\cdot\frac{P_0}{(S\cdot E)}}=187.3\text{ mm}\cdot\sqrt{1.537\cdot0.2\cdot\frac{27.58\text{ bar}}{(137.6\text{ N/mm}^2\cdot1)}}=14.7\text{ mm}$$

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

Available reinforcement area analogously to Fig. UG-37.1

If

Fig. UG-37.1

$$d_i>2\cdot(t_0+t_n)\Leftrightarrow d_i>2\cdot(17.15\text{ mm}+t_n)$$

then

Fig. UG-37.1

$$A_1=\left[D_i-2\cdot t_n\cdot\left(1-\frac{S_n}{S_B}\right)\right]\cdot t'=\left[D_i-2\cdot t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)\right]\cdot2.442\text{ mm}=A_1$$

else

Fig. UG-37.1

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

$$2\cdot\left[17.15\text{ mm}+t_n-t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)\right]\cdot2.442\text{ mm}=A_1$$

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

UG-39 (b)(1)

$$A=0.5\cdot t\cdot d_i+t\cdot t_n\cdot\left(1-\frac{S_n}{S_B}\right)=0.5\cdot14.7\text{ mm}\cdot d_i+14.7\text{ mm}\cdot t_n\cdot\left(1-\frac{S_n}{137.6\text{ N/mm}^2}\right)=A$$

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 )

## Appendix: Material documentation

Section 1: Flansch/E 4.16.1
Section 2: Boden/Platte/E 4.6.1

**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]: | 343,3333 | Pressure [bar]: | 9,30798 |
| Thickness [mm]: | 3 | Outside diameter [mm]: | 0 |

**Material values for test and design conditions:**

| | Test condition | Operating condition |
|---|---|---|
| Nominal design strength [N/mm²]: | 138.00 | 122.80 |
| Safety factor: | | |
| Allowable stress [N/mm²]: | 138.00 | 122.80 |
| Modulus of elasticity [kN/mm²]: | 201,3 | 178,6667 |

Wall thickness tolerance [mm]: 0.00 acc. to SA-105
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. lngt. % | Rupture elong. lat. % |
|---|---|---|---|---|---|
| | | | | | |

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 | 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 | 14.8 | 15.1 | 15.4 | | |

—

Section 1: Schraube/E 4.16.1

**Material specification:**

Regulation: ASMET3:2010 Spec. 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]: 343,3333 Pressure [bar]: 9,30798
Thickness [mm]: 3 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: | | |
| Allowable stress [N/mm²]: | 172.00 | 172.00 |
| Modulus of elasticity [kN/mm²]: | 204,3 | 183,4 |

Wall thickness tolerance [mm]: 0.00 acc. to SA-193
Notes:

--
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. lngt. % | Rupture elong. lat. % |
|---|---|---|---|---|---|
| | | | | | |

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 | 14.8 | 15.1 | 15.4 | | |

—

Section 3: Boden/Platte/E.4.6.2

**Material specification:**

Regulation: ASMET1A:2017Spec. No.: SA-516 Product: Plate
Material code: K02700-SA-516-70-Class:-Size: Short name: Carbon steel

**Design conditions and dimensions:**

Temperature [°C]: 260 Pressure [bar]: 27,5792
Thickness [mm]: 3 Outside diameter [mm]: 0

**Material values for test and design conditions:**

| | Test condition | Operating condition |
|---|---|---|
| Nominal design strength [N/mm²]: | 138.00 | 137.60 |
| Safety factor: | | |
| Allowable stress [N/mm²]: | 138.00 | 137.60 |
| Modulus of elasticity [kN/mm²]: | 202,35 | 188,2 |

Wall thickness tolerance [mm]: 0.00 acc. to SA-516
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.

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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 | Rm max MPa | ReH MPa | Rupture elong. lngt. % | Rupture elong. lat. % |
|---|---|---|---|---|---|
| | | | | | |

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 | 138 | 136 | 128 | 101 |

K-values as function of the temperature

| Diam./ Thickn. | 450°C | 500°C | 550°C | 600°C | 650°C | 700°C | 800°C |
|---|---|---|---|---|---|---|---|

| <= mm | MPa | MPa | MPa | MPa | MPa | MPa | MPa |
|---|---|---|---|---|---|---|---|
| | 67.1 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 100°C | 200°C | 300°C | 400°C | 500°C | 600°C | 700°C | 800°C | Heat | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| (20 °C) | | | | | | | | | cond. | capac. |
| kg/dm³ | 10E-6/K | 10E-6/K | 10E-6/K | 10E-6/K | 10E-6/K | 10E-6/K | 10E-6/K | 10E-6/K | W/Km | J/kgK |
| 7.85 | 12,1 | 12,7 | 13,3 | 13,8 | 14,4 | 14.8 | 15.1 | 15.4 | | |