How to use reference values

Preload and tightening torques

This procedure neither replaces the calculation as defined in VDI 2230 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 that the actual friction is lower than anticipated.

Step 1: Friction coefficient $\mu_K = \mu_G$
In case of uncertainty about **friction conditions in the threads and under the bearing surface,** the **lowest** possible practical friction coefficient (e.g. initial assembly, maintenance, repair) $\mu_K = \mu_G$ must be selected from table **F.049**.

Example:
Fasteners used are electro zinc plated
Friction coefficient $\mu_K = \mu_G$ = 0,14 – 0,24, lower friction coefficient $\mu_K = \mu_G$ = 0,14

Step 2: Tightening torque $M_{A\,max}$
Maximum permissible torque, 90 % utilisation of yield point (R_{eL}) respectively the 0.2 % yield strength ($R_{p0.2}$) can be found in the tables from page **F.053.** 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, M12 property class 8.8, zinc plated. In Table on page **F.054** look for M12 in the thread column, in the friction column look for $\mu_K = \mu_G$ = 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:
In the left half of the table in column «property class 8.8» and on line «M12/0,14», the resulting maximum installation 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 **F.051**.

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 to 2,0 must be applied. (see table at page **F.051**). 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 α_A = 1,8

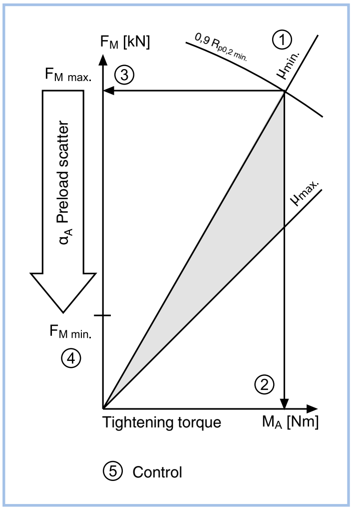
Minimum expected preload (clamp load):
$F_{M\,min} = F_{M\,max}/\alpha_A$ = 41,9 kN/1,8

$F_{M\,min}$ = 23,3 kN

Step 5: Double checking values,
checking using calculations in accordance with VDI 2230 is state of the art and is recommended for a safe design.
- 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)
- Inadequate knowledge of assembly personnel



Approximate values for metric coarse threads VDI 2230

Torque values are based on VDI 2230, edition 2015: The table lists maximum permissible tightening torques and the resulting maximum preload for hex cap screws and socket cap screws. Torque/preload values are applicable for other types of externally threaded fasteners also, as long as head strength and bearing areas are equivalent. The values are based on **90 % utilisation of yield point R_{eL}/0.2 % yield strength $R_{p0.2}$**. Clearance holes for bolts and screws acc. ISO 273-medium.

The listed values are maximum values and do not include a safety factor. This guideline assumes that the user has adequate fastener knowledge and is able to interpret the data accordingly.

Guideline tables F.053 and F.054
The guideline values are somewhat higher than in the earlier version VDI 2230, edition 1986 due to higher usage of screw strength reserves. Higher preload during assembly can be obtained.
Calculation of the fastened joint is needed! VDI 2230, edition 2015

Tightening torque, tables F.053 and F.054
With $M_A = F_M \cdot X$, the tightening torque can be calculated for other preloads (assuming the same friction coefficient and same thread size).

Threads	Friction coeff. $\mu_K = \mu_G$	Maximum preload $F_{M\,max}$ [N]							Maximum tightening torque $M_{A\,max}$ [Ncm]							Conversion factor X
		Property class based on ISO 898/1							Property class based on ISO 898/1							
		3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	
M1,6	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
M2	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
M2,5	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
M3	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

Threads	Friction coeff. $\mu_K = \mu_G$	Maximum preload $F_{M\,max}$ [kN]							Maximum tightening torque $M_{A\,max}$ [Nm]							Conversion factor X
		Property class based on ISO 898/1							Property class based on ISO 898/1							
		3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	
M4	0,08	1,3	1,74	2,17	3,48	4,6	6,8	8,0	0,63	0,84	1,05	1,68	2,3	3,3	3,9	0,50
	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
M5	0,08	2,12	2,83	3,54	5,67	7,6	11,1	13,0	1,2	1,65	2,06	3,3	4,4	6,5	7,6	0,58
	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
M6	0,08	3,00	4,01	5,01	8,02	10,7	15,7	18,4	2,1	2,8	3,6	5,7	7,7	11,3	13,2	0,72
	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
M8	0,08	5,4	7,3	9,1	14,6	19,5	28,7	33,6	5,2	6,9	8,6	13,8	18,5	27,2	31,8	0,95
	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

Threads	Friction coeff. $\mu_K = \mu_G$	Maximum preload $F_{M\,max}$ [kN]							Maximum tightening torque $M_{A\,max}$ [Nm]							Conversion factor X
		Property class based on ISO 898/1							Property class based on ISO 898/1							
		3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	3.6	4.6	5.6/4.8	6.8	8.8	10.9	12.9	
M10	0,08	8,7	11,6	14,5	23,2	31,0	45,6	53,3	10,2	13,6	17,0	27,2	36	53	62	1,16
	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	0,08	12,7	16,9	21,1	33,8	45,2	66,3	77,6	17	23	29	47	63	92	108	1,39
	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	0,08	17,4	23,2	29,0	46,4	62,0	91,0	106,5	28	37	46	74	100	146	171	1,60
	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	0,08	23,8	31,7	39,7	63,5	84,7	124,4	145,5	42	57	71	114	153	224	262	1,80
	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	0,08	29,1	38,8	48,5	77,6	107	152	178	60	80	100	160	220	314	367	2,06
	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	0,08	37,2	49,6	62,0	99,2	136	194	227	83	111	139	223	308	438	513	2,26
	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	0,08	46,3	61,7	77,2	123,5	170	242	283	113	151	189	303	417	595	696	2,46
	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	172	225	284	454	634	904	1057	3,97
M24	0,08	53,6	71,4	89,3	142,9	196	280	327	144	192	240	385	529	754	882	2,70
	0,10	52,1	69,5	86,9	139,0	192	274	320	170	222	280	450	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	0,08	70,2	93,6	117,0	187,2	257	367	429	210	280	351	561	772	1100	1287	3,00
	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	0,08	85,5	114,0	142,5	228,0	313	446	522	287	383	478	766	1053	1500	1755	3,36
	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	1428	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	0,08	106,1	141,5	176,9	283,1	389	554	649	385	514	643	1029	1415	2015	2358	3,64
	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	0,08	124,8	166,4	208,0	332,8	458	652	763	497	663	829	1327	1825	2600	3042	3,99
	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	0,08	149,5	199,4	249,2	398,8	548	781	914	640	854	1067	1708	2348	3345	3914	4,28
	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

Approximate values for metric fine threads VDI 2230

The details are based are based on VDI 2230, edition 2015: preloading forces and tightening torques for headless screws of property classes 8.8 to 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	Friction coeff. $\mu_K = \mu_G$	Preloading 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
M8x1	0,08	21,2	31,1	36,4	19,3	28,4	33,2
	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
M10x1,25	0,08	33,1	48,6	56,8	38	55	65
	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
M12x1,25	0,08	50,1	73,6	86,2	66	97	114
	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
M14x1,5	0,08	67,8	99,5	116,5	104	153	179
	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
M16x1,5	0,08	91,4	134,2	157,1	159	233	273
	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
M18x1,5	0,08	122	174	204	237	337	394
	0,10	120	171	200	283	403	472
	0,12	117	167	196	327	465	544
	0,14	115	163	191	368	523	613
M20x1,5	0,08	154	219	257	327	466	545
	0,10	151	215	252	392	558	653
	0,12	148	211	246	454	646	756
	0,14	144	206	241	511	728	852
M22x1,5	0,08	189	269	315	440	627	734
	0,10	186	264	309	529	754	882
	0,12	182	259	303	613	873	1022
	0,14	178	253	296	692	985	1153
M24x2	0,08	217	310	362	557	793	928
	0,10	213	304	355	666	949	1110
	0,12	209	297	348	769	1095	1282
	0,14	204	290	339	865	1232	1442

For an explanation of the friction coefficient µ
Page F.049

Stud bolts with reduced shank

Stud bolts from steel 21 CrMo V 5 7 (DIN 2510 L sheet 3)
Typical values for assembly preload 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	8,5	12	12	15	15	18	18
$\mu_K = \mu_G$	0,10	0,12	0,10	0,12	0,10	0,12	0,10	0,12
F_M [N]	21 600	21 600	43 500	43 500	67 800	67 800	97 800	97 800
M_A [Nm]	38	44	98	115	190	220	320	370

Tightening torques for plastic screws / Polyamide 6.6 and Polyamide 6.6-GF50

according to DIN 34810: 2018-04

The tables contain typical values for advisable tightening torques for screws made from polyamide 6.6 (PA6.6 + PA6.6-GF50) at 20 °C after storage in a normal climate (relative atmospheric humidity in acc. with DIN 50014) until the moisture stability has been reached. In order not to excessively exceed the tightening torques specified in the tables, a maximum speed of the screwdriving tool of 150 rpm is recommended.

Tightening torques for plastic screws / PA6.6						
Threads	M3	M4	M5	M6	M8	M10
M_A [Nm]	0,1	0,25	0,5	0,8	1,8	3,5

Tightening torques for plastic screws / PA6.6-GF50			
Threads	M5	M6	M8
M_A [Nm]	0,75	1,75	4,0

Tightening torques (typical values) for brass screws (CU2)

Threads	M2	M2,5	M3	M3,5	M4	M5	M6	M8	M10
M_A [Nm]	0,13	0,27	0,48	0,8	1,1	2,2	3,7	9,1	18,3

Approximate values for austenitic stainless steel A1 / A2 / A4

Clamp loads/tightening torques (standard metric thread) for shank bolts, property class 50/70/80 utilizing **90 % of max. yield strength $R_{p\,0,2}$.**

The table does not include any factors of safety and assumes the user is familiar with the design criteria.

Threads	$\mu_K = \mu_G$	Preload $F_{M\,max}$ [kN] Property class			Tightening torque $M_{A\,max}$ [Nm] Property class		
		50	70	80	50	70	80
M1,6	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
M2	0,1	0,35	0,74	1	0,11	0,23	0,30
	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
M2,5	0,1	0,58	1,23	1,64	0,22	0,46	0,62
	0,2	0,5	1,06	1,42	0,34	0,72	0,97
	0,3	0,42	0,9	1,21	0,42	0,89	1,19
M3	0,1	0,86	1,84	2,5	0,37	0,8	1,1
	0,2	0,75	1,6	2,12	0,59	1,26	1,7
	0,3	0,64	1,36	1,81	0,73	1,56	2,1
M4	0,1	1,5	3,2	4,2	0,86	1,85	2,4
	0,2	1,3	2,76	3,6	1,35	2,9	3,8
	0,3	1,1	2,35	3,1	1,66	3,6	4,7
M5	0,1	2,4	5,2	6,9	1,6	3,6	4,8
	0,2	2,1	4,51	6	2,6	5,7	7,6
	0,3	1,8	3,85	5,1	3,3	7	9,4
M6	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	12,2	16,3
M8	0,1	6,2	13,4	17,9	7,1	15,2	20,3
	0,2	5,4	11,6	15,5	11,2	24,1	32,1
	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	21,1	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	$\mu_K = \mu_G$	Preload $F_{M\,max}$ [kN] Property class			Tightening torque $M_{A\,max}$ [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	79,6	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	99,3	132	257	551	735
	0,3	39,7	85,2	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 surfaces (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 an explanation of the friction coefficient µ
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The safety in fastening technology requires a correct specification the lubrication status

The friction coefficient is, above all, influenced by the combinations of work materials, the application surfaces and their lubrication condition Knowledge of the friction coefficient together with the relationship to the «torque-preload force» is a prerequisite for safety in assembly.

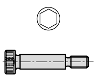
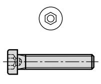
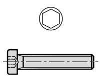
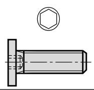
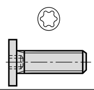
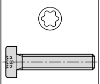
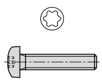
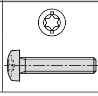
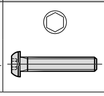
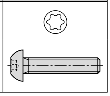
Corrosive attacks on the thread or on the application surface impair the solubility behavior after a certain period in operation various material combinations, high operational temperatures and moisture reinforce gailling and change the assembly operation to the worse.

For a safe and secure assembly – anti-friction-coatings are recommended

Tribological dry coating is a solution system for mechanically-loaded fasteners and components (screws, nuts, washers). The coating is a non-electrolytically applied thin-layer film with integrated lubrication properties and an additional corrosion protection.

The so-called antifriction coatings are touch-dry solid film lubricants which, in terms of their formulation, are similar to conventional industrial varnishes.
For example **CresaCoat®** as an economic solution guarantees constant friction coefficients and contributes to an additional simplification of the assembly processes.

Fasteners with internal drives and lower head shape

Values for reduced tightening torque M_A [Nm]										
Standard	ISO 7379	DIN 6912	DIN 7984	Bossard	Bossard	ISO 14580	ISO 14583	~ISO 14583	ISO 7380-1	~ISO 7380-1
Screw type										
Steel	012.9	08.8	08.8	010.9	08.8	08.8	08.8	08.8	010.9	08.8
	BN 1359	BN 15 BN 20737	BN 16 BN 17	BN 1206 BN 20697 BN 20698	BN 9524	BN 4850	BN 20005	BN 20228 BN 84405	BN 19 BN 13255 BN 30102	BN 6404
M2	–	–	–	0,22	0,19	0,25	0,25	–	0,27	0,25
M2,5	–	–	–	0,45	0,4	0,5	0,5	–	0,6	0,5
M3	–	1	0,9	0,8	0,7	0,9	0,9	0,9	0,95	0,9
M3,5	–	–	–	–	–	–	–	–	–	–
M4	–	2,3	2,1	1,95	1,6	2	2	2	2,3	2
M5	5,2	4,6	4	3,8	3,2	4	4	4	4,6	4
M6	9	8,1	7,2	6,6	5,4	7,2	7,2	7,2	8	7,2
M8	21,6	19,4	17,3	16	13	17	17	–	19	17,3
M10	43	38,7	34,4	32	23	34	34	–	38	34,5
M12	73	65	58	–	–	–	–	–	65	58
M14	–	105	–	–	–	–	–	–	–	–
M16	180	162	144	–	–	–	–	–	–	–
M20	363	330	290	–	–	–	–	–	–	–
M22	–	–	–	–	–	–	–	–	–	–
M24	–	560	500	–	–	–	–	–	–	–
Stainless steel		A2/A4	A2		A2	A2	A2/A4		A2/A4	
		BN 33001 BN 1350	BN 2844		BN 20146	BN 15857	BN 5687 BN 20038		BN 1593 BN 6971 BN 8699	
M2	–	–	–	–	0,14	0,19	0,19	–	0,19	–
M2,5	–	–	–	–	0,28	0,37	0,37	–	0,37	–
M3	–	–	0,6	–	0,5	0,64	0,64	–	0,64	–
M3,5	–	–	–	–	–	–	–	–	–	–
M4	–	1,5	1,3	–	1,1	1,5	1,5	–	1,5	–
M5	–	2,9	2,6	–	2,2	3	3	–	3	–
M6	–	5	4,5	–	3,8	5	5	–	5	–
M8	–	12	10	–	9,1	12	12	–	12	–
M10	–	24	21	–	18	24	24	–	24	–
M12	–	40	36	–	–	–	–	–	40	–
M14	–	65	–	–	–	–	–	–	–	–
M16	–	100	90	–	–	–	–	–	–	–
M20	–	200	180	–	–	–	–	–	–	–
M22	–	–	–	–	–	–	–	–	–	–
M24	–	340	310	–	–	–	–	–	–	–

Reduced load strength
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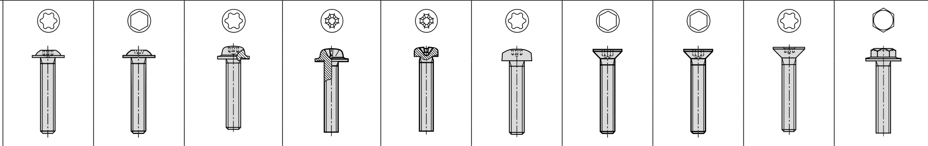
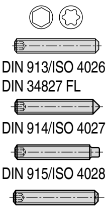
Check the boundary conditions!
The screws are not suitable for transferring high operating forces. The inner and outer actuation of these screws permits only reduced tightening torques to be used.

> **! Reduced loadability**
> Screws according to various specification are by virtue of their head geometry and / or drive form subject to a reduced loadability according to ISO 898-1, i.e. the reduced torque values are to be taken into account.
>
> The given tightening torques cannot always be applied reliably depending on the choice of the inner drive – conical bits in particular may be helpful.

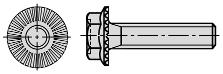
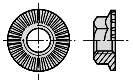
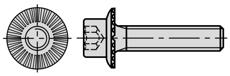
Values for reduced tightening torque M_A [Nm]

Stan- dard	Bossard ~ISO7380-2	Bossard ~ISO7380-2	ecosyn®-fix	ecosyn®-fix	SN 213307	ISO 14583	DIN 7991 ISO 10642	DIN 7991 ISO 10642	ISO 14581	ecosyn®-fix	DIN/ISO
Screw type											 DIN 913/ISO 4026 DIN 34827 FL DIN 914/ISO 4027 DIN 915/ISO 4028 DIN 916/ISO 4029 DIN 34827 CP
Steel	08.8	010.9	4.8	4.8	4.8	4.8	08.8	010.9	08.8	4.8	45 H[1]
	BN 20367	BN 11252 30104	BN 5128	BN 4825	BN 380 381	BN 30503	BN 30105 2100	BN 20 21 1422 2101 2102 2103	BN 4851	BN 5950	Diverse
M2,5	–	–	0,4	0,3	0,3	–	0,5	0,55	0,5	–	–
M3	1	1	0,7	0,5	0,5	0,7	0,9	0,95	0,9	0,5	0,5
M4	2,5	2,5	1,6	1,2	1,2	1,6	2	2,3	2	1,2	1,5
M5	5	5	3,2	2,4	2,4	3,2	4	4,6	4	2,4	3
M6	8	8	5,4	4	4	5,4	7,2	7,9	7,2	4,1	5
M8	20	20	–	–	–	–	17	19	17	10	12
M10	40	40	–	–	–	–	35	38	35	20	24
M12	66	66	–	–	–	–	58	65	58	34	40
M14	–	–	–	–	–	–	93	100	93	–	60
M16	–	–	–	–	–	–	144	158	144	–	100
M18	–	–	–	–	–	–	–	220	205	–	120
M20	–	–	–	–	–	–	–	310	290	–	180
M22	–	–	–	–	–	–	–	420	400	–	210
M24	–	–	–	–	–	–	–	530	500	–	310
Stain- less steel	A2		A2					A2/A4		A2	A2/A4
	BN 2058		BN 10649	BN 5952	BN 2845			BN 616 4719 2104 2105	BN 3803 20039	BN 5951	Diverse
M2,5	–	–	0,5	0,4	0,4	–	–	0,23	0,23	–	–
M3	0,64	–	0,8	0,8	0,8	–	–	0,4	0,4	0,8	0,2
M4	1,5	–	1,8	1,6	1,6	–	–	0,9	0,9	1,8	0,7
M5	3,0	–	3,6	3,2	3,2	–	–	1,8	1,8	3,6	1,5
M6	5,0	–	6,3	6	6	–	–	3,1	3,1	6,3	2,5
M8	12,0	–	–	–	–	–	–	7,6	7,6	15,2	6
M10	–	–	–	–	–	–	–	15	15	30	12
M12	–	–	–	–	–	–	–	25	25	51	20
M14	–	–	–	–	–	–	–	40	40	–	30
M16	–	–	–	–	–	–	–	63	63	–	50
M18	–	–	–	–	–	–	–	85	85	–	90
M20	–	–	–	–	–	–	–	120	120	–	105
M22	–	–	–	–	–	–	–	160	160	–	150
M24	–	–	–	–	–	–	–	200	200	–	–

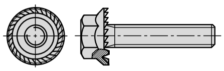
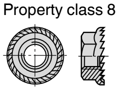
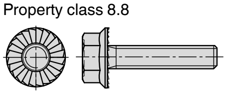
[1] Property classes and mechanical properties in compliance with ISO 898, part 5 do not apply for headless bolts subject to tension loads

Flange screws and flange nuts

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

Serrated flange	Mating Material	Friction coeff. ~μ_{tot}	Tightening torques M_A [Nm]						
			M5	M6	M8	M10	M12	M14	M16
Description **Property class**	Steel $R_m \geq$ 800 N/mm²	0,13 to 0,16	10	18	37	80	120	215	310
VERBUS RIPP® **BN 2797, BN 9727** Property class100 	Steel $R_m <$ 800 N/mm²	0,12 to 0,18	11	19	42	85	130	230	330
	Grey cast iron R_m ~150 to 450 N/mm²	0,125 to 0,16	9	16	35	75	115	200	300
	Aluminum alloy non heat treated	0,14 to 0,2	16	28	65	120	190	320	450
BN 2798, BN 14527 Property class 10 	Aluminum alloy heat treated	0,13 to 0,18	14	25	55	100	160	275	400
			~Preload force F_M [kN][1)]						
			9	12,6	23,2	37	54	74	102
INBUS RIPP® **BN 3873** Property class 100 	Steel $R_m \geq$ 800 N/mm²	0,13 to 0,16	11	20	42	85	140		
	Steel $R_m <$ 800 N/mm²	0,12 to 0,18	13	24	45	90	150		
	Grey cast iron R_m ~150 to 450 N/mm²	0,125 to 0,16	10	19	39	80	120		
			~Preload force F_M [kN][1)]						
			9	12,6	23,2	37	54		

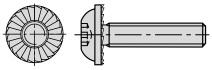
Tightening torques M_A [Nm] and achievable preload force F_M [kN] for VERBUS TENSILOCK® screws and nuts, at a 90 % utilisation of the elongation limit $R_{p\ 0,2}$

Serrated flange outer edges only	Mating Material	Friction coeff. ~μ_{tot}	Tightening torques M_A [Nm]						
			M5	M6	M8	M10	M12	M14	M16
Description **Property class**	Steel R_m ~500 to 900 N/mm²	0,14 to 0,18	9,5	16,5	40	79	137	218	338
VERBUS TENSILOCK® **BN 73** Property class 90 	Grey cast iron R_m ~150 to 450 N/mm²	0,12 to 0,18	7,6	13,2	31,8	63	108	172	264
	Aluminum alloy non heat treated	0,16 to 0,24	10,5	18,2	44	87	150	240	372
			~Preload force F_M [kN][1)]						
			6,35	9	16,5	26,6	38,3	52,5	73
BN 190, BN 30312, BN 20230, BN 80014 Property class 8 									
Hex serrated flange screw **BN 20170, BN 20226, BN 80007** Property class 8.8 	Steel R_m ~500 to 900 N/mm²	0,12 to 0,18	6,5	11,3	27,3	54	93	148	230
	Grey cast iron R_m ~150 to 450 N/mm²	0,12 to 0,16	5,9	10,1	24,6	48	84	133	206
	Aluminum alloy non heat treated	0,14 to 0,2	7,8	13,6	32,7	65	112	178	276
			~Preload force F_M [kN][1)]						
			7	9,9	18,1	28,8	41,9	57,5	78,8

[1)] Reference values for plain finish fasteners and mating steel parts with a tensile strength ≤ 800 N/mm²

! Assembling
Guideline values for achievable preload should be checked in field trials

Tightening torques M_A [Nm] and achievable preload force F_M [kN] for ecosyn®-grip screws, at a 90 % utilisation of the elongation limit $R_{p\,0,2}$

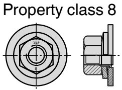
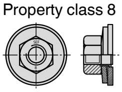
Serrated flange surface	Mating Material	Friction coeff. ~μ_{tot}	Tightening torques M_A [Nm]			
			M5	M6	M8	M10
Description **Property class**	Steel R_m ~500 to 900 N/mm²	0,15 to 0,20	8,5	15	29	67
ecosyn®-grip **BN 219** Property class 8.8 	Grey cast iron R_m ~150 to 450 N/mm²	0,11 to 0,25	10	17	21	47
	Aluminum alloy non heat treated	0,22 to 0,40	17	29	36	87
	Aluminum alloy heat treated	0,19 to 0,35	14	25	33	76
			~Preload force F_M [kN][1)]			
			7	9,9	18,1	28,8

[1)] Reference values for plain finish fasteners and mating steel parts with a tensile strength ≤ 800 N/mm²

! Assembling
Guideline values for achievable preload should be checked in field trials.

Tightening torques ecosyn®-SEF

Tightening torques M_A [Nm] and achievable assembly preload force F_M [kN] for ecosyn®-SEF nuts, at a 90 % utilisation of the elongation limit $R_{p\,0,2}$

Description nut	Screw material	Friction coeff. ~μ_{tot}	Tightening torques M_A [Nm]					
			M4	M5	M6	M8	M10	M12
Property class	Steel class 8.8	0,14 to 0,24	3,3	6,5	11,3	27,3	54	93
ecosyn®-SEF **BN 33855** (Type-L) Property class 8  **ecosyn®-SEF** **BN 33966** (Type-M) Property class 8 			**~Assembly preload force F_M [kN]**[1)]					
			4,3	7	9,9	18,1	28,8	41,9

[1)] Reference values for plain finish fasteners for achievable assembly preload force F_M [kN]

! Assembling
Guideline values for achievable preload should be checked in field trials.

Reference values for tightening torque NORD-LOCK® washers wedge-locking system

The recommended tightening torques
are based on laboratory tests and should be checked for each specific application prior to use.
Under certain practical conditions smaller friction coefficients can be achieved!

Reference value according ISO 16047 based on Molykote® 1000 graphite paste with NORD-LOCK® zinc flake coated washers paired with screws/bolts 8.8, 10.9, 12.9 and austenitic steel

NORD-LOCK®							
Property class	Lubricant Type	Friction coefficients					
	In thread & under head bearing	µThread min	µThread max	µHead min	µHead max	µtot min	µtot max
8.8	Molykote® 1000	0,10	–	0,13	–	0,12	0,20
10.9	Molykote® 1000	0,10	–	0,11	–	0,11	0,18
12.9	Molykote® 1000	0,10	–	0,10	–	0,11	0,17
A2-70, A4-70 A2-80, A4-80	Molykote® 1000	0,10	–	0,08	–	0,10	0,16

NORD-LOCK®													
Property class	Mating material	Lubricant Type In thread & under head bearing	Friction coefficients µtot	M5x0,8	M6x1	M8x1,25	M10x1,5	M12x1,75	M16x2	M20x2,5	M24x3	M27x3	M30x3,5
8.8	Steel Rm < 800 N/mm^2	Molykote® 1000	0,12 to 0,20	Tightening torque $M_{A\,max}$ [Nm]									
				5,9	10,1	24,6	48	84	206	415	714	1050	1420
	Max preload under the lowest friction coefficient			Max preload F_M [kN]									
				7,2	10,2	18,6	29,6	43	81	130	188	246	300
10.9	Steel Rm ≥ 800 N/mm^2	Molykote® 1000	0,11 to 0,18	Tightening torque $M_{A\,max}$ [Nm]									
				8,1	14	33,9	66,8	115	283	554	953	1400	1900
	Max preload under the lowest friction coefficient			Max preload F_M [kN]									
				10,7	15,2	27,7	44	64,1	120	188	270	355	432
12.9	Steel Rm ≥ 800 N/mm^2	Molykote® 1000	0,11 to 0,17	Tightening torque $M_{A\,max}$ [Nm]									
				9,4	16,4	39,7	78,2	134,9	331	648	1120	1640	2230
	Max preload under the lowest friction coefficient			Max preload F_M [kN]									
				12,5	17,7	32,4	51,5	75	141	220	317	416	506
A2-70 A4-70	Austenitic steel 100 – 200 HV	Molykote® 1000	0,10 to 0,16	Tightening torque $M_{A\,max}$ [Nm]									
				3,6	6,3	15,2	29,9	51,6	126	247	425	623	848
	Max preload under the lowest friction coefficient			Max preload F_M [kN]									
				5,2	7,3	13,4	21,3	31,1	58,3	91,1	131	172	209
A2-80 A4-80	Austenitic steel 200 – 300 HV	Molykote® 1000	0,10 to 0,16	Tightening torque $M_{A\,max}$ [Nm]									
				4,8	8,4	20,2	39,9	68,7	169	330	567	831	1131
	Max preload under the lowest friction coefficient			Max preload F_M [kN]									
				6,9	9,8	17,9	28,5	41,4	77,7	121	175	229	279

Assembly preload and tightening torque are based on following conditions:

- Hexagon bolts according to ISO 4014 or ISO 4017
- Cylindrical bolts according to ISO 4762
- Hole according to ISO 273-m
- v = 0,9 for shank bolts with metric standard thread according to ISO 68 or ISO 724

The scatter of the applied torque which will vary depending on selected tightening method should be considered when deciding the applied torque.

Details given are reference values which are in line with the initial condition of the material, the specified purpose and usage in lubricated condition.

Depending on the type of mechanical and dynamic stress, the surface conditions change character in relation to temperature, pressure and mounting speed and may influence the friction conditions of the components.

The friction values according to ISO 16047 for screws lubricated with MOLYKOTE® 1000 are based on the first tightening and the principles of VDI 2230, provided that the surface of the internal thread corresponds to the surface of the screw. For all other combinations of surfaces, the friction values should be checked.

In a few exceptional applications where the clamped parts have a high hardness and a low surface roughness the final rotation during tightening might occur against the clamped part and reduce the friction coefficient (µhead).

Disclaimer

The indicative torque values in this guideline have been verified in test laboratories and represent configuration examples. The guideline is intended as a help and guide for torque calculations and should be used as such. Any calculations based on the guideline should be verified and tested before use. Nord-Lock International AB and its subsidiaries do not take responsibility for any work or constructions made based on calculations based on the guideline.

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Torquelator from Nord-Lock

The «online-calculator» calculates pre-load and corresponding torque for bolted joints secured with Nord-Lock washers. Choose between two different calculation methods (Kellermann&Klein and VDI 2230), select the bolt size (metric and imperial), the property classes and lubricant to get the torque value

High strength structural bolts for steel constructions (HV sets)

With the Construction Products Regulation 305/2011 coming into effect, a **declaration of performance** is required for **CE marking** of the specified construction products. The regulation replaces the previous construction products directive **(Directive 89/106/EEC).** DIN 18800-7 for the realization of load-bearing components in steel and rules for manufacturer qualifications, is replaced by EN 1090. EN 1090 defines the requirements on the declaration of conformity of steel constructions, which are introduced into the market as construction products.

The individual requirements on connection elements are governed by harmonized standards EN 15048 and EN 14399 for **steel constructions resp. metal constructions.**
It must be explicitly highlighted that the CE marking only becomes mandatory, if the connection elements are used in a building construction, will remain permanently installed, and decisively influence the basic requirements on building constructions. Connection elements with specific requirements from structural engineering must already contain the reference to the respective **harmonized standard** or **declaration performance** in the case of inquiries / purchase orders with respective specification. Property classes of bolts and nuts and possibly surface treatment conditions must be defined together with all necessary selection possibilities permitted by the product standard.

The Eurocodes are defined as European standard reference with respect to the construction of buildings and other engineering structures. EN 1993 applies for steel construction dimensioning.

Bolting connection categories according to EN 1993-1-8

Shear connections		
Cat. A	Bearing-type connections	Preloading not required according to standard
Cat. B	Slip-resistant connection in the limit state of usability	Preloading required
Cat. C	Slip-resistant connection in the limit state of load capability	Preloading required

Tensile connections		
Cat. D	Not preloaded	Preloading not required according to standard
Cat. E	Preloaded	Preloading required

Collection of high strength sets for bolting connections in metal construction according to EN 14399

Type of the set for bolting connections		HR system				HV system		HRC system	
General requirements		EN 14399-1							
Suitable for preloading		EN 14399-2 and additional tests defined in the standard as needed							
Screw and nut		EN 14399-3		EN 14399-7		EN 14399-4	EN 14399-8	EN 14399-10	
Marking symbols	Screw	HR8.8	HR10.9	HR8.8	HR10.9	HV10.9	HVP10.9	HRC10.9	
	Nut	HR8 or HR10	HR10	HR8 or HR10	HR10	HV10		HR10	HRD10
Washer(s)		EN 14399-5[1] or EN 14399-6		EN 14399-5[1] or EN 14399-6		EN 14399-6		EN 14399-6	EN 14399-5[1] or EN 14399-6
Marking symbols		H or HR[2]		H or HR[2]		H or HV[2]		H or HR[2]	H or HR[2] or HD[3]

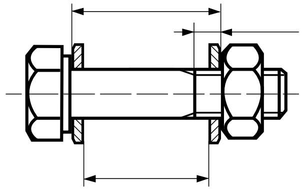
1) Washers according to EN 14399-5 can only be used under the nut.
2) At the discretion of the manufacturer.
3) Mandatory marking for washers with enlarged outer diameter according to EN 14399-5 only.

Correlation between DIN / EN standard

Standard	Content	Dimensions	Strength	Replaced by
DIN 6914	High strength preloaded (HV) bolts	M12–M36	10.9	EN 14399-4
DIN 6915	High strength preloaded (HV) nuts	M12–M36	10	EN 14399-4
DIN 6916	High strength preloaded (HV) washers, round	13–37	300–370 HV	EN 14399-6
DIN 6917	Square taper washers (for I-profiles)	13–37	295–350 HV	are kept
DIN 6918	Square taper washers (for U-profiles)	13–37	295–350 HV	are kept
DIN 7999	High strength preloaded (HV) locating bolts	M12–M30	10.9	EN 14399-8

Clamp length

In EN 14399-4, the clamp length is measured between the contact surface of the bolt head and the nut. The distance between the washers is designated as the grip length. Sufficient free threads should be taken into account.
In the case of preloaded bolts according to EN 14399-3, EN 14399-7, and EN 14399-10, at least four complete threads must be available between the contact surface of the nut and the thread-free part of the bolt shank.



Tightening process

Sets for non-preloaded bolting connections
Sets for non-preloaded bolting connections made on unalloyed steels, alloyed steels, and austenitic stainless steels, must comply with EN 15048-1.
Sets according to EN 14399-1 can also be used for non-preloaded bolting connections.

Sets for preloaded bolting connections
High strength preloaded bolting connections comprise the HR, HV, and HRC systems. They must meet the requirements in EN 14399-1 and the applicable European standard.
Unless specified differently, bolts made of non-rusting steel must not be used in preloaded applications. If they are used, they must be treated as special connectors.

Unless specified differently, the following must be assumed as nominal value for minimum preloading force $F_{p,C}$:
$F_{p,C} = 0{,}7 \times f_{ub} \times A_s$, where f_{ub} is the nominal strength of the bolt material and A_s the stressed cross-sectional area of the bolt.

Tightening for k-classes

Tightening method	Preloading	k-classes
Torque method	$F_{p,C}$	K2
Combined preloading method	$F_{p,C}$	K1 (or K2)
Modified preloading method	F_{p,C^*}	K1

So-called **k-classes** are defined for the delivered HV sets, which represent indirect information about the friction value condition of the set. **Class K1** specifies the lubrication condition of the nut as decisive element of a set so that the minimum preloading forces can be reliably achieved. Therefore, the tightening should always be done on the side of the nut.
The k-classes and possibly the tightening torques for the modified preloading method according to EN 1993-1-8/AC for F_{p,C^*} are specified on the packaging. All elements of a HV set can thus be combined from any production lots of the manufacturer and are delivered separately packed. The respective tightening torques and preloading forces can be found in EN 1993-1-8/AC.

Preload and tightening torques for HV bolting connection 10.9 according to EN 14399-4 / EN 14399-6 – k-class K1 according to EN 14399-1

Current standard	Tightening method	Special features
EN 1090-2	Torque method	Only approved with K2 test in Europe (except Germany)
EN 1090-2	Combined torque and rotation angle method	Only with K1 or K2
DIN EN 1993-1-8/AC	Modified torque and modified combined preload method	If screws are not tightened to the full preload

Torque method

The bolts must be tightened using a tightening device offering a suitable working range. Manually operated and automated screwdrivers can be used.

Combined preloading method with pre-tightening torques and prevailing angles for property class 10.9 (EN 1090)

In the case of the combined preloading method for HV sets 10.9 and k-class K1 according to EN 1090-2 to achieve the minimum preloading force $F_{p,C}$, a pre-tightening torque is applied in the first step according to table values. This first step must be fully completed for all bolts in a connection, before the second tightening step can be started according to the specifications with a prevailing angle.

Required preload and tightening torques (EN 1090)

EN 1090-2		Bolt diameter in mm							
		12	16	20	22	24	27	30	36
Standard preloading force $F_{p,C}$	[kN]	59	110	172	212	247	321	393	572
Reference torque (k-class K1) $M_{r,1}$	[Nm]	92	229	447	606	771	1127	1533	2677
Pre-tightening torque = 0,75 $M_{r,1}$	[Nm]	67	165	322	439	557	815	1107	1935

Required rotation angle for the combined preloading method on sets with property class 10.9 (EN 1090)

Total nominal thickness «t» of the parts to be joined (including all shims and washers) d = bolt diameter	Prevailing angle to be applied during the second tightening step
< 2 d	60°
$2\,d \leq t < 6\,d$	90°
$6\,d \leq t \leq 10\,d$	120°

Remark: If the surface under the bolt head or the nut (taking into account possibly inserted tapered washers) is not perpendicular to the bolt axis, the required prevailing angle should be determined experimentally.

Modified torque (DIN EN 1993-1-8/AC)

The tightening process using the modified torque method consist of two tightening steps. A specified pre-tightening torque of maximum 0,75 x modified reference torque must be applied for all bolts in a connection before the second tightening step can be started. With the modified reference torque listet in the table the standard preloading force F_{p,C^*} will be reached with the second step.

Modified combined preloading method (DIN EN 1993-1-8/AC)

In the case of the modified combined preloading method for application of the standard preloading force F_{p,C^*}, a pre-tightening torque is applied using the torque method. This first step must be fully completed for all bolts in a connection, before the second tightening step can be started according to the specifications with a rotation angle.

Required preload and tightening torques (DIN EN 1993-1-8/AC)

DIN EN 1993-1-8/NA		Bolt diameter in mm							
		12	16	20	22	24	27	30	36
Modified preloading force F_{p,C^*}	[kN]	50	100	160	190	220	290	350	510
Modified reference torque (k-class K1) M_A	[Nm]	100	250	450	650	800	1250	1650	2800
Pre-tightening torque for combined rotation	[Nm]	75	190	340	490	600	940	1240	2100

Required rotation angle for the combined preloading method on sets with property class 10.9 (DIN EN 1993-1-8/AC)

Total nominal thickness «t» of the parts to be joined (including all shims and washers) d = bolt diameter	Prevailing angle to be applied during the second tightening step
< 2 d	45°
2 d ≤ t < 6 d	60°
6 d ≤ t ≤ 10 d	90°

Remark: If the surface under the bolt head or the nut (taking into account possibly inserted tapered washers) is not perpendicular to the bolt axis, the required prevailing angle should be determined experimentally.