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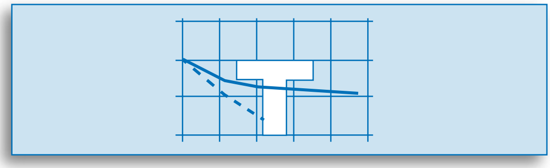

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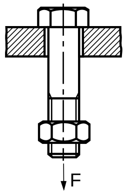
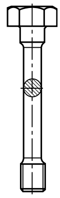
Tensile strength R_m [N/mm²]

The minimum tensile strength of a screw is the tensile stress from which there could be a rupture in the shank or the thread (not in the head/shank joint). If full size screws are tested, the yield strength can only be approximately established. Under ISO 898 Part 1, the exact yield strength and elongation after fracture can only be determined using machined samples. Exceptions are stainless steel screws A1–A4 (ISO 3506).



Tensile test on full size screw



Tensile test on machined screw

Tensile strength at rupture in thread:

$$R_m = \frac{\text{max. tensile force F}}{\text{Stress area As}} \quad \frac{\text{N}}{\text{mm}^2}$$

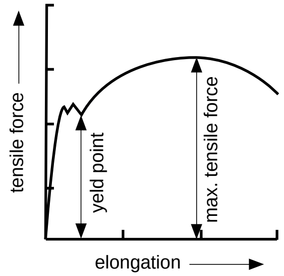
(Stress area As [mm²] of thread, see **T**.033)

Tensile strength at rupture in cylindrical shank:

$$R_m = \frac{\text{max. tensile force F}}{\text{cylindrical starting cross-section}} \quad \frac{\text{N}}{\text{mm}^2}$$

Yield strength R_{el} [N/mm²]

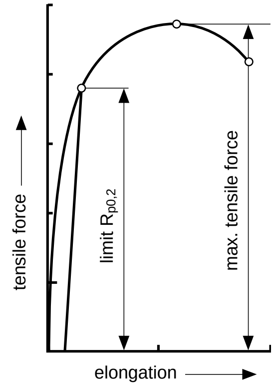
The yield strength is the tensile stress from which elongation begins to increase disproportionately with increasing tensileforce. A plastic elongation remains after relief.



0,2% limit $R_{p0,2}$ [N/mm²]

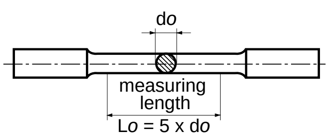
The yield strength of harder material is difficult to determine. The 0,2 limit is defined as the tensile stress from which aplastic elongation of exactly 0,2% remains after relief.

In practice, screws may be stressed by tightening and underworking load no more than up to the yield strength or the 0,2 limit.



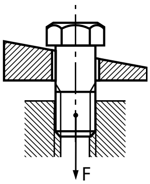
Elongation at fracture A [%]

This occurs on loading up to the rupture point of the screw. In a defined shank area, the remaining plastic elongation isdetermined using machined screws. Exceptions: screws A1–A4, where this is measured on fullsize screws (ISO 3506).



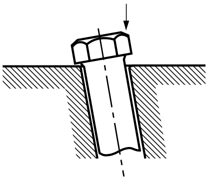
Wedge tensile strength

The tensile strength on whole screws is established and the head strength simultaneously tested on an angular load. The rupture must not occur in the head/shank joint.



Head soudness

The head of the screw must with stand several hammer blows. After being bent to a specified angle, the shank head fillet shall not show any signs of cracking. For details see ISO 898, part 1.



Hardness

Generally speaking hardness is the resistance which the material offers to the penetration of a test body under adefined load (see ISO 898, Part 1).
Hardness comparison tables, see **T**.065.

Vickers hardness HV: ISO 6507
Pyramid (encompasses the complete hardness range usual for screws).

Brinell hardness HB: ISO 6506
Ball.

Rockwell hardness HRC: ISO 6508
Cone.

Impact strength (Joule) ISO 83

is the impact work used in the notched bar impact bending test. A notched sample is taken from near the surface of the screw. This sample is broken with a single blow in apendulum ram impact testing machine, yielding information on the microstructure, melting behaviour, inclusion content, etc.. The measured value cannot be included in design calculations.

Surface defects

are slag inclusions, material overlaps and grooves stemming from the raw material. **Cracks**, on the other hand, are crystalline ruptures without inclusions. For details, see DIN 267 Part 20, ISO 6157.

Decarburization of the surface

is generally a reduction in the carbon content of the surface of the thread of heat treated screws, see ISO 898 Part 1.

Mechanical and physical properties of bolts, screws and studs

according to ISO 898, part 1

Screws
Property class
3.6 to 12.9

The mechanical properties are given for tests at room temperature.

Sub-clause number	Mechanical and physical property		Property class 3.6	4.6	4.8	5.6	5.8	6.8	8.8[1] $d \leq$ 16mm[3]	8.8[1] $d >$ 16mm[3]	9.8[2]	10.9	12.9
5.1 und **5.2**	Tensile strength Rm in N/mm² [4), 5)]	nominal value	300	400		500		600	800	800	900	1000	1200
		min.	330	400	420	500	520	600	800	830	900	1040	1220
5.3	Vickers hardness HV F ≥ 98 N	min.	95	120	130	155	160	190	250	255	290	320	385
		max.	220[6)]					250	320	335	360	380	435
5.4	Brinell hardness HB F = 30 D^2	min.	90	114	124	147	152	181	238	242	276	304	366
		max.	209[6)]					238	304	318	342	361	414
5.5	Rockwell hardness HR	min. HRB	52	67	71	79	82	89	—	—	—	—	—
		min. HRC	—	—	—	—	—	—	22	23	28	32	39
		max. HRB	95[6)]					99,5	—	—	—	—	—
		max. HRC	—					—	32	34	37	39	44
5.6	Surface hardness HV 0,3	max.	—						7)				
5.7	lower yield stress R_{eL}[8)] in N/mm²	nominal value	180	240	320	300	400	480	—	—	—	—	—
		min.	190	240	340	300	420	480	—	—	—	—	—
5.8	Stress at 0,2% non-proportional elongation $R_{p0,2}$[9)] in N/mm²	nominal value	—					—	640	640	720	900	1080
		min.	—					—	640	660	720	940	1100
5.9	Stress under proofing load S_p	S_p / R_{eL} or S_p / $R_{p0,2}$	0,94	0,94	0,91	0,93	0,9	0,92	0,91	0,91	0,9	0,88	0,88
		N/mm²	180	225	310	280	380	440	580	600	650	830	970
5.10	Breaking torque, M_B Nm min.		—						see ISO 898-7				
5.11	Percent elongation after fracture *A* in %	min.	25	22	—	20	—	—	12	12	10	9	8
5.12	Reduction area after fracture Z	% min.	—						52		48	48	44
5.13	Strength under wedge loading[5)]		The values for full size bolts and screws (not studs) shall not be smaller than the minimum values for tensile strength shown in 5.2										
5.14	Impact strength, *KU* in J	J min.	—			25	—		30	30	25	20	15
5.15	Head soudness		no fracture										
5.16	Minimum height of non-decarburized thread zone, *E*		—						1/2 H_1			2/3 H_1	3/4 H_1
	Maximum depth of complete decarburization, *G*	mm	—						0,015				
5.17	Hardness after retempering		—						Reduction of hardness 20 HV max.				
5.18	Surface integrity		In accordance with ISO 6157-1 or ISO 6157-3 as appropriate										

1) For bolts of porperty class 8.8 in diameters $d \leq$ 16 mm, there is an increased risk of nut stripping in the case of inadvertent over-tightening inducing a load in excess of proofing load. Reference to ISO 898–2 is recommended.
2) Applies only to nominal thread diameters $d \leq$ 16 mm.
3) For structural bolting the limit is 12 mm.
4) Minimum tensile properties apply to products of nominal length $l \geq$ 2,5 d. Minimum hardness applies to products of length l < 2,5 *d* and other products which cannot be tensile-tested (e.g. due to head configuration).
5) When testing full-size bolts, screws and studs, the tensile loads, which are to be applied for the calculation of R_m shall meet the values given on page **T.**005.
6) A hardness reading taken at the end of bolts, screws and studs shall be 250 HV, 238 HB or 99,5 HRB maximum.
7) Surface hardness shall not be more than 30 Vickers points above the measured core hardness on the product when readings of both surface and core carried out at HV 0,3. For property class 10.9, any increase in hardness at the surface which indicates that the surface hardness exceeds 390 HV is not acceptable.
8) In cases where the lower yield stress R_{eL} cannot be determined, it is permissible to measure the stress at 0,2 % non-proportional elongation $R_{p0,2}$. For the property classes 4.8, 5.8 and 6.8 the values for Rel are given for calculation purposes only, they are not test values.
9) The yield stress ratio according to the designation of the property class and the minimum stress at 0,2 % non-proportional elongation $R_{p0,2}$ apply tomachi-ned test specimens. These values if received from tests of full size bolts and screws will vary because of processing method and size effects.

Minimum ultimate tensile loads

according to ISO 898, part 1

Screws
Property classes
3.6 to 12.9

Minimum ulitmate tensile loads[3] – ISO metric coarse (standard) pitch thread

Thread[1]	Nominal stress area A_s mm²	Property class									
		3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
		Minimum ultimate tensile load ($A_s \cdot R_m$) in N									
M 3	5,03	1 660	2 010	2 110	2 510	2 620	3 020	4 020	4 530	5 230	6 140
M 3,5	6,78	2 240	2 710	2 850	3 390	3 530	4 070	5 420	6 100	7 050	8 270
M 4	8,78	2 900	3 510	3 690	4 390	4 570	5 270	7 020	7 900	9 130	10 700
M 5	14,2	4 690	5 680	5 960	7 100	7 380	8 520	11 350	12 800	14 800	17 300
M 6	20,1	6 630	8 040	8 440	10 000	10 400	12 100	16 100	18 100	20 900	24 500
M 7	28,9	9 540	11 600	12 100	14 400	15 000	17 300	23 100	26 000	30 100	35 300
M 8	36,6	12 100	14 600	15 400	18 300	19 000	22 000	29 200	32 900	38 100	44 600
M10	58,0	19 100	23 200	24 400	29 000	30 200	34 800	46 400	52 200	60 300	70 800
M12	84,3	27 800	33 700	35 400	42 200	43 800	50 600	67 400[2]	75 900	87 700	103 000
M14	115	38 000	46 000	48 300	57 500	59 800	69 000	92 000[2]	104 000	120 000	140 000
M16	157	51 800	62 800	65 900	78 500	81 600	94 000	125 000[2]	141 000	163 000	192 000
M18	192	63 400	76 800	80 600	96 000	99 800	115 000	159 000	–	200 000	234 000
M20	245	80 800	98 000	103 000	122 000	127 000	147 000	203 000	–	255 000	299 000
M22	303	100 000	121 000	127 000	152 000	158 000	182 000	252 000	–	315 000	370 000
M24	353	116 000	141 000	148 000	176 000	184 000	212 000	293 000	–	367 000	431 000
M27	459	152 000	184 000	193 000	230 000	239 000	275 000	381 000	–	477 000	560 000
M30	561	185 000	224 000	236 000	280 000	292 000	337 000	466 000	–	583 000	684 000
M33	694	229 000	278 000	292 000	347 000	361 000	416 000	576 000	–	722 000	847 000
M36	817	270 000	327 000	343 000	408 000	425 000	490 000	678 000	–	850 000	997 000
M39	976	322 000	390 000	410 000	488 000	508 000	586 000	810 000	–	1 020 000	1 200 000

[1] Where no thread pitch is indicated in a thread designation, coarse pitch is specified. (see ISO 261 and ISO 262).
[2] For structural bolting the values are 70 000, 95 500 and 130 000 N, respectively.
[3] Entsprechen nicht den Prüfkräften nach ISO 898 part 1

Minimum ultimate tensile loads[3] – ISO metric (fine) threads ISO 898 / 1

Thread	Nominal stress area A_s mm²	Property class									
		3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9
		Minimum ultimate tensile load ($A_s \cdot R_m$) in N									
M 8 x 1	39,2	12 900	15 700	16 500	19 600	20 400	23 500	31 360	35 300	40 800	47 800
M10 x 1	64,5	21 300	25 800	27 100	32 300	33 500	38 700	51 600	58 100	67 100	78 700
M10 x 1,25	61,2	20 200	24 500	25 700	30 600	31 800	36 700	49 000	55 100	63 600	74 700
M12 x 1,25	92,1	30 400	36 800	38 700	46 100	47 900	55 300	73 700	82 900	95 800	112 400
M12 x 1,5	88,1	29 100	35 200	37 000	44 100	45 800	52 900	70 500	79 300	91 600	107 500
M14 x 1,5	125	41 200	50 000	52 500	62 500	65 000	75 000	100 000	112 000	130 000	152 000
M16 x 1,5	167	55 100	66 800	70 100	83 500	86 800	100 000	134 000	150 000	174 000	204 000
M18 x 1,5	216	71 300	86 400	90 700	108 000	112 000	130 000	179 000	–	225 000	264 000
M20 x 1,5	272	89 000	109 000	114 000	136 000	141 000	163 000	226 000	–	283 000	332 000
M22 x 1,5	333	110 000	133 000	140 000	166 000	173 000	200 000	276 000	–	346 000	406 000
M24 x 2	384	127 000	154 000	161 000	192 000	200 000	230 000	319 000	–	399 000	469 000
M27 x 2	496	164 000	198 000	208 000	248 000	258 000	298 000	412 000	–	516 000	605 000
M30 x 2	621	205 000	248 000	261 000	310 000	323 000	373 000	515 000	–	646 000	758 000
M33 x 2	761	251 000	304 000	320 000	380 000	396 000	457 000	362 000	–	791 000	928 000
M36 x 3	865	285 000	346 000	363 000	432 000	450 000	519 000	718 000	–	900 000	1 055 000
M39 x 3	1030	340 000	412 000	433 000	515 000	536 000	618 000	855 000	–	1 070 000	1 260 000

Materials, heat treatment, chemical compositions

according to ISO 898, parte 5

Property class	Material and heat treatment	Chemical composition limits (check analysis) % C min.	C max.	P max.	S max.	B[1] max.	Tempering temperature °C min.
3.6[2]	Carbon steel	–	0,20	0,05	0,06	0,003	–
4.6[2]		–	0,55	0,05	0,06	0,003	–
4.6[2]							
5.6		0,13	0,55	0,05	0,06	0,003	–
5.8[2]		–	0,55	0,05	0,06		
6.8[2]							
8.8[3]	Carbon steel with additives (e.g. Boron, Mn or Cr), quenched and tempered	0,15[4]	0,40	0,035	0,035	0,003	425
	or Carbon steel, quenched and tempered	0,25	0,55	0,035	0,035		
9.8	Carbon steel with additives (e.g. Boron, Mn or Cr), quenched and tempered	0,15[4]	0,35	0,035	0,035	0,003	425
	or Carbon steel, quenched and tempered	0,25	0,55	0,035	0,035		
10.9[5), 6)]	Carbon steel with additives (e.g. Boron, Mn oder Cr), quenched and tempered	0,15[4]	0,35	0,035	0,035	0,003	340
10.9[6]	Carbon steel, quenched and tempered	0,25	0,55	0,035	0,035	0,003	425
	or Carbon steel with additives (e.g. Boron, Mn or Cr), quenched and tempered	0,20[4]	0,55	0,035	0,035		
	or Alloyed steel, quenched and tempered[7]	0,20	0,55	0,035	0,035		
12.9[6), 8), 9)]	Alloyed steel, quenched and tempered[7]	0,28	0,50	0,035	0,035	0,003	380

[1] Boron content can reach 0,005 % provided that non-effective boron is controlled by addition of titanium and/or aluminium.
[2] Free cutting steel is allowed for these property classes with the following maximum sulfur, phosphorus and lead contents: sulfur 0,34%, phosphorus 0,11%, lead 0,35%.
[3] For nominal diameters above 20 mm the steels specified for property class 10.9 may be necessary in order to achievesufficient hardenability.
[4] In case of plain carbon boron alloyed steel with a carbon content below 0,25% (ladle analysis), the minimum manganese content shall be 0,6% for property class 8.8 and 0,7% for 9.8 and 10.9.
[5] For products made from these steels, the identification sign indicating the strength class must also be underlined. 10.9 All the properties set out in the table on page **T.**004 for 10.9 must be achieved. However the lower tempering temperature for 10.9 leads to a different response to stress relaxation at higher temperatures.
[6] For the materials of these property classes, it is intended that there should be a sufficient hardenabiltity to ensure a structure consisting of approximately 90% martensite in the core of the threaded sections for the fasteners in the «as-hardened» condition before tempering.
[7] This alloy steel shall contain at least one of the following elements in the minimum quantity given: chromium 0,30%, nickel 0,30%, molybdenum 0,20%, vanadium 0,10%. Where elements are specified in combinations of two, three or four and have alloy contents less than those given above, the limit value to be applied for class determination is 70% of the sum of the individual limit values shown above for the two, three or four elements concerned.
[8] A metallographically detectable white phosphorous enriched layer is not permitted for property class 12.9 on surfaces subjected to tensile stress.
[9] The chemical composition and tempering temperature are under investigation.

Characteristics at elevated temperatures

according to ISO 898, part 1

Continuous operating at elevated service temperature may result in significant stress relaxation. Typically 100 h service at 300 °C will result in a permanent reduction in excess of 25 % of the initial clamping load in the bolt due to decrease in yield stress.

Property class	Temperature + 20 °C	+ 100 °C	+ 200 °C	+ 250 °C	+ 300 °C
	Lower yield stress, R_{eL} or stress at 0,2% non-proportional elongation [N/mm²]				
5.6	300	270	230	215	195
8.8	640	590	540	510	480
10.9	940	875	790	745	705
10.9	940	–	–	–	–
12.9	1100	1020	925	875	825

Mechanical properties of nuts with coarse (standard) threads
according to ISO 898, part 2

Nuts
Property classes
04 to 12

Thread-Ø		Property class														
		04			05			4			5			6		
		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV	
over	to	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.
—	M 4										520			600		
M 4	M 7							—	—	—	580			670		
M 7	M10	380			500						590	130		680	150	
M10	M16		188	302		272	353				610		302	700		302
M16	M39							510	117	302	630	146		720	170	

Thread-Ø		Property class														
		8			9			10			12					
		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV		Proof stress Sp	Vickers hardness HV	
over	to	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.	N/mm²	min.	max.
—	M 4	800	180		900	170		1040			1140			1150		
M 4	M 7	855		302	915			1040			1140	295[1]	535[1]	1150	272[2]	353[2]
M 7	M10	870	200		940		302	1040			1140			1160		
M10	M16	880			950	188		1050	272	353	1170			1190		
M16	M39	920	233	353	920			1060			—	—	—	1200		

1) Nuts style 1 (ISO 4032)
2) Nuts style 2 (ISO 4033)

Remarks
The minimum hardness values are binding only for nuts for which a test stress measurement cannot be performed and for hardened and tempered nuts. The minimum values are guide values for all other nuts.

Minimum bolt stress when stripping occurs for nuts with nominal height ≥ 0,5 d < 0,8 d according to ISO 898, part 2

The standard values for strip resistance relate to the given bolt classes. The exterior thread may be expected to strip if the nuts are paired with screws of lover property classes, while the thread of the nut will strip if it is paired with screws of higher property classes.

Property class of nut	Proof load stress of the nut	Minimum stress in the core of bolt when stripping occurs for bolts with porperty class N/mm²			
	N/mm²	6.8	8.8	10.9	12.9
04	380	260	300	330	350
05	500	290	370	410	480

Test loads for nuts

according to ISO 898, part 2

Thread[1)]	Stressed cross-section of the test mandrel *As*	Property class										
		04	05	4	5	6	8		9	10	12	
		Test load (*As* x Sp), N										
	mm²	–	–	Typ 1	Typ 1	Typ 1	Typ 1	Typ 2	Typ 2	Typ 2	Typ 2	Typ 2
M 3	5,03	1910	2500	–	2600	3000	4000	–	4500	5200	5700	5800
M 3,5	6,78	2580	3400	–	3550	4050	5400	–	6100	7050	7700	7800
M 4	8,78	3340	4400	–	4550	5250	7000	–	7900	9150	10000	10100
M 5	14,2	5400	7100	–	8250	9500	12140	–	13000	14800	16200	16300
M 6	20,1	7640	10000	–	11700	13500	17200	–	18400	20900	22900	23100
M 7	28,9	11000	14500	–	16800	19400	24700	–	26400	30100	32900	33200
M 8	36,6	13 900	18300	–	21600	24900	31800	–	34400	38100	41700	42500
M10	58,0	22000	29000	–	34200	39400	50500	–	54500	60300	66100	67300
M12	84,3	32000	42200	–	51400	59000	74200	–	80100	88500	98600	100300
M14	115	43700	57500	–	70200	80500	101200	–	109300	120800	134600	136900
M16	157	59700	78500	–	95800	109900	138200	–	149200	164900	183700	186800
M18	192	73000	96000	97900	121000	138200	176600	170900	176600	203500	–	230400
M20	245	93100	122500	125000	154000	176400	225400	218100	225400	259700	–	294000
M22	303	115100	151500	154500	190900	218200	278800	269700	278800	321200	–	363600
M24	353	134100	176500	180000	222400	254200	324800	314200	324800	374200	–	423600
M27	459	174400	229500	234100	289200	330500	422300	408500	422300	486500	–	550800
M30	561	213200	280500	286100	353400	403900	516100	499300	516100	594700	–	673200
M33	694	263700	347000	353900	437200	499700	638500	617700	638500	735600	–	832800
M36	817	310500	408500	416700	514700	588200	751600	727100	751600	866000	–	980400
M39	976	370900	488000	497800	614900	702700	897900	868600	897900	1035000	–	1171000

1) If the description of the thread does not include thread pitch then the reference is to coarse threads (see ISO 261 and ISO 262).

Test loads for nuts 0,8 d

according to DIN 267, part 4

Nuts with test loads above 350000 N (values below the stage lines shown) can be excluded from a test load trial. The buyer and the manufacturer must agree minimum hardnesses for these particular nuts.

Thread[1)]	Stressed cross-section of the test mandrel As	Property class (code number)					
		4	5	6	8	10	12
	mm²	Test load (*As* x Sp), N					
M 3	5,03	–	2500	3000	4000	5000	6000
M 3,5	6,78	–	3400	4050	5400	6800	8150
M 4	8,78	–	4400	5250	7000	8750	10500
M 5	14,2	–	7100	8500	11400	14200	17000
M 6	20,1	–	10000	12000	16000	20000	24000
M 7	28,9	–	14500	17300	23000	29000	34700
M 8	36,6	–	18300	22000	29000	36500	43000
M10	58,0	–	29000	35000	46000	58000	69500
M12	84,3	–	42100	50500	67000	84000	10000
M14	115	–	57500	69000	92000	115000	138000
M16	157	–	78500	94000	126000	157000	188000
M18	192	76800	96000	115000	154000	192000	230000
M20	245	98000	122000	147000	196000	245000	294000
M22	303	121000	151000	182000	242000	303000	364000
M24	353	141000	176000	212000	282000	353000	423000
M27	459	184000	230000	276000	367000	459000	550000
M30	561	224000	280000	336000	448000	561000	673000
M33	694	277000	347000	416000	555000	694000	833000
M36	817	327000	408000	490000	653000	817000	980000
M39	976	390000	488000	585000	780000	976000	1170000

1) If the designation of the thread does not indicate thread pitch then the reference is to coarse threads (see DIN 13).

Chemical compositions of nuts

according to ISO 898, part 2

Nuts
Property classes
04 to 12

Property class		Chemical composition in terms of % by weight (check analysis)			
		C	Mn	P	S
		max.	min.	max.	max.
4[1], 5[1], 6[1]	–	0,50	–	0,060	0,150
8, 9	**04[1]**	0,58	0,25	0,060	0,150
10[2]	**05[2]**	0,58	0,30	0,048	0,058
12[2]	–	0,58	0,45	0,048	0,058

[1] Nuts of these strength classes may be made from automatic steel, unless other arrangements have been agreed upon between the buyer and the supplier. When using automatic steel the following maximum proportions of sulphur, phosphorus and lead are permitted:

sulfur 0,34%
phosphorus 0,11%
lead 0,35%

[2] For these strength classes it may be necessary to add alloys in order to achieve the mechanical properties of the nuts.

Nuts of property classes 05, 8 (style 1 above M16), 10 and 12 must be quenched and tempered.

Mechanical properties
according to ISO 898, part 5

Set screws
Property classes
14 H to 45 H

The mechanical properties apply to grub screws and similar, which are **not subject to tension** and which have threads of diameter from 1.6 to 39 mm, made from unalloyed or alloyed steel.

Mechanical properties			Property class[1)]			
			14 H	**22 H**	**33 H**	**45 H**
Vickers hardness	HV	min.	140	220	330	450
		max.	290	300	440	560
Brinell hardness HB, $F = 30\ D^2$		min.	133	209	314	428
		max.	276	285	418	532
Rockwell hardness	HRB	min.	75	95	–	–
		max.	105	–	–	–
	HRC	min.	–	–	33	45
		max.	–	30	44	53
Surface hardness HV 0,3		max.	–	320	450	580

1) Festigkeitsklasse 14 H, 22 H und 33 H nicht für Gewindestifte mit Innensechskant

For further details of the mechanical properties of set screws please refer to ISO 898 part 5.

Materials, heat treatment and chemical composition
according to ISO 898, part 5

Property class	Material	Heat treatement	Chemical composition in % by weight (random analysis) C max.	C min.	P max.	S max.
14 H	High-carbon steel [1), 2)]	–	0,50	–	0,11	0,15
22 H	High-carbon steel [3)]	quenched and tempered	0,50	–	0,05	0,05
33 H	High-carbon steel [3)]	quenched and tempered	0,50	–	0,05	0,05
45 H	Alloy steel [3)], [4)]	quenched and tempered	0,50	0,19	0,05	0,05

1) Automatic steel with ghe following maximum content of lead, phosphorus and sulphur can be used: Pb = 0,35%, P = 0,11%, S = 0,34%.
2) Case hardening is permitted for square headed grub screws.
3) Steel with Pb max. = 0,35% is permitted.
4) The alloyed steel must contain one or more alloy element: chrome, nickel, molybdenum, vanadium or boron.

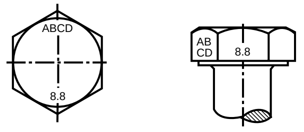
Other steels may also be used for strength class 45H, if the grub screws satisfy the requirements of the tightening test in ISO 898 part 5.

Marking of screws
according to ISO 898, part 1

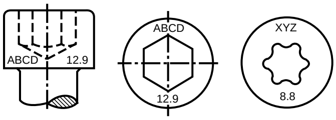
Property class	**3.6**	**4.6**	**4.8**	**5.6**	**5.8**	**6.8**	**8.8**	**9.8**	**10.9**[2]	**12.9**
Marking[1]	3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9

[1] The full-stop in the marking symbol may be omitted.
[2] When low carbon martensitic steels are used for property class 10.9 (see table on page **T.**006), the symbol 10.9 shall be underlined: 10.9

Identification with the manufacturer's mark and the property class is mandatory for hexagon screws 3.6 to 12.9 and sockethead cap screws 8.8 to 12.9 with thread diameter d ≥ 5 mm, where the shape of the screw always allows (it – preferably on the head).



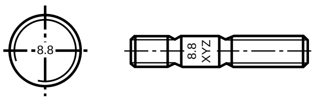
Examples of marking on hexagon screws



Examples of marking on socket head cap screws and hexalobular head bolts and screws.

Marking of studs
according to ISO 898, part 1

Marking is obligatory for property classes of or higher than 8.8 and is preferably to be made on the threaded part by an indentation. For adjustment bolts with locking, the marking must be on the side of the nut.
Marking is required for bolts of nominal diameter of or greater than 5 mm.

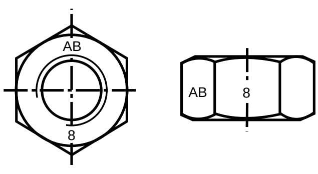


The symbols shown in the table on the right are also autorised as a method of identification.

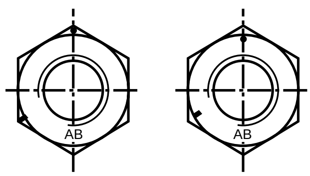
Property class	**5.6**	**8.8**	**9.8**	**10.9**	**12.9**
Marking symbol	▬	○	+	□	△

Marking of nuts
according to ISO 898, part 2

Identification with the manufacturer is mark and property class is mandatory for hexagon nuts with thread diameter d ≥ 5 mm. The´hexagon nuts must be marked with an indentation on the bearing surface or on the side or by embossing on the chamfer. Embossed markings must not protrude beyond the bearing surface of the nut.



Example of marking with the property class designation

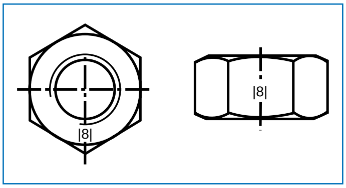


Example of marking with the code symbol (clock-face system)

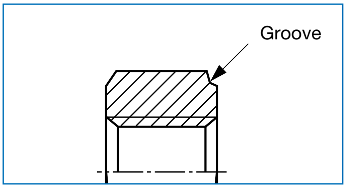
Marking of nuts
according DIN 267, part 4

Property class	Characteristic	4	5	6	8	10	12
	Indentification mark	|4|	|5|	|6|	|8|	|10|	|12|

Hexagon nuts with nominal thread diameter d ≥ 5 mm must be marked with the property class on the bearing surface or on the side. Embossed markings must not protrude beyond the bearing surface of the nut.



For hexagon nuts with nominal thread diameter d ≥ 5 mm acc. to DIN 934 and DIN 935 made from free-cutting steel, the marking must also include a groove on one chamfer of the nut (up to property class 6).



Pairing scrwes and nuts ≥ 0,8 d
according to ISO 898, part 2

Assignment of possible property classes of screws and nuts

Property class of nut	Mating bolts		Nuts	
			Typ 1	Typ 2
	Property class	Diameter range	Diameter range	
4	3.6 4.6 4.8	> M16	> M16	–
5	3.6 4.6 4.8	≤ M16	≤ M39	–
	5.6 5.8	≤ M39		
6	6.8	≤ M39	≤ M39	–
8	8.8	≤ M39	≤ M39	> M16 ≤ M39
9	9.8	≤ M16	–	≤ M16
10	10.9	≤ M39	≤ M39	–
12	12.9	≤ M39	≤ M16	≤ M39

Remark: In general, nuts of a higher property class are preferable to nuts of a lower property class. This is advisable for a bolt / nut assembly stressed higher than the yield stress or the stress under proof load.

Mechanical properties min. 0,2% yield strength values at increased temperatures

according to DIN EN 10269 (old DIN 17240)

Material abbreviation Name	Material number	Diameter range d [mm]	Tensile strenght R_m [N/mm²]	Elongation at facture $A_{min.}$ [%]	notch bar impact value $KV_{min.}$ [J]	Minimum value for the 0,2% limit $R_{p0,2}$ at N/mm² at a temperature [° C] of 20	100	200	300	400	500	600
hardened and tempered steels												
C35E	1.1181	d ≤ 60	500 to 650	22	55	300	270	229	192	173		
35B2	1.5511	d ≤ 60	500 to 650	22	55	300	270	229	192	173		
42CrMo4	1.7225	d ≤ 60	860 to 1060	14	50	730	702	640	562	475	375	
40CrMoV4-7	1.7711	d ≤ 100	850 to 1000	14	30	700	670	631	593	554	470	293
X22CrMoV12-1	1.4923	d ≤ 160	800 to 950	14	27	600	560	530	480	420	335	
X19CrMoNbVN11-1	1.4913	d ≤ 160	900 to 1050	12	20	750	701	651	627	577	495	305
work-hardened austenitic steels												
X5CrNi18-10	1.4301	d ≤ 35	700 to 850	20	80	350	155	127	110	98	92	
X5CrNiMo17-12-2	1.4401	d ≤ 35	700 to 850	20	80	350	175	145	127	115	110	
X5NiCrTi26-5	1.4980	d ≤ 160	900 to 1150	15	50	600	580	560	540	520	490	430

Typical values for thickness and static modulus of elasticity

according to DIN EN 10269 (old DIN 17240)

Material abbreviation Name	Material number	Density d [Kg/dm³]	Static modulus of elasticity E in kN/mm² at a temperature [°C] of 20	100	200	300	400	500	600
hardened and tempered steels									
C35E 40CrMoV4-7	1.1181 1.7711	7,85	211	204	196	186	177	164	127
X19CrMoNbVN11-1 X22 CrMoV12-1	1.4913 1.4923	7,7	216	209	200	190	179	167	127
work-hardened austenitic steels									
X5CrNi18-10 X5CrNiMo17-12-2	1.4301 1.4401	7,9 8,0	200	194	186	179	172	165	–
X5NiCrTi26-15	1.4980	8,0	211[1]	206[1]	200[1]	192[1]	183[1]	173[1]	162[1]

[1] Dynamic modulus of elasticity

Typical values for the coefficient of thermal expansion, thermal conductivity and heat capacity

excerpt from DIN EN 10269 (old DIN 17240)

Material abbreviation Name	Material number	Coefficient of thermal expansion in 10^{-6} / K between 20 °C and 100 °C	200 °C	300 °C	400 °C	500 °C	600 °C	Thermal conductivity at 20 °C $\frac{W}{m \cdot K}$	Specific thermal conductivity at 20 °C $\frac{J}{kg \cdot K}$
hardened and tempered steels									
C35E 40CrMoV4-7	1.1181 1.7711	11,1	12,1	12,9	13,5	13,9	14,1	42 33	460
work-hardened austenitic steels									
X5CrNi18-10 X5CrNiMo17-12-2	1.4301 1.4401	16,0	16,5	17,0	17,5	18,0	n.a.	15	500
X5NiCrTi26-15	1.4980	17,0	17,5	17,7	18,0	18,2	n.a.	n.a.	n.a.

Table of materials for temperature over +300 °C

according to DIN 267, part 13

Material abbreviation	Material number	Marking	Utilisation temperatur limits
C 35 N oder C 35 V	1.0501	Y	+350 °C
Ck 35	1.1181	YK	+350 °C
35 B 2	1.5511	YB	+350 °C
24 CrMo 5	1.7258	G	+400 °C
21 CrMoV 5 7	1.7709	GA	+540 °C
40 CrMoV 4 7	1.7711	GB	+500 °C
X 22 CrMoV 12 1	1.4923	V, VH	+580 °C
X 19 CrMoVNbN 11 1	1.4913	VW	+580 °C
X 8 CrNiMoBNb 16 16	1.4986	S	+650 °C
X 5 NiCrTi 26 15	1.4980	SD	+650 °C
NiCr20 TiAl	2.4952	SB	+700 °C

Table of materials for low temperatures from –200 °C to –10 °C

according to DIN 267, part 13

Material abbreviation	Material number	Marking	Utilisation temperatur limits
26 CrMo4	1.7219	KA	– 60 °C
12 Ni 19	1.5680	KB	–120 °C
X 5 CrNi 18 10	1.4301	A2	–200 °C
X 5 CrNi 18 12	1.4303	A2	–200 °C
X 6 CrNiTi 18 10	1.4541	A2	–200 °C
X 5 CrNiMo 17 12 2	1.4401	A4	[1] – 60 °C [2] –200 °C
X 6 CrNiMo Ti 17 12 2	1.4571	A4	[1] – 60 °C [2] –200 °C

[1] Screws with head. As a result of the molybdenum content when below the temperature shown these can no longer be expected to have a homogenous austenitic micro-structure.
[2] Screw without head.

For strength values see pictures on page T.015 **T.**015

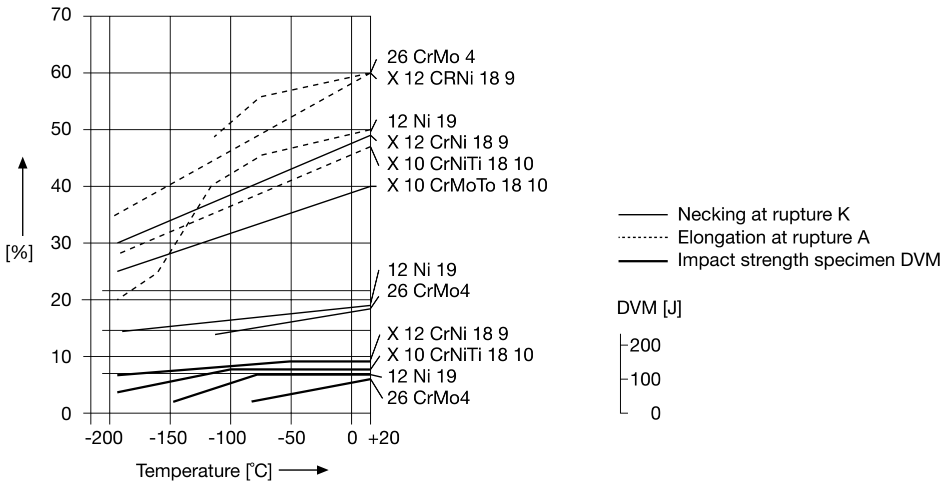
Pairing materials for screws and nuts

from heat-resistant, high-temperature resistant and sub-zero resistant steels according to DIN 267, part 13

Material	
Screw	**Nut**
Ck 35 35 B 2	C 35 N, C 35 V, Ck 35, 35 B 2
24 CrMo 5	Ck35, 35 B 2, 24 CrMo 5
21 CrMoV 5 7	24 CrMo 5 21 CrMoV 5 7
40 CrMoV 4 7	21 CrMoV 5 7
X 22 CrMoV 12 1 X 19 CrMoVNbN 11 1	X 22 CrMoV 12 1
X 8 CrNiMoBNb 16 16	X 8 CrNiMoBNb 16 16
X 5 NiCrTi 26 15	X 5 NiCrTi 26 15
NiCr 20 TiAl	Ni Cr 20 TiAl

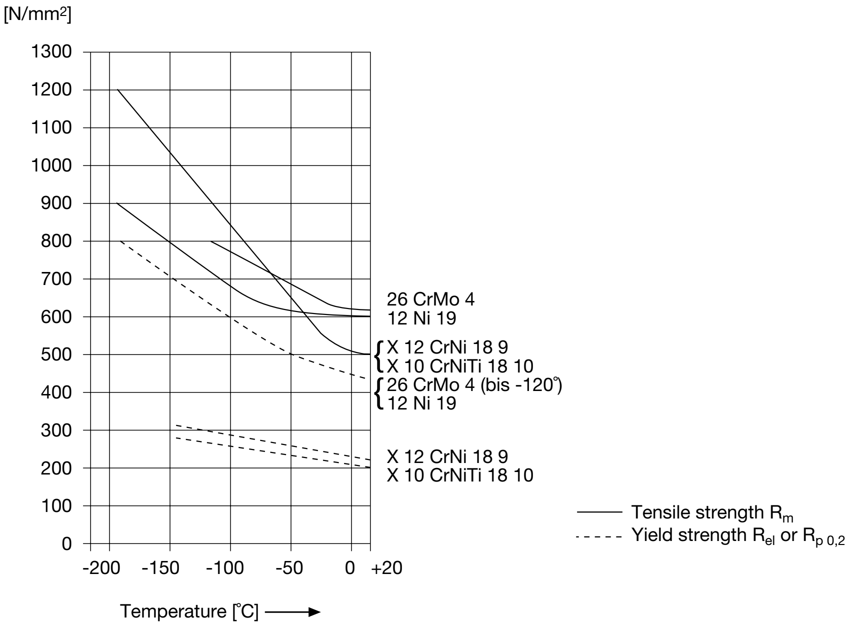
Ductility of steels at low temperatures

according to manufacurer's specifications



Yield strength and tensile strength of steels at low temperatures

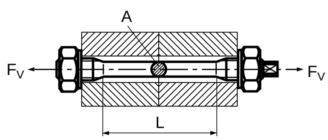
according to manufacurer's specifications



Elastic elongation of bolts with reduced shanks

according to DIN 2510

Materials	YK	G	GA	GB	V	VW	S	SB
	Overview of material **T.**014							
L = [mm]	Elastic elongation λ in [mm] prestressed up to approx. 70% of yield stress at room temperature							
60	0,056	0,088	0,109	0,139	0,116	0,152	0,107	0,116
70	0,065	0,102	0,127	0,162	0,136	0,177	0,125	0,136
80	0,074	0,117	0,146	0,186	0,155	0,202	0,143	0,155
90	0,084	0,131	0,164	0,209	0,175	0,228	0,161	0,175
100	0,093	0,146	0,182	0,232	0,194	0,253	0,179	0,194
110	0,102	0,161	0,2	0,255	0,213	0,278	0,197	0,213
120	0,112	0,175	0,218	0,278	0,233	0,304	0,215	0,233
130	0,121	0,19	0,237	0,302	0,252	0,329	0,233	0,252
140	0,13	0,204	0,255	0,325	0,272	0,354	0,251	0,272
150	0,140	0,291	0,273	0,348	0,291	0,28	0,269	0,291
160	0,149	0,234	0,291	0,371	0,31	0,405	0,286	0,31
170	0,158	0,248	0,309	0,394	0,33	0,43	0,304	0,33
180	0,167	0,263	0,328	0,418	0,349	0,455	0,322	0,349
190	0,177	0,277	0,346	0,441	0,369	0,481	0,34	0,69
200	0,186	0,292	0,364	0,464	0,388	0,506	0,358	0,388
210	0,195	0,307	0,382	0,487	0,407	0,531	0,376	0,407
220	0,205	0,321	0,4	0,51	0,427	0,557	0,394	0,427
230	0,214	0,336	0,419	0,534	0,446	0,582	0,412	0,446
240	0,223	0,35	0,437	0,557	0,466	0,607	0,43	0,466
250	0,233	0,365	0,455	0,58	0,485	0,633	0,448	0,485
260	0,242	0,38	0,473	0,603	0,504	0,658	0,465	0,504
270	0,251	0,394	0,491	0,626	0,524	0,683	0,483	0,524
280	0,26	0,409	0,51	0,65	0,543	0,708	0,501	0,543
290	0,27	0,423	0,528	0,673	0,563	0,734	0,519	0,563
300	0,279	0,438	0,546	0,696	0,582	0,759	0,537	0,582
E [103 N/mm2]	211	211	211	211	216	216	196	216



Length of reduced shank

Calculation

$$\lambda = \frac{F_V \cdot L}{E \cdot A} \text{ [mm]}$$

λ [mm] = elastic elongation under preload F_V

F_V [N] = preload

E [N/mm²] = elasticity module

A [mm²] = cross section area of reduced shank

L [mm] = reduced shank length

where:

$$0{,}7 \frac{F_V}{A} = 70\% \text{ de } R_{p\,0,2}$$

Example

X 8 CrNiMoBNb 16 16 = [S]

$R_{p\,0,2}$ = 500 N/mm²

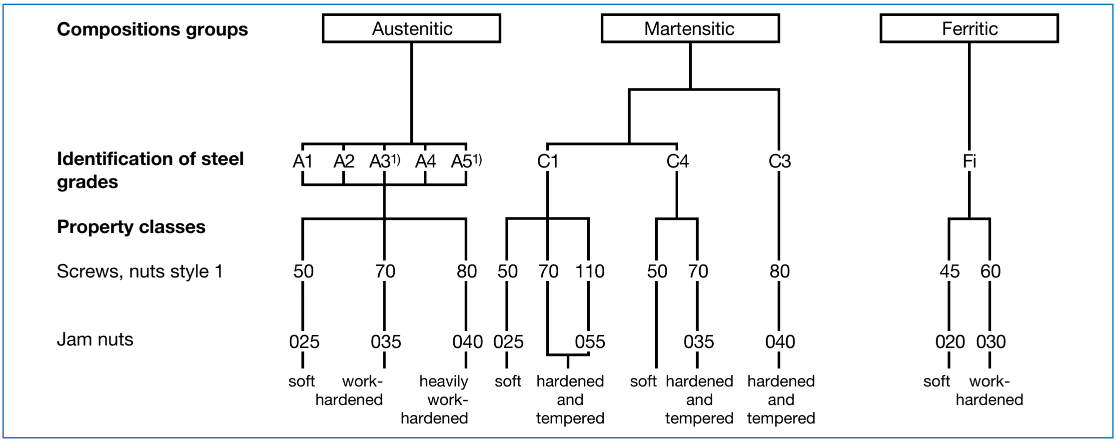
length of reduced shank L = 220 mm

Elastic elongation

$$\lambda = 0{,}7 \cdot 500 \frac{220}{196000} = 0{,}394 \text{ mm}$$

see table, column S for L = 220 mm

Designation of property classes
according to ISO 3506



Descriptions using a letter/figure combination mean the following:

A2 – 70

Abbreviation of composition group:
A = austenitic chromium-nickel steel

Abbreviation of chemical composition:
1 = free-cutting steel with sulphur additive
2 = cold-heading steel alloyed with chromium and nickel
3 = cold-heading steel alloyed with chromium and nickel stabilised with Ti, Nb, Ta
4 = cold-heading steel alloyed with chromium, nickel and molybdenum
5 = cold-heading steel alloyed with chromium, nickel and molybdenum stabilised with Ti, Nb, Ta

Abbreviation of property class:
50 = 1/10 of tensile strength (min. 500 N/mm²)
70 = 1/10 of tensile strength (min. 700 N/mm²)
80 = 1/10 of tensile strength (min. 800 N/mm²)

Flat nuts:
025 = proof stress min. 250 N/mm²
035 = proof stress min. 350 N/mm²
040 = proof stress min. 400 N/mm²

Chemical composition of austenitic stainless steels
according to ISO 3506

More than 97% of all fasteners made from stainless steels are produced from this steel composition group. They are characterised by impressive corrosion resistance and excellent mechanical properties.

Austenitic stainless steels are divided into 5 main groups whose chemical compositions are as follows:

Steel group	Chemical composition in % (maximum values, unless otherwise indicated, rest iron (Fe))								
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
A1	0,12	1,0	6,5	0,200	0,15–0,35	16–19	0,7	5–10	1,75–2,25
A2	0,10	1,0	2,0	0,050	0,03	15–20	–	8–19	4
A3[1]	0,08	1,0	2,0	0,045	0,03	19–19	–	9–12	1
A4	0,08	1,0	2,0	0,045	0,03	16–18,5	2–3	10–15	1
A5[1]	0,08	1,0	2,0	0,045	0,03	16–18,5	2–3	10,5–14	1

1) stabilised against intergranular corrosion through addition of titanium, possibly niobium, tantalum

Chemical composition of rust-resisiting stainless steel

Material number	Chemical composition, % by mass								
	C	Si max.	Mn max.	P max.	S max.	Cr	Mo	Ni	Other
Martensitic steels									
1.4006	0,08 to 0,15	1,0	1,5	0,04	0,030	11,0 to 13,5		max. 0,75	
1.4034	0,43 to 0,50	1,0	1,0	0,04	0,030	12,5 to 14,5			
1.4105	max. 0,08	1,0	1,5	0,04	0,035	16,0 to 18,0	0,20 to 0,60		
1.4110	0,48 to 0,60	1,0	1,0	0,04	0,015	13,0 to 15,0	0,50 to 0,80		V max. 0,15
1.4116	0,45 to 0,55	1,0	1,0	0,04	0,030	14,0 to 15,0	0,50 to 0,80		V 0,10 to 0,20
1.4122	0,33 to 0,45	1,0	1,5	0,04	0,030	15,5 to 17,5	0,80 to 1,30	max. 1,0	
Austenitic steels									
1.4301	max. 0,07	1,0	2,0	0,045	0,030	17,0 to 19,5		8,0 to 10,5	N max. 0,11
1.4305	max. 0,10	1,0	2,0	0,045	0,15 to 0,35	17,0 to 19,0		8,0 to 10,0	Cu max. 1,00 / N max. 0,11
1.4310	0,05 to 0,15	2,0	2,0	0,045	0,015	16,0 to 19,0	max. 0,80	6,0 to 9,5	N max. 0,11
1.4401	max. 0,07	1,0	2,0	0,045	0,030	16,5 to 18,5	2,00 to 2,50	10,0 to 13,0	
1.4435	max. 0,03	1,0	2,0	0,045	0,030	17,0 to 19,0	2,50 to 3,00	12,5 to 15,0	N max. 0,11
1.4439	max. 0,03	1,0	2,0	0,045	0,025	16,5 to 18,5	4,00 to 5,00	12,5 to 14,5	N 0,12 to 0,22
1.4529	max. 0,02	0,5	1,0	0,030	0,010	19,0 to 21,0	6,00 to 7,00	24,0 to 26,0	N 0,15 to 0,25 / Cu 0,5 to 1,5
1.4539	max. 0,02	0,7	2,0	0,030	0,010	19,0 to 21,0	4,00 to 5,00	24,0 to 26,0	N max. 0,15 / Cu 1,2 to 2,0
1.4462	max. 0,03	1,0	2,0	0,035	0,015	21,0 to 23,0	2,50 to 3,50	4,5 to 6,5	N 0,10 to 0,22
1.4568	max. 0,09	0,7	1,0	0,040	0,015	16,0 to 18,0		6,5 to 7,8	Al 0,70 to 1,50
1.4571	max. 0,08	1,0	2,0	0,045	0,030	16,5 to 18,5	2,00 to 2,50	10,5 to 13,5	Ti 5xC ≤ 0,70

Distinctive properties A1 / A2 / A3 / A4 / A5

Material designation	**A1**	**A2**	**A3**	**A4**	**A5**
Material number	1.4300 1.4305	1.4301 1.4303 1.4306	1.4541 1.4590 1.4550	1.4401 1.4435 1.4439	1.4436 1.4571 1.4580
Properties	for machining – rust-resistant to a certain degree – acid-resistant to a certain degree – weldable to a certain degree	**Standard quality** – rust-resistant – acid-resistant – weldable to a certain degree		Highest resistance to corrosion – rust-resistant – highly acid-resistant – easily weldable	
	A3, A5: as A2, A4 but stabilised against intergranular corrosion follwong welding, annealing or when used at high temperatures.				

Further details on the chemical stability of rust-resistant and acid-resistant steels can be found on page **T.**021

Mechanical properties for fasteners made from austenitic stainless steel
according to ISO 3506

Steel group	Steel grade	Property class of screw	Thread diameter range	Screws		
				Tensile strength R_m[1)] N/mm² min.	Stress at 0,2% permanent strain $R_{p\,0,2}$[1)] N/mm² min.	Elongation after fracture A[2)] mm min.
Austenitic	A1, A2	50	≤ M 39	500	210	0,6 d
	A3, A4	70	≤ M 24[3)]	700	450	0,4 d
	A5	80	≤ M 24[3)]	800	600	0,3 d

Steel group	Steel grade	Property class of nuts		Nuts		
				Thread diameter range	Stress under proof load S_P N/mm² min.	
		Nuts style 1 m ≥ 0,8 d	thin nuts 0,5 d ≤ m < 0,8 d	d mm	Nuts style 1 m ≥ 0,8 d	thin nuts 0,5 d ≤ m < 0,8 d
Austenitic	A1	50	025	≤ 39	500	250
	A2, A3	70	035	≤ 24[3)]	700	350
	A4, A5	80	040	≤ 24[3)]	800	400

m = nut height
d = nominal thread diameter

The standard commercial quality covers strength classes A2–70, A4–70 (tensile strength of 700 N/mm²), the range of diameters M5–M24 and for lengths up to 8x thread-ø (8xd).
We keep a wide range available for you from stock.

Use of screws of strength class 80 is only economically justifiable if the components are made from stainless steel (high strength).

[1)] All values are calculated values and refer to the stressed cross-section of the thread.
[2)] The elongation under fracture is to be determined for the whole screw and not for unscrewed test pieces.
[3)] Strength requirements for diameters above M24 must be specially agreed on between the buyer and the manufacturer.

Minimum breaking torque $M_{B\min.}$, for screws made from austenitic steel with threads M1,6 to M16 (normal thread)
according to ISO 3506

Threads	Minimum breaking torque $M_{B,\,min.}$ Nm — Property class		
	50	70	80
M 1,6	0,15	0,2	0,24
M 2	0,3	0,4	0,48
M 2,5	0,6	0,9	0,96
M 3	1,1	1,6	1,8
M 4	2,7	3,8	4,3
M 5	5,5	7,8	8,8
M 6	9,3	13	15
M 8	23	32	37
M10	46	65	74
M12	80	110	130
M16	210	290	330

Elongation limit $R_{p\,0,2}$ at elevated temperatures as % of the values at room temperature
according to ISO 3506

Steel grade	R_{eL} and $R_{p0,2}$ in %			
	+100 °C	+200 °C	+300 °C	+400 °C
A2, A4	85%	80%	75%	70%
applies for property classes 70 and 80				

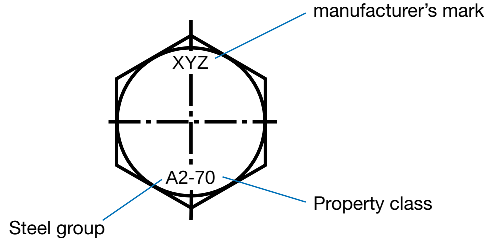
For applicability at low temperature see page **T**.014.

Marking of screws and nuts according to ISO 3506

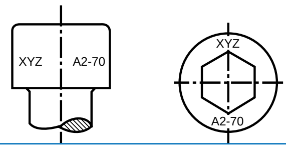
Requirement
Screws and nuts made from stainless austenitic steels mustbe marked.

Screws
Hexagon and hexagon socket screws from nominal diameter M5 must be marked. The marking must show the steel group, the property class and the manufacturer's mark. Locking screws must be marked on the shaft or screw end.

Hexagon screws

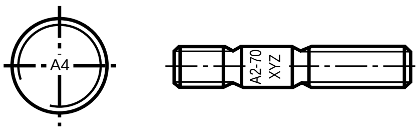


Socket head cap screws



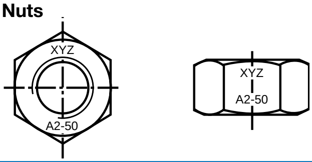
Studs
Bolts from nominal diameter M6 must be marked on theshank or the end of the thread with the steel group, the property class and the manufacturer's mark.

Studs

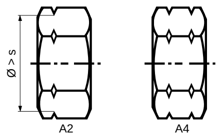


Nuts
Nuts from minimal diameter M5 must be marked with the steel group, the property class and the manufacturer's mark.

Nuts



Alternative groove marking



Caution!

Only those fasteners marked to standard will have the desired properties.
Products not marked to standard will often only correspond to property classes A2–50 or A4–50.

Chemical stability

based on information provieded by the to manufacturer's

Austenitic steels A1, A2 and A4 obtain their resistance to corrosion through a surface protective layer of oxide. If this is damaged it uses atmospheric oxygen to regenerate itself. If access to atmospheric oxygen is blocked by an unfavourable style of construction or through dirt, then even these steels will corrode!

General rules:

- **A2** above water, inland climate
- **A4** under water, coastal climate
- **A1** this steel contains small particles of sulphur, which gives it a good machinability. Its resistance to corrosion is lower than that of A2.

Please avoid: Cracks, separation joints, pockets of water, poor ventilation, layers of dirt

The resistance to corrosion can be reduced in the presence of a coating (prevents access to the air), or chemical blackening or a roughening of the surface.

Media containing chlorine can under certain conditions lead to dangerous inter-crystalline corrosion. This is often very difficult to see from the outside, and can lead to a sudden failure of the steel part.

ISO standard 3506 defines rust and acid-resistant steels. It also contains details of their mechanical properties, chemical composition and a number of notes on the selection of the right steel for high and low temperature applications.

The reference data with respect to corrosion resistance

Indications on resistance to corrosion are preferably obtained from laboratory and practical trials!

Ask for information on our **«Boss-Analysis»** service.

Martinistic chrome steels (e.g. 1.4110, 1.4116, 1.4112) are normally used for rust-resistant retaining rings and washers. The corrosion resistance of these steels is lower than that of austenitic chrome-nickel steels.

Recent experience indicates that there is a risk of stress corrosion cracking. In order to reduce this risk the depth of the nuts can be selected so that the fitted rings are not subjected to stress. This will reduce their load-bearing capacity.

Technical arguments

for the use of fasteners made from rust-resistant austenitic chrome-nickel steels A1, A2, A4.

Advantages	Avoidance of potential problems
Bright-finished surface, good appereance	Rusty screws create a bad impression. The customer loses trust in the product.
Savety	Corrosion reduces the strength and operational reliability of the fasteners. They become weak points.
No traces of rust	Red rust can discolour white-coloured plastic components and textiles and make them unusable.
No risk to health	Cutting yourself on a rusty part can lead to blood poisoning.
Food grade material	Parts made from zinc-coated steel must not be allowed to come into contact with foodstuffs.
Lick-resistant	Small children must not be able to get within reach of and lick small, zinc-coated or cadmium-coated parts.
Easy to clean and hygienic	Products or efflorescences caused by corrosion can build up on bright-polished or zinc-coated fasteners which then become difficult to remove.
Austenitic chrome-nickel steel is almost entirely non-magnetic	Magnetic fasteners used in the construction of types of apparatus or measuring devices can lead to disruptions. Magnetic parts attract iron filings. This gives rise to additional problems of corrosion.
Good temperature resistance	At temperatures above 80 °C the chromating on zinc-plated and chrome-plated fasteners is destroyed. The corrosion resistance drops dramatically.
The screw and nuts are bright-polished and so always remain workable.	If the permissible thickness of the coating on galvanically finished screws is exceeded, the parts jam up when being assembled.
No problems during maintenance work	Rusty screws or nuts just cannot be unscrewed. In order to disassemble the unit the fasteners have to be destroyed, and this involves considerable force and effort. This often results in damage to the parts.

Properties of screws and nuts made from alluminium alloys selection based on information provided by the manufacturers

The values in the table are for: density = 2,8 kg/dm³, coefficient of thermal expansion = 23,6 · 10^{-6} · K^{-1}, modulus of elasticity = 70000 N/mm²

Material designation EN AW-	Material number EN AW-	Old DIN designation Material number	from EN 28839	Stage of preparation of the screws / nuts		$R_{p\,0,2}$ N/mm²	R_m N/mm²	A_S %	Used for
Al Mg5	5019	3.3555	AL 2	soft work hardened	< M14 M14 / M20	205 200	310 280	6 6	very good level of corrosion-resistance low strength
Al Si1 Mg Mn	6082	3.2315	AL 3	hardened T6	< M6 M6 / M20	260 250	320 310	7 10	very good level of corrosion-resistance medium strength
Al Mg1 Si 0,8 Cu Mn	6013	–	–	hardened T8	< M20	370	400	10	still a good level of corrosion-resistance high strength
Al Cu4 Mg Si	2017 A	3.1325	AL 4	hardened T6 (F 42)	< M20	290	420	6	high strength mountings but lowest level of corrosion resistance *)
Al Zn6 Cu Mg Zr	7050	3.4144	–	hardened T73 (F 50)	< M30	400	500	6	high strength mountings but lowest level of corrosion resistance
Al Zn5,5 Mg Cu	7075	3.4365	AL 6	hardened T73 (F 51)	< M30	440	510	6	

*) subject to stress corrosion cracking due to the high copper content

Properties of screws an nuts made from copper alloys selection based on information provided by the manufacturer's

Material designation	Material number	Des. from EN 28839	State of structure $F = \frac{R_m}{10}$	Density ρ $\frac{kg}{dm^3}$	Electrical conductivity $\frac{m}{\Omega \cdot mm^2}$	Coefficient of thermal expansion $\frac{mm}{mm \cdot k}$ a 30/100 °C	mechanical properties at 20 °C $R_{p\,0,2}$ N/mm²	R_m N/mm²	$A_{S\,min.}$ %	E-Modul N/mm²	Used for
E-Cu 58 **OF-Cu**	2.0065 2.0040	Cu 1	F20 soft F20 kaltv.	8,94	58,0 56,0	17,0 · 10^{-6}	<150 <320	200 / 270 >350	40 7	110 000	parts with a high electrical conductivity
CuZn 37 **(brass)**	2.0321 · 10 2.0321 · 26	Cu 2	F29 soft F37 kaltv.	8,44	15,5	20,2 · 10^{-6}	<250 >250	>290 >370	45 27	110 000	normal fastenings
CuNi12 Zn24 **(nickel silver)**	2.0730 · 10 2.0730 · 30	–	F34 soft F54 soft	8,67	4,4	18,0 · 10^{-6}	<290 >440	330 / 440 540 / 640	40 8	125 000	very good corrosion resistant silver colours
CuNi1,5Si **CuNi3Si**	2.0853 · 73 2.0857 · 73	Cu 5 –	hardened hardened	8,8	> 18,0 > 15,0	16,0 · 10^{-6}	>540 >780	>540 >830	12 10	140 000 144 000	high-strength fastening, with very good electrical conductivity
CuBe2	2.124 · 75	–	hardened	8,3	~10	16,7 · 10^{-6}	1050/ 1400	1200/ 1500	2	125 000	high-strength fastening, corrosion resistant, good electrical conductivity

Minimum breaking torque for screws up to M5 according to ISO 8839

Threads nominal Ø	CU1	CU2	CU3	CU4	CU5	AL1	AL2	AL3	AL4	AL5	AL6
	Minimum breaking torque[1] [Nm]										
M1,6	0,06	0,10	0,10	0,11	0,14	0,06	0,07	0,08	0,1	0,11	0,12
M2	0,12	0,21	0,21	0,23	0,28	0,13	0,15	0,16	0,2	0,22	0,25
M2,5	0,24	0,45	0,45	0,5	0,6	0,27	0,3	0,3	0,43	0,47	0,5
M3	0,4	0,8	0,8	0,9	1,1	0,5	0,6	0,6	0,8	0,8	0,9
M3,5	0,7	1,3	1,3	1,4	1,7	0,8	0,9	0,9	1,2	1,3	1,5
M4	1	1,9	1,9	2	2,5	1,1	1,3	1,4	1,8	1,9	2,2
M5	2,1	3,8	3,8	4,1	5,1	2,4	2,7	2,8	3,7	4	4,5

Designation of the material: CU1–AL6

[1] the torque test is to be carried out in according to ISO 898-1

Designation Material number	Description and range of application, based on information provided by the manufacturer.
Hastelloy® B B-2 2.4617 B-3 2.4600	Highly corrosion resistant nickel-molybdenum alloy with excellent resistance against reducing media, in particular against all concentrations of hydrochloric acid up to boiling point, moist chlorine water gas, sulphuric acid, phosphoric acid and alkaline solutions. Adequate resistance to oxidising and reducing gases up to 800 °C. No recommended for strongly oxidising agents, iron and copper salts (see Hastelloy C). Application: Components subject to strong chemical action, turbo-superchargers for jet engines etc.
Hastelloy® C C-4 2.4610 C-22 2.4602 C-276 2.4819 C-2000 2.4675	Highly corrosion resistant nickel-chrome-molybdenum alloy with particularly high resistance against aggressive, oxidising and reducing media – bleach solutions which contain free chorine, chlorites, hypochlorites, sulphuric acid and phosphoric acid, organic acids such as vinegar and formic acid, solutions of nitrates, sulphates and sulphites, chlorides and chlorates, chromates and cyanogen compounds. Application: Components subject to strong chemical action, in chemical processes and plants, exhaust cleaning systems, in the production of fibres and paper, waste disposal etc.
Hastelloy® G G-3 2.4619 G-30 2.4603	Nickel-chrome-iron alloy with excellent resistance to corrosion in oxidising media. Application: In chemical process engineering, particularly suitable for the production of phosphoric acid and nitric acid, desulphurization plant etc.
Inconel® 600 2.4816 601 2.4851 625 2.4856 718 2.4668	Nickel-chrome alloy with good industrial properties at high temperatures up to and above 1000°C and an excellent resistance to oxidation. Even resists corrosion from caustic materials. Application: Heat treatment plant, nuclear energy technology, gas turbines, linings, ventilators and fans, chemical industry etc.
Monel® 400 2.4360 K-500 2.4375	Nickel-copper alloy with high strength and toughness over a wide range of temperatures. Excellent resistance to corrosion by salt water and a large number of acids and alkaline solutions. Also suitable for parts used in presses and forges. Application: Valves, pumps, mountings, mechanically stressed components exposed to seawater etc.
Nimonic® 75 2.4951 80A 2.4952 90 2.4969 105 2.4634	The nickel-based chrome materials are alloys with a particularly high fatigue strength and resistance to oxidisation. For high mechanical stresses at temperatures up to 1000 °C. A wide variety of penetration hardening methods allow the relaxation and creep behaviour to be controlled. Application: Rotating components subject to high temperatures, springs, fasteners, combustion chamber components, blades, washers, shafts etc.
Titanium Gr. 1 3.7025 Gr. 2 3.7035 Gr. 3 3.7055 Gr. 4 3.7065	Reactive material with high strength in relation to its low density. Excellent resistance to corrosion in oxidising metals which contain chloride. Application: Components for weight-saving construction requiring high strength, subject to strong oxidising stresses, particularly in the presence of chlorides. Chemical industry, seawater desalination, power station technology, medical technology etc.
Titanium Gr.5 3.7164 / 3.7165	Titanium alloy with a high specific strength. Application: Components for the air and space industries, chemical processing technology, rotating components, fasteners, vehicle engineering etc.
Titanium Gr. 7 3.7235 Gr. 11 3.7225	Pure titanium alloyed with palladium. Increased resistance to corrosion, particularly against moist media which contain chloride. Grade 11 has increased properties of deformation. Application: Chemical and petrochemical plant, housings etc.

Reference values of physical characteristics according to manufacturer's data

Material abbreviation DIN 7728	mechanical properties						
	Density g/cm³ DIN 53479	Tensile strenght N/mm² DIN 53455	Fracture resistance % DIN 53455	Elasticity module N/mm² DIN 53457	Ball penetration harness, 10-sec Value N/mm² DIN 53456	Impact strength kJ/m² DIN 53453	Ductility kJ/m² DIN 53453
PE-HD	0,94 / 0,96	18 / 35	100 / 1000	700 / 1400	40 / 65	without fracture	without fracture
PE-LD	0,914 / 0,928	8 / 23	300 / 1000	200 / 500	13 / 20	without fracture	without fracture
PP	0,90 / 0,907	21 / 37	20 / 800	1100 / 1300	36 / 70	without fracture	3 / 17
POM	1,41 / 1,42	62 / 70	25 / 70	2800 / 3200	150 / 170	100	8
PA 6	1,13	70 / 85	200 / 300	1400	75	without fracture	without fracture
PA 66	1,14	77 / 84	150 / 300	2000	100	without fracture	15 / 20

Material abbreviation DIN 7728	electrical properties									
			Dielectric constant DIN 53483		Dielectric loss factor δ DIN 53483		Dielectric strength		Surface leakage current resistance DIN 53480	
	Specific resistance Ω cm DIN 53482	Surface resistance Ω DIN 53482	50 Hz	10^6 Hz	50 Hz	10^6 Hz	kV / 25 µm ASTM D 149	kV / cm DIN 53481	KA	KB / KC
PE-HD	$> 10^{17}$	10^{14}	2,35	2,34	$2{,}4 \cdot 10^{-4}$	$2{,}0 \cdot 10^{-4}$	> 700	–	3 c	> 600
PE-LD	$> 10^{17}$	10^{14}	2,29	2,28	$1{,}5 \cdot 10^{4}$	$0{,}8 \cdot 10^{-4}$	> 700	–	3 b	> 600
PP	$> 10^{17}$	10^{13}	2,27	2,25	$< 4 \cdot 10^{-4}$	$< 5 \cdot 10^{-4}$	800	500 / 650	3 c	> 600
POM	$> 10^{15}$	10^{13}	3,7	3,7	0,005	0,005	700	380 / 500	3 b	> 600
PA 6	10^{15}	10^{10}	3,8	3,4	0,01	0,03	350	400	3 b	> 600
PA 66	10^{12}	10^{10}	8,0	4,0	0,14	0,08	400	600	3 b	> 600

Material abbreviation DIN 7728	thermal properties							
	Operating temperature °C			Dimensional stability °C				
	max. short therm	max. permanent	min. permanent	VSP (Vicat 5 kg) DIN 53460	ASTM D 648 1,86 / 0,45 N/mm²	Lienear coefficient of expansion $K^{-1} \cdot 10^6$	Thermal conductivitiy W/mK	Specific heat kJ/kg K
PE-HD	90 / 120	70 / 80	– 50	60 / 70	50	200	0,38 / 0,51	2,1 / 2,7
PE-LD	80 / 90	60 / 75	– 50	–	35	250	0,32 / 0,40	2,1 / 2,5
PP	140	100	0 / – 30	85 / 100	45 / 120	150	0,17 / 0,22	2,0
POM	110 / 140	90 / 110	– 60	160 / 173	110 / 170	90 / 110	0,25 / 0,30	1,46
PA 6	140 / 180	80 / 100	– 30	180	80 / 190	80	0,29	1,7
PA 66	170 / 200	80 / 120	– 30	200	105 / 200	80	0,23	1,7

Abbreviation / significance

PE-HD High density polyethylene
PE-LD Low density polyethylene
PP Polypropylene
POM Polymethylene, Polyacetale
PA 6 Polyamide
PA 66 Polyamide

Fasteners of various matrials

Chemical resistance

Material abbreviation	Water, cold	Water, hot	Acids, dilute	Acids, strong	Acids, oxidised	Acid hydrofluoric	Detegrents, weak	Detegrents, strong	Saline solutions	Halogen, dry	EC aliphatic	EC chlorinated	Water absorption, % ASTM D 570
PE-HD	●	●	●	●	○	◐	●	●	●	○	●	◐	< 0,01
PE-LD	●		●	◐	○	◐	●	●	●	○	●	○	< 0,01
PP	●	●	●	◐	○	◐	●	●	●	◐	●	○	0,01 to 0,03
POM	●	●	◐	○	○	○	●	●	●	○	●	●	0,22 to 0,25
PA 6	●	◐	○	○	○	○	●	◐	●	○	●	◐	1,3 to 1,9

Material abbreviation	Alcohol	Ether-salicylic	Cetone	Ether	Aldehydes	Amines	Organic acids	EC aromatic	Fuels	Mineral oils	Greases, oils	EC chlorinated, non-saturated	Turpentine	Water absorption, % ASTM D 570
PE-HD	●	●	●	◐	◐	●	●	◐	◐	●	●	○	○	< 0,01
PE-LD	◐	◐	◐	○			●	○	○	◐	◐	○	○	< 0,01
PP	●	◐	◐	○	●	●	◐	◐	◐	●	●	○	○	0,01 to 0,03
POM	●	○	◐	●	◐	◐	●	◐	●	●	●	●	◐	0,22 to 0,25
PA 6	●	●	●	●	◐	●	◐	●	●	●	○	◐	◐	1,3 to 1,9

● resistant ◐ resistant with reservation ○ inconstant

Abbreviation / significance

PE-HD High density polyethylene
PE-LD Low density polyethylene
PP Polypropylene
POM Polymethylene, Polyacetale
PA 6 Polyamide

Fasteners with galvanic coatings according to ISO 4042

Galvanizing – chromatizing
Galvanizing followed by chromatizing of fasteners is a procedure which has proven itself in terms of both corrosion resistance and appearance. We can offer you an extensive assortment from our range in stock. You will find our surface-protected parts in the catalog groups 1-10, indicated by the green tab.

Chromatizing (passivation) takes place immediately after the galvanizing, and is made by briefly dipping the part in solutions of chromic acid. The chromatization process increases the corrosion protection and prevents tarnishing and discoloration of the zinc coating. The protective effect of the layer of chromate differs with the different types of procedure (see the table!).

New developments in processes involving chromium (VI)-free coatings offering the same or similar protective effect spurred onwards by environmental regulations due to EU Directives 2000/53/EC (ELV) und 2002/95/EC (RoHS). Until now normal practice has been to use galvanic zinc coatings (ISO 4042) with chromatization based on chromium (VI) for the corrosion protection of fasteners. The new surface treatments based on chromium (VI) – free systems usually require a more complex process control and where necessary additional cover layers, since the «self-healing effect» is missing. Long-term experience gained under working conditions is largely not available and such experience is also influenced by specific conditions such as handling, transport and feeder devices. Consequently it is recommended that a review be made through the adjustment for the different operating conditions met in practice.

Types of procedure used for the chromatization of galvanic zinc coatings

Protective effect of zinc coatings with chromatization under conditions of salt spray fog testing to DIN 50021 SS.

Types of process	Designation of the chromatization	Chromate coating own colour	Nominal thickness ot the coating µm	First appearance of: White rust, hours Std.	Red rust, hours Std.
Colorless chromatizing	A	transparent	3	2	12
			5	6	24
			8	6	48
Blue chromatizing	B	transparent, with a tinge of blue	3	6	12
			5	12	36
			8	24	72
Yellow chromatizing	C	yellowish lustre to yellow-brown iridescent (standard)	3	24	24
			5	48	72
			8	72	120
Olive chromatizing	D	olive-green to olive-brown (rare)	3	24	24
			5	72	96
			8	96	144
Black chromatizing[1]	BK	blackish brown to black (decorative)	3	–	–
			5	12	–
			8	24	72

[1] On edges, the edges of the Phillips recess etc. use of the drum process means that you can practically always expect the black chromate coating to be rubbed off here and the underlying light-coloured zinc coating to become locally visible.

Reduction of the risk of hydrogen embrittlement (ISO 4042)

There is a risk of failure due to hydrogen embrittlement in galvanically finished fasteners which are under tensile stress and which are made from steels with tensile strengths of Rm ≥1000 N/mm², corresponding to ≥320 HV.

Heat treatment (tempering) of the parts, e.g. after the acid pickling or metal coating process, will reduce the risk of breakage.

However it cannot be guaranteed that the risk of hydrogen embrittlement will be removed completely. **If the risk of hydrogen embrittlement must be reduced, then other coating procedures should be considered.**

Alternative methods of corrosion protection or coating should therefore be selected for parts which are important to safety, alternatives such as anorganic zinc coating, mechanical galvanization or a switch to rust- and acid-resistant steels. Where the method of fabrication allows, fasteners in classes ≥ 10.9 (≥ HV320) are provided with an anorganic zinc coating or are mechanically galvanized.

The user of the fasteners knows the purposes and requirements for which the fasteners are to be used and he must specify the appropriate type of surface treatment!

Coating thicknesses for parts with external thread

according to ISO 4042

Corrosion protection

Thread pitch	Nominal thread diameter[1)]	Internal thread Tol. position G		External thread Tolerance position g					Tolerance position f					Tolerance position e				
		Funda-mental de-viation	Coating thick-ness max.	Funda-mental de-viation	Nom. coating thickness max. 2) Overall length	3) Nom. length l ≤ 5d	10d	15d	Funda-mental de-viation	Nom. coating thickness max. 2) Overall length	3) Nom. length l ≤ 5d	10d	15d	Funda-mental de-viation	Nom. coating thickness max. 2) Overall length	3) Nom. length l ≤ 5d	10d	15d
P	d1																	
	mm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm	µm
0,2		+17	3	–17	3	3	3	3										
0,25	**1; 1,2**	+18	3	–18	3	3	3	3										
0,3	**1,4**	+18	3	–18	3	3	3	3										
0,35	**1,6 (1,8)**	+19	3	–19	3	3	3	3	–34	8	8	5	5					
0,4	**2**	+19	3	–19	3	3	3	3	–34	8	8	5	5					
0,45	**2,5 (2,2)**	+20	5	–20	5	5	3	3	–35	8	8	5	5					
0,5	**3**	+20	5	–20	5	5	3	3	–36	8	8	5	5	– 50	12	12	10	8
0,6	**3,5**	+21	5	–21	5	5	3	3	–36	8	8	5	5	– 53	12	12	10	8
0,7	**4**	+22	5	–22	5	5	3	3	–38	8	8	5	5	– 56	12	12	10	8
0,75	**4,5**	+22	5	–22	5	5	3	3	–38	8	8	5	5	– 56	12	12	10	8
0,8	**5**	+24	5	–24	5	5	3	3	–38	8	8	5	5	– 60	15	15	12	10
1	**6 (7)**	+26	5	–26	5	5	3	3	–40	10	10	8	5	– 60	15	15	12	10
1,25	**8**	+28	5	–28	5	5	5	3	–42	10	10	8	5	– 63	15	15	12	10
1,5	**10**	+32	8	–32	8	8	5	5	–45	10	10	8	5	– 67	15	15	12	10
1,75	**12**	+34	8	–34	8	8	5	5	–48	12	12	8	8	– 71	15	15	12	10
2	**16 (14)**	+38	8	–38	8	8	5	5	–52	12	12	10	8	– 71	15	15	12	10
2,5	**20 (18; 22)**	+42	10	–42	10	10	8	5	–58	12	12	10	8	– 80	20	20	15	12
3	**24 (27)**	+48	12	–48	12	12	8	8	–63	15	15	12	10	– 85	20	20	15	12
3,5	**30 (33)**	+53	12	–53	12	12	10	8	–70	15	15	12	10	– 90	20	20	15	15
4	**36 (39)**	+60	15	–60	15	15	12	10	–75	15	15	15	12	– 95	20	20	15	15
4,5	**42 (45)**	+63	15	–63	15	15	12	10	–80	20	20	15	12	–100	25	25	20	15
5	**48 (52)**	+71	15	–71	15	15	12	10	–85	20	20	15	12	–106	25	25	20	15
5,5	**56 (60)**	+75	15	–75	15	15	15	12	–90	20	20	15	15	–112	25	25	20	15
6	**64**	+80	20	–80	20	20	15	12	–95	20	20	15	15	–118	25	25	20	15

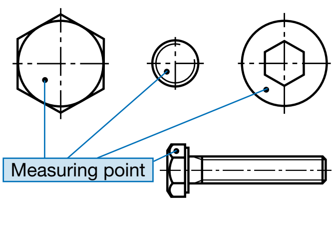
1) Information for coarse pitch threads is given for information. The determining characteristic is the thread pitch.
2) Maximum values of nominal coating thickness if local thickness measurement is agreed.
3) Maximum values of nominal coating thickness if batch average thickness measurment is agreed.

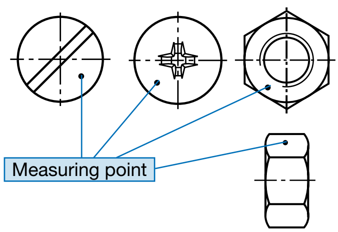
If no particular plating thickness is specified, the minimum plating thickness is applied. This is also considered the standard plating thickness.

In the case of parts with very long thread or small dimensions (≤ M4), an irregular coating thickness may occur due to the processing.
This can cause assembly problems. Possible solution: Use of a chemical nickel plating or stainless steel screws A2 or A4.

External threads are normally fabricated intolerance zone 6g.
e and f tolerance are not common and require special methods of screw manufacture. Minimum quantities, longer delivery periods and higher prices may make these economically unviable. An alternative is to use parts made from stainless steel A2.
Internal threads have a thinner coating due to technical reasons. How ever, this has no significance in practical use because when assembled these are protected by the coating of the external thread of the screw.

Measuring points for coating thickness





Further galvanic coating processes

Process	Details
Nickel-plating	Nickel-plating is decorative and provides effective corrosion protection. A hard coating, used in the electrical appliance and telecommunications industries. No coating abrasion occurs, especially with screws. Improves protection against impregnation, see table below.
Veralisation	A special method of hard nickel-plating.
Chromium-plating	Usually following nickel-plating. Coating thickness about 0,4 µm. Chromium is decorative, enhances resistance to tarnishing and improves corrosion protection. Bright chromium-plated: high brightness finish. Matt chromium-plated: matt lustre (silk finish). Polished chromium-plated: grinding, brushing and polishing of the surface prior to coating electrolytically (done by hand). Drum chromium plating not possible.
Brass-plating	Brass plating is mainly applied for decorative purposes. In addition, steel components are brass-plated in order to improve the adhesion of rubber to steel.
Copper-plating	Used when necessary as intermediate coating prior to nickel-plating-chromium-plating and silver-plating. Used for decorative purposes.
Silver-plating	Silver-plating is employed for decorative and technical applications.
Tin-plating	Tin-plating is carried out mainly to permit or improve soldering (soft-solder). Simultaneously serves as corrosion protection. Subsequent heat treatment not possible.
Anodizing	When aluminum is anodized (electrolytic oxidation), a coating which provides corrosion protection is produced – also prevents tarnishing. Practically any color can be produced for decorative purposes.

Further surface treatments

Process	Details
Hot-dip galvanizing	Immersion in molten zinc with a temp. of about 440 °C to 470 °C. Thickness of coating not less than 40 µm. Finish dull and rough. Color change possible after a certain time. Very good corrosion protection. Can be used for thread parts from M8. Threads need to be over or undercut to assure proper thread mating.
Dacromet (non-electrolytic)	Dacromet is an excellent coating for high strength components with tensile strength of ≥ 1100 MPa (Hardness ≥ HRC 31, Property class ≥ 10.9). This process practically eliminates the possibility of hydrogen embrittlement. Temperature resistant 300 °C. Can be applied to size M4 and up.
Mechanical plating	Mechanical /chemical process. The degreased parts are placed in a drum with powdered zinc and glass pellets. The pellets serve to transfer the zinc powder to the surface to be treated.
Black oxidizing Stainless steel	Chemical process. Corrosion resistance from A1–A4 may be low. For decorative purposes.
Black oxidizing	Chemical process, bath temperature about 140 °C. For decorative purposes; merely slight corrosion protection.
Phosphate (bonderizing, parkerizing, atramentizing)	Only slight corrosion protection. Good undercoat for painting. Grey to grey-black appearance. Better corrosion protection oiled.
Waterproofing / sealing	Particularly with nickel-plated parts, subsequent treatment in dewatering fluid with the addition of wax may seal the micropores with wax. Significantly improves the corrosion resistance. The wax film is dry and invisible.
Baking	Following electrolytic or pickling treatment, high tensile strength steel parts (from 1000 Nmm²) can become brittle due to hydrogen absorption (hydrogen embrittlement). This embrittlement increases for components with small cross sections. Part of the hydrogen can be eliminated by baking between 180 °C and 230 °C (below tempering temperature). Experience indicates that this is not guaranteed 100%. Thermal treatment must be carried out immediately after plating and before chromating.
Tribological coating (Solid film lubricants)	These coatings provide a friction reducing and wear resistant film. Reduce galling tendency.
Waxing	Provide a lubrication layer, reduces driving torque and thread-forming screws.

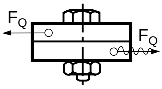
Estimation of screw diameters

according to VDI guideline 2230[1)]

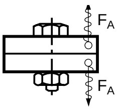
The following procedure allows a rough estimate to be made of the required screw dimensions for a particular screwed connection and temperature around 20 °C, in correspondence with the details in VDI 2230. The result should be checked mathematically in each case.

A Select in column 1 the next higher force to the work force $F_{A,Q}$ acting on the bolted joint.

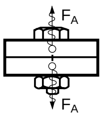
B The required minimum preload $F_{M\,min.}$ is found by proceeding from this number:
4 steps for static or dynamic transverse (shear) force

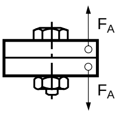


or
2 steps for dynamic, eccentric axial force

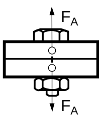


or
1 step for either dynamic and centrical or static and eccentric force





or
0 step for static, centrical axial force.



C The required maximum preload force $F_{M\,max.}$ is found by proceeding from this force $F_{M\,min.}$ by:
2 steps for tightening the screw with a motorized/pneumatic screwdriver which is set for a certain tightening torque
or
1 step for tightening with a torque wrench/or precision motorized screwdriver, which is set and checked by means of dynamic torque measurement or elongation measurement of the screw – **or**
0 step for «turn of the nut» method or yield point controlled method.

D Once the preload (force) has been estimated, the correct screw size is found next to it in column 2 to 4 underneath the appropriate strength class.

Example:
A joint is loaded dynamically and eccentrically by the axial force F_A = 8500 N. The screw of strength class 12.9 will be assembled with a manual torque wrench.

A 10000 N is the next higher force to F_A in column 1.
B 2 steps for «eccentric and dynamic axial force» lead to $F_{M\,min.}$ = 25000 N
C 1 step for «tightening with manual torque wrench» leads to $F_{M\,max.}$ = 40000 N
D for $F_{M\,max.}$ = 40000 N thread size **M10** is found in column 2 (strength class 12.9).

1	2	3	4
Force in N	**Nominal diameter mm**		
	Property class		
	12.9	**10.9**	**8.8**
250			
400			
630			
1000	M 3	M 3	M 3
1600	M 3	M 3	M 3
2500	M 3	M 3	M 4
4000	M 4	M 4	M 5
6300	M 4	M 5	M 6
10000	M 5	M 6	M 8
16000	M 6	M 8	M10
25000	M 8	M10	M12
40000	M10	M12	M14
63000	M12	M14	M16
100000	M16	M18	M20
160000	M20	M22	M24
250000	M24	M27	M30
400000	M30	M33	M36
630000	M36	M39	

[1)] VDI = Verein Deutscher Ingenieure

Strength under dynamic load

according to VDI 2230

Fatigue resistance

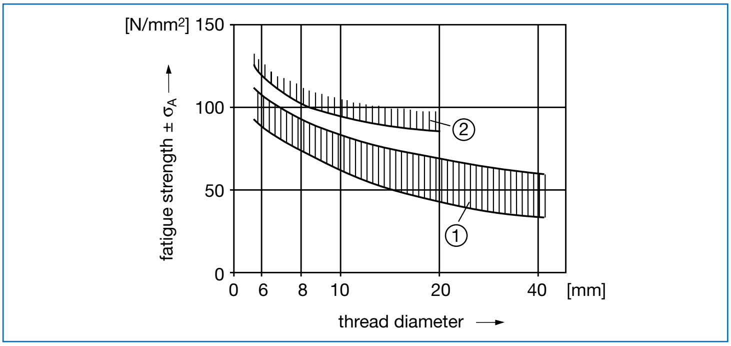
Screws are notched components; the notching is provided by the thread. Under conditions of changing load, fatigue fractures can occur in the screws. In 90% of the cases the break occurs in the first load-bearing part of the thread, at the entry into the internal (mother) thread. In these cases the design must allows for the fatigue strength ± σA of the screws; this amounts to a fraction of the tensile strength, **independent** of the static loading!

The fatigue strength of fine threads decreases with increasing rigidity and fineness of thread.

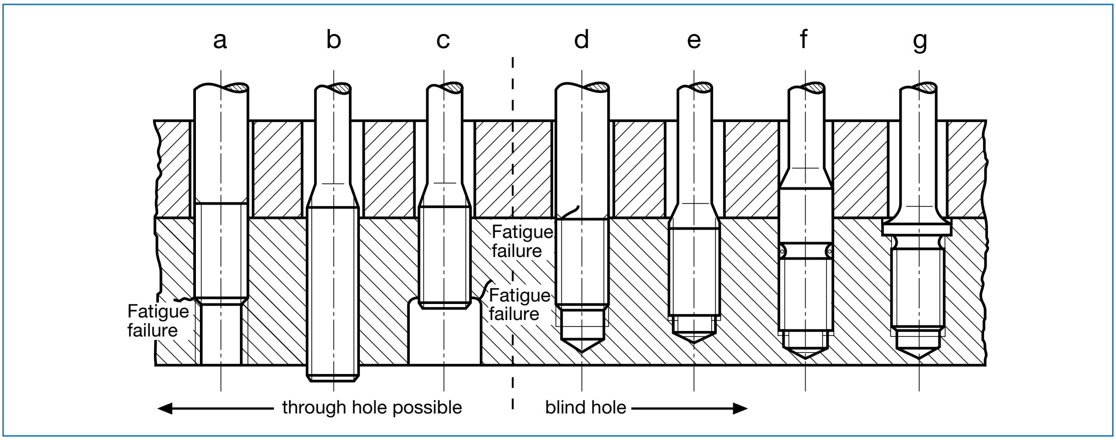
For fastenings of strength class 12.9, it can be up to 30% lower than for coarse threads.

For hot-dip galvanized screws the fatigue strength is ca. 20% lower than for screws hardened and tempered at the end of the manufacturing process.

Other constructive measures which can increase the fatigue strength:
Basically, all measures which can reduce the effective peak stresses or prevent combined loading (loading along more than one axis), are suitable for increasing the fatigue strength of the screwed connections. Long rather than short screws, screws with waisted shanks rather than screws with normal shanks, pins or fitted shoulder screws to absorb lateral forces, adequate and above all controlled prestressing of the screws.



Grafik: VDI 2230, Ausgabe 1986
① Thread rolled then hardened and tempered (standard practice)
② Hardened and tempered, then thread rolled



a) Danger of fatigue failure in the internal thread as well
b) reduces the danger of fatigue failure
   – in the internal thread through overlapping screw threads
   – in the first load-bearing part of the thread, through design which allows flexibility in the reduced shank
c) reduces the danger of fatigue failure in the internal thread through rounded indentation and overlapping screw threads
d) Danger of fatigue failure in jammed thread runout of the screw thread
e) reduces the danger of fatigue failure compared with (d) through design which allows flexibility, overlapping internal thread and bracing the screw with the starter head.
f) as for e) but here the centre belt serves to reduce bending stresses in the screw thread.
g) reduces the risk of fatigue failure through tensioning the belt against the bearing surfaces of the internal thread, leading to general release of the screw thread from bending stresses.

Recom. min. lengths of engaged thread in cut internal threads on components.

from information provided by manufacturer's, based on trail values M6 to M16

Where screws have to be screwed into internal threads and where full load-bearing capacity is required, then minimum lengths of engaged thread have to be defined which depend on the strength of the material from which the component is made.
There is normally less flexibility compared with standard nuts, so that when tightening up there is no need to worry about any resulting enlargement which might mean that the threads would not grip. On the other hand, in many cases the internal threads on the components are less strong than standard nuts of the same strength class for the screws which are being used.
This means that special attention must be given to achieving the required minimum length of engaged thread, in order to ensure adequate durability of the screwed connection.
The following recommended values have been determined from practical trials.

Component material with incised internal thread tolerance 6 g / 6 H	Rm in N/mm²	Recommended minimum length of engaged thread without countersinking for the strength class of the screw 8.8 coarse thread	8.8 fine thread	10.9 coarse thread	10.9 fine thread	12.9 coarse thread
S 235 (St37-2) 2C15 N (C15)	> 360 (ferrite / perlite structure)	1,0 · d [1,5 · d] 1)	1,25 · d	1,25 · d [1,8 · d] 1)	1,4 · d	1,4 · d [2,1 · d] 1)
E 285 (St50-2) S 355 (St52-3) 2C35 N (C35 N)	> 500 (ferrite / perlite structure)	0,9 · d [1,3 · d] 1)	1,0 · d	1,0 · d [1,6 · d] 1	1,2 · d	1,2 · d [1,8 · d] 1)
C45 V 35Cr4 V 34CrMo 4 V 42CrMo 4 V	> 800 (heat-treated sturcture)	0,8 · d [0,9 · d] 1)	0,8 · d	0,9 · d [1,1 · d] 1)	0,9 · d	1,0 · d [1,2 · d] 1)
GJL 250 (GG-25)	> 220	1,0 · d [1,3 · d] 1)	1,25 · d	1,25 · d [1,6 · d] 1)	1,4 · d	1,4 · d [1,8 · d]
Al 99,5	> 180			2,0 · d	2,5 · d	
AlMg3 F18	> 180	2 · d [3 · d] 1)	2 · d [3 · d] 1)			
AlMgSi1 F32	> 330	1,4 · d	1,4 · d	1,6 · d	2,0 · d	
AlMg4,5Mn F28	> 330	1,4 · d	1,4 · d	1,6 · d	2,0 · d	
AluMg1 F40 1	> 550	1,1 · d				
AlZn MgCu 0,5 F50	> 550	1,0 · d				
GMgAl9 Zn1	> 230	1,4 · d	1,4 · d	1,6 · d	2,0 · d	

1) Values in brackets are based on the formula from VDI 2230 (theoretical values)

For lengths of engaged thread above 1.5 d, external or internal threads at the extreme tolerance limits can lead to the screw becoming jammed.
ISO 965-1 defines the grades of tolerance for external and internal threads; compliance with these will ensure a problem-free assembly of the screwed fastening.

Surface pressure when mounted

Typical values for surface pressures for different materials

The surface pressure in the bearing surfaces following tightening up the screw or nut should not be exceeded, since otherwise the screwed connection may become loose as a result of settling effects.

Based on VDI 2230, 1986 edition, with proven limiting values

The values given apply to holes without chamfers and with sufficiently large external diameter for the tensioned part at room temperature.

Materials for the locking parts	Tensile strength R_m [N/mm²]	Surface pressure[2] P_G [N/mm²]
St 37	370	260
St 50	500	420
C 45	800	700
42 CrMo 4	1000	850
30 CrNiMo 8	1200	750
X 5 CrNiMo 18.10	500 to 700	210
X 10 CrNiMo 18 9	500 to 750	220
Titan, unlegiert	390 to 540	300
GG 15	150	600
GG 25	250	800
GG 35	350	900
GG 40	400	1100
GGG 35,5	350	480
DG MgAl 9	300	220
GK MgAl 9	200	140
AlZnMg Cu 0,5	450	370

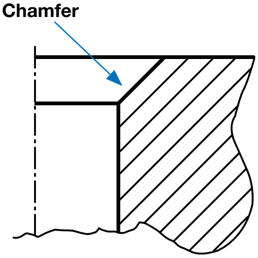
based on VDI 2230, edition of 2003 with typical values determined experimentally

Abbreviated term for the material EN designation	Material number	Tensile strength $R_{m\,min.}$ [N/mm²]	Surface pressure[1) 2)] P_G [N/mm²]
USt 37-2 (S235 JRG1)	1.0036	340	490
St 50-2 (E295)	1.0050	470	710
St 52-3U (S355 JO)	1.0553	510	760
Cq 45	1.1192	700	*630*
34 CrMo 4	1.7720	1000	*870*
34 CrNiMo 6	1.6582	1200	*1080*
38 MnSi-VS 5-BY	1.5231	900	*810*
16 MnCr 5	1.7131	1000	900
X5 CrNi 18 12	1.4303	500	630
X5 CrNiMo 17 12 2	1.4401	510	*460*
X5 NiCrTi 26 15	1.4980	960	*860*
NiCr20TiAl	2.4952	1000	700
GG-25 (GJL-250)	0.6020	250	900
GGG-40 (GJS-400-15)	0.7040	400	*700*
GGG-50 (GJS-500-7)	0.7050	500	*900*
GGG-60 (GJS-600-3)	0.7060	600	*1000*
AlMgSi 1 F31 (AW-6082)	3.2315.62	290	*260*
AlMgSi 1 F28	3.2315.61	260	*230*
AlMg4.5Mn F27 (AW-5083)	3.3547.08	260	*230*
AlZnMgCu 1.5 (AW-7075)	3.4365.71	540	*410*
GK-AlSi9Cu3	3.2163.02	180	*220*
GD-AlSi9Cu3	3.2163.05	240	*290*
GK-AlSi7Mg wa	3.2371.62	250	*380*
AZ 91	(3.5812)	310	*280*
TiAl6V4	3.7165.10	890	*890*

* Figures in italics have not yet been checked against the latest results from research and practice (TU Darmstadt).

1) Tightening procedures, supporting effects or the behaviour of anisotropic materials can often mean that a significantly higher value for pressure can be permitted than the pressure liquid limits for the particular material. The much higher limiting surface pressures are supported by experience gained in practice and should be checked for each specific case of application.

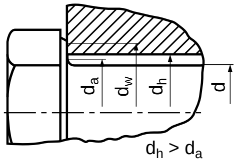
2) **Boundary conditions which affect the surface pressure**

Chamfer	Chamfers at the hole (contact surfaces with the fastening element) can for steels result in permitted values for surface pressure up to 25% higher being achieved (supporting effect).	**Power-operated screwdriver**	When tightening using a power screwdriver, for steels the permissible limiting value of surface pressure can be up to 25% lower!
			

Surface pressure when mounted

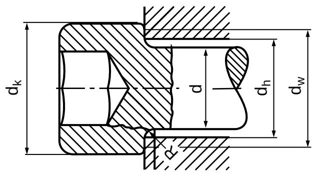
Surface pressure under the head of a hexagon screw DIN 931 / 933 (ISO 4014 / 4017) with coarse thread

Nominal thread Ø d	Width across flats s max. mm	Ø of the bearing surface dw min. mm	Through hole (ISO 273) dh mm	Bearing surface Ap mm²	Stressed cross-section As mm²	Surface pressure under the head [1] [N/mm²] 8.8	10.9	12.9
M 4	7	5,9	4,5	11,4	8,78	385	568	665
M 5	8	6,9	5,5	13,6	14,2	528	777	909
M 6	10	8,9	6,6	28	20,1	364	532	625
M 8	13	11,6	9	42,1	36,6	442	649	761
M10	16	14,63	11	73,1	58	405	594	695
M10	17	15,6	11	96,1	58	308	452	529
M12	18	16,63	13,5	74,1	84,3	580	853	999
M12	19	17,4	13,5	94,6	84,3	454	668	782
M14	21	19,64	15,5	114,3	115	517	759	888
M14	22	20,5	15,5	141,4	115	418	613	718
M16	24	22,5	17,5	157,1	157	515	756	885
M18	27	25,3	20	188,6	192	541	769	901
M20	30	28,2	22	244,4	245	532	761	888
M22	34	31,71	24	337,3	303	480	685	803
M22	32	30	24	254,5	303	637	908	1065
M24	36	33,6	26	355,8	353	528	750	880
M27	41	38	30	427,3	459	576	821	960
M30	46	42,7	33	576,7	561	520	740	865



Surface pressure under the head of a cheese head screw with hex socket to DIN 912 (ISO 4762) and coarse thread

Nominal thread Ø d	Ø of head dK mm	Ø of the bearing surface dw min. mm	Through hole (ISO 273) dh mm	Bearing surface Ap mm²	Stressed cross-section As mm²	Surface pressure under the head [1] [N/mm²] 8.8	10.9	12.9
M 4	7	6,53	4,5	17,6	8,79	250	370	432
M 5	8,5	8,03	5,5	26,9	14,2	268	394	461
M 6	10	9,38	6,6	34,9	20,1	292	427	502
M 8	13	12,33	9	55,8	36,6	333	489	574
M10	16	15,33	11	89,5	58	331	485	567
M12	18	17,23	13,5	90	84,3	478	702	822
M14	21	20,17	15,5	130,8	115	452	663	776
M16	24	23,17	17,5	181,1	157	447	656	767
M18	27	25,87	20	211,5	192	482	686	804
M20	30	28,87	22	274,5	245	474	678	791
M22	33	31,81	24	342,3	303	473	675	792
M24	36	34,81	26	420,8	353	447	635	744
M27	40	38,61	30	464	459	530	756	884
M30	45	43,61	33	638,4	561	470	669	782

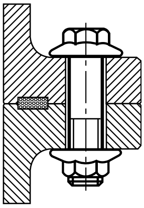


[1] The values shown in the tables for surface pressure are for a 90% utilisation of the yield strength of the screw $R_{p0,2}$ and μ_G = 0,12 (reference: 2003 edition of VDI 2230).

Surface pressure under the screw head

Surface pressure when mounted

Typical application



It is not possible to precisely define the permissible surface pressure for a particular type of material used to make a component. The effect of the production process, the alignment of fibers in the material, surface finishing and temperature changes all play a decisive role.

The following measures can help reduce the surface pressure:
- use of flange screws and flange nuts
- chamfered holes. Field investigations have shown up to a 20% increase in permissible surface pressure.
- through hole to ISO 273 – select a thin one

Advantages of flange screws and flange nuts:
- less intrusion
- clamping force in the fastening during mounting tends to remain stable
- flange products are more economic than large washers under normal screws and nuts (fewer fastening elements and quicker assembly)
- flange screws and nuts allow greater hole tolerances and so are more economically efficient.
- flange nuts have a better stability against shaking than normal screws and nuts.

Guide to the use of flat washers for screws and nuts

according to ISO 887

An overview of suitable combinations of flat washers with screws and nuts, allowing for different strength classes (hardness classes)

Washers	Hardness class		100 HV	200 HV	300 HV
	Assigned tensile strength	**[N/mm2]**	320	640	965
Screws	Property class	≤ 6.8	yes	yes	yes
		8.8	no	yes	yes
		9.8	no	no	yes
		10.9	no	no	yes
		12.9	no	no	no
Nuts	Property class	≤ 6	yes	yes	yes
		8	no	yes	yes
		9	no	no	yes
		10	no	no	yes
		12	no	no	no
case-hardened, thread-forming screws			yes	yes	yes
Stainless steel screws and nuts			–	yes	–
Surface pressure permitted values		[N/mm^2]	200 to 300	300 to 500	500 to 800

Limiting conditions such as strength of component, surface structure, production process, alignment of fibers and operating temperatures must be considered when making the selection.

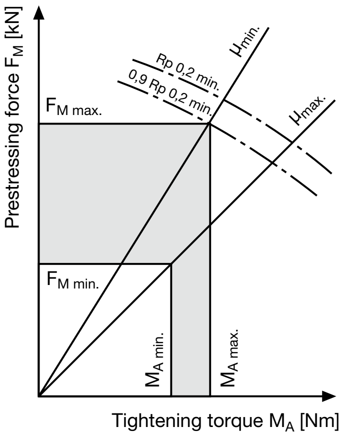
Friction and friction coefficients

The friction coefficients μ_{Ges}, μ_G, μ_K display variations since they are dependent on several factors, e.g. the material combinations, the quality of the surface finish (depth of roughness), the surface treatment (naked, blackened, galvanically zinc coated, dachromatized, etc.) and the method of lubrication (with/without oil, molybdenum disulfide, molycoat paste, anti-friction coating etc)! The following tables give friction coefficients for threads and for bearing surfaces.

Relation of firction coefficient classes to guidline values for various materials / surfaces and types of lubrication, for screw connections

according to VDI 2230 (the data in the table is valid at room temperature)

Friction coeff. class	range for μ_G and μ_K	Typical examples for: Material / surfaces	Lubrication
A	0,04–0,10	metallic, bright-polished black tempered phosphated galvanized coatings such as Zn, Zn/Fe, Zn/Ni zinc laminated coatings	solid lubricants such as MoS_2, graphite, PTFE, PA, PE, PI in lubricating lacquers, or in pastes wax glazes; wax dispersions
B	0,08–0,16	metallic, bright-polished black tempered phosphated galvanized coatings such as Zn, Zn/Fe, Zn/Ni zinc laminated coatings Al and Mg alloys	solid lubricants such as MoS_2, graphite, PTFE, PA, PE, PI in lubricating lacquers, or in pastes wax glazes; wax dispersions, greases oils, as-delivered condition
		hot-dip galvanized	MoS_2; graphite wax dispersions
		organic coatings	with integrated solid lubrificant or wax dispersion
		austenitic steel	solid lubricants or waxes; pastes
C	0,14–0,24	austenitic steel	wax dispersions, pastes
		metallic, bright-polished phosphated	as delivered state (lightly oiled)
		galvanic coatings such as Zn, Zn/Fe, Zn/Ni zinc lmainated coatings adhesive	none
D	0,20–0,35	austenitic steel	oil
		galvanic coatings such as Zn, Zn/Fe hot-dip galvanized	none
E	≥ 0,30	galvanised coatings such as Zn/Fe, Zn/Ni austenitic steel Al and Mg alloys	none



For a safe and secure mounting it is important to define the conditions for friction very precisely and to restrict their variations as much as possible.
If there is a large variation the desired prestress force can vary considerably. In contrast to this the normal range of tolerance for the tightening torque has only a limited effect.

Approximate values for static coefficient of friction μ_T in the separation joint

according to VDI 2230

Combination of materials	Static coefficient ofefficient in dry state	lubricated state
steel – steel / cast steel	0,1 – 0,23	0,07 – 0,12
steel – grey cast iron	0,12 – 0,24	0,06 – 0,1
grey cast iron – grey cast iron	0,15 – 0,3	0,2
bronze – steel	0,12 – 0,28	0,18
grey cast iron – bronze	0,28	0,15 – 0,2
steel – copper alloy	0,07	
steel – aluminium alloy	0,1 – 0,28	0,05 – 0,18
aluminium – aluminium	0,21	

Guideline values for the tightening factor α_A andteh resulting prestress forces in assembly (according to VDI 2230 – 2001)

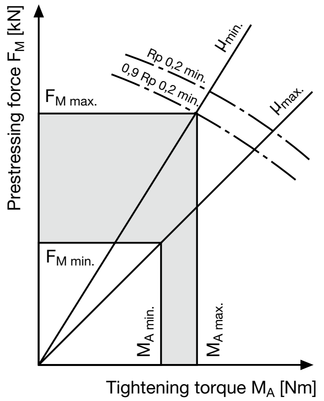
Tightening method tightening factor α_A

The tightening factor αA (a factor of uncertainty in assembly) allows for errors in estimating the friction coefficients, the tightening method, the equipment tolerances, operational failures, and inaccuracies in reading off values.
αA therefore covers the variation in the desired prestress force in assembly between $F_{M\,max.}$ and $F_{M\,min.}$ The design of the screw is based on the maximum tightening torque $M_{A\,max.}$, so that the screw will not be overloaded during assembly.
The tightening factor αA is then defined as:

$$\alpha A = \frac{\text{max. possible prestress force in assembly } F_{M\,max.}}{\text{min. required prestress force in assembly } F_{M\,min.}}$$

Today, even simple modern torque screwdrivers are able to provide torques to very close tolerances. Maximum variations in torque over a range of ± 2% are typical values quoted by manufacturers.
Nevertheless the resulting prestress forces in assembly, depending on the tightening factor, vary from ± 9% to as much as ± 60%.

- tightening method with measurement of extension – hydraulic tightening methods are practically independent of friction. Their αA factors are low.
- torque controlled tightening methods react to the effects of friction.
  The αA factors are generally higher: Smaller variations and so smaller αA factors occur for friction coefficients which have been derived from preliminary field trials. The same applies to cases involving hard screws with short grip lengths and for quick tightening methods.



Higher αA factors arise where friction coefficients are estimated, for cases involving soft screws and in tightening methods which are slower, as e.g. for impact screwdrivers and in hand assembly.

Tightening factor α_A	Variation $\frac{\triangle F_M}{2 \cdot F_{M\,middel}}$	Tightening method	Setting procedure	Comments	
1,2 to 1,4	±9% to ±17%	Yield-point controlled tightening, either power-assisted or manual.	Given value for the relative torque and turning angle coefficients.	The variation in the prestress force is largely determined by the variation in the yield point in the screws used. Here, the screw dimensions are selected based on $F_{M\,min.}$; for this tightening method there is no screw design for $F_{M\,max.}$ with the tightening factor αA.	
1,2 to 1,4	±9% to ±17%	rotation-angle controlled tightening, either power-assisted or manual.	Experimental determination of the pre-tightening and rotation angle (in stages)		
1,2 to 1,6	±9% to ±23%	hydraulic tightening.	Setting based on measurement of lengths and applied pressure.	lower values for long screws (l_k / d ≥ 5) higher values for short screws (l_k / d ≤ 2)	
1,4 to 1,6	±17% to ±23%	torque-controlled tightening with torque wrench, signal-emitting spanner or precision screwdriver with torque measurement.	Experimental determination of the desirable tightening torque on original screwed connection component, e.g. by measuring the elongation of the screw.	Lower values for: a large number of settings and control tests (e.g. 20) are necessary; low variation in the output torque (e.g. ±5 %) is required.	Lower values for: – small rotation angles, i.e. relatively stiff connections. – relatively low stiffness of the surface[1)] – surfaces which do not tend to corrode, e.g. phosphated surfaces or surfaces with adequate lubrication higher values for (at): – large rotation angles, i.e. relatively flexible connections and fine threads – high degree of stiffness of the surface, together with a rough surface
1,6 bis 2,0 (friction coeffiecient class B)	±23% to ±33%	torque-controlled tightening using a torque wrench, signal-emitting spanner or precision screwdriver with torque measurement.	Determination of the desirable tightening torque made by estimating the friction coefficient (surface and lubrication conditions).	Lower values for: measuring torque wrench – consistent tightening – precision screwdriver	
1,7 to 2,5 (friction coefficient class A)	±26% to ±43%			Lower values for: signal-emitting torque wrench or torque wrench with release mechanism.	
2,5 to 4	±43% to ±60%	tightening with impact wrench or impulse wrench.	Setting of the wrench based on post-torqueing, derived from the desirable tightening torque (for the estimated friction coefficient) plus an additional allowance.	Lower values for: – large number of settings trials (post-torque) – on the horizontal axis of the screwdriver characteristics – play-free impulse transmission	

[1)] Surface: Tensioned part, the surface of which is in contact with the tightening element of the connection (screw head or nut).

How to use reference values of preload and tightening torques
(aus Tabellen **T**.038)

Prestressing forces and tightening torques

This procedure neither replaces the calculation as defined in VDI 2230[1] nor meets the current state of technology. However, it will allow one to approximate a torque that does not cause a bolt fracture during assembly. The main reason for such fractures is that the actual friction is lower than anticipated.

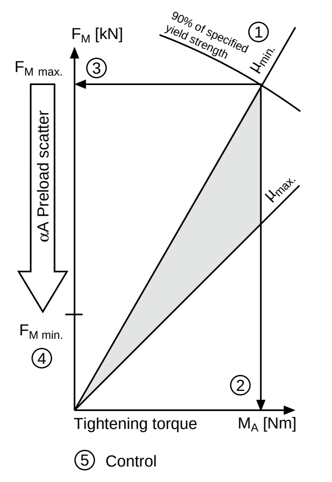
Step 1: **Friction coefficient μ_{total}[2]**

The exact conditions of surface roughness, finish, and lubrication in the thread and in the under-head bearing are often not known. To make sure the bolted joint is not over-tightened, one should use the lower friction coefficient. Also, if fasteners are re-used (retightened), the friction is likely to be different than when the joint was initially tightened (VDI 2230 friction table on page **T**.035)

Example: Fasteners used are electro zinc plated
zinc plated — Friction coefficient μ_{total} = 0,14 – 0,24, **lower friction coefficient μ_{total} = 0,14**

Step 2: **Tightening torque $M_{A\,max.}$**

Maximum permissible torque, utilizing 90% of the specified yield strength (0.2 limit), is found in torque and preload tables starting at page **T**.038. The values assume that one uses either precision torque wrenches or precision power drivers with a tool inaccuracy of maximum 5%.



Example: **Hex cap screw per ISO 4017 M12x40 property class 8.8, zinc plated.**
In Table on page **T**.038 look for M12 in the thread column, in the friction column look for 0.14. Now move over to the right half of the table under «maximum tightening torque under property class 8.8» you will find the
Maximum tightening — **$M_{A\,max.}$ = 93 Nm.**

Step 3: **Maximum Preload $F_{M\,max.}$**

the maximum resulting preload $M_{A\,max.}$ from that torque $F_{M\,max.}$ can be found in the same tables.

Example: To find the maximum preload, start again in the thread column, look for M12, then the fraction coefficient 0.14, move over into the left half of the table, the preload value can be found under property class 8.8
maximum preload — **$F_{M\,max.}$ = 41,9 kN**

Step 4: **Minimum preload $F_{M\,min.}$**

The minimum preload can be calculated by dividing the maximum preload through the tightening factor α_A – see table on page **T**.036.

Example: For installations with commercial, modern torque wrenches, tightened in a uniform, uninterrupted fashion, with an estimated friction coefficient, a tightening factor α_A = 1.6 – 2.0 must be applied. (see table at page **T**.036).
For a signal type torque wrench, as used in the example, a tightening factor α_A of 2.0 is adequate. We use a short screw (M12x40), which only requires a small torque angle. This results in a relative stiff joint, therefore a lower tightening factor can be applied.
Assumed tightening factor: **αA = 1,8**

Minimum expected preload (clamp load)
$F_{M\,min.} = F_{M\,max.} / \alpha A$ = 41,9 kN / 1,8 — **$F_{M\,min.}$ = 23,3 kN**

Step 5: **Double checking values, using calculations as stated in VDI 2230 is highly recommended. The calculations in VDI 2230 are state of the art**

Is the minimum preload $F_{M\,min.}$ adequate for the intended application?
Are surface pressures in the bearing areas brought in line with strength of clamped parts?
How high is the residual clamp force when work forces are applied?
Will the bolted joint be used in a manner not to exceed the fatigue limit?

If one applies a tightening torque M_A that is lower than the stated torque value in the table, the resulting maximum preload F_M will be lower as well. The minimum possible preload $F_{M\,min.}$ would be affected as explained in step 4. Users (engineers) ought to verify parameters to assure an adequate clamp load in the bolted joint.

Possible reason for the torque to be different:
- Friction is lower than anticipated, possibly leading to a bolt fracture during assembly
- Tightening tools are not as accurate as they should be, again leading to a premature bolt fracture either during assembly or in use.
- Clamped parts are deformed unexpectedly (head embeds into material)

Bossard engineering recommends using torque / tension equipment to verify specific parameters such as friction, tightening torque, clamp load, etc. To calculate the friction coefficient μ_{total} one can use DIN 946.

[1] Bolt calculation guideline prepared by: The German Engineering association available in English and German
[2] Under head and thread friction combined, assuming same friction underneath the head and in the thread.

Typical values for metric coarse threads

Prestressing forces and tightening torques

The details are based on the 2001 edition of VDI 2230: Maximum permitted tightening torques and the resulting maximum prestressing forces for hexagon head screws to ISO 4014 – 4018, hexagon socket head screws to ISO 4762 and for screws with similar strength heads and head bearing surfaces of strength classes 3.6 to 12.9 for a **90% utilisation of the yield point R_{el} / 0,2% elongation limit $R_{p\,0.2}$.** The table shows the permissible maximum values and does not include any additional factors of safety. It assumes the user is familiar with the appropriate guidelines and design criteria.

Threads	Friction coeff. $\mu_{ges.}$ see T.035	Maximum prestressing $F_{M\,max.}$ [N] Property class based on ISO 898 / 1 3.6	4.6	5.6 (4.8)	6.8	8.8	10.9	12.9	Maximum tightening torque $M_{A\,max.}$ [Ncm] Property class based on ISO 898 / 1 3.6	4.6	5.6 (4.8)	6.8	8.8	10.9	12.9	Conversion factor X
M 1,6	0,10	176	235	294	470	627	882	1058	4,2	5,7	7,1	11,3	15,1	21,2	25,5	0,024
	0,12	171	228	285	455	607	854	1025	4,7	6,3	7,9	12,6	16,9	23,7	28,5	0,028
	0,14	165	220	275	441	588	826	992	5,2	6,9	8,7	13,9	18,5	26	31,2	0,032
M 2	0,10	292	390	487	779	1039	1461	1754	9	11,9	14,9	23,8	31,7	44,5	53,5	0,031
	0,12	283	378	472	756	1008	1417	1701	10	13,3	16,7	26,7	35,6	50	60	0,035
	0,14	274	366	457	732	976	1373	1647	11	14,7	18,4	29,4	39,2	55	66	0,040
M 2,5	0,10	485	647	809	1294	1725	2426	2911	18	24	30	49	65	91	109	0,037
	0,12	471	628	785	1257	1676	2356	2828	21	27	34	55	73	103	123	0,044
	0,14	457	609	762	1219	1625	2285	2742	23	30	38	60	81	113	136	0,050
M 3	0,10	726	968	1210	1936	2582	3631	4357	32	42	53	84	112	158	190	0,044
	0,12	706	941	1177	1883	2510	3530	4236	36	48	60	95	127	179	214	0,051
	0,14	685	914	1142	1827	2436	3426	4111	40	53	66	105	141	198	237	0,058
		Maximum prestressing $F_{M\,max.}$ [kN]							Maximum tightening torque $M_{A\,max.}$ [Nm]							
M 4	0,10	1,26	1,68	2,10	3,36	4,5	6,7	7,8	0,73	0,97	1,21	1,94	2,6	3,9	4,5	0,58
	0,12	1,22	1,63	2,04	3,26	4,4	6,5	7,6	0,82	1,09	1,37	2,19	3,0	4,6	5,1	0,67
	0,14	1,19	1,58	1,98	3,17	4,3	6,3	7,4	0,91	1,21	1,51	2,42	3,3	4,8	5,6	0,76
M 5	0,10	2,06	2,74	3,43	5,48	7,4	10,8	12,7	1,4	1,9	2,4	3,8	5,2	7,6	8,9	0,70
	0,12	2,00	2,67	3,33	5,33	7,2	10,6	12,4	1,6	2,2	2,7	4,3	5,9	8,6	10,0	0,81
	0,14	1,94	2,59	3,23	5,18	7,0	10,3	12,0	1,8	2,4	3,0	4,8	6,5	9,5	11,2	0,93
M 6	0,10	2,90	3,87	4,84	7,74	10,4	15,3	17,9	2,5	3,3	4,1	6,6	9,0	13,2	15,4	0,86
	0,12	2,82	3,76	4,71	7,53	10,2	14,9	17,5	2,8	3,7	4,7	7,5	10,1	14,9	17,4	0,99
	0,14	2,74	3,65	4,57	7,31	9,9	14,5	17,0	3,1	4,1	5,2	8,3	11,3	16,5	19,3	1,14
M 8	0,10	5,3	7,1	8,8	14,2	19,1	28,0	32,8	6,0	8,0	10,0	16,1	21,6	31,8	37,2	1,13
	0,12	5,15	6,9	8,6	13,8	18,6	27,3	32,0	6,8	9,1	11,3	18,2	24,6	36,1	42,2	1,32
	0,14	5,0	6,7	8,3	13,4	18,1	26,6	31,1	7,5	10,1	12,6	20,1	27,3	40,1	46,9	1,51
M10	0,10	8,4	11,3	14,1	22,5	30,3	44,5	52,1	12	16,1	20,1	32,3	43	63	73	1,42
	0,12	8,2	11,0	13,7	21,9	29,6	43,4	50,8	13,7	18,3	22,9	36,5	48	71	83	1,65
	0,14	8,0	10,7	13,3	21,3	28,8	42,2	49,4	15,2	20,3	25,3	40,6	54	79	93	1,89
M12	0,10	12,3	16,4	20,5	32,8	44,1	64,8	75,9	20	27	34	55	73	108	126	1,65
	0,12	12,0	16,0	20,0	32,0	43,0	63,2	74,0	23	31	39	62	84	123	144	1,94
	0,14	11,6	15,5	19,4	31,1	41,9	61,5	72,0	26	34	43	69	93	137	160	2,22
M14	0,10	16,9	22,5	28,2	45,1	60,6	88,9	104,1	33	44	55	88	117	172	201	1,94
	0,12	16,5	21,9	27,4	43,9	59,1	86,7	101,5	37	50	62	100	133	195	229	2,26
	0,14	16,0	21,3	26,7	42,7	57,5	84,4	98,9	41	55	69	111	148	218	255	2,58
M16	0,10	23,2	30,9	38,6	61,8	82,9	121,7	142,4	50	67	84	134	180	264	309	2,17
	0,12	22,6	30,1	37,6	60,2	80,9	118,8	139,0	57	76	96	153	206	302	354	2,54
	0,14	22,0	29,3	36,6	58,6	78,8	115,7	135,4	64	85	107	171	230	338	395	2,92
M18	0,10	28,2	37,7	47,1	75,3	104	149	174	70	93	117	187	259	369	432	2,48
	0,12	27,5	36,7	45,8	73,4	102	145	170	80	106	133	212	295	421	492	2,90
	0,14	26,7	35,7	44,6	71,3	99	141	165	89	118	148	236	329	469	549	3,32
M20	0,10	36,2	48,3	60,3	96,5	134	190	223	98	131	164	262	363	517	605	2,71
	0,12	35,3	47,0	58,8	94,1	130	186	217	112	150	187	300	415	592	692	3,18
	0,14	34,3	45,8	57,2	91,6	127	181	212	125	167	209	334	464	661	773	3,65
M22	0,10	45,1	60,1	75,2	120,3	166	237	277	132	176	220	353	495	704	824	2,95
	0,12	44,0	58,7	73,4	117,4	162	231	271	151	202	252	403	567	807	945	3,46
	0,14	42,9	57,1	71,4	114,3	158	225	264	169	225	282	451	634	904	1057	3,97
M24	0,10	52,1	69,5	86,9	139,0	192	274	320	169	226	282	451	625	890	1041	3,25
	0,12	50,8	67,7	84,7	135,5	188	267	313	193	257	322	515	714	1017	1190	3,80
	0,14	49,4	65,9	82,4	131,8	183	260	305	215	287	359	574	798	1136	1329	4,36
M27	0,10	68,4	91,2	114,0	182,4	252	359	420	248	331	414	662	915	1304	1526	3,63
	0,12	66,7	89,0	111,2	178,0	246	351	410	284	379	474	759	1050	1496	1750	4,26
	0,14	65,0	86,7	108,3	173,3	240	342	400	318	424	530	848	1176	1674	1959	4,89
M30	0,10	83,2	111,0	138,7	222,0	307	437	511	338	450	563	901	1246	1775	2077	4,06
	0,12	81,2	108,3	135,3	216,5	300	427	499	386	515	644	1031	1420	2033	2380	4,76
	0,14	79,0	105,3	131,7	210,8	292	416	487	431	575	719	1151	1597	2274	2662	5,46
M33	0,10	103,5	138,0	172,5	276,0	381	543	635	456	608	760	1216	1679	2392	2799	4,41
	0,12	101,0	134,7	168,4	269,4	373	531	621	523	697	871	1395	1928	2747	3214	5,17
	0,14	98,4	131,2	164,0	262,5	363	517	605	585	780	975	1560	2161	3078	3601	5,95
M36	0,10	121,6	162,1	202,7	324,3	448	638	747	587	783	979	1566	2164	3082	3607	4,83
	0,12	118,7	158,2	197,8	316,4	438	623	729	672	897	1121	1793	2482	3535	4136	5,67
	0,14	115,6	154,1	192,6	308,1	427	608	711	752	1002	1253	2005	2778	3957	4631	6,51
M39	0,10	145,9	194,5	243,1	389,0	537	765	895	758	1011	1264	2022	2791	3975	4652	5,20
	0,12	142,4	189,9	237,4	379,8	525	748	875	870	1160	1450	2321	3208	4569	5346	6,11
	0,14	138,8	185,0	231,3	370,0	512	729	853	974	1299	1624	2598	3597	5123	5994	7,02

The relationship $M_A = F_M \cdot X$, can be used to calculate the tightening torque for every other value of prestressing force.

Typical values:
The typical values are somewhat higher than in the earlier version of VDI 2230 / 1986. This is because making an allowance for reserves which have not so far been utilised means that better use can be made of the screw strength through applying a higher prestressing force during assembly.

Calculations toprove this are required!
VDI 2230 – 2003

Typical values for metric fine threads

Prestressing forces and tightening torques

The details are based on the 2001 edition of VDI 2230: prestressing forces and tightening torques for headless screws of strength classes 8.8 – 12.9 for a **90% utilisation of the yield point $R_{p\,0.2}$.** The table does not include any factors of safety and assumes the user is familiar with the design criteria.

Threads	$\mu_{ges.}$[1)]	Prestressing force $F_{M\,max.}$ [kN]			Tightening torque $M_{A\,max.}$ [Nm]		
		Property class based on ISO 898 / 1			Property class based on ISO 898 / 1		
		8.8	**10.9**	**12.9**	**8.8**	**10.9**	**12.9**
M 8 x 1	0,10	20,7	30,4	35,6	22,8	33,5	39,2
	0,12	20,2	29,7	34,7	26,1	38,3	44,9
	0,14	19,7	28,9	33,9	29,2	42,8	50,1
M10 x 1,25	0,10	32,4	47,5	55,6	44	65	76
	0,12	31,6	46,4	54,3	51	75	87
	0,14	30,8	45,2	52,9	57	83	98
M12 x 1,25	0,10	49,1	72,1	84,4	79	116	135
	0,12	48,0	70,5	82,5	90	133	155
	0,14	46,8	68,7	80,4	101	149	174
M14 x 1,5	0,10	66,4	97,5	114,1	124	182	213
	0,12	64,8	95,2	111,4	142	209	244
	0,14	63,2	92,9	108,7	159	234	274
M16 x 1,5	0,10	89,6	131,6	154,0	189	278	325
	0,12	87,6	128,7	150,6	218	320	374
	0,14	85,5	125,5	146,9	244	359	420
M18 x 1,5	0,10	120	171	200	283	403	472
	0,12	117	167	196	327	465	544
	0,14	115	163	191	368	523	613
M20 x 1,5	0,10	151	215	252	392	558	653
	0,12	148	211	246	454	646	756
	0,14	144	206	241	511	728	852
M22 x 1,5	0,10	186	264	309	529	754	882
	0,12	182	259	303	613	873	1022
	0,14	178	253	296	692	985	1153
M24 x 2	0,10	213	304	355	666	949	1110
	0,12	209	297	348	769	1095	1282
	0,14	204	290	339	865	1232	1442

[1)] For an explanation of the friciton coefficient $\mu_{ges.}$ see page **T.**035.

Typical values:
The typical values are somewhat higher than in the earlier version of VDI 2230 / 1986. This is because making an allowance for reserves which have not so far been utilised means that better use can be made of the screw strength through applying a higher prestressing force during assembly.

Calculations to prove this are required! VDI 2230 – 2003

Double-end studs with reduced shank

(DIN 2510 L sheet 3) from steel **21 CrMo V 5 7**
Typical values for prestressing foreces and tightening torques used in assembly and **at 70% of the minimum yield point** (0,2 limit)

Coarse thread	**M12**		**M16**		**M20**		**M24**	
Shank-Ø	8,5		12		15		18	
$\mu_{ges.}$	0,10	0,12	0,10	0,12	0,10	0,12	0,10	0,12
F_M [N]	21600	21600	43500	43500	6800	67800	97800	97800
M_A [Nm]	38	44	98	115	190	220	320	370

Polyamide 6.6

Typical values for advisable tightening torques for screws made from polyamide 6.6 at 20 °C after storage in a normal climate (relative atmospheric humidity in accordance with DIN 50014) until the moisture stability has been reached. The prestressing force can ease off as a result of relaxation processes.

Threads	**M3**	**M4**	**M5**	**M6**	**M8**	**M10**	**M12**	**M16**
Screws $M_{A\,max.}$ [Nm]	0,1	0,25	0,5	0,8	1,8	3,5	–	–
Nuts $M_{A\,max.}$ [Nm]	0,1	0,25	0,5	0,8	1,8	3,5	6,0	12

Screws made from austenitic stainless steel A1 / A2 / A4:

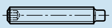
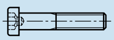
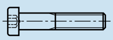
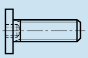
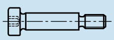
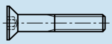
maximum permissible preload and tightening torques at **90% utilization of yield point $R_{p\,0,2}$.**

Threads	$\mu_{ges.}$	Preload F_M [kN] Property class			Tightening torque M_A [Nm] Property class		
		50	70	80	50	70	80
M 1,6	0,1	0,21	0,45	0,6	0,05	0,11	0,15
	0,2	0,18	0,39	0,5	0,08	0,17	0,22
	0,3	0,15	0,33	0,44	0,09	0,2	0,27
M 2	0,1	0,35	0,74	1	0,1	0,23	0,3
	0,2	0,3	0,64	0,85	0,16	0,35	0,46
	0,3	0,25	0,55	0,7	0,2	0,43	0,57
M 2,5	0,1	0,58	1,23	1,6	0,22	0,46	0,62
	0,2	0,5	1,06	1,4	0,34	0,72	0,97
	0,3	0,42	0,9	1,2	0,42	0,89	1,19
M 3	0,1	0,86	1,84	2,5	0,37	0,8	1,1
	0,2	0,75	1,6	2	0,59	1,25	1,7
	0,3	0,64	1,35	1,8	0,73	1,55	2,1
M 4	0,1	1,5	3,2	4,2	0,86	1,85	2,4
	0,2	1,3	2,7	3,6	1,35	2,9	3,8
	0,3	1,1	2,3	3,1	1,66	3,6	4,7
M 5	0,1	2,4	5,2	6,9	1,6	3,6	4,8
	0,2	2,1	4,5	6	2,6	5,7	7,6
	0,3	1,8	3,8	5,1	3,3	7	9,4
M 6	0,1	3,4	7,3	9,7	2,9	6,3	8,4
	0,2	3	6,4	8,4	4,6	10	13,2
	0,3	2,5	5,5	7,2	5,7	12	16,3
M 8	0,1	6,2	13,4	17,9	7,1	15	20
	0,2	5,4	11,6	15,5	11,2	24	32
	0,3	4,6	9,9	13,3	13,9	30	40
M10	0,1	9,9	21,3	28,4	14	30	39
	0,2	8,6	18,5	24,7	22,2	47,7	63
	0,3	7,4	15,8	21	27,6	59,3	79
M12	0,1	14,4	31	41,4	24	51	68
	0,2	12,6	27	36	38	82	109
	0,3	10,7	23	30,8	47	102	136
M14	0,1	19,8	42,6	56,8	38	82	109
	0,2	17,3	37	49,5	61	131	175
	0,3	14,8	31,7	42,3	76	163	217
M16	0,1	27,2	58	77,7	58	126	168
	0,2	23,7	51	67,9	95	204	272
	0,3	20,3	43,5	58,2	119	255	340

Threads	$\mu_{ges.}$	Preload F_M [kN] Property class			Tightening torque M_A [Nm] Property class		
		50	70	80	50	70	80
M18	0,1	33,2	71	94	82	176	235
	0,2	28,9	62	82	131	282	376
	0,3	24,7	53	70	164	352	469
M20	0,1	42,5	91	121	115	247	330
	0,2	37,1	79	106	187	401	534
	0,3	31,8	68	90	234	501	669
M22	0,1	52,9	113	151	157	337	450
	0,2	46,3	99	132	257	551	735
	0,3	39,7	85	114	323	692	923
M24	0,1	61,2	131	175	198	426	568
	0,2	53,5	115	153	322	690	920
	0,3	45,8	98	131	403	863	1151
M27	0,1	80,2			292		
	0,2	70,3			478		
	0,3	60,3			601		
M30	0,1	97,6			397		
	0,2	85,5			648		
	0,3	73,3			831		
M33	0,1	121			536		
	0,2	106			880		
	0,3	91			1108		
M36	0,1	143			690		
	0,2	125			1130		
	0,3	107			1420		
M39	0,1	171			890		
	0,2	150			1467		
	0,3	129			1848		

Fasteners made from these steels tend to erode during fitting. This risk can be reduced through smooth, clean thread sufaces (rolled threads), lubricants, molykote smooth varnish coating (black), low number of revolutions of the screwdriver, or continuous tightening without interruption (impact screwdriver not recommended). For coefficients of friction, see **T.**035.

Fasteners with hexagon and hexalobular socket and flat heads

Maximum tightening torques $M_{A\,max.}$ [Nm]															 ISO 4026 / DIN 913  ISO 4027 / DIN 914  ISO 4028 / DIN 915  ISO 4029 / DIN 916	
Screw type	 DIN 6912		 DIN 7984		 BN 1206	BN 9524	 ISO 7379	 DIN 7991	ISO 14581	DIN 7991	 ISO 7380	BN 6404	ISO 7380			
Gewinde	8.8	A2-70 A4-70	8.8	A2-70 A4-70	10.9	8.8	12.9	10.9	8.8	A2-70 A4-70	10.9	8.8	A2-70 A4-70	45 H[1]	A2 A4	
M 3			1	0,6				1	1	0,5	1	1	0,5	0,5	0,2	
M 4	2	1	2	1,2	2	2		2	2	1	2	2	1	1	0,5	
M 5	6	4	4	2,5	3,5	3,5	4	5	5	2,5	4	4	2	3	1,5	
M 6	9	5	8	5	5	5	9	9	9	4,5	8	8	4	5	2,5	
M 8	20	12	12	7	10	10	25	15		8	12	12	6	10	5	
M10	40	24	35	21	18		40	40		20	30		15	20	10	
M12	65	40	50	30			70	65		33	60		30	45	22	
M14	110	66						100		50				45	22	
M16	180	110	110	66			200	110		55				90	45	
M18														140	70	
M20	280	170	200	120			400	150		75				140	70	
M22														220	110	
M24			390	235				400		200				220	110	

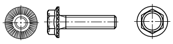
[1] The mechanical characteristics and property classes according to ISO 898, part 5 are valid for headless screws not subjected to tensile forces.

Locking screws and nuts, flange screws and nuts

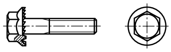
based on manufacturer's specifications

Prestress forces and tightening torques

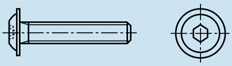
Tightening torques M_A [Nm] and achievable prestress forces F_M [Nm] for VERBUS RIPP® screws and nuts and for INBUS RIPP® screws, at a 90% utilisation of the elongation limit $R_{p\,0,2}$.

Classe	Counter material	Coefficient of friction for $\mu_{ges.}$	Tightening torques $M_{A\,max.}$ [Nm]						
			M5	M6	M8	M10	M12	M14	M16
Screws – Property class 100 Nuts – Property class 10	Steel R_m > 800 N/mm²	0,13 to 0,16	10	18	37	80	120	215	310
	Steel R_m < 800 N/mm²	0,14 to 0,18	11	19	42	85	130	230	330
	Grey cast iron GG tensile strenght R_m ca. 150 to 450 N/mm²	0,125 to 0,16	9	16	35	75	115	200	300
	**Guideline values for achievable prestress forces should be checked in field trials.**		**Prestress force F_M [kN]**						
			9	12,6	23,2	37	54	74	102

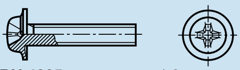
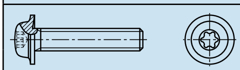
Tightening torques M_A [Nm] and achievable prestress forces F_M [Nm] for VERBUS TENSILOCK® screws and nuts, at a 90% utilisation of the elongation limit $R_{p\,0,2}$.

Classe	Counter material	Coefficient of riction for $\mu_{ges.}$	Tightening torques $M_{A\,max.}$ [Nm]						
			M5	M6	M8	M10	M12	M14	M16
Screws – Property class 90 Nuts – Property class 8	Steel R_m ≈ 500 to 1000 N/mm²	0,16 to 0,22	9	16	34	58	97	155	215
	Grey cast iron GG R_m ≈ 150 to 450 N/mm²	0,16 to 0,22	7	13	28	49	83	130	195
	**Guideline values for achievable prestress forces should be checked in field trials.**		**Prestress force F_M [kN]**						
			6,35	9	16,5	26,2	38,3	52,5	73

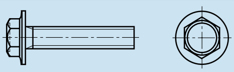
Tightening torques M_A for pan washer head screws with hexagon socket and pressed-on flange*)

		**Tightening torques $M_{A\,max.}$ [Nm]** Guideline values should be checked in field trials						
		M3	M4	M5	M6	M8	M10	M12
BN 11252	~10.9	1	2,5	5	8	21	42	72

Tightening torques M_A for eco-fix® pan washer head screws with flange*)

		**Tightening torques $M_{A\,max.}$ [Nm]** Guideline values should be checked in field trials				
		M2,5	M3	M4	M5	M6
BN 4825	4.8	0,3	0,5	1,2	2,2	3,8
BN 5952	A2	0,4	0,8	1,6	3,2	5,6
		M2,5	M3	M4	M5	M6
BN 5128	4.8	0,4	0,7	1,7	3,4	5,7
BN 10649	A2	–	1,1	2,5	5	8,5

Tightening torques M_A for eco-fix® hexagon screws with flange*)

		**Tightening torques $M_{A\,max.}$ [Nm]** Guideline values should be checked in field trials				
		M3	M4	M5	M6	M8
BN 5950	4.8	0,6	1,4	2,7	4,6	11
BN 5951	A2	0,8	1,8	3,4	6	–

Guideline values*)
The screws are not suitable for transferring high operating forces. The inner and outer actuation of these screws permits only reduced tightening torques to be used.

Check the boundary conditions!

High-strength structural steel bolts

according to DIN 6914
(HV sets according to DIN 6914 / 15 / 16)

Preload and tightening torques

Dimensioning, design and manufacture of fasteners with high-strength structural steel bolts are regulated in DIN 18800, parts 1.

The strength of high-strength structural steel bolts correspondsto the value stipulated in DIN 267, respectively ISO 898.

- ISO 898, part 1 for bolts DIN 6914
- DIN 267, part 4 for nuts DIN 6915
- Washers DIN 6916, 6917, 6918
  of steel hardened to 295–350 HV 10

The following methods are available for applying preload to the bolt:

- with hand operated torque wrench (torque process)
- with power screwdriver which must be regulated to a well defined torque (angular torque)
- angle of rotation process, in which after having applied a certain preload, the nut or bolt is retightened with a well definedangel of rotation.

Table 1, which is taken from DIN 18800 part 7, shows the necessary preloads, torques and tightening angles. The screwsmay be tightened either by the nut or by the screw.

	1	2	3	4	5	6	7	8	9
	Screw diameter	Required preload F_V in in the screw	Screw prestressed according to the						
			Torque procedure		**Impact procedure**	**Angle of rotation procedure**			
			Tightenint torque M_A to be applied		Preload to be applied F_M[2)	Pre-tightening torque to be applied M_A[2)	Clamping length	Angle or rotation or number of revolutions	
			lubricated with MoS_2[1)	lightly oiled			l_k[3)	φ[2)	U[2)
	mm	kN	Nm	Nm	kN	Nm	mm		
1	M12	50	100	120	60	10			
2	M16	100	250	350	110	50			
3	M20	160	450	600	175				
4	M22	190	650	900	210	100			
5	M24	220	800	1100	240				
6	M27	290	1250	1650	320	200			
7	M30	350	1650	2200	390				
8	M36	510	2800	3800	560				
9	M12					see lines 1 to 8	0 to 50	180°	1/2
10	to						51 to 100	240°	2/3
11	M36						101 to 240	270°	3/4

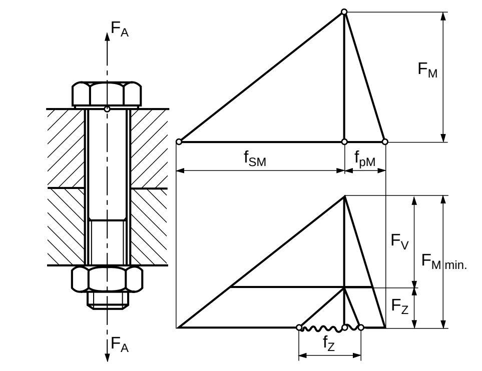
1) Since the values M_A are highly dependent upon the thread lubricant, observance of these values must be confirmed by the screw manufacturer.
2) Does not depend on the lubrication of the thread and the contact surfaces of nut and screw.
3) For screws M12 to M22 with clamping lengths 171 to 240 mm, an angle of rotation φ 360° and U = 1 must be used.
To apply a partial preload force $\geq 0{,}5 \cdot F_V$, half the values of columns 3 to 5 and 8 or 9 and hand-tightening according tocolumn 6 is sufficient.

Summary of constructive measures for locking screw joints

In principle, there are two reasons why bolted connections may need locking

Loosening due to setting

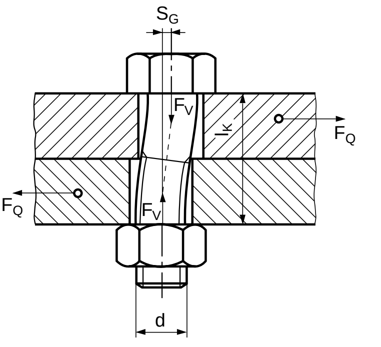
Loosening of bolted joints results in preload loss. This loss is caused by setting of the joint members or by a permanent elongation of the screw after tightening or under the operation force F_A.



F_M = assembly preload
f_{SM} = elongation of screw through F_M
f_{PM} = shortening of compressed parts through F_M
F_V = final preload
F_Z = loss of prelaod due to setting
f_Z = amount of setting
F_A = operation force
$F_{M\,min.} = F_V + F_Z$

Rotational loosening

Dynamic shear forces F_Q acting upon the bolted joint can cause the joint members to slip back and forth. This will prompt screws and nuts to rotate, this reducing the preload until it is zero.



F_V = preload
F_Q = shear force
l_K = clamping length
S_G = displacement of clamped parts
d = nominal diameter

The following locking methods are possible:

Locking against loosening due to setting

Measures	Effect achieved
Clean, smooth joiint interfaces minimum number of interfaces No soft, plastically deformable joint members	Reduction of setting possibilities.
Long screws (l_K > 4 x d). Screws with reduced shank Spring washers	High elasticity, compensation of preload loss.
Fasteners with flange	A larger bearing surface prevents the permitted limiting value of surface pressure from being exceeded. Larger tolerance for hole-Ø.
Special washers with 200 HV hardness.	The same advantages as above. Use up to strength class 8.8.

Locking against rotational loosening

Measures	Effect achiefed
Bigger screws Higher property classes	Lateral movement of the joint member can be prevented by a higher preload.
Shoulder screws Parallel or dowel pins	No possibility for lateral movements
Long screws (l > 4 x d) Screws with reduced shank	Flexible joint Better fatique resistance.
Ribbed screws or ribbed washers.	Rolling effect leads to compression of the surface with the embedding of the grooves.

List of additional ways of securing screwed connections and retaining collars against working loose or coming unscrewed

Securely fastened screwed connections

Caution!
The locking effects listed in the following table against loosening, unscrewing and/or loss of screws are based entirely on field experience.
It is the responsibility of the user to check the various elements and methods based on his knowledge of exactly how they are to be used in each particular case.

Designation of the part / Standard	Security against									Comments
	Loosening up to				Rotational loosening up to				Loss	
	div.	5.6	8.8	10.9	div.	5.6	8.8	10.9		
Screws and nuts with ribbed flange (VERBUS RIPP®)				○				●		For unhardened components, increased loosening torque due to ribbed flange.
Screws and nuts with serrated flange (VERBUS TENSILOCK®)							●			Serrated flange surface prevents unscrewing of unhardened components.
Screws with concave pan washer (eco-fix®)		◐				◐				Increased loosening torque due to the large concave pan washer.
ThreeBond, DELO, Precote® type 30 / 80 / 85					●	●	●	●	●	Chemical thread locking adhesives eliminate thread play and provide a seal.
Screws with a polyaminide coating Tuflok®									●	Protection against loss through sticky thread, max. 120 °C.
Thread-forming screws for metals DIN 7500	◐				◐				◐	Total security through formed, play-free thread fitting.
Thread-forming screws for thermoplastic materials PT® and DELTA PT®	◐				●				●	Total security through formed, play-free thread fitting.
Prevailing torque nuts to DIN 982 / 985 etc.									●	Protection against loss through polyaminide locking element, max. 120 °C.
Prevailing torque nuts to DIN 980 / ISO 7042 etc.									●	Protection against loss through metallic locking element.
Sealing nuts with locking element (Seal-Lok®) etc.									●	Increased loosening torque due to integrated, rotatable toothed lock washer.
Elastic nuts (Serpress®) etc.		◐				○				Reduced surface pressure with larger friction area.
Castle nuts to DIN 935 etc.					◐	◐	◐		●	Sealing and protection against loss through polyaminide locking element, max. 120 °C.
Hexagon nuts with spring washer			◐							Locking effect due to the elasticity (not locking).
Hexagon nuts with toothed lock washer (BN 1364)							○			Cotter pin prevents loss, although a limited amount of loosening is possible.
Flange nuts / flange screws			○				○			Integrated spring washer compensates for setting.
Spring washers to DIN 127 / DIN 128 / DIN 7980 etc.		◐				○				Springy effect, slight increase in the loosening torque.
Serrated lock washers and tooth washers to DIN 6798 / 6797 etc.						◐				High loosening torque on soft bearing surfaces.
Rip-Lock® Profiled spring washers			◐	○			◐	○		Springy, profiled universal washer: increased loosening torque with unhardened components.
Ribbed washers (ribs on both sides)			○				●	◐		Spring washer profiled on both sides with increased loosening torque with unhardened components.
Spring washers to DIN 6796 etc.			●	◐						High contact forces with corresponding spring characteristics.

Locking effect:
● very good ◐ good ○ moderate

Screws which should be locked

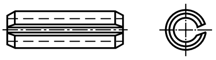
Grip length L_k / Thread Ø d	Loading			
	static		dynamic	
	in the direction of the axis	transverse to the axis	in the direction of the axis	transverse to the axis
short $L_k < 2$ d	none	Clarify locking effect	Clarify locking effect	Locking required
medium 5 d > $L_k \geq 2$ d	none	none	Depends on the conditions clarify locking effect	Locking required
long $L_k \geq 5$ d	none	none	none	Depends on the conditions clarify locking effect

Dowel pins (clamping sleeves) heavy finish

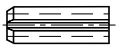
Shear loads for pins

Spiral pins, heavy finish according to ISO 8752

up to 8 mm nominal diameter



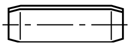
from 10 mm nominal diameter



Material: spring steel hardened and tempered to 420 to 560 HV

Nominal diameter, mm	1	1,5	2	2,5	3	3,5	4	4,5	5	6	8	10	12	13	14	16	18	20
Shear force min. [kN] double lap joint	0,7	1,58	2,82	4,38	6,32	9,06	11,24	15,36	17,54	26,04	42,76	70,16	104,1	115,1	144,7	171	222,5	280,6

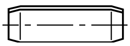
Spiral pins, standard finish according to ISO 8750



Material: spring steel hardened and tempered to 420 to 545 HV

Nominal diameter, mm	0,8	1	1,2	1,5	2	2,5	3	3,5	4	5	6	8	10	12	14	16	20
Shear force min. [kN] double lap joint	0,4	0,6	0,9	1,45	2,5	3,9	5,5	7,5	9,6	15	22	39	62	89	120	155	250

Spiral pins, heavy finish according to ISO 8748

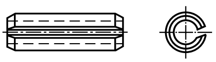


Material: spring steel hardened and tempered 420 to 545 HV

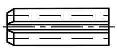
Nominal diameter, mm	1,5	2	2,5	3	4	5	6	8	10	12	14	16	20
Shear force min. [kN] double lap joint	1,9	3,5	5,5	7,6	13,5	20	30	53	84	120	165	210	340

Dowel (clamping sleeves) light finish according to ISO 13337

up to 8 mm nominal diameter

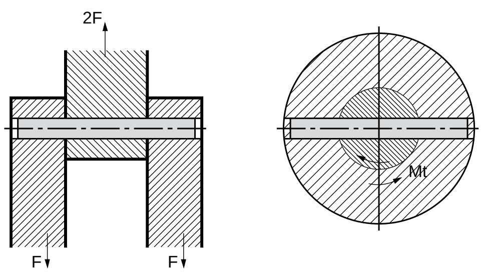


from 10 mm nominal diameter



Material: spring steel hardened and tempered 420 to 560 HV

Nominal diameter, mm	2	2,5	3	3,5	4	4,5	5	6	8	10	12	13	14	16	18	20
Shear force min. [kN] double lap joint	1,5	2,4	3,5	4,6	8	8,8	10,4	18	24	40	48	66	84	98	126	158



double lap joint

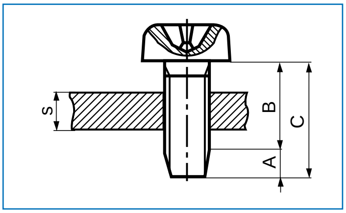
Direct screwed connections in metals using thread-forming screws
according to DIN 7500

Construction recommendations

What should be considered in the design and construction processes?

- Thread-forming screws to DIN 7500 (trilobular) produce a chip-free, gauge-correct metric internal thread.
- The screws are heat-treated to give a tensile strength in use of ca. 800 N/mm².
- It is possible to form threads in ductile metals such as steel, non-ferrous metals and light metals up to ca. 140–160 HV.
- Thread forming is not suitable for brittle metals such as grey cast iron.
- Screws made from A2 stainless steel can only safely be screwed into light metals. **In doing this the size of the pilot holes must be 5% larger than the values in the table.**
- No other safety features (such as retaining rings) are necessary. Resistance to vibration is provided by the thread friction.
- They can be re-used 10–20 times
- For thin sheets, the use of punch holes can help improve the mechanical properties of the fastening.
- It is recommended that preliminary trials be made for «laser-bored» holes (the cut surfaces may be to hard.)
- Preliminary trials should be made for critical applications. Get in touch with Bossard Engineering as early as possible in the development stage of your product.

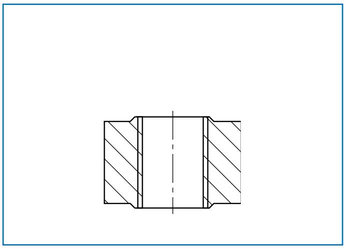
Functionally appropriate design of components and selection of the correct type of fastening element are essential requirements for a secure screw connection.

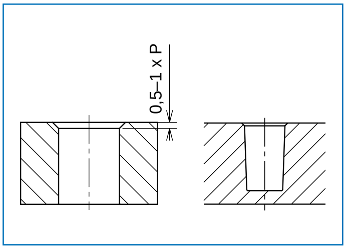


A = cone-shaped end of screw, max. 4 P
B = usable thread length
C = total length, tolerance js 16
s = thickness of material

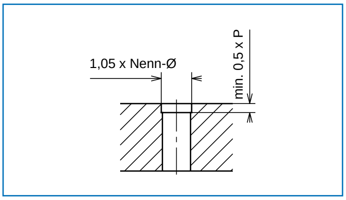
The length of the cone-shaped end of the screw, which is not fully load-bearing, should be allowed for when deciding on the screw length.

Forming the pilot holes

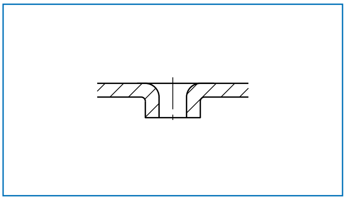




The displacement of the material which occurs when tapping the thread creates a small bulge at the edges of the tapping hole. This can create a problem when screwing smooth parts together. It is therefore recommended that you 90 °Countersink the edges of the tapping hole to a depth of 0,5 to 1x the thread pitch P or that you make a cylindrical countersunk hole.



Die zylindrische Ansenkung hat den Vorteil, dass durch das Anpassen der Ansenktiefe die Einschraubtiefe bei verschieden dicken Befestigungsteilenkonstant gehalten werden kann. Das bedeutet bei gleichen Materialien und Schraubendimensionen gleiche Montagemomente. Empfiehlt sich auch bei Druckguss.



In thin plates a through hole increases the load-bearing capacity of the fastening.

Ask Bossard Engineering for more detailed information.

Direct screwed connections in metals using thread-forming screws
according to DIN 7500

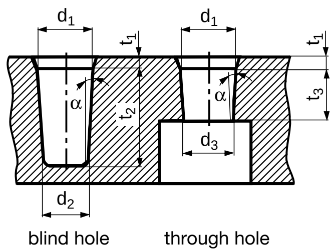
Strength characteristics, geometry of tapping holes

Technical details		Nominal thread diameter							
		M2	M2,5	M3	M3,5	M4	M5	M6	M8
Thread pitch P	mm	0,4	0,45	0,5	0,6	0,7	0,8	1	1,25
max. tightening torque	Nm	ca. 80% of breaking torque							
min. breaking torque[1)]	Nm	0,5	1	1,5	2,3	3,4	7,1	12	29
min. tensile force[1)]	kN	1,65	2,7	4	5,4	7	11,4	16	29
Thickness of material s	**mm**	**Diameter of tapping hole d – H11 for steel, HB max. 135; bored or punched**							
2 and smaller		1,8	2,25	2,7	3,2	3,6	4,5	5,4	7,25
4		1,85	2,3	2,75	3,2	3,65	4,55	5,45	7,25
6			2,35	2,75	3,2	3,7	4,6	5,5	7,4
8						3,7	4,65	5,55	7,4
10							4,65	5,65	7,5
12									7,5
14									7,5

1) as Bossard per supplier and test specification

Tapping holes for die-cast metal

All the recommendations must be tested by means of trial assemblies which closely resemble conditions in practice.



General

t_1 [mm]: fillets which provide an advantage for die-cast metals strengthening of the mandrel, centering of the screw, prevention of buckling of the material and adaptation to suit cost-effective standard screw lengths

t_2 / t_3 [mm]: bearing part of the tapping hole, taper angle α max. 1°

Nominal thread diameter			M2	M2,5	M3	M3,5	M4	M5	M6	M8
d_1[1)]		mm	1,9	2,36	2,86	3,32	3,78	4,77	5,69	7,63
d_2[1)]		mm	1,75	2,2	2,67	3,11	3,54	4,5	5,37	7,24
d_3[1)]		mm	1,8	2,27	2,76	3,23	3,64	4,6	5,48	7,35
1) Tolerance for d_1, d_2, d_3	+	mm	0,04	0,06	0,06	0,075	0,075	0,075	0,075	0,09
	–	mm	0	0	0	0	0	0	0	0
t_1 x 45°		mm	variable, minimum 1 x thread pitch P							
t_2[2)]		mm	5,3	5,3	6	6,9	7,8	9,2	11	14
2) Tolerance for t_2	+	mm	0,2	0,2	0,2	0,6	0,5	0,5	0,5	0,5
	–	mm	0	0	0	0	0	0	0	0
t_3		mm	2,5	2,5	3	3,5	4	5	6	8

What should you consider during assembly?

- Secure and cost-effective fastenings can only be produced with screwdrivers which have controlled torque and/or turning angle.
- The speed should lie between 300 and 1000 rpm.
- Both electrically- and pneumatically-powered screwdrivers can be used.
- The repeatability of the accuracy of the screwing process should be checked in trials using building components, in order to allow for effects which have not yet been detected.
- If you want to assemble components using automatic screwing machines then get in touch with us as early as possible, so that we can define and have your screws manufactured to the **required quality for automatic machines** (delivery period ca. 10 to 16 weeks). The automatic assembly of «standard stock screws» is not normally economically justifiable.

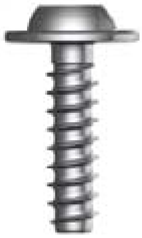
Calculating the torques
see page **T.**049

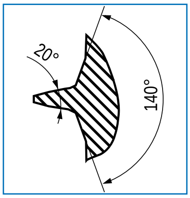
Direct assembly in thermoplastics using Delta PT® screws

Construction recommendations

The Delta PT® has all the well-known properties of the PT® screw. In addition the Delta PT® screw offers all the following advantages:

- New thread angle geometry with the main angle of thread of 20° favours the working of the plastic
- Up to 50% more tensional and torsional strength for the same nominal Ø d1, thanks to the increased cross-section of the core
- Increased stability against vibration thanks to the smaller thread pitch
- Substantially increased working life for the connection.
- Smaller Ø tolerances
- Robust fastener, which can transfer more prestress loading.
- The Delta PT® calculation program DELTACALC® allows a design based on prestress force in accordance with VDI 2230





Cost-effective connections

The following example shows that, for the same depth of thread engagement A_{FL}, thanks to the smaller thread pitch P it is possible to design for a smaller length of thread engagement t_e. The required screw depth for the Delta PT® screw can be calculated from the given depth of thread engagement A_{FL}.
A comparison of the Delta PT® with the PT® screw shows that:
Use of the Delta PT® allows you to use a shorter and so more cost-effective screw.

	A_{FL} mm²	P mm	d mm	t_e mm
PT® K50	35	2,24	4	13,24
Delta PT® 50	35	1,8	4	10,42
Delta PT® 40	35	1,46	3,2	11,75

$$A_{FL} = (d_1^2 - d^2) \times \frac{\pi}{4} \times \frac{t_e}{P}$$

Construction recommendations

- For simple fastenings the recommended published here are quite adequate
- We would be pleased to help you with the design of fastenings under operational loadings, and can also provide support through the use of DELTACALC®
- Select larger head diameters (BN 20040) for fastening together parts made of plastic. The head friction increases the safety of the process during assembly, a smaller surface pressure results in less relaxation and so in greater residual locking forces.
- Avoid using countersunk screws for clamping parts made from plastic. The 90° angle results in radial as well as axial relaxation, and where the edge distance is small this can lead to large losses in prestressing force, and so to a break in the part being clamped.
- Avoid using slot holes in clamping parts made from plastic. Lack of bearing surface can lead to the forming torque being greater than the head friction torque and this can make it impossible to construct a secure mounting.
- Transverse forces should be taken up by the engagement between the components.
- Provide a pressure relief hole d_e (avoids stress cracks)

Shape of the hole

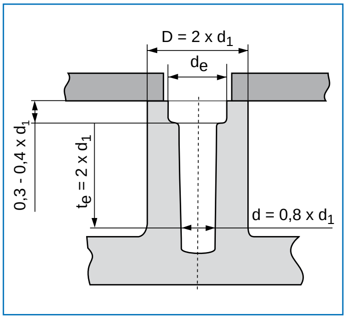
The maximum achievable prestress force when overtightening is the criteria for determining the optimum **hole Ø d**. It is less dependent on the tube material and the length of engaged thread t_e, and more dependent on the thread pitch P and the nominal diameter Ø d_1 of the screw thread. The design applies to all conventional plastics with a modulus of elasticity of up to E = 15000 N/mm² (hole-Ø d for special plastics available on request):

$d = 0{,}8 \times d_1$
$d_e = d_1 + 0{,}2$ mm

The **pressure relief hole d_e** is particularly important, since it gives a favourable distribution of edge stresses and so prevents the tube from shattering, particularly with plastics such as polycarbonates which are subject to stress cracking. It also ensures the even support of the clamping part. Bulging of the plastic when forming the first turn of the thread. To optimise the fastening the **hole diameter should not exceed Ø d = 0,88 x d1.**

In practice deviations from these recommendations may arise, for the following reasons:

- Processing conditions during manufacture of the plastic
- Design of the injection moulding equipment
- Position of the injection point
- Creation of flow seams
- Local texture, e.g. through use of additives and fillers such as colour pigments and fibres.
- The plastics can be modified in different ways, depending on the manufacturer.



We recommend that **control assembly runs** be made using the first available parts.
Ask for informationon our **«BossAnalytik»** service.

Berechenbar mehr Leistung

The preliminary design of screwed connections in thermoplastic can be simulated using the DELTACALC® calculation program. Based on VDI 2230, it permits a design to be made related to the prestressing force. These possibilities range from dimensioning through load capacity and on to the working life of the connection.
If you are working with **connections which are under operational loadings**, then ask for a copy of the form for the input data (bossard@bossard.com), fill it in and send it to Engineering at Bossard AG.
DELTACALC® cannot be purchased.

DELTA CALC

Tensile fracture laod

PT 10 version (Steel, hardened and tempered, strength analogous to 10.9)

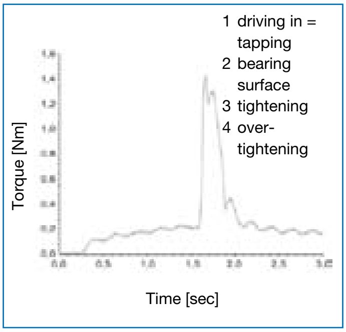
Nominal size of Delta PT®	Nominal Ø (d1) in mm	Min. tensile fracutre load in kN
20	2	1,6
22	2,2	1,9
25	2,5	2,7
30	3	3,8
35	3,5	5,2
40	4	6,8
45	4,5	8,6
50	5	10
60	6	15
70	7	21
80	8	28
100	10	44

What should you consider during assembly?

- Secure and cost-effective fastenings can only be produced with screwdrivers which have controlled torque and/or turning angle. The heat needed for low-stress formation of the thread in plastics is created by friction generated when driving in the screw.
- The rotational speed should be between 300 and 800 rpm.
- Both electrically- and pneumatically-powered screwdrivers can be used.
- Trials using components should be made to check the calculated values and the repeatability of the screwing process, in order to allow for effects which have not yet been detected.
- If you want to assemble components using automatic screwing machines then get in touch with us as early as possible, so that we can define and have your screws manufactured to the **required quality for automatic machines** (delivery times ca. 10 to 16 weeks). The automatic assembly of «standard stock screws» is not normally economically justifiable.

Calculating the torque

In order to achieve optimal safety during assembly, the difference between the driving torque (Me) and the stripping torque (Mü) must be as large as possible. The true screwing parameters can be established by Bossard, using original components in their «Applications testing laboratory» The optimum tightening torque M_A to be set on the screwdriver for the assembly process is determined based on customer-specific requirements. The results are then documented in the form of a «Technical Report».



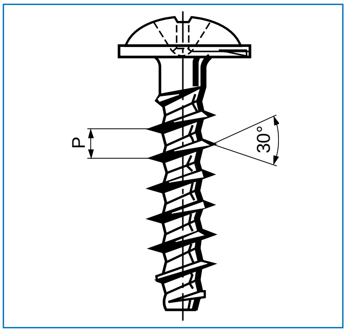
Direct assembly in thermoplastics using Delta PT® screws

Construction recommendations

The PT® screw has been used successfully for years. PT® screws have the necessary features to enable a secure joint in thermoplastics.

Advantages of PT® screws

- Low driving torque, high stripping torque
- High assembly safety
- Excellent vibration resistance
- Low bursting tendency
- No excessive joint relaxation therefore plastic components do not shift
- Cost-effective fastener for direct fastening in thermoplastics



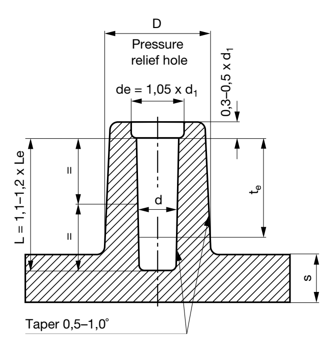
Design guidelines

- For fastening plastic parts, specify a large head diameter (BN 20040). This increases friction under the head, making a safer joint. Also a larger head reduces the surface pressure which in turn minimizes joint relaxation and ultimately increases the residual clamp load.
- Do not use flat head screws. The 90° head angle not only results in axial forces but also radial forces, hence causing greater joint relaxation in parts with narrow edge margins. The preload would be unsafe.
- Avoid elongated holes in plastic parts, as they would create a small bearing area, possibly causing the driving torque to be bigger than the under-head friction torque. Such a joint would be unsafe.
- Shear forces should be absorbed by form-fitting components.
- Furnish the pilot hole entrance with a counterbore (avoids stress cracking)

Boss design for PT® screws

An optimum boss design that will hold up in the application, requires the boss geometry to be adjusted to the different plastics.

The details shown here are based on laboratory testing. Some changes may be needed to fit your application. We recommend that users conduct application testing and joint analyses.



Material	hole Ø d	external Ø D	length of thread engagement t_e
ABS / PC blend	0,80 x d_1	2,00 x d_1	2,00 x d_1
ASA	0,78 x d_1	2,00 x d_1	2,00 x d_1
PA 4.6	0,73 x d_1	1,85 x d_1	1,80 x d_1
PA 4.6 - GF 30	0,78 x d_1	1,85 x d_1	1,80 x d_1
PA 6	0,75 x d_1	1,85 x d_1	1,70 x d_1
PA 6 - GF 30	0,80 x d_1	2,00 x d_1	1,90 x d_1
PA 6.6	0,75 x d_1	1,85 x d_1	1,70 x d_1
PA 6.6 - GF 30	0,82 x d_1	2,00 x d_1	1,80 x d_1
PBT	0,75 x d_1	1,85 x d_1	1,70 x d_1
PBT - GF 30	0,80 x d_1	1,80 x d_1	1,70 x d_1
PC	0,85 x d_1	2,50 x d_1	2,20 x d_1 [1)]
PC - GF 30	0,85 x d_1	2,20 x d_1	2,00 x d_1 [1)]
PE (soft)	0,70 x d_1	2,00 x d_1	2,00 x d_1
PE (hard)	0,75 x d_1	1,80 x d_1	1,80 x d_1
PET	0,75 x d_1	1,85 x d_1	1,70 x d_1
PET - GF 30	0,80 x d_1	1,80 x d_1	1,70 x d_1
PMMA	0,85 x d_1	2,00 x d_1	2,00 x d_1
POM	0,75 x d_1	1,95 x d_1	2,00 x d_1
PP	0,70 x d_1	2,00 x d_1	2,00 x d_1
PP - TV 20	0,72 x d_1	2,00 x d_1	2,00 x d_1
PPO	0,85 x d_1	2,50 x d_1	2,20 x d_1 [1)]
PS	0,80 x d_1	2,00 x d_1	2,00 x d_1
PVC (hard)	0,80 x d_1	2,00 x d_1	2,00 x d_1
SAN	0,77 x d_1	2,00 x d_1	1,90 x d_1

d_1 = nominal thread diameter Ø

[1)] Since these materials are more susceptible to stress cracking, it is highly recommended to carry out application testing. Also, a counterbore (relief bore) is strongly recommended to minimize stress risers.

Direct assembly in thermoplastics using Delta PT® screws

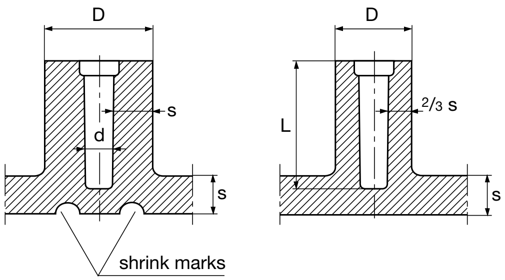
Construction recommendations

Changes of shape

Occur for the given shrink hole shape, shrink marks or extended injection cycles; the form can be changed as follows:

- Reduce external diameter D of the tube.
- Increase the diameter d of the hole
- Increase tapping hole depth and so length of screw thread engagement, in order to compensate for the losses in resistance to stripping.

Select tapping holes which are sufficiently deep so that under no circumstances can the assembled screws rest in the base of the hole.



unsuitable tube shape　　improved tube shape

Tensile fracture load

Steel, hardened and tempered, strength analogous to 10.9

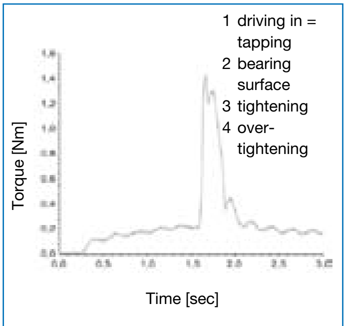
Nominal size PT®	Nominal Ø (d_1) in mm	Min. tensile fracture load in kN
K 18	1,8	1,1
K 20	2	1,3
K 22	2,2	1,6
K 25	2,5	2
K 30	3	2,7
K 35	3,5	3,6
K 40	4	4,6
K 50	5	7
K 60	6	9,8
K 70	7	13
K 80	8	16
K100	10	25

What should you consider during assembly?

- Secure and cost-effective fastenings can only be produced with screwdrivers which have controlled torque and/or turning angle. The heat needed for low-stress formation of the thread in plastics is created by friction generated when driving in the screw.
- The rotational speed should lie between 300 and 800 rpm.
- Both electrically- and pneumatically-powered screwdrivers can be used.
- Trials made using components should be made to check the calculated values and the repeatability of the screwing process, in order to allow for effects which have not yet been detected.
- If you want to assemble components using automatic screwing machines then get in touch with us as early as possible, so that we can define and have your screws **manufactured to the required quality for automatic** machines. (delivery times ca. 10 to 16 weeks). Automatic assembly using screws from stock is not normally economically justifiable.

Calculating the torque

In order to achieve optimal safety during assembly, the difference between the driving torque (Me) and the stripping torque (Mü) must be as large as possible. The true screwing parameters can be established by Bossard, using original components in their «Applications testing laboratory» The optimum tightening torque M_A to be set on the screwdriver for the assembly process is determined based on customer-specific requirements. The results are then documented in the form of a «Technical Report».



Sheet metal joints
(use) according to DIN 7975

Design guideline

The informtion below represents general recommendations for the use of screws for sheet metal joints. The different types are shown by way of example.

Minimum total thickness of the sheet metals to be fastened
The total thickness of the fastened parts shall be bigger than the thread pitch of the applied tapping screw; or else, because of the thread run out underneath the head, a sufficient tightening torque can not be applied. Should this be the case, joints such as shown in figure 3 to 6 should be applied.

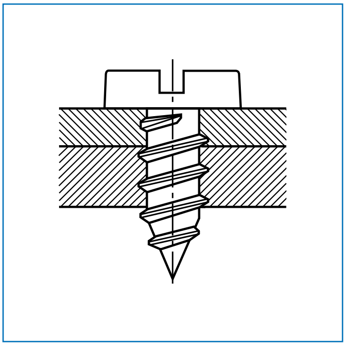


Fig. 1: Simple fastening (two core holes)

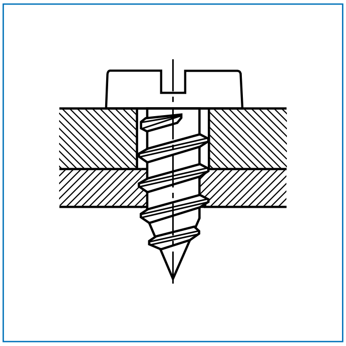


Fig. 2: Simple fastening with clearance hole

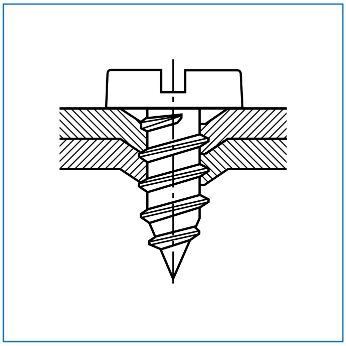


Fig. 3: Pierced core hole (thin sheet metal)

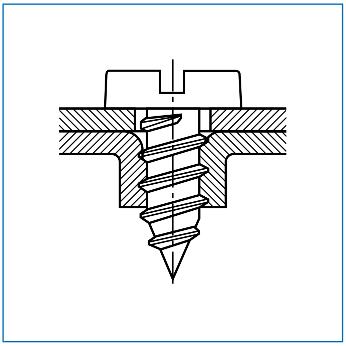


Fig. 4: Extruded core hole (thin sheet metal)

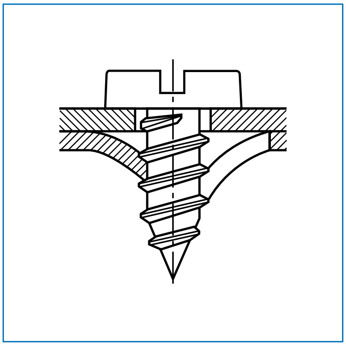


Fig. 5: Pressed hole fastening joint

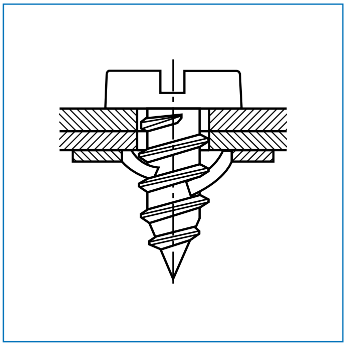


Fig. 6: Fastening with spring nut

Sheet metal joints

Pilot hole diameter

Design guideline

Self-tapping screws / sheet metal thickness / pilot hole diameters

The following reference values are valid only for case hardened steel self-tapping screws as shown in Figure 2 on page **T.**052. The tightening torques are max. 50% of the minimum breaking torque. Prior tests must be carried for the utilisation of other screws or other sheet metal materials. Punched pilot holes must be 0,1–0,3 mm larger. The screws must be tightened in the direction the hole was punched.

Thread diameter	Pitch P	Material strength Rm [MPa]	Diameter of the pilot hole for d_b thread dimensions ST 2,2 to ST 6,3 for a sheet metal thickness s [mm]																				
			0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0	2,2	2,5	2,8	3,0	3,5	4,0	4,5	5,0
ST 2,2	0,8	from 100	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,8										
		approx. 300	1,7	1,7	1,7	1,7	1,7	1,7	1,8	1,8	1,9	1,9	1,9										
		up to 500	1,7	1,7	1,7	1,8	1,8	1,8	1,9	1,9	1,9	1,9	1,9										
ST 2,9	1,1	from 100				2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,3							
		approx. 300				2,2	2,2	2,2	2,2	2,3	2,3	2,3	2,4	2,4	2,4	2,4							
		up to 500				2,2	2,2	2,3	2,3	2,4	2,4	2,4	2,4	2,5	2,5	2,5							
ST 3,5	1,3	from 100						2,6	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,8	2,9					
		approx. 300						2,6	2,7	2,7	2,7	2,7	2,8	2,8	2,9	2,9	3,0	3,0					
		up to 500						2,7	2,8	2,8	2,9	2,9	2,9	2,9	3,0	3,0	3,1	3,1					
ST 3,9	1,4	from 100						2,9	2,9	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,1	3,2	3,3				
		approx. 300						2,9	2,9	3,0	3,0	3,1	3,1	3,2	3,2	3,2	3,3	3,3	3,3				
		up to 500						3,0	3,1	3,1	3,2	3,2	3,3	3,3	3,3	3,3	3,4	3,4	3,5				
ST 4,2	1,4	from 100							3,1	3,2	3,2	3,2	3,2	3,2	3,2	3,2	3,2	3,3	3,4	3,5			
		approx. 300							3,1	3,2	3,2	3,2	3,3	3,3	3,4	3,4	3,5	3,6	3,6	3,6			
		up to 500							3,3	3,3	3,4	3,4	3,4	3,4	3,5	3,5	3,6	3,6	3,6	3,7			
ST 4,8	1,6	from 100									3,6	3,6	3,6	3,6	3,6	3,6	3,7	3,8	3,9	4,0	4,1		
		approx. 300									3,6	3,7	3,8	3,8	3,9	3,9	4,0	4,1	4,1	4,2	4,2		
		up to 500									3,9	3,9	4,0	4,0	4,0	4,1	4,1	4,2	4,2	4,2	4,3		
ST 5,5	1,8	from 100											4,2	4,2	4,2	4,2	4,2	4,4	4,5	4,6	4,7	4,8	
		approx. 300											4,3	4,4	4,4	4,5	4,7	4,7	4,8	4,8	4,9	4,9	
		up to 500											4,6	4,6	4,6	4,7	4,8	4,8	4,9	4,9	5,0	5,0	
ST 6,3	1,8	from 100											4,9	4,9	4,9	4,9	5,0	5,2	5,3	5,4	5,5	5,6	5,7
		approx. 300											5,0	5,1	5,2	5,3	5,4	5,5	5,6	5,7	5,7	5,8	5,8
		up to 500											5,3	5,4	5,4	5,5	5,6	5,7	5,7	5,7	5,8	5,8	5,8

Minimum breaking torque

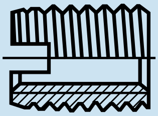
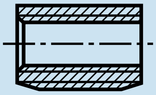
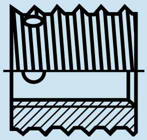
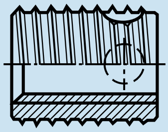
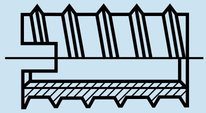
per DIN 267, type 12

Self-tapping screws	nominal Ø [mm]	ST 2,2	ST 2,9	ST 3,5	ST 3,9	ST 4,2	ST 4,8	ST 5,5	ST 6,3
Minimum breaking torque	[Nm]	0,45	1,5	2,8	3,4	4,5	6,5	10	14

Selection crieria for self-tapping Ensat® inserts

Construction recommendations

Grouping of materials, types and finishes.

				
Ensat® **Type 302**	**Ensat®** **Type 305**	**Ensat®** **Type 307 / 308**	**Ensat®** **Type 337 / 338**	**Ensat®** **Type 309**

Material Group	**Base material**	**Recommended works standards**	**Finishes / materials**
I	Heat-treated aluminium with a tensile strength above 350 N/mm²	302 / 337 307 / 338 308	Steel hardened zinc yellow dichromate
	Cast iron in higher hardness range. brass, bronze and other non-ferrous metals.	302	Steel hardened zinc yellow dichromate
II	Aluminium with a tensile strength up to 350 N/mm²	302 / 337 307 / 338 308	Steel hardened zinc yellow dichromate
	Cast iron	302	Steel hardened zinc yellow dichromate
	Thermoplastics Thermosetting plastics (Polyester plastics, Nylon 66 both reinforced, Plexiglas)	302 / 337 307 / 338 308	Steel hardened zinc yellow dichromate or Brass
III	Aluminium with a tensile strength up to 300 N/mm²	302 / 337 307 / 338 308	Steel hardened zinc yellow dichromate
	Soft cast iron	302	Steel hardened zinc yellow dichromate
	Thermoplastics Thermosetting plastics (Nylon 66, Laminates)	302 / 337 307 / 338 308	Steel hardened zinc yellow dichromate
		302	Brass
IV	Aluminium with a tensile strength up to 250 N/mm²	302	Steel hardened zinc yellow dichromate
	Soft metals and aluminium with tensile strength up to180 N/mm²	302	Steel hardened zinc yellow dichromate or INOX A1
	Laminates soft (press-board)	302	Steel hardened zinc yellow dichromate or Brass or INOX A1
	Thermoplastics, Thermosetting plastics, (Polyethylene, polypropylene etc.) Hardwoods	302	Steel hardened zinc yellow dichromate or Brass or INOX A1
V	Hardwoods	309	Brass
VI	Softwoods and plywood Wood fiber materials	309	Brass
VII	Thermoplastics	305	Brass

Selection crieria for self-tapping Ensat® inserts

Construction recommendations

Recommended pilot hole diameters and material thickness / blind hole depths for threaded inserts Ensat®

The recommended hole diameter depends on the Ensat® external thread, the strength and the physical characteristics of the work-piece material.

Hard and brittle materials require a larger hole than soft and flexible ones. Whenever necessary, the most suitable hole diameter should be determined through application testing.

Ensat® Type 302	For material groups				Material thickness A min.	Blind hole depth B min.
	I	II	III	IV		
	Attainable percentage of overlapping threads					
	30%–40%	40%–50%	50%–60%	60%–70%		
Thread	Hole diameter D [mm]					
M 2,5	4,3– 4,2	4,2–4,1	4,1	4,1– 4	6	8
M 2,6	4,3– 4,2	4,2	4,1	4,1– 4	6	8
M 3	4,8– 4,7	4,7	4,6	4,6– 4,5	6	8
M 3,5	5,7– 5,6	5,6–5,5	5,5– 5,4	5,4– 5,3	8	10
M 4	6,2– 6,1	6,1–6	6 – 5,9	5,9– 5,8	8	10
M 5	7,6– 7,5	7,5–7,3	7,3– 7,2	7,2– 7,1	10	13
M 6a	8,6– 8,5	8,5–8,3	8,3– 8,2	8,2– 8,1	12	15
M 6	9,4– 9,2	9,2–9	9 – 8,8	8,8– 8,6	14	17
M 8	11,4–11,2	11,2–11	11 –10,8	10,8–10,6	15	18
M10	13,4–13,2	13,2–13	13 –12,8	12,8–12,6	18	22
M12	15,4–15,2	15,2–15	15 –14,8	14,8–14,6	22	26
M14	17,4–17,2	17,2–17	17 –16,8	16,8–16,6	24	28
M16	19,4–19,2	19,2–19	19 –18,8	18,8–18,6	22	27
M20	25,4–25,2	25,2–25	25 –24,8	24,8–24,6	27	32
M24	29,4–29,2	29,2–29	29 –28,8	28,8–28,6	30	36

Ensat® Type 309	For material groups		Material thickness A min.	Blind hole depth B min.
	V	VI		
	Attainable percentage of overlapping threads			
	85%–90%	90%–95%		
Thread	Hole diameter D [mm]			
M 2,5	3,8– 3,6	3,6– 3,5	6	8
M 3	4,3– 4,2	4,2– 4,1	6	8
M 4	5,3– 5,2	5,2– 5,1	10	13
M 5	6,9– 6,7	6,7– 6,6	12	15
M 6	7,9– 7,7	7,7– 7,6	14	17
M 8	10,3–10,1	10,1– 9,9	20	23
M10	12,8–12,6	12,6–12,4	23	26
M12	15,8–15,6	15,6–15,4	26	30

Ensat® Type 305	For material groups	Material thickness A min.	Blind hole depth B min.
	VII		
	Hole diameter D [mm]		
Thread			
M 3	4,6–4,7	6	7
M 4	6 –6,1	8	9
M 5	7,3–7,4	10	11
M 6	9 –9,2	14	15

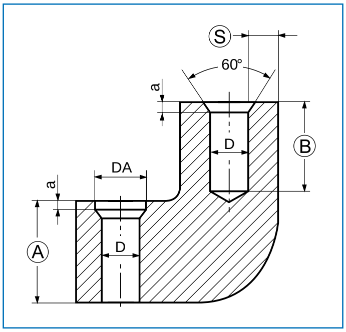
Ensat® Type 307 / 308 337 / 338	For material groups			Material thickness A min.	Blind hole depth B min.
	I	II	III		
	Attainable percentage of overlapping threads				
	50%–60%	60%–70%	70%–80%		
Thread	Hole diameter D [mm]				
M 3,5	5,7– 5,6	5,6	5,6– 5,5	5/8	7/10
M 4	6,2– 6,1	6,1	6,1– 6	6/8	8/10
M 5	7,7– 7,6	7,6– 7,5	7,5– 7,4	7/10	9/13
M 6	9,6– 9,5	9,5– 9,4	9,4– 9,3	8/12	10/15
M 8	11,5–11,3	11,3–11,2	11,2–11,1	9/14	11/17
M10	13,5–13,3	13,3–13,2	13,2–13,1	10/18	13/22
M12	15,4–15,2	15,2–15,1	15,1–15	12/22	15/26
M14	17,4–17,2	17,2–17,1	17,1–17	14/24	17/28

The pilot hole can be drilled or formed during die-casting

Countersinking the hole is usually not necessary; however it would facilitate installation and possibly prevent damage to the workpiece surface.
It also would enable the insert to be flush with the work-piece.

Material thickness:
Length of Ensat® = shortest permissible Material thickness Ⓐ

Blind hole depth:
Minimum depth Ⓑ



D_A = + 0,2 to 0,4 mm

a = 1–1,5 x the pitch of the external thread of the Ensat®

Minimum wall thickness:
The wall thickness is dependant upon the hardness and / or strength of the work-piece material.

Recommendation for aluminum:
Ⓢ ≥ 0.3 to ≥ 0.6 d_2

Recommendation for cast iron:
Ⓢ ≥ 0.3 to ≥ 0.5 d_2

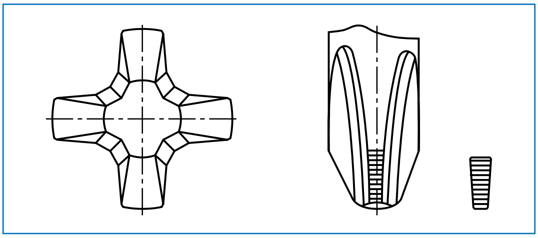
d_2 = Outside diameter (mm) of Ensat® insert

Internal drives for screws

Construction recommendations

– Technical progress and economic factors have resulted in the increasing replacement of slotted head screws by other internaldrive systems.
– It is very important today to take into account the most frequently used drives and their possibilities in design, logistics, procurement and assembly.

Cross recess H (Phillips) according to ISO 4757

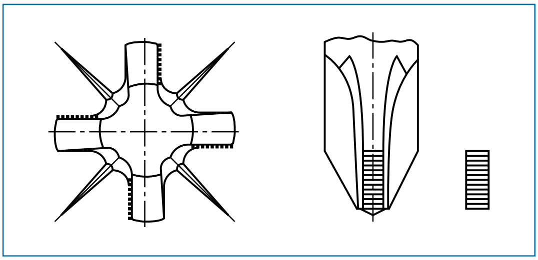


– The Phillips cross recessed head is the world’s most widely used system.

– Has a conventional cruciform recess with all walls inclined, the end of the screwdriver having trapezoid webs.

– The general dimensions are given in the product information in the catalogue.

Cross recess Z (Pozidriv) according to ISO 4757

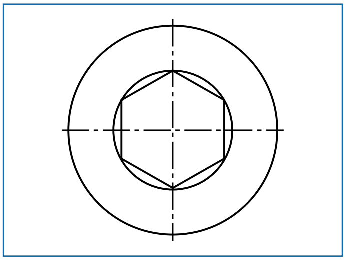


– The Pozidriv cross recessed head is used principally in Europe.

– The four «tightening walls» of the cruciforme recess in contact with the screwdriver when tightening, are perpendicular. The other walls are inclined. This can improve assembly if the recess production is reliable. The Pozidriv screwdriver has rectangular webs at its extremity.

– The general dimensions are given in the product information in the catalogue.

Hexagon socket

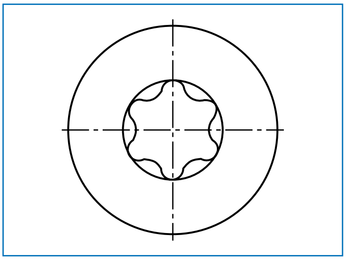


– Screws with hexagon socket head have proved their worth in the machine and apparatus construction fields.

– The width across flats of hexagon socket head screws is smaller than the WAF of hexagon head screws, permitting more economic design with smaller sizes.

– The general dimensions are given in the product information in the catalogue.

Hexalobular socket

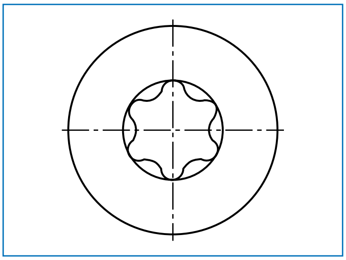


– The notion of a drive with hexalobular sockets are a decisive step in developing drives better adapted to manual and automated assembly. This drive is becoming increasingly popular throughout the world.

– Compared to drives like cross recesses and conventional hexagon sockets, this system is characerised by a lower risk of deterioration and a lower pressure force requirement. The typical «cam out» slipping of the tool has hence been eliminated and the force transmission improved.

– The general dimensions are given in the product information in the catalogue.

Torx plus®

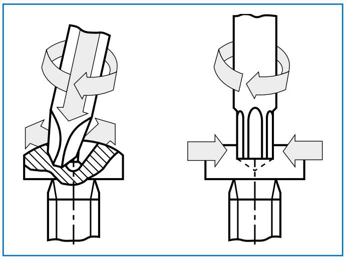


– The Torx plus® drive is defined by ellipses and represents an improvement over the original hexalobular system which is defined by a series of radii.

– The Torx plus® system is compatible with the tools provided for the (Torx®) hexalobular system. However, the specific geometric benefits of Torx plus® can only optimise assembly when using the Torx plus® screwdriver bits (tool).

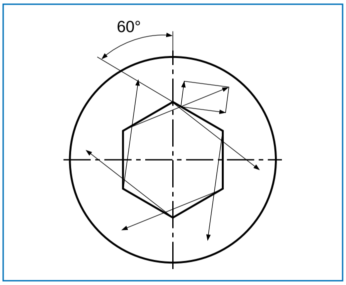
– The general dimensions are given in the product designations in the catalogue.

Technical advantages of hexalobular socket and Torx plus® drives and their economic benefit

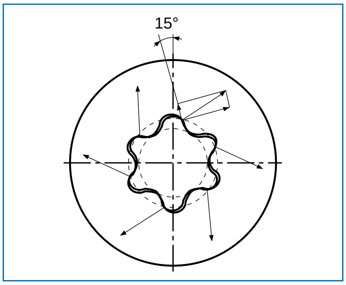


- No need for pressure force as is necessary when using cross recessed drives.
- Can accept the tightening torques for all property classes.
- No deterioration of the internal drive; hence reliable unscrewing.
  Very low assembly tool wear.
- High rationalisation potential for the assembly technique, as the drive is suitable for all types of screw
- Economic head from the aspect of size, form and material, corresponding to cheese head screws DIN 84 and DIN 7984, however able to cope with high stresses with respect to permissible surface pressure.
- No problem assembling round head screws according to ISO 7380 and recessed flat head screws DIN 7991. The high property class 10.9 of these screws permitting increased strength of the hexagon socket can be reduced toproperty class 8.8.

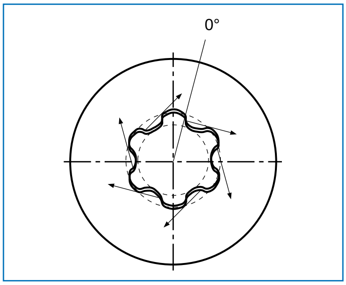
The hexalobular socket and the Torx plus® systems have benefits due to their design parameters



Force transmission angle of 60° with hexagon socket drives



Force transmission angle of 15° with hexalobular socket drives



Force transmission angle of 0° with Torx plus® drives

– The effective transmission angle of the hexalobular socket is 15° and that of the Torx plus® is 0°. The force applied is that actually used for tightening the screw. The geometries of the hexalobular socket and the Torx plus® therefore extend the service life of the screwdriver bits by up to 100%.
– The cross section of the Torx plus® drive is larger compared to the hexa-lobular system. Therefore the torsional strength of the driving tool is increased.
– The good force transmission enables low penetration depths.

Metric ISO threads

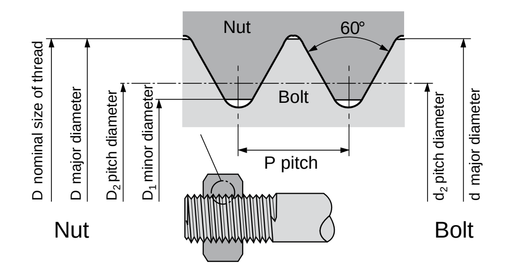
General

The thread dimensions and profile accuracy are crucial for determining:

- whether a coating can still be applied to the screw thread.
- whether the parts to be joined can be screwed together on assembly without difficulty or the need for reworking.
- whether the thread can transmit the forces for which the components were dimensioned.
- Tolerances are very small in screw manufacturing. Terms and fitting systems are difficult to understand. To assist. the following illustrations explain dimensions and tolerances.

Basic concept and nominal dimensions according to ISO 724

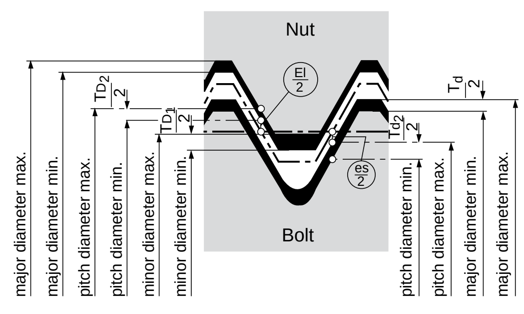
The dimension system for threads is based on the nominal dimensions for thread, pitch and minor diameter.



Clearance fit on metric ISO threads according to ISO 965

Screw and nut threads have different tolerance zone positions: screw thread dimensions are situated at the nominal dimensionand below, nut thread dimensions, at the nominal dimensionand above.

This produces the necessary clearance and a defined range for permissible plating thicknesses: a plated screw thread must never exceed the nominal dimensions, while a plated nut thread must never fall below them (see **T.**027).

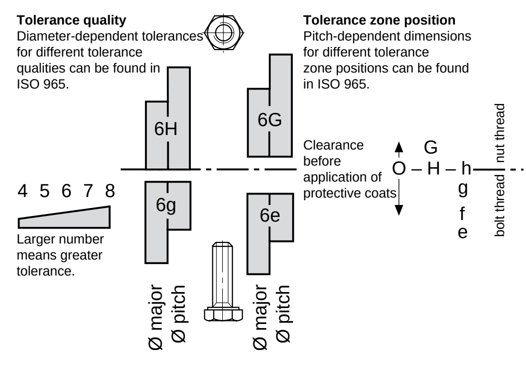


Tolerance fields for commercial screws and nuts according to ISO 965

The ISO 965 thread standard recommends tolerance fields which give the desired clearance. For threads ≥ M1,4, the following tolerance fields are standard!

Mutter	Bolzen	Oberflächenzustand
6H	6g	bright, phosphated or for standard electroplatings
6G	6e	bright (with large clearance) or for very thick electroplatings

6g-ring ganges for plain screw threads
6h-ring ganges for plated screws



Tolerance fields of screw and nut threads

Limits for metric (standard) coarse threads

according to ISO 965

Screws, tolerance 6g (*6h)

Thread	Length of thread engagement		Major diameter d (mm)		Pitch diameter d_2 (mm)		Thread root radius (mm)
	from	to	max.	min.	max.	min.	min.
M 1*	0,6	1,7	1,000	0,933	0,838	0,785	0,031
M 1,2*	0,6	1,7	1,200	1,133	1,038	0,985	0,031
M 1,4*	0,7	2	1,400	1,325	1,205	1,149	0,038
M 1,6	0,8	2,6	1,581	1,496	1,354	1,291	0,044
M 1,8	0,8	2,6	1,781	1,696	1,554	1,491	0,044
M 2	1	3	1,981	1,886	1,721	1,654	0,050
M 2,5	1,3	3,8	2,480	2,380	2,188	2,117	0,056
M 3	1,5	4,5	2,980	2,874	2,655	2,580	0,063
M 3,5	1,7	5	3,479	3,354	3,089	3,004	0,075
M 4	2	6	3,978	3,838	3,523	3,433	0,088
M 5	2,5	7,5	4,976	4,826	4,456	4,361	0,100
M 6	3	9	5,974	5,794	5,324	5,212	0,125
M 7	3	9	6,974	6,794	6,324	6,212	0,125
M 8	4	12	7,972	7,760	7,160	7,042	0,156
M10	5	15	9,968	9,732	8,994	8,862	0,188
M12	6	18	11,966	11,701	10,829	10,679	0,219
M14	8	24	13,962	13,682	12,663	12,503	0,250
M16	8	24	15,962	15,682	14,663	14,503	0,250
M18	10	30	17,958	17,623	16,334	16,164	0,313
M20	10	30	19,958	19,623	18,334	18,164	0,313
M22	10	30	21,958	21,623	20,334	20,164	0,313
M24	12	36	23,952	23,577	22,003	21,803	0,375
M27	12	36	26,952	26,577	25,003	24,803	0,375
M30	15	45	29,947	29,522	27,674	27,462	0,438
M33	15	45	32,947	32,522	30,674	30,462	0,438
M36	18	53	35,940	35,465	33,342	33,118	0,500
M39	18	53	38,940	38,465	26,342	26,118	0,500

Nuts, tolerance 6H (*5H)

Thread	Length oft thread engagement		Pitch diameter D_2 (mm)		Minor diameter D_1 (mm)	
	from	to	max.	min.	max.	min.
M 1*	0,6	1,7	0,894	0,838	0,785	0,729
M 1,2*	0,6	1,7	1,094	1,038	0,985	0,929
M 1,4*	0,7	2	1,265	1,205	1,142	1,075
M 1,6	0,8	2,6	1,458	1,373	1,321	1,221
M 1,8	0,8	2,6	1,658	1,573	1,521	1,421
M 2	1	3	1,830	1,740	1,679	1,567
M 2,5	1,3	3,8	2,303	2,208	2,138	2,013
M 3	1,5	4,5	2,775	2,675	2,599	2,459
M 3,5	1,7	5	3,222	3,110	3,010	2,850
M 4	2	6	3,663	3,545	3,422	3,242
M 5	2,5	7,5	4,605	4,480	4,334	4,134
M 6	3	9	5,500	5,350	5,153	4,917
M 7	3	9	6,500	6,350	6,153	5,917
M 8	4	12	7,348	7,188	6,912	6,647
M10	5	15	9,206	9,026	8,676	8,376
M12	6	18	11,063	10,863	10,441	10,106
M14	8	24	12,913	12,701	12,210	11,835
M16	8	24	14,913	14,701	14,210	13,835
M18	10	30	16,600	16,376	15,744	15,294
M20	10	30	18,600	18,376	17,744	17,294
M22	10	30	20,600	20,376	19,744	19,294
M24	12	36	22,316	22,051	21,252	20,752
M27	12	36	25,316	25,051	24,252	23,752
M30	15	45	28,007	27,727	26,771	26,211
M33	15	45	31,007	30,727	29,771	29,211
M36	18	53	33,702	33,402	32,270	31,670
M39	18	53	36,702	36,402	35,270	34,670

Selection series for coarse threads

according to ISO 262

Thread nominal diameter		Pitch
Reihe 1	Reihe 2	P
		0,25
1,2		0,25
	1,4	0,3
1,6		0,35
	1,8	0,35
2		0,4
2,5		0,45
3		0,5
	3,5	0,6
4		0,7
5		0,8
6		1
	7	1
8		1,25
10		1,5
12		1,75
	14	2
16		2
	18	2,5
20		2,5
	22	2,5
24		3
	27	3
30		3,5
	33	3,5
36		4
	39	4
42[1]		4,5
	45[1]	4,5
48[1]		5

[1] Not contained in ISO 262–1973

Limits for metric fine threads

according to ISO 965

Screws, tolerance 6g

Thread	Length of thread engagement		Major diameter d (mm)		Pitch diameter d_2 (mm)		Thread root radius (mm)
	from	to	max.	min.	max.	min.	min.
M 8x1	3	9	7,974	7,794	7,324	7,212	0,125
M10x1	3	9	9,974	9,794	9,324	9,212	0,156
M10x1,25	4	12	9,972	9,760	9,160	9,042	0,156
M12x1,25	4,5	13	11,972	11,760	11,160	11,028	0,156
M12x1,5	5,6	16	11,968	11,732	10,994	10,854	0,156
M14x1,5	5,6	16	13,968	13,732	12,994	12,854	0,188
M16x1,5	5,6	16	15,968	15,732	14,994	14,854	0,188
M18x1,5	5,6	16	17,968	17,762	16,994	16,854	0,188
M18x2	8	24	17,952	17,682	16,663	16,503	0,188
M20x1,5	5,6	16	19,968	19,732	18,994	18,854	0,188
M20x2	8	24	19,962	19,682	18,663	18,503	0,188
M22x1,5	5,6	16	21,968	21,732	20,994	20,854	0,188
M22x2	8	24	21,962	21,682	20,663	20,503	0,188
M24x2	8,5	25	23,962	23,682	22,663	22,493	0,250
M27x2	8,5	25	26,962	26,682	25,663	25,483	0,250
M30x2	8,5	25	29,962	29,682	28,663	28,493	0,250
M33x2	8,5	25	32,962	32,682	31,663	31,493	0,250
M36x3	12	36	35,952	35,577	34,003	33,803	0,375
M39x3	12	36	38,952	38,577	37,003	36,803	0,375

Nuts, tolerance 6H

Thread	Length of thread engagement		Pitch diameter D_2 (mm)		Minor diameter D_1 (mm)	
	from	to	max.	min.	max.	min.
M 8x1	3	9	7,500	7,350	7,153	6,917
M10x1	3	9	9,500	9,350	9,153	8,917
M10x1,25	4	12	9,348	9,188	8,912	8,647
M12x1,25	4,5	13	11,368	11,188	10,912	10,647
M12x1,5	5,6	16	11,216	11,026	10,676	10,376
M14x1,5	5,6	16	13,216	13,026	12,676	12,376
M16x1,5	5,6	16	15,216	15,026	14,676	14,376
M18x1,5	5,6	16	17,216	17,026	16,676	16,376
M18x2	8	24	16,913	16,701	16,210	15,835
M20x1,5	5,6	16	19,216	19,026	18,676	18,376
M20x2	8	24	18,913	13,701	18,210	17,835
M22x1,5	5,6	16	21,216	21,026	20,676	20,376
M22x2	8	24	20,913	20,701	20,210	19,835
M24x2	8,5	25	22,925	22,701	22,210	21,835
M27x2	8,5	25	25,925	25,701	25,210	24,834
M30x2	8,5	25	28,925	28,701	28,210	27,835
M33x2	8,5	25	31,925	31,701	31,210	30,835
M36x3	12	36	34,316	34,051	33,252	32,752
M39x3	12	36	37,316	37,051	36,252	35,752

Selection series for fine threads

according to ISO 262

Nominal thread diameter		Pitch P	
series 1	series 2		
8		1	
10		1,25	1[1)]
12		1,25	1,5[1)]
	14	1,5	
16		1,5	
	18	1,5	2[1)]
20		1,5	2[1)]
	22	1,5	2[1)]
24		2	
	27	2	
30		2	
	33	2	
36		3	
	39	3	

[1)] Not contained in ISO 262–1973

Permissible tolerances for plastic fasteners

Dimension	for screw threads	for nut threads
major Ø	e8	2 x G7
minor Ø	2 x g8	H7
pitch Ø	2 x g8	
pitch	± 5%	

Dimensions of the head, screw length and thread approximate according to DIN. Acceptance according to VDI 2544. The tolerances must be observed 24 hours after fabrication, for all other tolerances, refer to **ISO 4759, part 1, but with the factor 2. These technical recommendations are of a general nature. For moredetailed specifications, please refer to VDI 2544.**

Home

Basic tolerances and tolerance fields

Extract from ISO 286-2

Nominal dim. range	Standard tolerances [mm]							Tolerance fields for internal dimensions [mm]											
	IT11	IT12	IT13	IT14	IT15	IT16	IT17	D12	F8	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15
up to 3	0,06	0,1	0,14	0,25	0,4	0,6	1	+0,12 +0,02	+0,02 +0,006	+0,006 0	+0,01 0	+0,014 0	+0,025 0	+0,04 0	+0,06 0	+0,1 0	+0,14 0	+0,25 0	+0,4 0
over 3 up to 6	0,075	0,12	0,18	0,3	0,48	0,75	1,2	+0,15 +0,03	+0,028 +0,01	+0,008 0	+0,012 0	+0,018 0	+0,03 0	+0,048 0	+0,075 0	+0,12 0	+0,18 0	+0,3 0	+0,48 0
over 6 up to 10	0,09	0,15	0,22	0,36	0,58	0,9	1,5	+0,19 +0,04	+0,035 +0,013	+0,009 0	+0,015 0	+0,022 0	+0,036 0	+0,058 0	+0,09 0	+0,15 0	+0,22 0	+0,36 0	+0,58 0
over 10 up to 18	0,11	0,18	0,27	0,43	0,7	1,1	1,8	+0,23 +0,05	+0,043 +0,016	+0,011 0	+0,018 0	+0,027 0	+0,043 0	+0,07 0	+0,11 0	+0,18 0	+0,27 0	+0,43 0	+0,7 0
over 18 up to 30	0,13	0,21	0,33	0,52	0,84	1,3	2,1	+0,275 +0,065	+0,053 +0,02	+0,013 0	+0,021 0	+0,033 0	+0,052 0	+0,084 0	+0,13 0	+0,21 0	+0,33 0	+0,52 0	+0,84 0
over 30 up to 50	0,16	0,25	0,39	0,62	1	1,6	2,5	+0,33 +0,08	+0,004 +0,025	+0,016 0	+0,025 0	+0,039 0	+0,062 0	+0,1 0	+0,16 0	+0,25 0	+0,39 0	+0,62 0	+1 0
over 50 up to 80	0,19	0,3	0,46	0,74	1,2	1,9	3	+0,4 +0,1	+0,076 +0,03	+0,019 0	+0,03 0	+0,046 0	+0,074 0	+0,12 0	+0,19 0	+0,3 0	+0,46 0	+0,74 0	+1,2 0
over 80 up to 120	0,22	0,35	0,54	0,87	1,4	2,2	3,5	+0,47 +0,12	+0,09 +0,036	+0,022 0	+0,035 0	+0,054 0	+0,087 0	+0,14 0	+0,22 0	+0,35 0	+0,54 0	+0,87 0	+1,4 0
over 120 up to 180	0,25	0,4	0,63	1	1,6	2,5	4	+0,545 +0,145	+0,106 +0,043	+0,025 0	+0,04 0	+0,063 0	+0,1 0	+0,16 0	+0,25 0	+0,4 0	+0,63 0	+1 0	+1,6 0
over 180 up to 250	0,29	0,46	0,72	1,15	1,85	2,9	4,6	+0,63 +0,17	+0,122 +0,05	+0,029 0	+0,046 0	+0,072 0	+0,115 0	+0,185 0	+0,29 0	+0,46 0	+0,72 0	+1,15 0	+1,85 0
over 250 up to 315	0,32	0,52	0,81	1,3	2,1	3,2	5,2	+0,71 +0,19	+0,137 +0,056	+0,032 0	+0,052 0	+0,081 0	+0,13 0	+0,21 0	+0,32 0	+0,52 0	+0,81 0	+1,3 0	+2,1 0
over 315 up to 400	0,36	0,57	0,89	1,4	2,3	3,6	5,7	+0,78 +0,21	+0,151 +0,062	+0,036 0	+0,057 0	+0,089 0	+0,14 0	+0,23 0	+0,36 0	+0,57 0	+0,89 0	+1,4 0	+2,3 0
over 400 up to 500	0,4	0,63	0,97	1,55	2,5	4	6,3	+0,86 +0,23	+0,165 +0,068	+0,04 0	+0,063 0	+0,097 0	+0,155 0	+0,25 0	+0,4 0	+0,63 0	+0,97 0	+1,55 0	+2,5 0

Nominal dim. range	Tolerance fields for external dimensions [mm]																	
	f9	h6	h7	h8	h9	h10	h11	h12	h13	h14	h15	h16	h17	js14	js15	js16	js17	m6
up to 3	-0,006 -0,031	0 -0,006	0 -0,01	0 -0,014	0 -0,025	0 -0,04	0 -0,06	0 -0,1	0 -0,14	0 -0,25	0 -0,4	0 -0,6		±0,125	±0,2	±0,3		+0,008 +0,002
over 3 up to 6	-0,01 -0,04	0 -0,008	0 -0,012	0 -0,018	0 -0,03	0 -0,048	0 -0,075	0 -0,12	0 -0,18	0 -0,3	0 -0,48	0 -0,75	0 -1,2	±0,15	±0,24	±0,375	±0,6	+0,012 +0,004
over 6 up to 10	-0,013 -0,049	0 -0,009	0 -0,015	0 -0,022	0 -0,036	0 -0,058	0 -0,09	0 -0,15	0 -0,22	0 -0,36	0 -0,58	0 -0,9	0 -1,5	±0,18	±0,29	±0,45	±0,75	+0,015 +0,006
over 10 up to 18	-0,016 -0,059	0 -0,011	0 -0,018	0 -0,027	0 -0,043	0 -0,07	0 -0,11	0 -0,18	0 -0,27	0 -0,43	0 -0,7	0 -1,1	0 -1,8	±0,215	±0,35	±0,55	±0,9	+0,018 +0,007
over 18 up to 30	-0,02 -0,070	0 -0,013	0 -0,021	0 -0,033	0 -0,052	0 -0,084	0 -0,13	0 -0,21	0 -0,33	0 -0,52	0 -0,84	0 -1,3	0 -2,1	±0,26	±0,42	±0,65	±1,05	+0,021 +0,008
over 30 up to 50	-0,025 -0,087	0 -0,016	0 -0,025	0 -0,039	0 -0,062	0 -0,1	0 -0,16	0 -0,25	0 -0,39	0 -0,62	0 -1	0 -1,6	0 -2,5	±0,31	±0,5	±0,8	±1,25	+0,025 +0,009
over 50 up to 80	-0,03 -0,104	0 -0,019	0 -0,03	0 -0,046	0 -0,074	0 -0,12	0 -0,19	0 -0,3	0 -0,46	0 -0,74	0 -1,2	0 -1,9	0 -3	±0,37	±0,6	±0,95	±1,5	+0,03 +0,011
over 80 up to 120	-0,036 -0,123	0 -0,022	0 -0,035	0 -0,054	0 -0,087	0 -0,14	0 -0,22	0 -0,35	0 -0,54	0 -0,87	0 -1,4	0 -2,2	0 -3,5	±0,435	±0,7	±1,1	±1,75	+0,035 +0,013
over 120 up to 180	-0,043 -0,143	0 -0,025	0 -0,04	0 -0,063	0 -0,1	0 -0,16	0 -0,25	0 -0,4	0 -0,63	0 -1	0 -1,6	0 -2,5	0 -4	±0,5	±0,8	±1,25	±2	+0,04 +0,015
over 180 up to 250	-0,05 -0,165	0 -0,029	0 -0,046	0 -0,072	0 -0,115	0 -0,185	0 -0,29	0 -0,46	0 -0,72	0 -1,15	0 -1,85	0 -2,9	0 -4,6	±0,575	±0,925	±1,45	±2,3	+0,046 +0,017
over 250 up to 315	-0,056 -0,185	0 -0,032	0 -0,052	0 -0,081	0 -0,13	0 -0,21	0 -0,32	0 -0,52	0 -0,81	0 -1,3	0 -2,1	0 -3,2	0 -5,2	±0,65	±1,05	±1,6	±2,6	+0,052 +0,02
over 315 up to 400	-0,062 -0,202	0 -0,036	0 -0,057	0 -0,089	0 -0,14	0 -0,23	0 -0,36	0 -0,57	0 -0,89	0 -1,4	0 -2,3	0 -3,6	0 -5,7	±0,7	±1,15	±1,8	±2,85	+0,057 +0,021
over 400 up to 500	-0,068 -0,223	0 -0,04	0 -0,063	0 -0,097	0 -0,155	0 -0,25	0 -0,4	0 -0,63	0 -0,97	0 -1,55	0 -2,5	0 -4	0 -6,3	±0,775	±1,25	±2	±3,15	+0,063 +0,023

SI units system

SI is the modern system of units for measurement, accepted and used world wide. It is used in all areas of international standards and is commonly referred to as the metric system. SI is used in all areas of science, technology and trade and is applied in the same way world wide. SI is built of: Base units, Supplementary units, Additional units, Prefixes. The figures given in the conversion tables are rounded up to 3 or 4 digits.

1. Basic units of the SI system

Quantity	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Termodynamic temperature	kelvin	K
Luminous intensity	candela	dc
Amount of substance	mole	mol
Plan angle	radian	rad
Solid angle	steradian	sr

2. Derived SI units

Quantity	Name	Symbol	Defining equation	
Frequency	hertz	Hz	1 Hz	$= 1\ s^{-1} = 1/s$
Force	newton	N	1 N	$= 1\ kg \cdot m/s^2$
Pressure and mechanical stress	pascal	Pa	1 Pa	$= 1\ N/m^2$
Work (energy, heat)	joule	J	1 J	$= 1\ N \cdot m = 1\ W \cdot s$
Power, energy flow, heat flow	watt	W	1 W	$= 1\ N \cdot m/s = J/s$
Electrical charge, quantity of electricity	coulomb	C	1 C	$= 1\ A \cdot s$
Plectrical potential, potential, diffenrence voltage	volt	V	1 V	= 1 W/A
Electric capacitance	farad	F	1 F	$= 1\ A \cdot s/V$
Impedance	ohm	Ω	1 Ω	= 1 V/A
Electrical conductivity	siemens	S	1 S	$= 1\ \Omega^{-1} = 1\ A/V$
Magnetic flux	weber	Wb	1 WB	$= 1\ V \cdot s$
Magnetic flux density	tesla	T	1 T	$= 1\ Wb/m^2$
Industance	henry	H	1 H	$= 1\ Wb/A = 1\ V \cdot s/A$
Luminous flux	lumen	lm	1 lm	$= 1\ cd \cdot sr$
Illumination	lux	lx	1 lx	$= 1\ lm/m^5$

Conversion tables

Conversion table for units of force

	N	p	kp	dyn
1 Newton = 1 N	1	102	0,102	10^5
1 pond = 1 p	$9{,}81 \cdot 10^{-3}$	1	10^{-3}	981
1 Kilopond = 1 kp	9,81	1000	1	$9{,}81 \cdot 10^5$
1 dyn	10^{-5}	$1{,}02 \cdot 10^{-3}$	$1{,}02 \cdot 10^{-6}$	1

Conversion table for units of mechanical stress

	Pa	N/mm^2	kp/cm^2	kp/mm^2
$1\ Pa = 1\ N/m^2$	1	10^{-6}	$1{,}02 \cdot 10^{-5}$	$1{,}02 \cdot 10^{-7}$
$1\ N/mm^2 = 1$ Mpa	10^6	1	10,2	0,102
$1\ kp/cm^2 = 1$ at	$9{,}81 \cdot 10^4$	$9{,}81 \cdot 10^{-2}$	1	10^{-2}
$1\ kp/mm^2$	$9{,}81 \cdot 10^6$	9,81	100	1

Conversion tables

Conversion table for units of work, energy and heat

	J	kJ	kWh	kcal	kpm
1 J = 1 N · m = 1 W · s	1	10^{-3}	2,78 · 10^{-7}	2,39 · 10^{-4}	0,102
1 kJ	1000	1	2,78 · 10^{-4}	0,239	102
1 kWh	3,6 · 10^{6}	3,6 · 10^{3}	1	860	3,67 · 10^{5}
1 kcal	4,19 · 10^{3}	4,19	1,16 · 10^{-3}	1	427
1 kpm	9,81	9,81 · 10^{-3}	2,72 · 10^{-6}	2,34 · 10^{-3}	1

Conversion table for units of power and heat flow

	W	kW	kcal/s	kcal/h	kpm/s
1 W = 1 N · m/s = 1 J/s	1	10^{-3}	2,39 · 10^{-4}	0,860	0,102
1 kW	1000	1	0,239	860	102
1 kcal/s	4,9 · 10^{3}	4,19	1	3,6 · 10^{3}	427
1 kcal/h	1,16	1,6 · 10^{-3}	2,78 · 10^{-4}	1	0,119
1 kpm/s	9,81	9,81 · 10^{-3}	2,34 · 10^{-3}	8,34	1

Conversion table for units of pessure for gases, vapours and liquides

	Pa	bar	kp/m²	at	Torr
1 Pa = 1 N/m²	1	10^{-5}	0,102	1,02 · 10^{-5}	7,5 · 10^{-3}
1 bar = 0,1 MPa = 0,1 N/mm²	10^{5}	1	1,02 · 10^{4}	1,02	750
1 kp/m²	9,81	9,81 · 10^{-5}	1	10^{-4}	7,36 · 10^{-2}
1 at = 1 kp/cm²	9,81 · 10^{4}	0,981	10^{4}	1	736
1 Torr = 1/760 atm	133	1,33 · 10^{-3}	13,6	1,36 · 10^{-3}	1

Conversion of othe units into SI units

Value	Previous unit	Symbol	New unit	Symbol	Defining equation
Length	Ångström	Å	meter	m	1 Å = 10^{-10}m
Pressure	mm mercury	mm Hg	pascal	Pa	1 mm Hg = 133,3 Pa
Energy	Erg	erg	joule	J	1 erg = 10^{-7} J
Power	horsepower	PS	watt	W	1 PS = 735,5 W
Dynamic viscosity	Poise	P	pascal second	Pa · s	1 P = 0,1 Pa · s / 1c P = 1 m Pa · s
Kineamtic viscosity	Stokes	St	cm² / s		1 St = 1 cm²/s = 10^{-4} m²/s
Impact value	kpm / cm²		J / cm²		1 kpm/cm² = 9,087 J/cm²
Heat capacity	kcal / °C		J / K		1 kcal/°C = 4,187 · 10^{3} J/K
Heat conductivity	kcal / m.h °C		W / K · m		1 kcal/m · h · °C = 1,163 W/K · m
Specific heat	kcal / kg °C		J / kg · K		1 kcal/kg · °C = 4,187 · 10^{3} J/kg · K
Magnetic field strength	Oersted	Oe	ampere / meter	A / m	1 Oe = 79,6 A/m
Magnetic flux density	Gauss	G	tesla	T	1 G = 10^{-4} T
Magnetic flux	Maxwell	M	weber	Wb	1 M = 10^{-8} Wb
Luminous intensity	internat. candle	IK	candela	cd	1 IK = 1,019 cd
Luminace	Stilb	sb	cd / m²		1 sb = 10^{4} cd/m²
Absorbed dose	Rem	rem	J / kg		1 rem = 0,01 J/kg
Ion dose	Röntgen	R	C / kg		1 R = 2,58 · 10^{-4} C/kg

Conversions of part volumes

Example: one lump of sugar dissolved in:	 2700 litres	**1 ppm** (part per million) is 1 part out of 1 million parts	**1 milligram** per kilogramm	0,001 g / kg (10^{-3})
	 2,7 million litres	**1 ppb** (part per billion) is 1 part out of 1 milliard parts (b = billion, US English for milliard)	**1 mikrogram** per kilogram	0,000 001 g / kg (10^{-6})
	 2,7 billion litres	**1 ppt** (part per trillion) is 1 part out of 1 billion parts (t = trillion US English for billion)	**1 nanogram** per kilogram	0,000 000 001 g / kg (10^{-9})
	 2,7 trillion litres	**1 ppq** (part per quadrillion) is 1 part out of 1 billiard parts (q = quadrillion US English for billiard)	**1 picogram** per kilogram	0,000 000 000 001 g / kg (10^{-12})

Conversion tables
metric – USA
USA – metric

Measures of length

metric – USA

1 millimeter	(mm)	0,039337	inches	(in.)
1 centimeter	(cm)	0,39370	inches	(in.)
1 meter	(m)	39,3700	inches	(in.)
1 meter	(m)	3,2808	feet	(ft.)
1 meter	(m)	1,0936	yards	(yd.)
1 kilometer	(km)	0,62137	miles	(m.)

USA – metric

1 inch	25,400	mm
1 inch	2,540	cm
1 foot	304,800	mm
1 foot	30,480	cm
1 foot	0,3048	m
1 yard	91,4400	cm
1 yard	0,9144	m
1 mile	1609,35	m
1 mile	1,609	km

Measures of area

metric – USA

1 mm^2	0,00155	sq.inches	(sq.in.)
1 cm^2	0,1550	sq.inches	(sq.in.)
1 m^2	10,7640	sq.feet	(sq.ft.)
1 m^2	1,196	sq.yard	(sq.yd.)
1 km^2	0,38614	sq.miles	(sq.m.)

USA – metric

1 sq.inch	645,16	mm^2
1 sq.inch	6,4516	cm^2
1 sq.foot	929,00	cm^2
1 sq.foot	0,0929	m^2
1 sq.yard	0,836	m^2
1 sq.mile	2,5889	km^2

Measures of capacity

metric – USA

1 milliliter	(ml)	0,27	fluid drachms	(dr.fl.)
1 centiliter	(cl)	0,338	fluid ounces	(oz.fl.)
1 deziliter	(dl)	0,0528	pints	(pt.)
1 liter	(l)	1,0567	quarts	(qt.)
1 liter	(l)	0,26	gallons	(gal.)
1 hectoliter	(hl)	26,417	gallons	(gal.)

USA – metric

1 fluid ounce	2,957	cl
1 pint	4,732	dl
1 pint	0,4732	l
1 quart	0,9463	l
1 gallon	3,7853	l
1 barrel (bl)	119,237	l
1 barrel	1,192	hl

Weights

metric – USA

1 gram	(gr.)	15,432	grains	(gr.)
1 kilogram	(kg)	2,2046	pounds	(lb.)
1 quintal	(dz.)	220,46	pounds	(lb.)
1 tonne	(t)	2204,6	pounds	(lb.)
1 tonne	(t)	1,102	short tons	(tn.sh.)

USA – metric

1 grain	64,7989	mg
1 ounce	28,35	g
1 pound	0,4536	kg
1 short	907,200	kg
1 short	9,072	dz.
1 short	0,9072	t

Various

metric – USA

1 N/mm^2 = 1 MPa = 10 bar	145,14	psi
1 Nm	8,85	in lb
1 Nm	0,74	in lb

USA – metric

1 psi	0,00689	N/mm^2
1 in lb	0,113	Nm
1 ft lb	1,35	Nm70

Temperature

°C = °F (exact)

Conversion from Celsius into Fahrenheit: Multiply by 1,8; add 32 to result.

Conversion from Fahrenheit into Celsius: Subract 32; divide result by 1,8.

°F	°C	°F	°C	°C	°F	°C	°F
212	100	104	40	100	212	35	95
200	93,3	100	37,8	95	203	30	86
194	90	90	32,2	90	194	25	77
190	87,8	86	30	85	182	20	68
180	82,8	80	26,7	80	176	15	59
176	80	70	21,1	75	167	10	50
170	76,7	68	20	70	158	5	41
160	71,1	60	15	65	149	–	–
158	70	50	10	60	140	0	32
150	65,6	40	4,4	55	131	– 5	23
140	60	–	–	50	122	–10	14
130	54,4	32	0	45	113	–15	5
122	50	30	– 1,1	40	104	–17,8	0
120	48,9	20	– 6,7				
110	43,3	14	–10				
		10	–12,2				
		0	–17,8				

Hardness comparison table
according to DIN 50150

The comparison table below is valid only for carbon steels, low alloy steels and cast steels in the hot formed and heat treated condition. For high alloyed and / or cold headed steels [4.8. 5.8] (6.8. A1 to A4) there are considerable differences to be expected

Tensile strength N/mm²	Vickers hardness [F ≥ 98 N]	Brinell hardness[1)]	Rockwell hardness		
			HRB	HRC	HRA
255	80	76			
270	85	80,7	41		
285	90	85,5	48		
305	95	90,2	52		
320	100	95	56,2		
335	105	99,8			
350	110	105	62,3		
370	115	109			
385	120	114	66,7		
400	125	119			
415	130	124	71,2		
430	135	128			
450	140	133	75		
465	145	138			
480	150	143	78,7		
495	155	147			
510	160	152	81,7		
530	165	156			
545	170	162	85		
560	175	166			
575	180	171	87,1		
595	185	176			
610	190	181	89,5		
625	195	185			
640	200	190	91,5		
660	205	195	92,5		
675	210	199	93,5		
690	215	204	94		
705	220	209	95		
720	225	214	96		
740	230	219	96,7		
755	235	223			
770	240	228	98,1	20,3	60,7
785	245	233		21,3	61,2
800	250	238	99,5	22,2	61,6
820	255	242	(101)	23,1	62
835	260	247		24	62,4
850	265	252	(102)	24,8	62,7
865	270	257		25,6	63,1
880	275	261	(104)	26,4	63,5
900	280	268		27,1	63,8
915	285	271	(105)	27,8	64,2
930	290	276		28,5	64,5
950	295	280		29,2	64,8
965	300	285		29,8	65,2
995	310	295		31	65,8
1030	320	304		32,2	66,4
1060	330	314		33,3	67
1095	340	323		34,3	67,6
1125	350	333		35,5	68,1
1155	360	342		36,6	68,7
1190	370	352		37,7	69,2
1220	380	361		38,8	69,8
1255	390	371		39,8	70,3
1290	400	380		40,8	70,8
1320	410	390		41,8	71,4
1350	420	399		42,7	71,8
1385	430	409		43,6	72,3
1420	440	418		44,5	72,8
1455	450	428		45,3	73,3
1485	460	437		46,1	73,6
1520	470	447		46,9	74,1
1555	480	(465)		47,7	74,5
1595	490	(466)		48,4	74,9
1630	500	(475)		49,1	75,3
1665	510	(485)		49,8	75,7
1700	520	(494)		50,5	76,1
1740	530	(504)		51,1	76,4
1775	540	(513)		51,7	76,7
1810	550	(523)		52,3	77
1845	560	(532)		53	77,4
1880	570	(542)		53,6	77,8
1920	580	(551)		54,1	78
1955	590	(561)		54,7	78,4
1995	600	(570)		55,2	78,6
2030	610	(580)		55,7	78,9
2070	620	(589)		56,3	79,2
2105	630	(599)		56,8	79,5
2145	640	(608)		57,3	79,8
2180	650	(618)		57,8	80
	660			58,3	80,3
	670			58,8	80,6
	680			59,2	80,8
	690			58,7	81,1
	700			60,1	81,3
	720			61	81,8
	740			61,8	82,2
	760			62,5	82,6
	780			63,3	83
	800			64	83,4
	820			64,7	83,8
	840			65,3	84,1
	860			65,9	84,4
	880			66,4	84,7
	900			67	85
	920			67,5	85,3
	940			68	85,6

The figures in brackets represent hardness values beyond the defined scope of the standardised hardness test but which are frequently used as appoximate values in practice. Furthermore the Brinell hardness values in brackets are only valid if the test was carried out with a hard metal ball.

1) Calculated with: HB = 0,95 · HV

The Vickers testing method is applicable over a wide hardness range. The referee method per ISO 898/1 is the Vickers method. The Rockwell C method is suitable for hardened steels, Rockwell A for sintered steel and Rockwell B for soft steels, copper alloys, etc. The Brinell hardness method extends over a wide hardness range too.

Designations of different national standards according to ISO

Country	Abbreviation
Algeria	IANOR
Argentina	IRAM
Australia	SAI
Austria	ON
Bangladesh	BSTI
Belgium	IBN
Brazil	ABNT
Bulgaria	BDS
Canada	SCC
Chile	INN
China	CSBTS
Colombia	ICONTEC
Cuba	NC
Cyprus	CYS
Czech Republic	CSNI
Denmark	DS
Egypt	EOS
Ethiopia	QSAE
Europe	EN
Finland	SFS
France	AFNOR
Germany	DIN
Ghana	GSB
Greece	ELOT
Hungary	MSZT
India / Inde	BIS
Indonesia	BSN
International	ISO
Iran	ISIRI
Ireland	NSAI
Israel	SII
Italy	UNI
Jamaica	JBS
Japan	JISC
Kenya	KEBS

Country	Abbreviation
Korea, Dem.P.Rep.of	CSK
Korea, Rep. of	KATS
Libian Arab Jamhiriya	LNCSM
Malaysia	DSM
Mexico	DGN
Mongolia	MNCSM
Marocco	SNIMA
Netherlands	NEN
New Zealand	SNZ
Nigeria	SON
Norway	NSF
Pakistan	PSI
Philipines	BPS
Poland	PKN
Portugal	IPQ
Romania	ASRO
Saudi Arabia	SASO
Singapore	PSB
South Africa, Rep. of	SABS
Spain	AENOR
Sri Lanka	SLSI
Sweden	SIS
Switzerland	SNV
Syria	SASMO
Tanzania	TBS
Thailand	TISI
Trinidad and Tobago	TTBS
Turkey	TSE
United Kingdom	BSI
USA	ANSI
Uzbekistan	UZGOST
Venezuela	FONDONORMA
Viet Nam	TCVN
Yugoslavia	SZS

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