STANDARD
ISO : 3506
EN : –
DIN ISO : 3506
DIN : 267 Part 11(W)

STAINLESS STEEL

Material properties

Steel grades A1 - A2 - A4

info

1. Normative information

The German standard DIN 267 Part 11 on corrosion-resistant stainless steel fasteners has been withdrawn due to the mandatory implementation of the European EN-productstandards of hexagon bolts, screws and nuts. These EN-productstandards are indentical with existing international ISO-standards, which refer to appropriate ISO-standards with regard to the specifications and reference standards.
Consequently these ISO-standards are also operative when EN-productstandards are applied.

However, Europe is of the opinion that the existing ISO-standard 3506:1979 does not meet all requirements of the present state of technics.
The European Technical Committee for Standardization CEN/TC 185 "Mechanical Fasteners" therefore decided to wait with the issue of an EN-standard untill ISO 3506, which is now under revision, will be acceptable for Europe.

In spite of this, Germany recommends as an intermediate compromis to use DIN ISO 3506 (unchanged German translation of ISO 3506:1979), when EN-productstandards are applied.
DIN ISO 3506 is also valid for all cases, in which is still referred to DIN 267 Part 11.

2. Scope and field of application

These specifications apply to fasteners (primarily bolts, screws and nuts) made from austenitic grades of corrosion-resistant stainless steels with sizes from 1,6 up to and including 39 mm, metric (ISO) thread and also to nuts with widths across flats or outside diameters ≥ 1,45 d and an effective thread engagement of at least 0,6 d.
This International Standard does not define corrosion or oxidation resistance in particular environments. It does specify grades for fasteners made from corrosion-resistant stainless steels. Some have mechanical properties allowing use at temperatures down to -200°C or up to +800°C in air. Acceptable corrosion and oxidation performances and use at elevated or sub-zero temperatures must be subject of agreement between user and manufacturer appropriate to the proposed service environment.

3. Choice of material

“STAINLESS” steel contains a great number of variants, all with at least 12% chromium (Cr) and mostly also other alloying elements, nickel (Ni) and molybdenum (Mo) being the most important. This extensive field has been divided for fasteners into 3 MATERIAL GROUPS based on their metallurgical structure:

austenitic (A)	martensitic (C)	ferritic (F)

The martensitic and ferritic groups are hardly of any importance to commercial fasteners. They are not available from stock and are only manufactured on order in great quantities.

The austenitic material group - also called chromium-nickel steels - is the most used for fasteners and is further subdivided into 3 steel grades, each with a different resistance to corrosion and a specific field of application.

A1 = a free-cutting quality, having a superior machinability due to a higher phosphorus and sulphur percentage. As a consequence, however, the general corrosion resistance is decreased. This “automatic lathe” stainless steel is seldom used for mass production fasteners.

A2 = the most current steel grade - also called 18/8 (18% Cr, 8% Ni) - with outstanding corrosion resistance under normal atmospheric conditions, in wet surroundings, oxidizing and organic acids, many alkalic and salt solutions.

A4 = the most corrosion resistant steel grade - also called “acid proof” - with an increased nickel percentage and addition of molybdenum. Better resistance to agressive media such as sea climate (chlorides), industrial atmosphere (sulphur dioxide), oxidizing acids and there where pitting may occur.

See corrosion table on page 15-60-4
Unless otherwise specified fasteners from austenitic stainless steel shall be clean and bright. For maximum corrosion resistance passivation is recommended.

4. Chemical composition of austenitic stainless steel A.

The wide limits of percentages of the alloying elements in ISO 3506 allow within every steel grade a great choice out of the special austenitic steel types. The final choice is at the discretion of the manufacturer, depending on the requirements and method of manufacturing. If a special type within the specified grade is wanted, the appropriate German Werkstoffnummer, the American AISI or ISO type number has to be indicated. The most popular types are summarized in the following table.

Stainless steel-		chemical composition in % 1)								Stainless steel types			
Material group	Steel grade	C	Si	Mn	P	S	Cr	Mo 8)	Ni	DIN Werkstoffnr.	AISI types	ISO 683/XIII	Foot notes
Austenitic A	A1	0,12	1,0	2,0	0,20	0,15-0,35	17,0-19,0	0,6	8,0-10,0	1.4305	303	17	2) 3)
	A2	0,08	1,0	2,0	0,05	0,03	17,0-20,0		8,0-13,0	1.4301	304	11	3) 4) 6) 7)
										1.4541	321	15	5)
	A4	0,08	1,0	2,0	0,05	0,03	16,0-18,5	2,0-3,0	10,0-14,0	1.4401	316	20	3) 4) 6)
										1.4571	316 Ti	21	5)

1) Maximum values, unless otherwise specified.
2) Sulphur may be replaced by selenium.
3) May contain titanium ≥ 5 X C up to 0,8%.
4) May contain niobium (columbium) and/or tantalum ≥ 10 X C up to 1%.
5) Containing titanium ≥ 5 X C up to 0,8%.
6) May contain copper up to 4%.
7) Molybdenum may also be present at the option of the manufacturer.
8) If for some applications a maximum molybdenum content is essential, this shall be stated at the time the customer orders.

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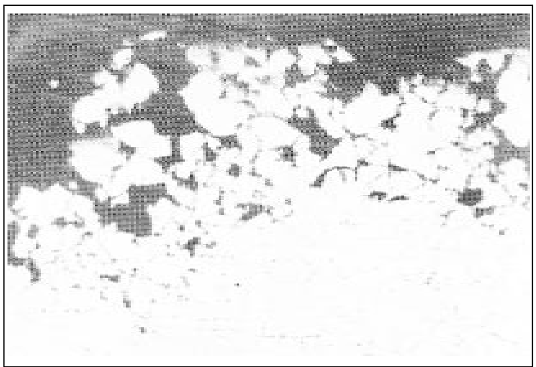
5. Performance under different kinds of corrosion

5.1 Atmospheric (chemical) corrosion

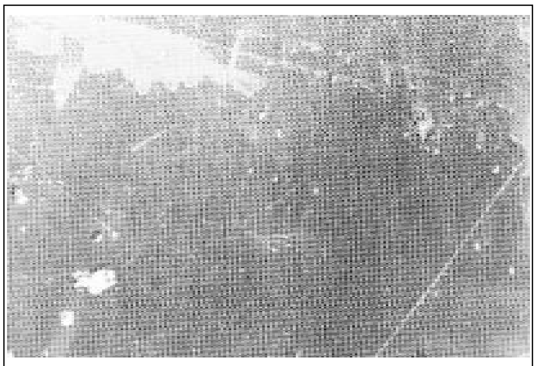
This kind of general corrosion is caused by chemical attack from the atmosphere or aggressive media and is mostly defined as the loss of surface material in µm/year. The attack passes evenly and gradually, mostly visibly and it is checkable. Sudden collapse does not occur, so this type of corrosion is not dangerous.
Generally grade A2 is very satisfactory, but under more aggressive conditions A4 is recommended. See chemical corrosion table on page 15-60-4.

5.2 Contact (galvanic) corrosion

When two metals in the presence of an electrolyte create a difference of electrical potential, a galvanic action occurs which causes the lesser noble metal (anode) to corrode and to sacrifice itself, protecting the nobler metal (kathode). The higher the difference in electrical potentials and the larger the contacting area of the nobler metal relative to that of the lesser noble, the more severely this contact corrosion will attack the anode. Passive austenitic stainless steel is relatively noble, whereas fasteners generally have a comparatively small surface in relation to the construction.
Aluminium performs very well, as practice has proven, because of the formation of an insulating layer of aluminum oxide.
Steel and cast iron have to be covered with a closed protective layer e.g. zinc or lacquer.
Copper and brass are applicable, when the fasteners are relatively small. Generally this combination can only be advised when an adequate insulation is applied.
Dry wood will not cause problems. In socked condition pitting corrosion may occur on the long run, however the time of resistance is much longer than with plated steel.
Plastic performs well, although deformation of washers, for example, may cause crevice corrosion.
Asbestos cement and concrete are permissable, given the good experience with, for instance, stainless steel anchors in concrete.
For further information see the contact corrosion table elsewhere in this section. In all cases contact corrosion cannot be avoided, the contact areas have to be insulated with, for example, non-acid fat, insulating lacquers or pastes, plastic bushes or washers, insulating tape.



microstructure of intercrystalline attack



typical phenomenon of pitting corrosion in a chloride solution

5.3 Intercrystalline corrosion

Austenitic stainless steel grades A2 and A4 shall not show chromium carbides between 400° and 800°C causing an attack between the material crystals at the grain boundaries. This is achieved by the choice of the right steel type with, for example, either a lower carbon content, or by addition of stabilizing elements e.g. Titanium (Werkstoffnummer 1.4541 and 1.4571). For fasteners the first method is the most used.
A2 and A4 have to meet the test requirements on intercrystalline corrosion according to ISO 3651.
A1 is not resistant to intercrystalline corrosion due to the higher carbon content and is therefore not suitable for higher temperatures e.g. welding.

5.4 Pitting corrosion

Local pore-like holes may form, growing fast and deep into the material causing the product to be attacked suddenly and severely. This type of corrosion appears especially in halogen (chloride) environments e.g. sea climate and brackish water. A4 offers the best resistance to pitting due to the addition of molybdenum.

5.5 Crevice corrosion

In presence of an aqueous environment corrosion may occur in crevices, for example, of spring washers and under sediments or layers of paint where insufficient air (oxygen) can circulate to restore the passivity of the stainless steel.

5.6 Stress (transcrystalline) corrosion

Cracking across the material crystals may occur when parts are exposed to external or internal stresses in a chloride atmosphere. This corrosion-related phenomenon however will seldom appear with cold headed fasteners.

6. Magnetic properties

Austenitic stainless steel fasteners are normally non-magnetic. The right choice of steel type will limit the permeability (that is the rate of penetration in a magnetic field) to below 1,05 G/Oe.
However after cold working some ability to be magnetized may be evident. In this respect A4 is less sensible than A2 and A1 is the most unfavourable.
Some special applications like for electrotechnical equipment, and in the marine and nuclear industry, require a permeability as close as possible to 1,0. Fasteners on stock are not suitable for these purposes and special non-magnetizable steel types have to be applied in agreement (see Stahl-Eisen-Werkstoffblatt SEW 390, the standard VG 85539 of the Bundesamt für Wehrtechnik and the Grohmannbook “Wissenswertes über Edelstahlschrauben”).

7. Temperature range

Heat-resistant up to,+ 400° C according to AD-Merkblatt W2 for pressure vessels and TRD 106 for steam-boilers and oxidation-resistant up to +800° C according to ISO 3506.
Allowing use at very low temperatures: A2 down to -196° C and A4 down to -60° C according to AD-Merkblatt W10 for pressure vessels and DIN 267 Part 13.

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STAINLESS STEEL

Mechanical properties

Property classes 50 - 70 - 80

1. System of designation of property classes

A characteristic property of austenitic stainless steel is that - contrary to the heat treated steels, which are used for the property classes 8.8, 10.9 and 12.9 - this material cannot be hardened and tempered, but can only be strengthened by cold-working, increasing the mechanical properties considerably.

The 3 austenitic steel grades A1, A2 and 4 are divided into 3 property classes 50, 70 and 80 depending on the method of manufacturing and on sizes. The number of the property class corresponds with 1/10 of the tensile strength in N/mm^2, e.g. class 80 has a minimum tensile strength: 80 X 10= 800 N/mm^2.

50 = the soft condition of turned and hot-pressed fasteners. This is seldom used for current fasteners.

70 = the most universal and applied property class for all cold-formed fasteners.This class is the standard class and is delivered when no other class is ordered.

80 = the highest property class, having obtained mechanical values by extra cold deformation to the level of the 8.8 heat-treated steel bolts. Exchange does not require a new strength calculation or adaption of the construction.

2. Mechanical properties

2.1 For sizes above M5

Stainless steel		Property class	For sizes d	Bolts and screws			Nuts
Material group	Steel grade			Tensile strength R_m 3) N/mm^2, min.	0,2%-proof stress $R_{p\,0,2}$ 3) N/mm^2, min.	Elongation at fracture A_L 4) in mm, min.	Proof load stress S_p N/mm^2
Austenitic	A1, A2 and A4	50	≤M39	500	210	0,6d	500
		70 1)	≤M20	700	450	0,4d	700
		80 2)	≤M20	800	600	0,3d	800

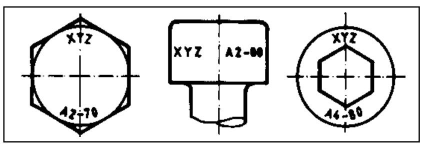
1) These values shall apply only to lengths up to max. 8 x d. In the steel groups A2 and A4 class 70 is the most current.
2) The whole diameter/length-programme of class 80 that we carry on stock possess these properties
3) All values are calculated and reported in terms of the tensile stress area of the thread (see Tables of screw thread elsewhere in this section)
4) The elongation at fracture shall be determined on the actual screw or bolt length ≥3 x d and not on a prepared test piece of gauge length 5 d.

2.2 Breaking torques for sizes up to and including M5

Nominal thread size	Minimum breaking torque Nm Property class 50	Property class 70	Property class 80
M 1,6	0,15	0,2	0,27
M 2	0,3	0,4	0,56
M 2,5	0,6	0,9	1,2
M 3	1,1	1,6	2,1
M 4	2,7	3,8	4,9
M 5	5,5	7,8	10,0

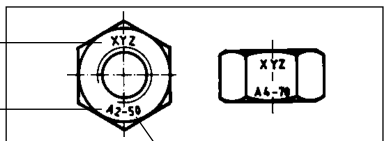
3. Marking: guarantee for quality

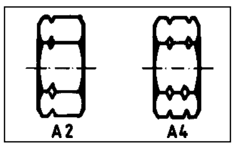
Stainless steel hexagon head bolts and nuts, socket cap screws of size M5 and greater and all packaging shall be marked with the manufacturer's identification mark and the steel grade followed by the two digits of the property class or in the case of turned nuts on the alternative way of groove marking, see examples below. Marking of studs and other fasteners shall be agreed on by user and manufacturer.



HEXAGON HEAD BOLT SOCKET CAPSCREW

MANUFACTURER
STEEL GRADE
PROPERTY CLASS 1)





HEXAGON NUT

1) Property class of nuts only for lower strength grades

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ISO	: –
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STAINLESS STEEL

Guidelines for assembling

General

In many cases corrosion resistance is still the only criterion for the application of stainless steel fasteners. However these articles are being used more and more as mechanical jointing elements, requiring strength and construction reliability. For this purpose it is necessary to gain some understanding of the typical behaviour of stainless steel during assembly and, in particular, of factors related to preload and torque.

1. Maximum admissable surface pressure

For a good connection the admissable surface pressure is of primary importance. It shall not be exceeded after preloading and under the external load between the contact surfaces of bolt head and nut and the clamped material of the construction, otherwise the preload decreases due to plastic deformation and the connection will loosen.

Guide values of the admissable surface pressure of the construction material in N/mm^2				
austenitic stainless steel	aluminium alloys	St 37	St 50	cast iron
400*	200	260	420	700

* This value applies to the annealed condition. May rise up to 700 N/mm^2 depending on the rate of cold deformation.

	Contact surface in mm^2																		
nominal size	M3	M4	M5	M6	M8	M10	M10	M12	M12	M14	M14	M16	M18	M20	M22	M22	M24	M27	M30
width across flats in mm	5,5	7	8	10	13	16*	17	18*	19	21*	22	24	27	30	32	34*	36	41	46
hexagon bolts DIN 931/933 hexagon nuts DIN 934	7,54	11,4	13,6	28,0	42,0	72,3	96,1	73,2	94,6	113	141	157	188	244	254	337	356	427	576
socket cap screws DIN 912	11,1	17,6	26,9	34,9	55,8	89,5	–	90,0	–	131	–	181	211	274	342	–	421	464	638

These surfaces can be enlarged by using washers.
* These are the new ISO-widths across flats.

2. Friction coëfficients of stainless steel

The greater ductility of austenitic stainless steel does not only cause higher friction coëfficients u_G on the screw thread and u_K under the head, but also a greater scatter than the normal steels. This means that a lower preload is created at the same torque. A suitable lubricant can diminish the friction, but the scatter remains. Because of the great number of variable factors it is adviseable to establish the friction coëfficients by experiment per application with, for example, a torque-tension tester.

Guide values of friction coëfficients u_G and u_K (according to VDI Richtlinien 2230)							
construction material from	bolt from	nut from	lubricant		elasticity of the connection	friction coëfficient	
			on screw thread	under the head		screw thread u_G	under the head u_K
A2	A2	A2	without	without	very great	**0,26** - 0,50	**0,35** - 0,50
			special lubricant (chloride-parafine base)			**0,12** - 0,23	**0,08** - 0,12
			corrosion-resistant grease			**0,26** - 0,45	**0,25** - 0,35
			without	without	small	**0,23** - 0,35	**0,12** - 0,16
			special lubricant (chloride-parafine base)			**0,10** - 0,16	**0,08** - 0,12
		Al Mg Si	without		very great	**0,32** - 0,43	**0,08** - 0,11
			special lubricant (chloride-parafine base)			**0,28** - 0,35	**0,08** - 0,11

3. Approach of bolt size

For the dimensioning of the bolt size a global comparison can be made with the usual strength classes of the normal steels on the basis of the 0,2% proof stress (see table on page 15-40-3, par. 2.1):

– Class 50 is well over 10% lower than class 4.6, so exchange will not be possible in all cases.
– Class 70 in the sizes up to and including M20 can replace class 8.8 right away when for stainless steel one standardized size greater is taken e.g. M10 A2-70 instead of M8-8.8. Up to 30% higher loads can then be allowed.
  Above M20 up to and including M30 class 70 is only equivalent with class 4.6 and exchange is possible right away.
– Class 80 is 7% lower than class 8.8. Generally exchange will be possible without problems. In critical situations this difference has to be taken into account and especially the surface pressure has to be controlled.

For a more accurate method of calculation see the VDI Richtlinien 2230 “Systematic calculation of high duty bolted joints.”

4. Galling (seizing) of stainless steel

The great ductility means that austenitic stainless steel in general is more susceptible to galling than the normal steels. From many years of experience, however, it has been proven that this genuine problem seldom occurs with bolts, because nowadays they are cold-formed and get a harder cold-worked surface and a smooth, rolled screw thread. Also the positive clearance of iso-metric screw thread contributes favourably against galling.
One condition however, is that the products shall be clean, free of burs, strange metal particles, chips, sand, etc. and that one-sided clamping due to damaging of the screw thread or assembling out of alignment shall be avoided.
Rigid joints are better than elastic ones.
It is advisable to torque as uniformly as possible and at low speed and not to use impact wrenches. It is noted that to induce a certain preload not only are the friction coëfficients important, but also the accuracy of the method of torquing (tightening factor).
The combination of 2 different stainless steel grades, e.g. A2 and A4, is not advantageous as far as galling is concerned. Under special circumstances and for special requirements a suitable lubricant shall be used e.g. chloride-parafine, molykote lacquer, high pressure oil, corrosion-resistant grease.

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STAINLESS STEEL

Guidelines for assembling

Pre-loads and tightening torques

		Assembly pre-load F_M in kN								Tightening torque M_A in Nm							
Friction coëfficient		0,1	0,12	0,14	0,16	0,18	0,20	0,30	0,40	0,1	0,12	0,14	0,16	0,18	0,20	0,30	0,40
Nom. size	Class																
M4	50	1,38	1,33	1,27	1,22	1,17	1,12	0,90	0,74	0,8	0,9	1,0	1,1	1,2	1,3	1,5	1,6
	70	2,97	2,85	2,73	2,62	2,50	2,40	1,94	1,60	1,7	2,0	2,2	2,3	2,5	2,6	3,0	3,3
	80	3,97	3,80	3,64	3,49	3,34	3,20	2,59	2,13	2,3	2,6	2,9	3,1	3,3	3,5	4,1	4,4
M5	50	2,26	2,18	2,09	2,00	1,92	1,83	1,49	1,22	1,6	1,8	2,0	2,1	2,2	2,4	2,8	3,2
	70	4,85	4,66	4,47	4,29	4,11	3,93	3,19	2,62	3,4	3,8	4,2	4,6	4,9	5,1	6,1	6,6
	80	6,47	6,22	5,96	5,72	5,48	5,24	4,25	3,50	4,6	5,1	5,6	6,1	6,5	6,9	8,0	8,8
M6	50	3,20	3,07	2,94	2,82	2,70	2,59	2,09	1,73	2,8	3,1	3,5	3,7	4,0	4,1	4,8	5,3
	70	6,85	6,57	6,31	6,05	5,79	5,54	4,49	3,70	5,9	6,7	7,4	7,9	8,4	8,8	10,4	11,3
	80	9,13	8,77	8,41	8,06	7,72	7,39	5,98	4,93	8,0	9,1	9,9	10,5	11,2	11,8	13,9	15,0
M8	50	5,86	5,63	5,40	5,18	4,96	4,75	3,85	3,17	6,8	7,6	8,4	9,0	9,6	10,1	11,9	12,9
	70	12,6	12,1	11,6	11,1	10,6	10,2	8,25	6,80	14,5	16,3	17,8	19,3	20,4	21,5	25,5	27,6
	80	16,7	16,1	15,4	14,8	14,2	13,6	11,0	9,1	19,3	21,7	23,8	25,7	27,3	28,7	33,9	36,8
M10	50	9,32	8,96	8,60	8,27	7,91	7,58	6,14	5,05	13,7	15,4	16,7	18,1	19,3	20,3	24,0	26,2
	70	20,0	19,2	18,4	17,7	16,9	16,2	13,1	10,8	30	33	36	39	41	44	51	56
	80	26,6	25,6	24,6	23,6	22,6	21,7	17,5	14,4	39,4	44	47,8	51,6	55,3	58	69	75
M12	50	13,6	13,1	12,6	12,0	11,6	11,1	9,00	7,38	23,3	26,0	28,9	30,8	32,8	34,8	41,0	44,6
	70	29,1	28,1	26,9	25,8	24,8	23,7	19,2	15,8	50	56	62	66	70	74	88	96
	80	38,8	37,4	35,9	34,4	33,0	31,6	25,6	21,1	67	74	82	88	94	100	117	128
M14	50	18,7	17,9	17,3	16,5	15,8	15,2	12,3	10,1	37,1	41,7	45,6	49	52	56	66	71
	70	40,6	38,5	37,0	35,4	34,0	32,6	26,4	21,7	79	89	98	105	112	119	141	152
	80	53,3	51,3	49,3	47,3	45,3	43,3	35,2	29,0	106	119	131	140	150	159	188	204
M16	50	25,7	24,7	23,8	22,8	21,9	20,9	17,0	14,0	56	63	70	75	81	86	102	110
	70	55,0	52,9	50,9	48,9	46,8	44,9	36,4	30,0	121	136	150	162	173	183	218	237
	80	73,3	70,6	67,9	65,2	62,4	59,8	48,6	40,0	161	181	198	217	231	245	291	316
M18	50	32,2	31,0	29,8	28,5	27,3	26,2	21,2	17,5	81	91	100	108	115	122	144	156
	70	69,0	66,4	63,8	61,2	58,6	56,2	45,5	37,5	174	196	213	232	246	260	308	334
	80	92,0	88,5	85,0	81,6	78,1	74,9	60,7	50,1	232	261	285	310	329	346	411	447
M20	50	41,3	39,8	38,3	36,7	35,2	33,8	27,4	22,6	114	128	142	153	164	173	205	223
	70	88,6	85,4	82,0	78,7	75,4	72,4	58,7	48,1	244	274	303	328	351	370	439	479
	80	118	114	109	105	101	96,5	78,3	64,6	325	366	404	438	467	494	586	639
M22	50	51,6	49,8	47,9	46,0	44,1	42,3	34,3	28,3	154	174	191	208	222	234	279	303
	70	61,5	59,3	57,0	54,7	52,5	50,3	40,9	33,7	182	206	227	247	263	279	332	361
	80	148	142	137	131	126	121	98,2	80,9	437	494	545	593	613	670	797	866
M24	50	59,6	57,4	55,1	52,9	50,7	48,6	39,4	32,6	197	222	243	264	282	298	354	385
	70	70,9	68,3	65,6	63,0	60,4	57,9	47,0	38,8	234	264	290	314	336	355	421	458
	80	170	170	157	151	145	139	113	93,1	561	634	696	754	806	852	1010	1099
M27	50	75,6	72,9	70,1	67,3	64,5	61,9	50,2	41,5	275	311	344	377	399	421	503	548
	70	90,0	86,8	83,4	80,1	76,9	73,7	59,8	49,4	328	371	410	444	475	502	599	652
M30	50	91,9	88,6	85,2	81,7	78,4	75,2	61,0	50,3	374	423	467	506	540	571	680	740
	70	104	105	101	97,3	93,3	89,5	72,6	59,9	445	503	556	602	643	680	809	881
M33	50	114	110	106	102	98	94	76	63	506	573	634	688	763	779	929	1013
M36	50	135	130	125	120	115	110	89	74	651	737	814	882	944	998	1189	1296
M39	50	162	156	150	144	138	133	108	89	842	955	1057	1147	1228	1300	1553	1694

These values apply to austenitic stainless steel hexagon bolts and hexagon nuts.
The torques are theoretically calculated values depending on the friction coëfficient chosen and based on a pre-load, utilizing 90% of the minimum 0,2% proof stress during assembly.
This table shall only be used as a guideline. No liability can result from its use.