Tightening torque

For a screw joint to work properly and be able to resist large static or changing forces for a long period of time, the screws must be pretightened, for example by tightening with a certain torque. The pretightening must normally be held at such a level, that the total stress in the screw does not exceed the yield stress of the screw material.

Calculation of tightening torque
To specify a tightening torque you must know four factors:

1. Screw thread diameter	2. Screw property class
3. The friction conditions	4. Tightening method

There are several different collections of tables. The tables that follow apply to a common condition - the tightening of untreated oiled screws/nuts, using a hand torque wrench or a screw driver/nut runner with torque control (variation ≤ ± 5%).

Table 18 = Metric coarse threads M (untreated, oiled).
Table 18.1 = Metric coarse threads M (untreated, oiled, Holo-krome®screws).
Table 19 = Metric fine threads M (untreated, oiled).
Table 20 = Unified coarse threads UNC (untreated, oiled).
Table 20.1 = Unified fine threads UNF (untreated, oiled).
Table 21 = Metric coarse threads M (waxed, stainless or acidproof).
Table 22 = Unified coarse threads UNC (waxed, stainless or acidproof).
Table 23 = Calculation values and conversion factors (C) for different friction conditions.

For every other method or every other friction condition the values must be adjusted. In the column to the left the thread diameters are listed and the table heading states the different property classes. How the tables are used is described below.

Theory:
Tightening torque Mv in Nm is calculated using the following equation:

$$M_v = \frac{k}{\kappa\left(1 + \frac{S_F}{F_{Fm}}\right)} (d + P) \cdot A_s \cdot \sigma_s \cdot 10^{-3}$$

The included factors are:

M_v = tightening torque, Nm
k = factor in the torque equation (see the following)
κ = the relationship between effective and tensile stress (see the following)
S_F = the pre-stress force's spread when tightening, N (see table 23)
F_{Fm} = $\sigma_F \cdot A_s$ = average pre-stress force, N
d = the screw thread's outer diameter, mm
P = pitch, mm
A_s = the stress area for the thread, mm^2
σ_s = general denomination for $R_{p0,2}$ or R_{eL} in formulas, N/mm^2
$R_{p0,2}$ = extension limit at 0,2% extension, N/mm^2
R_{eL} = lower yield stress, N/mm^2

The factor k takes into account the pitch's and the friction's effect on the torque and is, in its basic form written:

$$k = \frac{d_2 \cdot \tan(\varphi + \rho') + D_k \cdot \mu_u}{2\,(d + P)}$$

Due to geometrical correlations and because there usually are the same friction coefficients in thread and contact surface, k can be written as follows:

$$k = \frac{[0{,}161 \cdot P + \mu_{tot}(0{,}583 \cdot d_2 + 0{,}5 \cdot D_k)]}{d + P}$$

An analysis of the k-value at different thread diameters and friction conditions shows that the faults are no bigger than approximately ±5% if the expression finally is simplified to:

$$k = 1{,}078 \cdot \mu_{tot} + 0{,}0168$$

The included factors are:

d_2 = the screw thread's average diameter, mm
φ = the thread's pitch angle
ρ' = the thread's friction angle (depends on friction coefficient μ_g in the thread and is received from $\tan \rho' = \mu_g$)
D_k = the contact surface's friction diameter, mm
μ_u = friction coefficient at contact surface (see first column in table 23)
μ_{tot} = at torque-force-exchange active friction coefficient (see table 23)

The factor κ pays regard to the torsional stress that arises in the screw due to the thread friction. The torsional stress decreases the possibility to load a screw axially. With help from the deviation working hypothesis for calculation of the active stress (the comparison stress), you get:

$$\kappa = \frac{\sigma_e}{\sigma_F} = \sqrt{1 + \frac{12}{d_{As}^2}\left(\frac{P}{\pi} + 1{,}155 \cdot \mu_g \cdot d_2\right)^2}$$

The included factors are:

σ_e = active stress, with maximum value = σ_s, N/mm^2
σ_F = the screw's pre-stress, N/mm^2
d_{As} = $\sqrt{4\,As/\pi}$ = diameter of the stress area, mm
P = pitch, mm
μ_g = the friction coefficient in thread (see table 23)
d_2 = screw thread's average diameter, mm

Values for k and κ at different friction coefficients (different materials, surfaces and lubrication states), received from the formulas, are presented in table 23. The value of κ mainly depends on the friction coefficient in the thread (μ_g) and has therefore in the table been regarded as independent from the thread, as well as from the value of k.

Degree of pre-stress

The relationship between the pre-tension (σ_F) and the screw's yield stress or extension limit (σ_s) is denoted degree of pre-stress and can be calculated with the formula:

$$G_F = \frac{F_{Fm}}{F_s} = \frac{\sigma_F}{\sigma_s} = \frac{1}{\kappa\left(1 + \frac{S_F}{F_{Fm}}\right)}$$

The included factors are:

G_F = degree of pre-stress

F_{Fm} = $\sigma_F \cdot A_s$ = average pre-stressing force, N

F_s = $\sigma_s \cdot A_s$ = the screw's yield load, N

σ_F = the screw's pre-stress, N/mm^2

σ_s = general denomination for $R_{p0,2}$ or R_{eL} in formulas, N/mm^2

S_F = spread of the pre-stress when tightening, N

The degree of pre-stress cannot be freely chosen. The practicable pre-stress is limited by both the friction relationship and by the uncertainty of the tightening. A certain friction relationship and tightening method therefore gives a definite degree of pre-stress, because the active stress is not allowed to exceed the nominal yield stress (σ_s).

Conversion for different friction conditions

Table 23 contains values that can be used in the formulas when calculating tightening torque. Furthermore the table contains a conversion factor (C), that is used for converting tightening torques stated in other tables, so that they are vaild for other friction conditions.

The conversion factor (C) is 1,00 for screws and nuts made of steel that are untreated (not surface treated) before oiled, because the two following torque tables for steel joints refer to this combination. At more effective lubrication, for example with molybdenum disulphide (MoS_2), the friction decreases and the conversion factor becomes 0,86, which means a decrease from the table value for tightening torque with 14%.

From the table it is evident that the degree of pre-stress (G_F) increases from 0,71 to 0,75 when lubricating with molybdenum disulphide, thanks to lower torsional stress (lower κ) and lower variation of the pre-stress force (S_F), in spite of a lower torque.

If you choose screws and nuts that are untreated and dry instead of untreated and oiled, it leads to an increase in friction but in spite of this the torque should be decreased, because the conversion factor decreases from 1,00 to 0,96. The reason for this is that the higher friction increases the torsional stress at the same time as the variation of the pre-stress increases. This is why the degree of pre-stress (G_F) has to be decreased so that the active stress does not exceed the yield stress (σ_s). Consequently the degree of pre-stress gives valuable information about how efficiently the joints are used.

The conversion factor (C) is equal to 1,00 even for screws and nuts of stainless steel that are waxed, because the last torque table refers to this combination. Lubrication with oil or emulsion instead increases the friction and the variation of the pre-stress which leads to that the torque should be decreased even in these cases (the conversion factor decreases from 1,00 to 0,84). Otherwise the yield stress (σ_s) could be exceeded.

Tightening torque for steel screw joints

A screw joint from steel in property class 8.8 according to ISO 898-1 and with thread M10 requires, according to the torque table for steel joints with metric coarse threads, a tightening torque of 47 Nm. An increase of property to class 12.9 increases the torque requirement to 79 Nm. A screw joint in the lowest included property class 4.6 requires 17 Nm fo M10, which is less than 1/4 of what is required for property class 12.9. From this you see how important it is to adjust the torque based on the property class and not only based on screw diameter.

In most cases the manufacturer of screw and nut drivers specifies suitable screw diameters for a particular machine. This information is however completely worthless for the user. What he needs to know is which torque interval the machine is meant for. According to the example a torque of 79 Nm was suitable for property class 12.9 and screw M10. Almost the same torque, 81 Nm, is needed for a screw in property class 8.8 with the thread diameter M12. In these two cases a machine that delivers 75-90 Nm can be chosen.

The following example shows how the tables can be used:

Hexagon screw M10 in property class 8.8, nut in property class 8 and washers with hardness min. 200 HB. All fasteners are bright zincplated and dry. For tightening, a screw driver should be used that has an adjustable torque control with the spread max ±5%.

From the torque table you receive the tightening torque M_V = 47 Nm for untreated, oiled steel joints.
Also you receive σs = 640 N/mm^2 and A_s = 58 mm^2.

This gives the yield load F_s =
$\sigma s \cdot A_s = 640 \cdot 58$ N = 37120 N = 37,1 kN.

From table 23 you receive the following calculation values and conversion factor for the friction relationship:

$S_F/F_{Fm} = \pm\ 0{,}29$ $G_F = 0{,}62$ $C = 0{,}96$

No conversion with regards to the screw type is needed.

This gives:

Tightening torque =
$M_V \cdot C = 47 \cdot 0{,}96$ Nm = 45 Nm

The average pre-stress force F_{Fm} =
$F_s \cdot G_F = 37{,}1 \cdot 0{,}62$ kN = 23 kN

The variation of the pre-stress force S_F =

$$\frac{S_F}{F_{Fm}} \cdot F_{Fm} = \pm\ 0{,}29 \cdot 23 \text{ kN} = \pm\ 6{,}7 \text{ kN}$$

Table 18

Tightening torque (M_V) in Nm for non-treated, oiled steel screw joints when using dynamometric wrenches. (Torque variation max ± 5%).
Metric coarse threads, M

Thread M	d mm	P mm	A_s mm²	Property class according to ISO 898-1				
				4.6	5.8	8.8	10.9	12.9
1,6	1,6	0,35	1,27	0,065	0,10	0,17	0,24	0,29
1,8	1,8	0,35	1,70	0,096	0,16	0,25	0,36	0,43
2	2	0,4	2,07	0,13	0,22	0,35	0,49	0,58
2,2	2,2	0,45	2,48	0,17	0,29	0,46	0,64	0,77
2,5	2,5	0,45	3,39	0,26	0,44	0,70	0,98	1,2
3	3	0,5	5,03	0,46	0,77	1,2	1,7	2,1
3,5	3,5	0,6	6,78	0,73	1,2	1,9	2,7	3,3
4	4	0,7	8,78	1,1	1,8	2,9	4,0	4,9
4,5	4,5	0,75	11,3	1,6	2,6	4,1	5,8	7,0
5	5	0,8	14,2	2,2	3,6	5,7	8,1	9,7
6	6	1	20,1	3,7	6,1	9,8	14	17
8	8	1,25	36,6	8,9	15	24	33	40
10	10	1,5	58	17	29	47	65	79
12	12	1,75	84,3	30	51	81	114	136
14	14	2	115	48	80	128	181	217
16	16	2	157	74	123	197	277	333
18	18	2,5	192	103	172	275	386	463
20	20	2,5	245	144	240	385	541	649
22	22	2,5	303	194	324	518	728	874
24	24	3	353	249	416	665	935	1 120
27	27	3	459	360	600	961	1 350	1 620
30	30	3,5	561	492	819	1 310	1 840	2 210
33	33	3,5	694	663	1 100	1 770	2 480	2 980
36	36	4	817	855	1 420	2 280	3 210	3 850
39	39	4	976	1 100	1 830	2 930	4 120	4 940
42	42	4,5	1 121	1 360	2 270	3 640	5 110	6 140
45	45	4,5	1 306	1 690	2 820	4 510	6 340	7 610
48	48	5	1 473	2 040	3 400	5 450	7 660	9 190
52	52	5	1 758	2 620	4 370	6 990	9 830	11 800
56	56	5,5	2 030	3 270	5 440	8 710	12 200	14 700
60	60	5,5	2 362	4 050	6 750	10 800	15 200	18 200
64	64	6	2 676	4 900	8 170	13 100	18 400	22 000
68	68	6	3 055	5 910	9 860	15 800	22 200	26 600
72	72	6	3 460	7 060	11 800	18 800	26 500	31 800
76	76	6	3 889	8 340	13 900	22 200	31 300	37 500
80	80	6	4 344	9 770	16 300	26 100	36 600	44 000
85	85	6	4 948	11 800	19 600	31 400	44 200	53 000
90	90	6	5 591	14 000	23 400	37 400	52 700	63 200
95	95	6	6 273	16 600	27 600	44 200	62 200	74 600
100	100	6	6 995	19 400	32 300	51 700	72 700	87 300
$\sigma_s = R_{eL}$ or $R_{p0,2}$ N/mm² nominal				240	400	640	900	1 080
$\frac{k}{\kappa\left(1+\frac{S_F}{F_{Fm}}\right)} \cdot \sigma_s$ N/mm²				26,16	43,60	69,76	98,10	117,72

Table 19 **Tightening torque (M_V) in Nm for non-treated, oiled steel screw joints when using dynamometric wrenches. (Torque variation max ± 5%). Metric fine threads, M**

Thread M	d mm	P mm	A_s mm^2	Property class according to ISO 898-1				
				4.6	5.8	8.8	10.9	12.9
2 × 0,25	2	0,25	2,45	0,14	0,24	0,38	0,54	0,65
2,2 × 0,25	2,2	0,25	3,03	0,19	0,32	0,52	0,73	0,87
2,5 × 0,25	2,5	0,25	3,70	0,28	0,46	0,74	1,0	1,2
3 × 0,35	3	0,35	5,60	0,49	0,82	1,3	1,8	2,2
3,5 × 0,35	3,5	0,35	7,90	0,80	1,3	2,1	3,0	3,6
4 × 0,5	4	0,5	9,79	1,2	1,9	3,1	4,3	5,2
4,5 × 0,5	4,5	0,5	12,8	1,7	2,8	4,5	6,3	7,5
5 × 0,5	5	0,5	16,1	2,3	3,9	6,2	8,7	10
6 × 0,75	6	0,75	22,0	3,9	6,5	10	15	17
8 × 1	8	1	39,2	9,2	15	25	35	42
10 × 1,25	10	1,25	61,2	18	30	48	68	81
10 × 1	10	1	64,5	19	31	49	70	84
12 × 1,5	12	1,5	88,1	31	52	83	117	140
12 × 1,25	12	1,25	92,1	32	53	85	120	144
14 × 1,5	14	1,5	125	51	84	135	190	228
16 × 1,5	16	1,5	167	76	127	204	287	344
18 × 1,5	18	1,5	216	110	184	294	413	496
20 × 1,5	20	1,5	272	153	255	408	574	688
22 × 1,5	22	1,5	333	205	341	546	768	921
24 × 2	24	2	384	261	435	696	979	1 170
27 × 2	27	2	496	376	627	1 000	1 410	1 690
30 × 2	30	2	621	520	866	1 390	1 950	2 340
33 × 2	33	2	761	697	1 160	1 860	2 610	3 130
36 × 3	36	3	865	883	1 470	2 350	3 310	3 970
$\sigma_s = R_{eL}$ or $R_{p0,2}$ N/mm² nominal				240	400	640	900	1 080
$\frac{k}{\kappa\left(1 + \frac{S_F}{F_{Fm}}\right)} \cdot \sigma_s$ N/mm²				26,16	43,60	69,76	98,10	117,72

Table 20 **Tightening torque (M_V) in Nm for non-treated, oiled steel screw joints when using dynamometric wrenches. (Torque variation max ± 5%). Unified coarse threads, UNC**

Thread UNC	d mm	P mm	A_s mm^2	Property class				
				4.6	5.8	8.8	10.9	12.9
No 4	2,845	0,635	3,90	0,31	0,58	0,94	1,3	1,7
No 5	3,175	0,635	5,14	0,45	0,84	1,4	1,9	2,4
No 6	3,505	0,794	5,86	0,58	1,1	1,7	2,5	3,1
No 8	4,166	0,794	9,04	1,0	1,9	3,1	4,4	5,5
No 10	4,826	1,058	11,31	1,5	2,9	4,6	6,5	8,1
No 12	5,486	1,058	15,58	2,3	4,4	7,0	10	12
1/4	6,35	1,270	20,5	3,6	6,7	11	15	19
5/16	7,938	1,411	33,8	7,3	14	22	31	38
3/8	9,525	1,588	50,0	13	24	38	54	68
7/16	11,112	1,814	68,6	20	38	61	87	108
1/2	12,7	1,954	91,5	31	57	93	131	163
9/16	14,288	2,117	117	44	82	133	187	234
5/8	15,875	2,309	146	61	114	183	259	323
3/4	19,05	2,540	216	107	200	322	455	568
7/8	22,225	2,822	298	172	320	516	729	909
1	25,4	3,175	391	257	479	772	1 090	1 360
1 1/8	28,575	3,629	492	365	679	1 090	1 550	1 930
1 1/4	31,75	3,629	625	509	947	1 530	2 160	2 690
1 3/8	34,925	4,233	745	672	1 250	2 020	2 850	3 550
1 1/2	38,1	4,233	907	884	1 650	2 650	3 750	4 680
1 3/4	44,45	5,080	1 225	1 400	2 600	4 190	5 930	7 390
2	50,8	5,644	1 612	2 100	3 900	6 290	8 890	11 100
2 1/4	57,15	5,644	2 095	3 030	5 640	9 090	12 800	16 000
2 1/2	63,5	6,350	2 580	4 150	7 720	12 500	17 600	21 900
2 3/4	69,85	6,350	3 183	5 590	10 400	16 800	23 700	29 500
3	76,2	6,350	3 850	7 320	13 600	22 000	31 000	38 700
3 1/4	82,55	6,350	4 580	9 380	17 740	28 100	39 800	49 600
3 1/2	88,9	6,350	5 373	11 800	21 900	35 400	50 000	62 300
3 3/4	95,25	6,350	6 230	14 600	27 100	43 700	61 800	77 100
4	101,6	6,350	7 150	17 800	33 100	53 300	75 400	94 000
$\sigma_s = R_{eL}$ or $R_{p0,2}$ N/mm² nominal				248	393	634	896	1117
$\frac{k}{\kappa\left(1 + \frac{S_F}{F_{Fm}}\right)} \cdot \sigma_s$ N/mm²				23,03	42,84	69,11	97,66	121,75

Table 20.1

Tightening torque (M_V) in Nm for non-treated, oiled steel screw joints when using dynamometric wrenches. (Torque variation max ± 5%).

Unified fine threads UNF

Thread UNF	d	P	A_s	Property class				
	mm	mm	mm^2	4.6	5.8	8.8	10.9	12.9
No 4	2,845	0,529	4,26	0,33	0,62	0,99	1,4	1,8
No 5	3,175	0,577	5,36	0,46	0,86	1,4	2,0	2,4
No 6	3,505	0,635	6,55	0,62	1,2	1,9	2,6	3,3
No 8	4,166	0,706	9,50	1,1	2,0	3,2	4,5	5,6
No 10	4,826	0,794	12,90	1,7	3,1	5,0	7,1	8,8
No 12	5,486	0,907	16,64	2,5	4,6	7,4	10	13
1/4	6,35	0,907	23,5	3,9	7,3	12	17	21
5/16	7,938	1,058	37,5	7,8	14	23	33	41
3/8	9,525	1,058	56,7	14	26	41	59	73
7/16	11,112	1,27	76,6	22	41	66	93	115
1/2	12,7	1,27	103	33	62	99	141	175
9/16	14,288	1,411	131	47	88	142	201	250
5/8	15,875	1,411	165	66	122	197	279	347
3/4	19,05	1,588	241	115	213	344	486	606
7/8	22,225	1,814	329	182	339	547	772	963
1	25,4	2,117	428	271	505	814	1 150	1 430
1 1/8	28,575	2,117	552	390	726	1 170	1 660	2 060
1 1/4	31,75	2,117	692	540	1 000	1 620	2 290	2 850
1 3/8	34,925	2,117	848	723	1 350	2 170	3 070	3 820
1 1/2	38,1	2,117	1 020	945	1 760	2 840	4 000	5 000
$\sigma_s = R_{eL}$ or $R_{p0,2}$ N/mm^2 nominal				248	393	634	896	1 117
$\frac{k}{\kappa\left(1 + \frac{S_F}{F_{Fm}}\right)} \cdot \sigma_s$ N/mm^2				27,03	42,84	69,11	97,66	121,75

Tightening torque for stainless screw joints

To be able to pre-stress stainless screws (including acidproof screws), effective lubrication is needed - otherwise the threads will jam. The property values according to ISO 3506 for stainless screws do not correspond with those for ordinary steel screws. A special torque table has for that reason been included for stainless screw joints. There, the torque values are calculated for waxed products, which is regarded to be a normal state. The degree of pre-stress at this state is used when comparing with other friction conditions.

Lubrication with molybdenum disulphide (MoS_2) provides similar friction conditions as with waxing.

The following example shows how the table could be used:

A hexagon screw M10 in property class A4 - 80 is pre-stressed with a waxed nut in the same property class. The tightening is made by using a dynamometric wrench on the nut.

From the torque table you receive the tightening torque M_V = 44 Nm, for waxed stainless screw joints.
You also get σ_s = 600 N/mm^2 and A_s = 58 mm^2.

This gives the yield load F_s =
$\sigma_s \cdot A_s$ = 600 • 58 N = 34800 N = 34,8 kN

From table 23 you receive the following calculation values and conversion factor for the friction relationship:

S_F/F_{Fm} = ± 0,23 G_F = 0,65 C = 1,00

No conversion with regards to the screw type is needed.

This gives:

Tightening torque =
$M_V \cdot C$ = 44 • 1,00 Nm = 44 Nm

The average pre-stress force F_{Fm} =
$F_s \cdot G_F$ = 34,8 • 0,65 kN = 22,6 kN

The variation of the pre-stress force S_F =
$\frac{S_F}{F_{Fm}} \cdot F_{Fm}$ = ± 0,23 • 22,6 kN = ± 5,2 kN

Table 21

Tightening torque (M_V) in Nm for waxed, stainless or acidproof screw joints when using dynamometric wrenches. (Torque variation max ± 5%). Metric coarse threads, M

Thread M	d mm	P mm	A_S mm²	Property class according to ISO 3506: Austenitic (A) 50	70	80	Ferritic (F) and martensitic (C) 45 | 50	60 | 70	80
1,6	1,6	0,35	1,27	0,057	0,12	0,16	0,068	0,11	0,17
2	2	0,4	2,07	0,11	0,25	0,33	0,14	0,22	0,35
2,5	2,5	0,45	3,39	0,23	0,50	0,66	0,28	0,45	0,70
3	3	0,5	5,03	0,41	0,87	1,2	0,48	0,79	1,2
3,5	3,5	0,6	6,78	0,64	1,4	1,8	0,76	1,3	2,0
4	4	0,7	8,78	1,0	2,0	2,7	1,1	1,9	2,9
5	5	0,8	14,2	1,9	4,1	5,4	2,3	3,7	5,8
6	6	1	20,1	3,3	7,0	9,3	3,9	6,3	9,9
8	8	1,25	36,6	7,8	17	22	9,3	15	24
10	10	1,5	58	15	33	44	18	30	47
12	12	1,75	84,3	27	57	76	32	52	82
14	14	2	115	43	91	121	51	83	130
16	16	2	157	65	140	187	78	127	199
18	18	2,5	192	91	195	260	108	178	277
20	20	2,5	245	127	273	364	152	249	388
22	22	2,5	303	171	367	490	204	335	523
24	24	3	353	220	472	629	262	430	671
27	27	3	459	318	682	909	379	621	969
30	30	3,5	561	434	930	1 240	517	848	1 320
33	33	3,5	694	585	1 250	1 670	697	1 140	1 780
36	36	4	817	755	1 620	2 160	899	1 470	2 300
39	39	4	976	969	2 080	2 770	1 150	1 890	2 950
$\sigma_S = R_{eL}$ or $R_{p0,2}$ N/mm² nominal				210	450	600	250	410	640
$\frac{k}{\kappa\left(1+\frac{S_F}{F_{Fm}}\right)} \bullet \sigma_S$ N/mm²				23,10	49,50	66,00	27,50	45,10	70,40

(Excerpt + completing from SMS handbook 516:1990)

Table 22

Tightening torque (M_V) in Nm for waxed, stainless or acidproof screw joints when using dynamometric wrenches. (Torque variation max ± 5%). Unified coarse threads, UNC

Thread UNC	d mm	P mm	A_s mm²	Property class: Austenitic (A) 50	70	80	Ferritic (F) and martensitic (C) 45 | 50	60	70	80
1/4	6,35	1,270	20,5	3,6	7,0	10	4,3	7,0	7,7	11
5/16	7,938	1,411	33,8	7,3	14	21	8,7	14	16	22
3/8	9,525	1,588	50,0	13	25	37	15	25	28	39
7/16	11,112	1,814	68,6	20	40	59	24	40	44	62
1/2	12,7	1,954	91,5	31	60	89	37	60	66	94
9/16	14,288	2,117	117	44	87	127	53	87	95	135
5/8	15,875	2,309	146	61	120	175	73	120	131	187
3/4	19,05	2,540	216	108	210	308	128	210	231	328
7/8	22,225	2,822	298	172	337	493	205	337	369	525
1	25,4	3,175	391	258	504	737	307	504	553	787
1 1/8	28,575	3,629	492	366	715	1 050	436	715	784	1 120
1 1/4	31,75	3,629	625	511	997	1 460	608	997	1 090	1 560
1 3/8	34,925	4,233	745	674	1 320	1 930	802	1 320	1 440	2 050
1 1/2	38,1	4,233	907	887	1 730	2 530	1 060	1 730	1 900	2 700
$\sigma_S = R_{eL}$ or $R_{p0,2}$ N/mm² nominal				210	410	600	250	410	450	640
$\frac{k}{\kappa\left(1+\frac{SF}{F_{Fm}}\right)} \cdot \sigma_s$ N/mm²				23,10	45,10	66,00	27,50	45,10	49,50	70,40

Table 18.1

Recommended tightening torque (M_V) in Nm for non-treated, oiled steel Holo-Krome® screws when using dynamometric wrenches. (Torque variation max ± 5%).
Metric coarse threads, M

Thread M	d mm	P mm	A_S mm^2	Holo- Krome®
1,6	1,6	0,35	1,27	0,29
2	2	0,4	2,07	0,66
2,5	2,5	0,45	3,39	1,32
3	3	0,5	5,03	2,4
4	4	0,7	8,78	5,6
5	5	0,8	14,2	11,4
6	6	1	20,1	19,3
8	8	1,25	36,6	46,3
10	10	1,5	58	88,3
12	12	1,75	84,3	161,8
14	14	2	115	257,4
16	16	2	157	397,3
18	18	2,5	192	551,6
20	20	2,5	245	772,3
24	24	3	353	1338,9
30	30	3,5	561	2684,5
36	36	4	817	4708,7
42	42	4,5	1 121	7538,8

Table 23

Calculation values and conversion factors (C) for different friction conditions. (Tightening with dynamometric wrenches, torque variation max ± 5%)

Material, surface condition 1) Screw	 Nut or goods thread	Lubrication state	μ_{tot}	$\frac{S_F}{F_{Fm}}$ ±	k	κ	G_F	C 3)
Steel, untreated	Steel, untreated	dry oil MoS_2 wax	0.14 0.125 0.10 0.06	0.29 0.16 0.16 0.11	0.168 0.152 0.125 0.082	1.24 1.21 1.15 1.08	0.62 0.71 0.75 0.83	0.96 1.00 0.86 0.63
Steel, phos	Steel, phos or untreated	dry oil MoS_2 wax	0.125 0.10 0.08 0.06	0.29 0.16 0.11 0.11	0.152 0.125 0.103 0.082	1.21 1.15 1.11 1.08	0.64 0.75 0.81 0.83	0.90 0.86 0.77 0.63
Steel, fzb, fzy or fzm	Steel, fzb, fzy, fzm or untreated	dry oil/emulsion wax	0.14 0.10 0.06	0.29 0.16 0.11	0.168 0.125 0.082	1.24 1.15 1.08	0.62 0.75 0.83	0.96 0.86 0.63
	Light metal	oil/emulsion	0.125	0.23	0.152	1.21	0.67	0.94
Zinc-iron	Zinc-iron	dry wax	0.16 0.06	– 0.082	– 1.08	– 0.11	–	1.05 0.63
Steel, fzv	Steel, fzv or untreated	oil (state of delivery) dry oil/emulsion wax	0.14 0.20 0.14 0.06	0.16 0.29 0.16 0.11	0.168 0.232 0.168 0.082	1.24 1.41 1.24 1.08	0.69 0.55 0.69 0.83	1.07 1.17 1.07 0.63
	Light metal	oil/emulsion	0.16	0.29	0.189	1.29	0.60	1.04
Steel, Polyseal	Steel, Polyseal or untreated	dry oil emulsion wax	0.20 0.14 0.10 0.06	0.29 0.16 0.16 0.11	0.232 0.168 0.125 0.082	1.41 1.24 1.15 1.08	0.55 0.69 0.75 0.83	1.17 1.07 0.86 0.63
Stainless steel 2)	Stainless steel or 2) light metal	wax oil/emulsion	0.14 0.20	0.23 0.29	0.168 0.232	1.24 1.41	0.65 0.55	1.00 0.84

1) Phos = phosphatised, fzb = zincplated + bright chromated, fzy = zincplated + yellow chromated, fzm = mechanically zincplated, fzv = hot dip galvanized.
2) Stainless steel also embodies, like in ISO 3506, so called acid-proof steel.
3) Use conversion factor C when converting the tightening torque for another material, other surface treatment or other lubrication state has been set to 1,00 for untreated, oiled screws and nuts from steel, and also for waxed screws and nuts from stainless steel. The torques in previous tables refer to these combinations. You can easily recalculate them for other combinations by multiplying with the factor C that is stated in the table for the actual combination.

Tightening of screws

For each screw joint's function the achieved clamping force when assembling is crucial. As a principal the screw should be tightened to its yield stress. As friction also arises when tightening, something that further loads the screw, the active clamping force must stay below the yield stress. The allowed tightening torque and the achieved clamping force can be seen in the following tables.

These values depend very much on the actual friction.

Some friction values:

Untreated, lightly oiled:	0,10-0,14
Dacromet 500:	0,12-0,18
Hot dip galvanized:	0,16-0,30
Zincplated + wax Gleitmo 605:	0,09-0,11

In normal cases (black, lightly oiled) it is possible to calculate with the friction value 0,12. For other cases values could be found in the table below.

Screw acc. to ISO 4014, 4017, 4762, DIN 931, 933, 912.

Table 97 Torque up to 90% of yield stress (Friction coefficient = 0,08 and 0,10)

Only recommended values.

	Friction coefficient = 0,08						Friction coefficient = 0,10					
Diameter	Clamping force N			Tightening torque Nm			Clamping force N			Tightening torque Nm		
	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9
M 4	4 350	6 150	7 400	2,1	2,9	3,5	4 200	5 900	7 100	2,4	3,3	4,0
M 5	7 150	10 100	12 100	4,2	6,0	7,1	6 900	9 700	11 600	4.9	7,0	8,0
M 6	10 100	14 200	17 000	7,0	10	12	9 750	13 700	16 400	8,0	12	14
(M 7)	14 800	20 700	24 900	12	16	20	14 400	20 200	24 200	13	19	23
M 8	18 500	26 100	31 300	17	24	29	17 900	25 100	30 200	20	28	34
(M 9)	24 700	34 700	41 600	25	35	43	23 800	33 400	40 100	29	41	49
M 10	29 500	41 400	49 700	34	48	58	28 400	40 000	48 000	40	56	67
M 12	43 000	60 500	72 500	60	84	100	41 500	58 500	70 000	69	98	115
M 14	59 000	82 500	99 000	95	135	160	56 500	80 000	96 000	110	155	185
M 16	81 000	114 000	137 000	145	205	245	78 500	110 000	132 000	170	240	285
M 18	98 500	138 000	166 000	200	285	340	95 000	134 000	160 000	235	330	395
M 20	127 000	178 000	214 000	285	400	480	122 000	172 000	206 000	330	465	560
M 22	158 000	222 000	266 000	380	530	640	152 000	214 000	257 000	445	620	750
M 24	183 000	257 000	308 000	490	690	830	176 000	248 000	298 000	570	800	960
M 27	239 000	337 000	404 000	720	1 000	1 200	232 000	326 000	391 000	840	1 200	1 400
M 30	292 000	410 000	493 000	980	1 400	1 650	282 000	397 000	476 000	1 150	1 600	1 950
M 8 x 1	20 200	28 400	34 100	18	26	31	19 500	27 000	33 000	22	30	36
M 10 x 1,25	31 600	44 400	53 300	36	51	61	30 500	42 900	51 500	42	59	71
M 12 x 1,25	48 200	68 000	81 500	64	91	110	46 600	65 500	78 500	76	105	130
M 12 x 1,5	45 400	64 000	76 500	62	87	105	43 900	62 000	74 000	72	100	120
M 14 x 1,5	65 000	91 500	110 000	100	140	170	63 000	88 500	106 000	120	165	200
M 16 x 1,5	88 000	124 000	148 000	150	215	255	85 000	120 000	144 000	180	250	300
M 18 x 1,5	114 000	161 000	193 000	220	310	370	111 000	156 000	187 000	260	365	435
M 20 x 1,5	144 000	203 000	244 000	305	430	510	140 000	197 000	236 000	380	510	610
M 22 x 1,5	178 000	250 000	300 000	405	570	680	172 000	242 000	291 000	480	680	810
M 24 x 2	203 000	286 000	343 000	520	730	880	197 000	277 000	332 000	610	860	1 050
M 27 x 2	264 000	371 000	445 000	760	1 050	1 300	256 000	359 000	431 000	900	1 250	1 500
M 30 x 2	331 000	466 000	559 000	1 050	1 500	1 800	321 000	452 000	542 000	1 250	1 750	2 100

Table 98 Torque up to 90% of yield stress (Friction coefficient = 0,125 and 0,14)

Only recommended values.

	Friction coefficient = 0,125						Friction coefficient = 0,14					
Diameter	Clamping force N			Tightening torque Nm			Clamping force N			Tightening torque Nm		
	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9
M 4	4 000	5 650	6 750	2,7	3,8	4,6	3 900	5 450	6 550	2,9	4,1	4,9
M 5	6 550	9 200	11 100	5,5	8,0	9,5	6 350	8 950	10 700	6,0	8,5	10
M 6	9 250	13 000	15 600	9,5	13	16	9 000	12 600	15 100	10	14	17
(M 7)	13 600	19 100	22 900	15	22	26	13 200	18 500	22 200	16	23	28
M 8	17 000	23 900	28 700	23	32	39	16 500	23 200	27 900	25	35	41
(M 9)	22 600	31 900	38 200	34	47	57	22 000	30 900	37 100	36	51	61
M 10	27 100	38 000	45 700	46	64	77	26 200	36 900	44 300	49	69	83
M 12	39 500	55 500	66 700	80	110	135	38 300	54 000	64 500	86	120	145
M 14	54 000	76 000	91 300	125	180	215	52 500	74 000	88 500	135	190	230
M 16	75 000	105 000	126 000	195	275	330	73 000	102 000	123 000	210	295	355
M 18	90 500	127 000	153 000	270	390	455	88 000	124 000	148 000	290	405	485
M 20	117 000	164 000	197 000	385	540	650	114 000	160 000	192 000	410	580	690
M 22	145 000	205 000	245 000	510	720	870	141 000	199 000	239 000	550	780	930
M 24	169 000	237 000	284 000	660	930	1 100	164 000	230 000	276 000	710	1 000	1 200
M 27	221 000	311 000	374 000	980	1 400	1 650	215 000	302 000	363 000	1 050	1 500	1 800
M 30	269 000	379 000	454 000	1 350	1 850	2 250	262 000	368 000	442 000	1 450	2 000	2 400
M 8 × 1	18 600	26 200	31 500	25	35	42	18 100	25 500	30 600	27	38	45
M 10 × 1,25	29 100	40 900	49 100	49	68	82	28 300	39 800	47 700	52	73	88
M 12 × 1,25	44 600	62 500	75 000	88	125	150	43 300	61 000	73 000	95	135	160
M 12 × 1,5	41 900	59 000	70 500	83	115	140	40 700	57 000	68 500	90	125	150
M 14 × 1,5	60 500	85 000	102 000	140	195	235	58 500	82 500	99 000	150	210	250
M 16 × 1,5	81 500	114 000	137 000	210	295	350	79 000	111 000	133 000	225	315	380
M 18 × 1,5	106 000	149 000	179 000	305	425	510	103 000	145 000	174 000	325	460	550
M 20 × 1,5	134 000	189 000	226 000	425	600	720	130 000	183 000	220 000	460	640	770
M 22 × 1,5	165 000	232 000	279 000	570	800	960	161 000	226 000	271 000	610	880	1 050
M 24 × 2	188 000	265 000	318 000	720	1 000	1 200	183 000	257 000	309 000	780	1 100	1 300
M 27 × 2	245 000	344 000	413 000	1 050	1 500	1 800	238 000	335 000	402 000	1 150	1 600	1 950
M 30 × 2	308 000	433 000	520 000	1 450	2 050	2 500	300 000	422 000	506 000	1 600	2 250	2 700

Table 99 Torque up to 90% of yield stress (Friction coefficient = 0,16 and 0,20)

Only recommended values.

	Friction coefficient = 0,16						Friction coefficient = 0,20					
Diameter	Clamping force N			Tightening torque Nm			Clamping force N			Tightening torque Nm		
	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9	8,8	10,9	12,9
M 4	3 700	5 200	6 250	3,1	4,4	5,0	3 400	4 800	5 750	3,5	4,9	6
M 5	6 100	8 600	10 300	6,5	9,0	11	5 600	7 900	9 450	7,0	10	12
M 6	8 600	12 100	14 500	11	15	18	7 900	11 100	13 300	12	17	20
(M 7)	12 600	17 800	21 300	18	25	30	11 600	16 300	19 600	20	28	34
M 8	15 800	22 300	26 700	26	37	45	14 500	20 500	24 500	30	40	50
(M 9)	21 100	29 700	35 600	39	55	66	19 400	27 300	32 700	44	62	74
M 10	25 200	35 500	42 600	53	75	90	23 400	32 600	39 100	60	84	100
M 12	36 800	51 500	62 000	92	130	155	33 900	47 600	57 000	105	145	175
M 14	50 500	71 000	85 000	145	205	250	46 300	65 000	78 000	165	230	280
M 16	70 000	98 000	118 000	230	320	385	64 500	90 500	108 000	255	380	435
M 18	84 000	118 000	142 000	310	435	520	77 500	109 000	131 000	350	495	590
M 20	109 000	153 000	184 000	445	630	750	100 000	141 000	169 000	500	710	850
M 22	136 000	191 000	229 000	600	840	1 000	125 000	176 000	211 000	680	950	1 150
M 24	157 000	221 000	265 000	770	1 100	1 300	145 000	203 000	244 000	870	1 200	1 450
M 27	207 000	291 000	349 000	1 150	1 600	1 950	190 000	268 000	321 000	1 300	1 800	2 200
M 30	252 000	354 000	425 000	1 550	2 200	2 600	232 000	326 000	391 000	1 750	2 450	2 950
M 8 × 1	17 400	24 400	29 300	29	41	49	16 000	22 500	27 000	33	46	55
M 10 × 1,25	27 200	38 200	45 900	57	80	95	25 000	35 100	42 200	64	90	105
M 12 × 1,25	41 600	58 500	70 000	105	145	175	38 400	54 000	64 500	115	165	195
M 12 × 1,5	39 100	55 000	66 000	97	135	165	36 000	50 500	60 500	110	155	185
M 14 × 1,5	56 500	79 000	95 000	160	225	270	52 000	73 000	87 500	185	255	310
M 16 × 1,5	76 000	107 000	128 000	245	345	410	70 000	98 500	118 000	275	390	465
M 18 × 1,5	99 000	139 000	167 000	355	500	600	91 000	128 000	154 000	405	570	680
M 20 × 1,5	126 000	176 000	212 000	500	700	840	116 000	163 000	195 000	570	800	960
M 22 × 1,5	154 000	217 000	261 000	670	940	1 150	143 000	201 000	241 000	760	1 050	1 300
M 24 × 2	176 000	248 000	297 000	850	1 200	1 450	163 000	229 000	275 000	960	1 350	1 600
M 27 × 2	229 000	322 000	387 000	1 250	1 750	2 100	211 000	297 000	357 000	1 400	2 000	2 400
M 30 × 2	288 000	406 000	487 000	1 750	2 450	2 950	266 000	374 000	449 000	2 000	2 800	3 350

Fasteners with socket head cap screw grip, sixpoint socket grip and low head

Table 100

Screw type	DIN 6912		DIN 7984		BN 1206	BN 9524	ISO 7379	DIN 7991	ISO14581	DIN 7991	ISO 7380	BN 6404	ISO 7380	ISO 4026/DIN 913, ISO 4027/DIN 914, ISO 4028/DIN 915, ISO 4029/DIN 916	
	Maximum tightening torque (Nm)														
< Thread	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	5	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) Property class and mechanical features according to ISO 898-5 are valid for set screws without extension strain.

Friction

Screw DIN 912 zincplated 8 µm + blue chromated class 8.8 M10x60. Test performed at Nylok Scandinavia. Machine Schatz Analyse.

5 tests were made in each round. Average values of the total friction are presented.

Table 101

Type of treatment:	Friction:
Zincplating	0,11
Zincplating + wax Gleitmo 605	0,08
Zincplating + Tuflok 2 - 180 degrees	0,12
Zincplating + Tuflok 2 - 180 degrees + wax Gleitmo 605	0,07
Zincplating + Tuflok 2 - 360 degrees	0,13
Zincplating + Tuflok 2 - 360 degrees + wax Gleitmo 605	0,08

Correction factors for screws and nuts

Screws with countersunk head: Due to the size of the contact surface and the sinking angle, these screws, meet a larger friction force contact surfaces and therefore require that the tightening torque is increased with approx. 30%.

Stud screws: For assembly of stud screw joints it is first required to fasten the end of the goods into the threaded hole, and then the joint's nut is tightened. When fastening the end of the goods the torque does not need to overcome friction against any contact surface. In line with what has been said about the distribution of the tightening torque, you could calculate with approximately half of the torque required for pre-stressing the screw through tightening the nut.

Collar screws and collar nuts: Even these have a larger contact surface than ordinary screws and nuts, and consequently a greater friction radius, which leads to that the tightening torque has to be increased with approx. 10%.

Set screws: When assembling set screws no friction against any contact surface has to be overcomed. However the bedding's resistance against the screws end must be overcomed. The screw's end design and the bedding's shape (plane or cylindrical surface, pre-drilled hole etc) will effect, but the required torque is 50% - 70% of what is required for ordinary screws. Set screws with point requires the lower torque, while set screws with chamfered, plane, or cupped ends have larger friction radius and therefore require the higher torque.

Table 102 Tightening torques in Nm for locking nuts

Tightening torques according to DIN 267/15 for locking nuts according to DIN 6925, ISO 7042. Clamping part according to DIN 267/15.

	class 8	class 10 and 12		class 8	class 10 and 12
M3	0,43	0,6	M18	42,0	56,0
M4	0,9	1,2	M20	54,0	72,0
M5	1,6	2,1	M22	68,0	90,0
M6	3,0	4,0	M24	80,0	106,0
M8	6,0	8,0	M27	94,0	123,0
M10	10,5	14,0	M30	108,0	140,0
M12	15,5	21,0	M33	122,0	160,0
M14	24,0	31,0	M36	136,0	180,0
M16	32,0	42,0	M39	150,0	200,0

Table 103 Tightening torque for Brass

Thread *d*	**M2**	**M2,5**	**M3**	**M3,5**	**M4**	**M5**	**M6**	**M8**	**M10**
M_A max [Nm]	0,14	0,28	0,5	0,79	1,2	2,2	3,9	9	17

For more information regarding tightening torques for fasteners in brass, copper and aluminium, please refer to min. breaking torque on page 217 table 197.

Table 104 Tightening torque for Copper

Thread *d*	**M4**	**M5**	**M6**	**M8**	**M10**	**M12**
F_V (N)	3000	5550	7800	14300	22800	33400
M_A max [Nm]	2,4	4,7	8	19	39	67

For more information regarding tightening torques for fasteners in brass, copper and aluminium, please refer to min. breaking torque on page 217 table 197.

Table 105 Tightening torque for Nylon, Polyamide 6.6

Thread *d*	**M3**	**M4**	**M5**	**M6**	**M8**	**M10**	**M12**	**M14**	**M16**
Screws M_A max [Nm]	0,1	0,2	0,5	1	2	3	4	6	7,5
Nuts M_A max [Nm]	0,1	0,3	0,6	1,5	3	4	5	7,5	9