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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 **8.31.2**			
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%

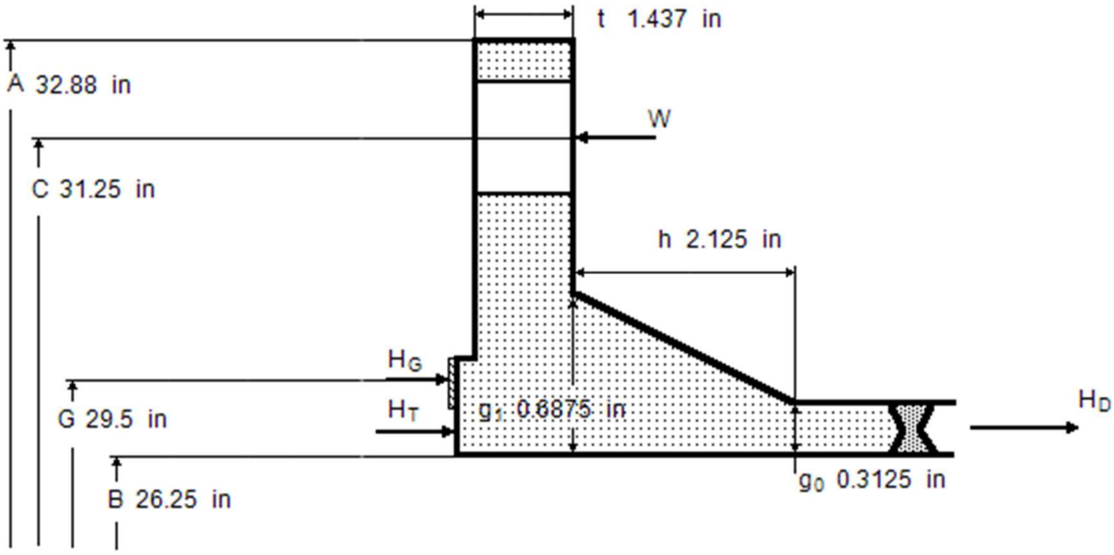
E 4.16.1 - Bolted flanges - ASME BPVC VIII Division 1 App. 2: 2019

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	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:

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	
$M_D = H_D \cdot h_D$	=	**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)

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

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: 2019

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

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

UG-34 (c-2) (2)

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

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

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

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

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

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

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

else

Fig. UG-37.1

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

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

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: 2019

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)

Appendix: Material documentation

Section 1: Flansch/E 4.16.1
Section 3: Boden/Platte/E 4.6.1

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

Section 1: Schraube/E 4.16.1	

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

Section 5: Boden/Platte/E.4.6.2	

Material specification:		
Material code: K02700-SA-516-70-Class:-Size:	Regulation: ASME II.D Table 1A:2017	Spec. No.: SA-516
Short name: Carbon steel	Product: Plate	
Delivery condition:		

Design conditions and dimensions:	
Temperature [°C]: 260	Thickness [mm]:
Pressure [bar]: 27.58	Outside diameter [mm]:

Material values for test and design conditions:		
	Test condition	Operating condition
Nominal design strength [N/mm²]:	138	137.6
Safety factor:	1	1
Allowable stress [N/mm²]:	138	137.6
Modulus of elasticity [kN/mm²]:	202.4	188.2

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
260	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	138	132	123	83.8	51	21.3

Young's modulus-values in dependence of the temperature															
T	°C	-200	-125	-75	25	100	150	200	250	300	350	400	450	500	550
E	kN/mm²	216	212	209	202	198	195	192	189	185	179	171	162	151	137

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