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Sealing surface pressure and bolt force

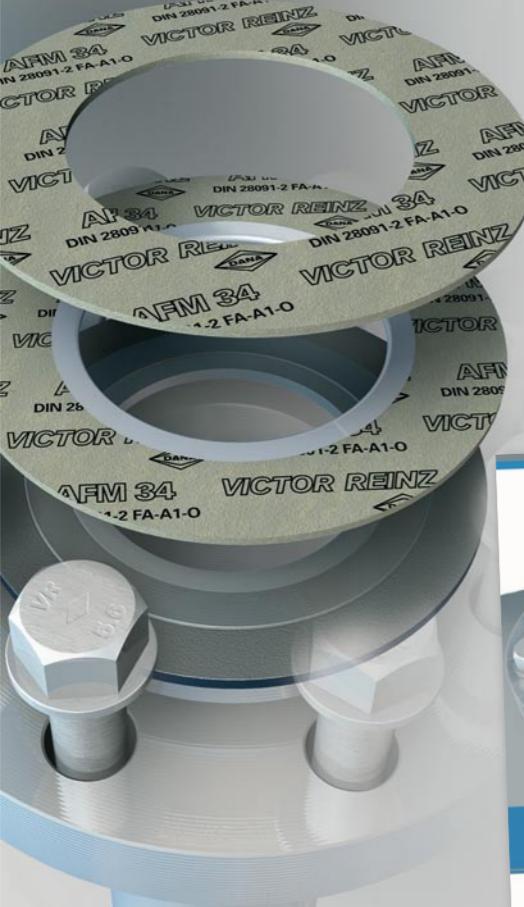
PN-designated welding neck flange with raised-face in accordance with EN 1092-1

For fiber-composite gaskets in accordance with EN 1514-1 and spiral-wound gaskets in accordance with EN 1514-2

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Notes about the tables



The tables provide an overview of the average sealing surface pressure on welding neck flanges with raised-face in accordance with EN 1092-1 for flat gaskets in accordance with EN 1514-1, and spiral-wound gaskets in accordance with EN 1514-2 with use of bolts of various materials and designs (rigid or expansion bolts). The numerical values of the sealing surface pressure for spiral-wound gaskets with an interior and exterior eccentric and back-up ring are based on the precondition that only the zone of the spiral-wound gasket ring is

compressed – this means that the massive steel eccentric and back-up ring are not subjected to axial load, but merely serve as radial support. They are also based on the additional precondition that the width and therefore the compressed area of the spiral-wound gasket sealing ring zone remain constant.

In certain cases, however, high internal and external radial force may occur due to force transfer of the shaped metal bands of the spiral-wound gasket in combination with the high mounted bolt force (axial sealing force) and with graphite or PTFE

as a low-friction value sealing tape material, which on the one hand increases the radial compression or deformation of the sealing tape material and thus the cross-sectional sealing, but can also be so large that they lead to an enlargement of some mm Ø of the eccentric and back-up rings that are subject to tensile load, and thus to a modification of the sealing surface pressure. Even the inner ring can show significant compression deformation or indentation.

If the eccentric and back-up rings do in fact take on axial load, the deformation

and thus the sealing surface pressure of the spiral-wound gasket zone would then hardly increase, aside from the fact that in this situation the spiral-wound gasket would certainly be tightly sealed.

Table 1

This table contains the specification for number and size of bolts, total bolt force F_S and average sealing surface pressure Q . When using standardized flat gaskets, the size of the sealing surface is determined by the outer diameter of the seal and the inner diameter of the gasket. Because the number and size of bolts are determined by the size of the particular flange, the average sealing surface pressure necessarily stems from the strength of the bolts that are used. In order to achieve the minimum sealing surface pressure required for installing a gasket while also avoiding exceeding the maximum compression of the gasket in question (referring to manufacturer's specifications), you must make the right choice from among the approved bolt steels and types (rigid or expansion bolts). The conversion factors in Table 2 provide practical help for doing this.

The table values for F_S and Q , based on the bolt quality 8.8 when exploiting the yield point at normal temperature to 80%: $\sigma_{\text{allowed}} = \sigma_{0,2} \times 0.8 = 512 \text{ N/mm}^2$. When using this bolt quality, the sealing surface pressures that occur lie within a range in which the required minimum sealing surface pressure is achieved whereas the maximum allowable surface pressure is not exceeded. Calculation of the bolt force for rigid bolts is based on the stressed cross-section of the thread; for expansion bolts it is based on the reduced-shaft cross-section – see Table 3.

In the selection of bolts, the application criteria to be considered include those of operating pressure, operating temperature, corrosion, nominal diameter and bolt size, which are more precisely specified

in relevant regulations, such as AD 2000 - Bulletin B7, W2, W7, W10, DIN EN ISO 3506-1 and -2, DIN 2510-2, -3 and -5, DIN EN 10088-2 and -3, among others.

Table 2

This table contains a selection of bolts of various qualities and steel types, as well as their mechanical strength properties. With the help of conversion factors, which are given for each bolt quality for both the cold yield strength and the various warm yield strengths, you can determine the total bolt force and sealing pressure for bolts other than 8.8 as well (see example). The stability calculation must also be carried out with consideration of various (100,000 h) rupture stress values, such as creep breaking and yield points, at the calculation temperature. According to AD 2000-B7, the bolt stability calculation should be based on the lowest characteristic value from these mechanical strength properties.

Table 3

Specifications are consolidated here for dimensions, cross-sections, maximum allowable bolt force, and maximum allowable tightening torque for all bolts from M5 to M100x6 for rigid bolts (stressed cross-section), and expansion bolts (reduced-shaft cross-section). For organization's sake, bolt force and tightening torque of the expansion bolts also relate to the bolt quality 8.8 (allowable stress $\sigma_{\text{allowed}} = 512 \text{ N/mm}^2$). Expansion bolts are, however, mostly manufactured of high-temperature steels. Thus, determining the total bolt force and average sealing surface pressure requires conversion based on the steel type used (conversion factors can be found in Table 2). Table 3 contains further specifications required for known bolt force F_S for calculation of the tightening torque M_A according to the following formula:

$$M_A = F_S [0.161 \times P + 0.583 \times \mu_{\text{total}} \times d_2 + 0.25 \times \mu_{\text{total}} (s + d_L)]$$

Here, the following definitions apply:

P = Thread pitch in mm

μ_{total} = Total coefficient of friction for all friction surfaces

d_2 = Diameter of screw thread flank in mm

s = Outer diameter of bolt and nut bearing faces in mm.

For expansion bolts, d_M is to be used instead.

d_L = Bolt hole size in mm

Here, the following is selected: $\mu_{\text{total}} = 0.14$. This applies to oiled friction surfaces that are not galvanized, cadmium-plated, phosphatized or the like. For MoS₂ pastes, this formula applies: $\mu_{\text{total}} \approx 0.10$.

Table 1a

Bolt forces and surface pressures for nonmetallic flat gaskets

Gaskets in accordance with EN 1514-1: 1997, Flanges in accordance with EN 1092-1 (Type 11 Form B: welding neck flange with raised-face)

Example of conversion of bolt quality 8.8 into other materials and to 300 °C, DN 100/PN 40 (8 M20 bolts)

a) 8.8 bolts at 20 °C
Q = 98 N/mm² in accordance with Table 1

b) 5.6 bolts at 20 °C
Bolt material conversion factor = 0.47 in accordance with Table 2
Q = 98 x 0.47 N/mm² = 46 N/mm²

c) 25 CrMo4 bolts at 300 °C
Bolt material conversion factor = 0.57 in accordance with Table 2
Q = 98 x 0.57 N/mm² = 56 N/mm²

d) 25 CrMo4 expansion bolts at 300 °C
Bolt material conversion factor = 0.57 in accordance with Table 2

F_S allowed (expansion bolts) / F_S allowed (rigid bolts) = 90.6 kN / 125 kN = 0.72 (see Table 3)
Q = 98 x 0.57 x 0.72 N/mm² = 40.2 N/mm²

Nominal diameter DN	Gasket diameter d ₁ x d _a in mm		Number and size of bolts		Total bolt force F _S total in kN		Average sealing surface pressure Q in N/mm ²		Gasket diameter d ₁ x d _a in mm		Number and size of bolts		Total bolt force F _S total in kN		Average sealing surface pressure Q in N/mm ²		Gasket diameter d ₁ x d _a in mm		Number and size of bolts		Total bolt force F _S total in kN		Average sealing surface pressure Q in N/mm ²		Gasket diameter d ₁ x d _a in mm		Number and size of bolts		Total bolt force F _S total in kN		Average sealing surface pressure Q in N/mm ²	
	Nominal pressure PN		2.5		Nominal pressure PN		6		Nominal pressure PN		10		Nominal pressure PN		16		Nominal pressure PN		25		Nominal pressure PN		40		Nominal pressure PN		63					
	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN	Nominal pressure PN			
10	18x39	4xM10	118.8	168	18x39	4xM10	118.8	168	18x46	4xM12	172.6	172	18x46			4xM12	172.6	172	18x46	4xM12	172.6	172	18x46	4xM12	172.6	172	18x56	4xM12	172.6	172		
15	22x44	4xM10	118.8	136	22x44	4xM10	118.8	136	22x51	4xM12	172.6	143	22x51			4xM12	172.6	143	22x51	4xM12	172.6	143	22x51	4xM12	172.6	143	21x61	4xM12	172.6	139		
20	27x54	4xM10	118.8	85	27x54	4xM10	118.8	85	27x61	4xM12	172.6	83	27x61			4xM12	172.6	83	27x61	4xM12	172.6	83	27x61	4xM12	172.6	83	25x72	4xM16	321.5	149		
25	34x64	4xM10	118.8	62	34x64	4xM10	118.8	62	34x71	4xM12	172.6	63	34x71			4xM12	172.6	63	34x71	4xM12	172.6	63	34x71	4xM12	172.6	63	30x82	4xM16	321.5	110		
32	43x76	4xM12	172.6	72	43x76	4xM12	172.6	72	43x82	4xM16	321.5	97	43x82			4xM16	321.5	97	43x82	4xM16	321.5	97	43x82	4xM16	321.5	97	41x88	4xM20	501.8	145		
40	49x86	4xM12	172.6	55	49x86	4xM12	172.6	55	49x92	4xM16	321.5	77	49x92			4xM16	321.5	77	49x92	4xM16	321.5	77	49x92	4xM16	321.5	77	47x103	4xM20	501.8	115		
50	61x96	4xM12	172.6	50	61x96	4xM12	172.6	50	61x107	4xM16	321.5	61	61x107			4xM16	321.5	61	61x107	4xM16	321.5	61	61x107	4xM16	321.5	61	59x113	4xM20	501.8	92		
65	77x116	4xM12	172.6	36	77x116	4xM12	172.6	36	77x127	8xM16	643.1	91	77x127			8xM16 ¹⁾	643.1	91	77x127	4xM16	643.1	91	77x127	8xM16	643.1	91	73x138	8xM20	1003.5	134		
80	89x132	4xM16	321.5	48	89x132	4xM16	321.5	48	89x142	8xM16	643.1	74	89x142			8xM16	643.1	74	89x142	8xM16	643.1	74	89x142	8xM16	643.1	74	86x148	8xM20	1003.5	110		
100	115x152	4xM16	321.5	47	115x152	4xM16	321.5	47	115x162	8xM16	643.1	70	115x162			8xM16	643.1	70	115x168	8xM20	1003.5	98	115x168	8xM20	1003.5	98	110x174	8xM24	1445.9	130		
125	141x182	8xM16	643.1	69	141x182	8xM16	643.1	69	141x192	8xM16	643.1	53	141x192			8xM16	643.1	53	141x194	8xM24	1445.9	119	141x194	8xM24	1445.9	119	135x210	8xM27	1880.1	140		
150	169x207	8xM16	643.1	67	169x207	8xM16	643.1	67	169x218	8xM20	1003.5	78	169x218			8xM20	1003.5	78	169x224	8xM24	1445.9	97	169x224	8xM24	1445.9	97	163x247	8xM30	2297.9	140		
200	220x262	8xM16	643.1	45	220x262	8xM16	643.1	45	220x273	8xM20	1003.5	55	220x273			12xM20	1505.3	82	220x284	12xM24	2168.8	96	220x290	12xM27	2820.1	109	210x309	12xM33	4263.9	146		
250	273x317	12xM16	964.6	54	273x317	12xM16	964.6	54	273x328	12xM20	1505.3	69	273x329			12xM24	2168.8	99	273x340	12xM27	2820.1	95	273x352	12xM30	3446.8	99	264x364	12xM33	4263.9	110		
300	324x373	12xM20	1505.3	68	324x373	12xM20	1505.3	68	324x378	12xM20	1505.3	60	324x384			12xM20	2168.8	73	324x400	16xM27	3760.1	94	324x417</									

Table 1b
Bolt forces and surface pressures for spiral-wound gaskets

Gaskets in accordance with EN 1514-2 2005: 1997,
Flanges in accordance with EN 1092-1 (Type 11 Form
B: welding neck flange with raised-face)

Example of conversion of bolt quality 8.8 into other materials and to 300 °C, DN 100/PN 40 (8 M20 bolts)

a) 8.8 bolts at 20 °C
 $Q = 98 \text{ N/mm}^2$ in accordance with Table 1

b) 5.6 bolts at 20 °C
 Bolt material conversion factor = 0.47 in accordance with Table 2
 $Q = 98 \times 0.47 \text{ N/mm}^2 = 46 \text{ N/mm}^2$

c) 25 CrMo4 bolts at 300 °C
 Bolt material conversion factor = 0.57 in accordance with Table 2
 $Q = 98 \times 0.57 \text{ N/mm}^2 = 56 \text{ N/mm}^2$

d) 25 CrMo4 expansion bolts at 300 °C
 Bolt material conversion factor = 0.57 in accordance with Table 2

$F_S \text{ allowed (expansion bolts)} / F_S \text{ allowed (rigid bolts)} = 90.6 \text{ kN} / 125 \text{ kN} = 0.72$ (see Table 3)
 $Q = 98 \times 0.57 \times 0.72 \text{ N/mm}^2 = 40.2 \text{ N/mm}^2$

Nominal diameter DN	Nominal pressure PN												Nominal pressure PN											
	10				25				40				63				100				160			
	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2	Gasket diameter $d_g \times d_a$ in mm	Number and size of bolts	Total bolt force F_S total in kN	Average sealing surface pressure Q in N/mm^2
10	18x46	4xM12	172.6	379	18x46	4xM12	172.6	379	18x46	4xM12	172.6	379	18x56	4xM12	172.6	379	18x56	4xM12	172.6	379	18x56	4xM12	172.6	379
15	23x51	4xM12	172.6	323	23x51	4xM12	172.6	323	23x51	4xM12	172.6	323	23x61	4xM12	172.6	323	23x61	4xM12	172.6	323	23x61	4xM12	172.6	323
20	28x61	4xM12	172.6	229	28x61	4xM12	172.6	229	28x61	4xM12	172.6	229	35x71	4xM12	172.6	195	35x82	4xM16	321.5	363	35x82	4xM16	321.5	363
25	35x71	4xM12	172.6	195	35x71	4xM12	172.6	195	35x71	4xM12	172.6	195	43x82	4xM16	321.5	310	50x92	4xM16	321.5	275	50x92	4xM16	321.5	275
32	43x82	4xM16	321.5	310	43x82	4xM16	321.5	310	43x82	4xM16	321.5	310	61x107	4xM16	321.5	164	61x107	4xM16	321.5	164	61x107	4xM16	321.5	164
40	50x92	4xM16	321.5	275	50x92	4xM16	321.5	275	50x92	4xM16	321.5	275	61x113	4xM20	501.8	429	50x103	4xM20	501.8	429	50x103	4xM20	501.8	429
50	61x107	4xM16	321.5	164	61x107	4xM16	321.5	164	61x107	4xM16	321.5	164	77x127	8xM16	643.1	272	77x127	8xM16	643.1	272	77x137	8xM20	1003.5	333
65	77x127	8xM16	643.1	272	77x127	8xM16	643.1	272	77x127	8xM16	643.1	272	90x142	8xM16	643.1	239	90x148	8xM20	1003.5	293	90x154	8xM24	1445.9	479
80	90x142	8xM16	643.1	239	90x142	8xM16	643.1	239	90x142	8xM16	643.1	239	115x168	8xM20	1003.5	296	115x174	8xM24	1445.9	336	115x180	8xM27	1880.1	437
100	115x162	8xM16	643.1	190	115x168	8xM20	1003.5	296	115x168	8xM20	1003.5	296	140x192	8xM16	643.1	126	140x194	8xM24	1445.9	284	140x210	8xM27	1880.1	304
125	140x192	8xM16	643.1	126	140x194	8xM24	1445.9	284	140x194	8xM24	1445.9	284	167x217	8xM20	1003.5	169	167x224	8xM24	1445.9	244	167x247	8xM30	2297.9	319
150	167x217	8xM20	1003.5	169	167x224	8xM24	1445.9	244	167x224	8xM24	1445.9	244	216x272	8xM20	1003.5	134	216x284	12xM24	2168.8	290	216x290	12xM27	2820.1	377
200	216x272	8xM20	1003.5	134	216x284	12xM24	2168.8	290	216x284	12xM24	2168.8	290	267x327	12xM20	1505.3	137	267x340	12xM27	2820.1	257	267x352	12xM33	3446.8	314
250	318x377	12xM20	1505.3	117	318x400	16xM27	3760.1	292	318x400	16xM27	3760.1	292	360x437	16xM20	2007	137	360x457	16xM30	4595.7	314	360x474	16xM33	5685	389
300	360x437	16xM20	2007	137	360x457	16xM30	4595.7	314	360x457	16xM33	5685.2	296	410x488	16xM24	2891.8	151	410x514	16xM33	5685.2	296	410x546	16xM36	6692.9	349
400	410x488	16xM24	2891.8	151	410x514	16xM33	5685.2	296	410x514	16xM33	5685.2	296	510x593	20xM24	3614.7	153	510x624	20xM33	7106.6	301	510x628	20xM39	9994.2	424
500	510x593	20xM24	3614.7	153	510x624	20xM33	7106.6	301	510x624	20xM33	7106.6	301	610x695	20xM27	4700.2	168	610x731	20xM36	8366.1	299	610x747	20xM45	13373.4	478
700	710x810	24xM27	5640.2	143	710x833	24xM39	11993.1	304	710x833	24xM45	16048.1	355	810x917	24xM30	6893.6	152	810x942	24xM45	16048.1	355	910x1017	28xM30	8042.5	159
900	910x1017	28xM30	8042.5	159	910x1042	28xM45	18722.8	370	910x1042	28xM45	18722.8	370	1010x1124	28xM33	9949.2	137								

Table 2

Bolt materials and mechanical strength properties (in N/mm ²)										
Material	Material number	Tensile strength R _m min.	Yield point R _{el} or 0.2 % of yield point R _{p 0.2}							
			20 °C	20 °C	100 °C	200 °C	300 °C	400 °C	500 °C	600 °C
Carbon steel										
DIN EN ISO 898-1: 1999				Values in brackets: conversion factors compared to material quality 8.8 at 20 °C (= 1.00)						
4.6		400	240 (0.38)							
5.6		500	300 (0.47)	270 (0.42)	230 (0.36)	195 (0.30)				
6.8		600	480 (0.75)							
8.8		800	640 (1.00)	590 (0.92)	540 (0.84)	480 (0.75)				
10.9		1040	940 (1.47)	875 (1.37)	790 (1.23)	705 (1.10)				
12.9		1220	1100 (1.72)	1020 (1.59)	925 (1.45)	825 (1.29)				
High-temperature steels										
DIN EN 10269: 1999										
25CrMo4 (Ø ≤ 100 mm)	1.7218	600	440 (0.69)	428 (0.67)	412 (0.64)	363 (0.57)	304 (0.48)	235 (0.37)		
42CrMo4 (Ø ≤ 60 mm)	1.7225	860	730 (1.14)	702 (1.10)	640 (1.00)	562 (0.88)	475 (0.74)	375 (0.59)		
~ ASTM: B7										
21CrMoV5-7 (Ø ≤ 160 mm)	1.7709	700	550 (0.86)	530 (0.83)	500 (0.78)	460 (0.72)	410 (0.64)	350 (0.55)		
40CrMoV4-6 (Ø ≤ 100 mm)	1.7711	850	700 (1.09)	670 (1.05)	631 (0.99)	593 (0.93)	554 (0.87)	470 (0.73)		
~ ASTM: B16										
High-temperature steels										
DIN EN 10269: 1999										
X22CrMoV12-1	1.4923	800	600 (0.94)	560 (0.88)	530 (0.83)	480 (0.75)	420 (0.66)	335 (0.52)		
X7CrNiMoBNb16-16	1.4986	650	500 (0.78)	470 (0.73)	432 (0.68)	393 (0.61)	353 (0.55)	314 (0.49)	255 (0.40)	
X6NiCrTiMoVB25-15-2	1.4980	900	600 (0.94)	580 (0.91)	560 (0.88)	540 (0.84)	520 (0.81)	490 (0.77)	430 (0.67)	
Stainless steels										
DIN EN 10088-3: 2005 ¹⁾										
X5CrNi18-10	1.4301	500	190 (0.30)	155 (0.24)	127 (0.20)	110 (0.17)	98 (0.15)	92 (0.14)		
~ AISI 304										
X5CrNiMo17-12-2	1.4401	500	200 (0.31)	175 (0.27)	145 (0.23)	127 (0.20)	115 (0.18)	110 (0.17)		
~ AISI 316										
X6CrNiTi18-10	1.4541	500	190 (0.30)	175 (0.27)	155 (0.24)	136 (0.21)	125 (0.20)	119 (0.19)		
~ AISI 321										
X6CrNiMoTi17-12-2	1.4571	500	200 (0.31)	185 (0.29)	165 (0.26)	145 (0.23)	135 (0.21)	129 (0.20)		
~ AISI 316Ti										
Stainless steels for bolts										
DIN EN ISO 3506-1: 1998										
A2-50, A4-50, A5-50, ≤ M 39		500	210 (0.33)	3)	3)	3)	3)			
A2-70, A4-70, A5-70, ≤ M 24 ²⁾		700	450 (0.70)	382 (0.60)	360 (0.56)	338 (0.53)	315 (0.49)			
A2-80, A4-80, A5-80, ≤ M 24 ²⁾		800	600 (0.94)	510 (0.80)	480 (0.75)	450 (0.70)	420 (0.66)			

¹⁾ Data applies to quenched steel. Strain-hardened steels possess significantly higher values.

See «Stainless steels for bolts» A2-70 to A5-80

²⁾ For larger nominal diameters, the mechanical properties must be stipulated in consultation with the manufacturer.

³⁾ Apply values for the corresponding «Stainless steels» types in accordance with DIN EN 10088-3

Supply values for the corresponding stainless steel types in accordance with DIN EN 10000-8.

Table 3

Units and conversions

This table applies only with relation to color coding of the SI system to fps system.

SI (metric) system	
Anglo-American fps system (foot-pound-second)	

Power of ten	Prefix	Prefix symbol	Unit of length	
10^{12}	Tera	T	1 Kilometer (km)	$= 0.621 \text{ mile} = 1094 \text{ yd} = 3280 \text{ ft} = 39370 \text{ in}$
10^9	Giga	G	1 Meter (m)	$= 1.0936 \text{ yd} = 3,2808 \text{ ft} = 39,3701 \text{ in}$
10^6	Mega	M	1 Centimeter (cm)	$= 3.281 \times 10^{-2} \text{ ft} = 0.3937 \text{ in} = 393.7 \mu\text{in}$
10^3	Kilo	k	1 Millimeter (mm)	$= 10^3 \mu\text{m} = 3.281 \times 10^{-3} \text{ ft} = 3.937 \times 10^{-2} \text{ in} = 39.37 \text{ mil}$
10^2	Hecto	h	1 Micrometer (μm)	$= 10^{-3} \text{ mm} = 3.937 \times 10^{-5} \text{ in} = 3.937 \times 10^{-2} \text{ mil} = 39.37 \mu\text{in}$
10^1	Deca	da		
10^{-1}	Dezi	d	1 (statute) mile	$= 1760 \text{ yd} = 5280 \text{ ft} = 6,336 \times 10^4 \text{ in} = 1,609 \text{ km}$
10^{-2}	Centi	c	1 yard (yd)	$= 3 \text{ ft} = 36 \text{ in} = 0.9144 \text{ m} = 914.4 \text{ mm}$
10^{-3}	Milli	m	1 foot (ft)	$= 0.3333 \text{ yd} = 12 \text{ in} = 0.3048 \text{ m} = 304.8 \text{ mm}$
10^{-6}	Micro	μ	1 inch (in)	$= 2.778 \times 10^{-2} \text{ yd} = 8,3333 \times 10^{-2} \text{ ft} = 10^3 \text{ mil} = 25.4 \text{ mm}$
10^{-9}	Nano	n	1 millinch (mil)	$= 10^{-3} \text{ in} = 10^3 \mu\text{in} = 2.54 \times 10^{-2} \text{ mm}$
10^{-12}	Pico	p	1 microinch (μin)	$= 10^{-6} \text{ in} = 10^{-3} \text{ mil} = 2.54 \times 10^{-2} \mu\text{m}$
Inch / Millimeter				
1/32 in	= 0.0313 in	= 0.794 mm	7/16 in	= 0.4375 in = 11.113 mm
1/16 in	= 0.0625 in	= 1.588 mm	15/32 in	= 0.4688 in = 11.906 mm
3/32 in	= 0.0938 in	= 2.381 mm	1/2 in	= 0.5000 in = 12.700 mm
1/8 in	= 0.1250 in	= 3.175 mm	9/16 in	= 0.5625 in = 14.288 mm
5/32 in	= 0.1563 in	= 3.969 mm	5/8 in	= 0.6250 in = 15.865 mm
3/16 in	= 0.1875 in	= 4.763 mm	11/16 in	= 0.6875 in = 17.463 mm
7/32 in	= 0.2188 in	= 5.566 mm	3/4 in	= 0.7500 in = 19.050 mm
1/4 in	= 0.2500 in	= 6.350 mm	13/16 in	= 0.8125 in = 20.638 mm
9/32 in	= 0.2813 in	= 7.144 mm	7/8 in	= 0.8750 in = 22.225 mm
5/16 in	= 0.3125 in	= 7.938 mm	15/16 in	= 0.9375 in = 23.815 mm
11/32 in	= 0.3438 in	= 8.731 mm	1 in	= 25.400 mm
3/8 in	= 0.3750 in	= 9.525 mm	10 in	= 254.00 mm
13/32 in	= 0.4063 in	= 10.319 mm	24 in	= 609.60 mm
Temperature				
0 Kelvin (K)	= 0.0313 in	= 0.794 mm	7/16 in	= 0.4375 in = 11.113 mm
0 Degree Celsius (°C)	= 0.0625 in	= 1.588 mm	15/32 in	= 0.4688 in = 11.906 mm
0 Degree Fahrenheit (°F)	= 0.0938 in	= 2.381 mm	1/2 in	= 0.5000 in = 12.700 mm
100 °C	= 0.1250 in	= 3.175 mm	9/16 in	= 0.5625 in = 14.288 mm
Temp. in °C: t_c	= 0.1563 in	= 3.969 mm	5/8 in	= 0.6250 in = 15.865 mm
Temp. in °F: t_f	= 0.1875 in	= 4.763 mm	11/16 in	= 0.6875 in = 17.463 mm
Temp. in K: T	= 0.2188 in	= 5.566 mm	3/4 in	= 0.7500 in = 19.050 mm
Temperature difference: $1 \text{ K} = 1 \text{ }^{\circ}\text{C}$	= 0.2500 in	= 6.350 mm	13/16 in	= 0.8125 in = 20.638 mm
	= 0.2813 in	= 7.144 mm	7/8 in	= 0.8750 in = 22.225 mm
	= 0.3125 in	= 7.938 mm	15/16 in	= 0.9375 in = 23.815 mm
	= 0.3438 in	= 8.731 mm	1 in	= 25.400 mm
	= 0.3750 in	= 9.525 mm	10 in	= 254.00 mm
	= 0.4063 in	= 10.319 mm	24 in	= 609.60 mm
Units of area				
1 km ²	= 1.0625 in	= 0.3861 mile ²	7/16 in	= 0.4375 in = 11.113 mm
1 m ²	= 0.0625 in	= 1.588 mm	15/32 in	= 0.4688 in = 11.906 mm
1 dm ²	= 0.0938 in	= 2.381 mm	1/2 in	= 0.5000 in = 12.700 mm
1 cm ²	= 0.1250 in	= 3.175 mm	9/16 in	= 0.5625 in = 14.288 mm
1 mile ²	= 0.1563 in	= 3.969 mm	5/8 in	= 0.6250 in = 15.865 mm
1 yd ²	= 0.1875 in	= 4.763 mm	11/16 in	= 0.6875 in = 17.463 mm
1 ft ²	= 0.2188 in	= 5.566 mm	3/4 in	= 0.7500 in = 19.050 mm
1 in ²	= 0.2500 in	= 6.350 mm	13/16 in	= 0.8125 in = 20.638 mm
Units of volume				
1 m ³	= 1.0625 in	= 0.3861 mile ³	7/16 in	= 0.4375 in = 11.113 mm
1 dm ³	= 0.0625 in	= 1.588 mm	15/32 in	= 0.4688 in = 11.906 mm
1 cm ³	= 0.0938 in	= 2.381 mm	1/2 in	= 0.5000 in = 12.700 mm
1 mile ³	= 0.1250 in	= 3.175 mm	9/16 in	= 0.5625 in = 14.288 mm
1 yd ³	= 0.1563 in	= 3.969 mm	5/8 in	= 0.6250 in = 15.865 mm
1 ft ³	= 0.1875 in	= 4.763 mm	11/16 in	= 0.6875 in = 17.463 mm
1 in ³	= 0.2188 in	= 5.566 mm	3/4 in	= 0.7500 in = 19.050 mm
Units of mass and weight				
1 Ton (t) = 10^3 kg	= 0.9842 long tn	= 1.1023 sh tn	= 2204.5 lb	
1 Kilogram (kg) = 10^3 g	= 2.0246 lb	= 35.274 oz		
1 Gramm (g)	= 3.527	10^{-2} oz		
1 long ton (long tn)	= 1.12 sh tn	= 2240 lb		
1 short ton (sh tn)	= 0.8929 long tn	= 2000 lb		
1 pound (lb)	= 16 oz			
1 ounce (oz)	= 6.25×10^{-2} lb			
Units of pressure and tension				
1 N/m ² = 1 Pascal (Pa)	= 10^{-6} N/mm ² = 10^{-5} bar = 10^{-2} mbar	= 1.45037×10^{-4} lbf/in ² (psi)		
1 N/mm ²	= 10^6 N/m ² = 10 bar = 10^4 mbar	= 145.037 lbf/in^2 (psi)		
1 bar	= 10^5 N/m ² = 10^3 mbar	= $2.0886 \times 10^4 \text{ lbf/ft}^2$ = 14.5037 lbf/in^2 (psi)		
1 m bar	= 100 N/m ² = 10^{-4} N/mm ² = 10^{-3} bar	= 2.0886 lbf/ft^2 = $1.45 \times 10^{-2} \text{ lbf/in}^2$ (psi)		
1 long tn force/in ² (tonf/in ²)	= 3.2256×10^5 lbf/ft ² = 2240 lbf/in^2	= 15.4443 N/mm^2 = 154.443 bar		
1 lbf/in ²	= 6.9442×10^{-3} lbf/in ²	= 47.8803 N/m^2 = 0.4788 mbar		
1 lbf/in ² **	= 144 lbf/ft^2	= $6.8947 \times 10^3 \text{ N/m}^2$ = 6.89×10^{-2} bar = 68.9 mbar		
* In the literature, «lb» or «lb/ft ² » or «lb/in ² » are often given rather than «lb» or «lb/ft ² » or «lb/in ² ».				
** «Pound-force/square inch» also abbreviated as «psi» (1 lbf/in ² = 1 lb/in ² = 1 psi).				
Units of force				
1 Newton (N)	= 0.224809 lbf	= 7.233011 pdl		
1 pound-force (lbf)	= 32.174 pdl	= 4.44822 N		
1 poundal* (pdl)	= 3.108×10^{-2} lbf	= 0.13825 N		
* Force that accelerates a mass of 1lb by 1ft/s.				
Units of work or energy or quantity of heat				
1 Joule (J) = 1 Nm = 1 Ws	= $1 \text{ kg m}^2/\text{s}^2$ = 2.778×10^{-7} kWh	= $0.73756 \text{ lbf x ft} = 0.94776 \text{ btu}$		
1 Kilowatt hour (kWh)	= 3.6×10^6 J	= $2.6553 \times 10^6 \text{ lbf x ft} = 3412.14 \text{ btu}$		
1 pound-force-foot (lbf-ft)	= 1.285×10^{-3} x btu	= $1.3558 \text{ J} = 0.3766 \times 10^6 \text{ kWh}$		
1 British thermal unit*	= 778.17 lbf x ft	= $105506 \text{ kJ} = 0.2931 \times 10^3 \text{ kWh}$		
* Quantity of heat required to warm up 1 lb of water by 1°F.				
Unit of power or heat flow				
1 Watt (W) = $1 \text{ J/s} = 1 \text{ Nm/s}$	= 0.9478×10^{-3} btu/s = 1.341×10^{-3} hp = $0.73891 \text{ ft x lbf/s}$			
1 kW = 1000 W	= 0.9478 btu/s = 1.341 hp = 738.91 ft x lbf/s			
1 btu/s	= 1.4149 hp = 780.14073 ft x lbf/s			
1 horsepower (hp)	= $0.70678 \text{ btu/s} = 551.0249 \text{ ft x lbf/s}$			
1 ft x lbf/s	= 1.28182×10^{-3} btu/s = 1.8148×10^{-3} hp			

A few terms for surface roughness in accordance with DIN EN ISO 4287:1998

Arithmetical average roughness Ra: