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Technical data sheet

Title	Mechanical properties of corrosion-resistant stainless steel fasteners. Part 1 Bolts, screws and studs.
Standard	ISO 3506-1:2009-11-15

1.- Purpose and field of application.

This part of the ISO 3506 standard specifies the mechanical properties of corrosion-resistant austenitic, martensitic and ferritic stainless steel bolts, screws and studs, tested at an ambient temperature of between 15ºC and 25ºC. These properties will vary at higher and lower temperatures.

It applies to bolts, screws and studs:

- with nominal thread diameter (*d*) of up to 39 mm, inclusive;
- With ISO triangular metric thread with diameter and pitch in accordance with the ISO 68-1, ISO 261 and ISO 262 standards;
- or any shape.

This part of the ISO 3506 standard does not apply to screws with special characteristics such as weldability.

This part of the ISO 3506 standard does not define resistance to corrosion or oxidation in particular environments. The ISO 8044 standard includes the definitions of corrosion and resistance to corrosion.

This part of the ISO 3506 standard aims to establish a classification of the quality classes of the corrosion-resistant stainless steel fasteners. Some materials can be used at low temperatures, up to -200ºC, while others can be used at high temperatures, up to 800ºC in the air. Annex F provides some information about how temperature influences the mechanical properties.

Resistance to corrosion and oxidation, as well as the mechanical properties at high temperatures or at temperatures below zero degrees, must be agreed upon between the customer and the manufacturer for each case. Annex G shows how the risk of intergranular corrosion at high temperatures depends on the carbon content.

All the austenitic stainless steel fasteners are non-magnetic in hyper-tempered [annealing status]; some magnetic properties may be revealed after a cold deformation (see Annex H).

2- Designation, marking and finish.

2.1 Designation

The designation system for the stainless steel quality classes for bolts, screws and studs is illustrated in figure 1. The material designation consists of two groups of characters separated by a dash. The first designates the steel classed product and the second designates the quality class.

The designation of the steel classed product (first group) consists of one of the following letters:

A for austenitic steels;

C for martensitic steels;

F for ferritic steels.

Which designates the steel group and a number that designates the chemical composition within the steel group.

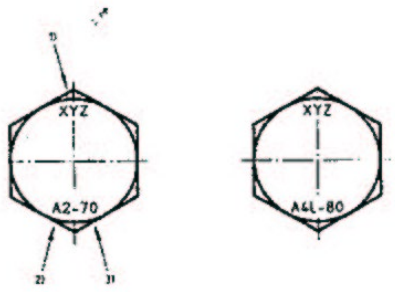
The designation of the quality class (second group) consists of two numbers that indicate 1/10 of the fastener's tensile strength.

2.2 Marking

The pieces must be marked and/or described with the designation system described in section 2.1, only if all the conditions established in this part of the ISO 3506 standard are met.

2.2.1 Bolts and screws. All the hex-head bolts and screws and Allen bolts and screws with hexagon socket and six internal lobes with nominal thread diameter $d \geq 5$ mm must be clearly marked according to the indications in section 2.1 and in figures 1 and 2. The marking must include the classed product and the quality class of the steel as well as the manufacturer identification mark. Other bolts and screws may be marked in the same way, to the extent possible, and only on the head. Other supplementary markings are allowed as long as they do not cause confusion.

2.2.2. Studs. Studs with nominal thread diameter $d \geq 6$ mm must be clearly marked according to the indications of section 2.1 and in figures 1 and 2. The marking must be located on the non-threaded part of the stud and must include the manufacturer identification mark, the classed product and the quality class of the steel. If it is not possible for the marking to be on the non-threaded part only, only the steel classed product may be marked at the end of the threaded part of the bolt (see figure 2).

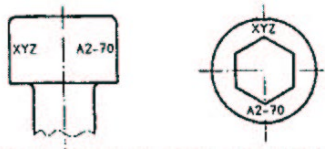


1) Manufacturer identification mark

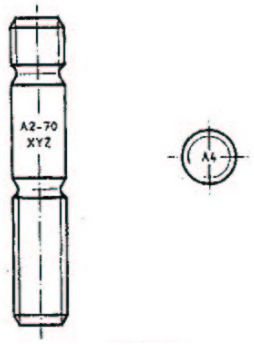
2) Classed product

3) Quality class

Marking of hex-head bolts and screws



Marking of Allen bolts and screws with hexagon socket and six lobes (alternative shapes)



Marking of studs (for other possibilities, see section 2.2.2)

NOTE – The marking for left-hand threads is described in the ISO 898-1 standard

Fig. 2 – Marking of bolts, screws and studs

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2.2.3 Packaging. All packages of any size must be marked with the designation and with the manufacturer's registered trademark, as indicated in the ISO 16426 standard.

2.3. Finish. Except when indicated otherwise, fasteners that meet the requirements of this part of the ISO 3506 standard must be supplied clean and shiny. If a passivation is required for greater resistance to corrosion, it must be done in accordance with ISO 16048 and marked with a "P" symbol.

3- Chemical composition.

The chemical composition of the stainless steels of the fasteners that meet the requirements of this part of the ISO 3506 standard are included in table 1.

Except when otherwise agreed upon beforehand by the buyer and the manufacturer, the definitive chemical composition chosen for the steel classed product is left to the manufacturer.

For applications with a risk of intergranular corrosion, it is recommended to do the test described in the ISO 3651-1 standard or in the ISO 3651-2 standard. In these cases, stabilised steels A3 and A5 or stainless steels A2 and A4 with carbon content not exceeding 0.03% are recommended.

Table 1

Stainless steel classed products. Chemical composition

Group	Classed product	Chemical composition % (m/m)[1)]									Notes
		C	Si	Mn	P	S	Cr	Mo	Ni	Cu	
Austenitic	A1	0.12	1	6.5	0.2	0.15-0.35	16 to 19	0.7	5 to 10	1.75 to 2.25	bcd
	A2	0.1	1	2	0.05	0.03	15 to 20	-[e]	8 to 19	4	fg
	A3	0.08	1	2	0.045	0.03	17 to 19	-[e]	9 to 12	1	h
	A4	0.08	1	2	0.045	0.03	16 to 18.5	2 to 3	10 to 15	4	gi
	A5	0.08	1	2	0.045	0.03	16 to 18.5	2 to 3	10.5 to 14	1	hi
Martensitic	C1	0.09 to 0.15	1	1	0.05	0.03	11.5 to 14	--	1	--	i
	C3	0.17 to 0.25	1	1	0.04	0.03	16 to 18	--	1.5 to 2.5	--	--
	C4	0.08 to 0.15	1	1.5	0.06	0.15-0.35	12 to 14	0.6	1	--	bi
Ferritic	F1	0.12	1	1	0.04	0.03	15 to 18	-[j]	1	--	kl

NOTES
1 Annex B includes a description of the groups and stainless steel classed products, including their properties and applications.
2 Annexes C and D include examples of stainless steels that are standardised in the ISO 683-13 and ISO 4954 standards, respectively.
3 Annex E includes some materials for specific applications.

a) Except when indicated otherwise, the values are maximum values.
b) Sulphur may be substituted for selenium.
c) If the nickel content is under 8%, the minimum magnesium content must be 5%.
d) There is no limit on the copper content as long as the nickel content is above 8%.
e) Molybdenum may be added at the manufacturer's discretion. However, when it is necessary to limit the content of this element for certain applications, the customer must specify this in the order.
f) If the chromium content is under 17%, the minimum nickel content must be 12%.
g) For austenitic stainless steels with a maximum carbon content of 0.03%, the nitrogen may be limited to 0.22%. But it must not exceed 0.12% in austenitic steels.
h) If to stabilise the steel it is necessary to add titanium, niobium or tantalum, in order to designate these steels according to this table, the titanium content must be 5 x C or above, with a maximum of 0.8%, or the niobium and/or tantalum content must be 10 x C or above, with a maximum of 1%.
i) The carbon content may be increased, at the manufacturer's discretion, when required to obtain the mechanical properties at larger diameters, but it must not excee austenitic steels.
j) Molybdenum may be added at the manufacturer's discretion.
k) It may contain titanium at≥ 5 x C to a maximum of 0.8%.
k) It may contain niobium and/or tantalum at≥ 10 x C to a maximum of 1%.

4- Mechanical properties.

The mechanical properties of the bolts, screws and studs that meet the requirements of this part of the ISO 3506 standard must comply with the values given in tables 2, 3 and 4.

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For martensitic steel bolts and screws, the tensile strength with wedge loads must not be less than the minimum tensile strength values given in table 3.

For the purposes of acceptance, the mechanical properties specified in this chapter apply and must be tested in accordance with the testing programmes described in chapter 7.

5- Tests.

5.1 Testing programme

The tests that must be done depend on the steel classed product and the length of the screw or bolt, and are indicated in table 5.

5.2 Testing methods

5.2.1 Generalities. The accuracy of measurement of all the lengths must be ± 0.05 mm or higher.

All the tensile strength and load tests must be done on testing machines with automatic aligning grips to avoid any non-axial stresses (see figure 6).

To do the tests in accordance with sections 5.2.2 to 5.2.4, the lower adaptor must be tempered and hardened. Its hardness must be at least 45 HRC.

The internal tolerance of the thread must be 5H6G.

Table 2

Mechanical properties of bolts, screws and studs. Austenitic steels

Group	Classed product	Quality class	Tensile strength Rm[1)] min. N/mm^2	Conventional Yield strength at 2% $R_{p0.2}$[1)] min. N/mm2	Elongation after rupture A[2)] min. mm
Austenitic	A1, A2	50	500	210	0.6 *d*
	A3, A4	70	700	450	0.4 *d*
	A5	80	800	600	0.3 *d*

[1)] The tensile strength is calculated based on the resistant section (see Annex A).

[2)] It is determined according to the indications of section 7.2.4, on the actual screw length and not on the prepared test tube; d is the nominal thread diameter.

Table 3

Mechanical properties of bolts, screws and studs. Martensitic and ferritic steels

Group	Classed product	Quality class	Tensile strength Rm[a] min.	Conventional yield strength at 0.2% $R_{p0.2}$[a] min.	Elongation after rupture A[b] min.	Hardness

			MPa	MPa	mm	HB	HRC	HV
Martensitic	C1	50	500	250	0.2 *d*	147 to 209	--	155 to 220
		70	700	410	0.2 *d*	209 to 314	20 to 34	220 to 330
		110[c]	1100	820	0.2 *d*	--	36 to 45	350 to 440
	C3	80	800	640	0.2 *d*	228 to 323	21 to 35	240 to 340
	C4	50	500	250	0.2 *d*	147 to 209	--	155 to 220
		70	700	410	0.2 *d*	209 to 314	20 to 34	220 to 330
Ferritic	F1[d]	45	450	250	0.2 *d*	128 to 209	--	135 to 220
		60	600	410	0.2 *d*	171 to 271	--	180 to 285

[a] The tensile strength is calculated based on the resistant section (see Annex A).

[b] It is determined according to the indications of section 7.2.4, on the actual screw length and not on the prepared test tube.

[c] Tempered and hardened at a minimum temperature of 275ºC.

[d] Nominal thread diameter d ≤ 24 mm.

Table 4

Minimum breaking torque, $M_{B\ min.}$ for austenitic steel bolts and M1.6 to M16 screws

(coarse pitch thread)

Thread	Minimum breaking torque, $M_{B\ min.}$ Nm		
	Quality class		
	50	70	80
M1.6	0.15	0.2	0.24
M2	0.3	0.4	0.48
M2.5	0.6	0.9	0.96
M3	1.1	1.6	1.8
M4	2.7	3.8	4.3
M5	5.5	7.8	8.8
M6	9.3	13	15
M8	23	32	37
M10	46	65	74
M12	80	110	130
M16	210	290	330

The minimum breaking torque values of martensitic and ferritic steel fasteners must be agreed upon between the customer and the manufacturer.

Table 5

Testing programme

Classed product	Tensile strength[1)]	Breaking torque	Conventional yield strength at 0.2%, $R_{p\ 0.2}$[1)]	Elongation after rupture[1)]	Hardness	Load test with wedges
A1	l≥2.5 d^c	l<2.5 *d*	l≥2.5 d^c	l≥2.5 d^c	--	--
A2	l≥2.5 d^c	l<2.5 *d*	l≥2.5 d^c	l≥2.5 d^c	--	--
A3		l<2.5 *d*	l≥2.5 d^c	l≥2.5 d^c	--	--

	$l \geq 2.5\ d^c$					
A4	$l \geq 2.5\ d^c$	$l < 2.5\ d$	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	--	--
A5	$l \geq 2.5\ d^c$	$l < 2.5\ d$	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	--	--
C1	$l \geq 2.5\ d^{cd}$	--	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	Required	$l_s \geq 2d$
C3	$l \geq 2.5\ d^{cd}$	--	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	Required	$l_s \geq 2d$
C4	$l \geq 2.5\ d^{cd}$	--	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	Required	$l_s \geq 2d$
F1	$l \geq 2.5\ d^{cd}$	--	$l \geq 2.5\ d^c$	$l \geq 2.5\ d^c$	Required	$l_s \geq 2d$

l is the length of the bolt.

d is the nominal diameter of the thread.

l_s is the length of the non-threaded part.

a) For measures ≥M5.

b) For measures M1.6<=d<5, the test applies for all lengths.

c) For studs the requirement is $l \geq 3.5d$.

d) For $l < 2.5d$, the acceptance shall be agreed upon between the manufacturer and the customer.

ANNEX E (Informative)

AUSTENITIC STAINLESS STEELS WITH PARTICULAR RESISTANCE TO CHLORIDE-INDUCED CORROSION

(extracted from the EN 10088-1:2005 standard)

The risk of defects occurring in bolts, screws and studs due to chloride-induced corrosion (for instance in covered swimming pools) can be reduced by using the materials indicated in table E.1.

Table E.1

Austenitic stainless steel (Material symbol and numbering)	**Chemical composition % (m/m)**									
	C max.	**Si max.**	**Mn max.**	**P max.**	**S max.**	**N**	**Cr**	**Mo**	**Ni**	**Cu**
X2CrNiMoN17-13-5 (1.4439)	0.03	1.0	2.0	0.045	0.015	0.12 to 0.22	16.5 to 18.5	4.0 to 5.0	12.5 to 14.5	
X1NiCrMoCu25-20-5 (1.4539)	0.02	0.7	2.0	0.030	0.010	≤0.15	19.0 to 21.0	4.0 to 5.0	24.0 to 26.0	1.2 to 2.0
X1NiCrMoCuN25-20-7 (1.4529)	0.02	0.5	1.0	0.030	0.010	0.15 to 0.25	19.0 to 21.0	6.0 to 7.0	24.0 to 26.0	0.5 to 1.5
X2CrNiMoN22-5-3[a] (1.4462)	0.03	1.0	2.0	0.035	0.015	0.10 to 0.22	21.0 to 23.0	2.5 to 3.5	4.5 to 6.5	

[a)] For austenitic-ferritic steels.

ANNEX F (Informative)

MECHANICAL PROPERTIES AT HIGH TEMPERATURES; APPLICATION AT LOW TEMPERATURES

NOTE – If the bolts, screws and studs are calculated correctly, the corresponding nuts will automatically meet the requirements. However, in applications at high and low temperatures, it is enough to consider the mechanical properties of the bolts, screws and studs.

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F.1 Yield stress limit or conventional yield strength at 0.2% at elevated temperatures

The values given in this annex are for information purposes only. Users must understand that due to the current chemistry, the loads to which the fasteners are subjected and the medium may vary significantly. Customers must consult the manufacturer of the loads fluctuate and if there are long periods of operating at high temperatures or if the possibility of increased corrosion is significant.

Table F.1 includes the variation percentages of the yield stress limit (R_{eL}) and the conventional yield strength ($R_{p0.2}$) at high temperatures, compared to these yield strength limits at ambient temperature.

Table F.1 – Influence of temperature on R_{eL} and $R_{p0.2}$

Steel classed product	**R_{eL} and $R_{p0.2}$ % Temperature**			
	+100ºC	+200ºC	+300ºC	+400ºC
A2, A3, A4, A5	85	80	75	70
C1	95	90	80	65
C3	90	85	80	60

NOTE – Only for quality classes 70 and 80.

F.2 Application at low temperatures

For the application at low temperatures of stainless steel bolts, screws and studs, see table F.2.

Table F.2

Application of stainless steel bolts, screws and studs at low temperatures
(Only austenitic steels)

Steel classed product	**Lower operating temperature limits in continuous use**	
A2, A3	-200 ºC	
A4, A5	Bolts and screws[a]	-60 ºC
	Studs	-200 ºC

[a] In relation to the alloying element Mo, the stability of the austenite is reduced and the transition temperature is brought to higher values during manufacturing, the fastener is subjected to a strong deformation.

ANNEX H (Informative)

MAGNETIC PROPERTIES OF AUSTENITIC STAINLESS STEELS

All the austenitic stainless steel fasteners are normally not magnetic; after a cold deformation some magnetic properties may be revealed.

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Every material is characterised by its ability to magnetize (magnetization), and this law also applies to stainless steels. They are only likely to be completely non-magnetic in a vacuum. The measure of permeability of a material placed in a magnetic field is the permeability value μ_r of this material in relation to a vacuum. The material has a weaker permeability the closer μ_r gets to 1.

EXAMPLES:

- A2: $\mu_r \approx 1.8$
- A4: $\mu_r \approx 1.015$
- **A4L:** $\mu_r \approx 1.005$
- **F1:** $\mu_r \approx 5$