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Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 6: General rules for the selection of stainless steels and nickel alloys for fasteners

Fixations — Caractéristiques mécaniques des fixations en acier inoxydable résistant à la corrosion —

Partie 6: Règles générales pour la sélection des aciers inoxydables et des alliages de nickel pour les fixations

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 2, *Fasteners*.

A list of all parts in the ISO 3506 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

When revising ISO 3506-1 and ISO 3506-2, annexes common to several parts have been withdrawn and included in this document in order to avoid uncessery repetition and to ease further revision of parts as necessary (these annexes have also been technically revised). This document replaces:

— ISO 3506-1:2009, Annexes B, C, D, E, G and H, and

— ISO 3506-2:2009, Annexes A, B, C, D, F and G.

The ISO 3506 series consists of the following parts, under the general title *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners*:

— *Part 1: Bolts, screws and studs with specified grades and property classes*

— *Part 2: Nuts with specified grades and property classes*

— *Part 3*[1)]*: Set screws and similar fasteners not under tensile stress*

— *Part 4*[1)]*: Tapping screws*

— *Part 5*[2)]*: Special fasteners (also including fasteners from nickel alloys) for high temperature applications*

— *Part 6: General rules for the selection of stainless steels and nickel alloys for fasteners*

1) It is intended to revise ISO 3506-3 and ISO 3506-4 in the future in order to include the reference to ISO 3506-6.

2) Under preparation.

Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 6:
General rules for the selection of stainless steels and nickel alloys for fasteners

1 Scope

This document specifies general rules and provides technical information on stainless steels and their properties, which are relevant when using other parts of the ISO 3506 series. It includes specifications for corrosion-resistant stainless steels and nickel alloys, which are suitable for the manufacture of fasteners.

It applies to austenitic, martensitic, ferritic and duplex (austenitic-ferritic) stainless steel grades and nickel alloys for fasteners, and is intended to be used together with the relevant parts of the ISO 3506 series.

Common designations of stainless steels and nickel alloys used for fasteners are given in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3506-1, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes*

ISO 3506-2, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 2: Nuts with specified grades and property classes*

ISO 3506-5[3)], *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 5: Special fasteners (also including fasteners from nickel alloys) for high temperature applications*

3 Terms and definitions

For the purpose of this document, terms and definitions specified in ISO 3506-1, ISO 3506-2 and ISO 3506-5 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3) Under preparation.

4 Groups and grades of stainless steels

4.1 General

The ISO 3506 series deals with stainless steel grades of the following groups:

— austenitic steel A1 to A5 and A8,

— martensitic steel C1, C3 and C4,

— ferritic steel F1,

— duplex (austenitic-ferritic) steel D2, D4, D6 and D8.

Stainless steels cover a great variety of materials providing different corrosion resistant properties and different functional properties. A specific fastener manufactured from stainless steel shall be carefully chosen by taking into account all the conditions in the expected environment of the bolted joint.

The condition of the surface of the fasteners (passivated, surface roughness, etc.) can influence the capacity of the fastener to resist corrosion.

In special cases, it is advised to consult an experienced fastener manufacturer and/or stainless steel metallurgist in order to make the appropriate choice for a given application.

Corrosion depends on several factors related to the fasteners themselves, the design of the bolted joint, service environment, surface and material conditions, mechanical stresses, temperature and corrosion caused by contact between dissimilar metals (known as galvanic corrosion or contact corrosion), etc.

NOTE When combining different stainless steel grades, the corrosion resistance of the assembly depends on the lowest corrosion resistance grade.

When stainless steel fasteners are intended to be used in a high or low temperature environment:

— austenitic stainless steels are suitable for service environment typically down to –196 °C[4] and up to +300 °C;

— martensitic stainless steels are suitable for service environment typically down to –40 °C and up to +230 °C;

— ferritic stainless steels are suitable for service environment typically down to –20 °C and up to +250 °C;

— duplex stainless steels are suitable for service environment typically down to –40 °C and up to +280 °C.

4.2 Stainless steel group A (austenitic structure)

4.2.1 General

Several grades of austenitic stainless steels (A1 to A5 and A8) are included in the ISO 3506 series. They are generally classified as chromium-nickel austenitic grades (A1 to A3) and chromium-nickel-molybdenum austenitic grades (A4 to A8).

Austenitic stainless steels cannot be hardened by quenching; the mechanical properties of the fasteners are usually achieved by work hardening. Copper may be added in order to enhance the plasticity of the austenitic matrix (see chemical compositions specified in ISO 3506-1 and ISO 3506-2).

Stainless steel grades A2 and A4 with carbon content lower than 0,030 % may be identified by adding the letter L to the grade, i.e. A2L and A4L, respectively. Stainless steel grades A2 and A4 with carbon

4) –196 °C is a limit for testability corresponding to liquid nitrogen at a normal atmosphere pressure.

content above 0,030 % and/or exposed to high temperatures (either during the manufacturing process, welding process or in the service environment) can have a higher susceptibility to intergranular corrosion; see Clause 8. In these cases, the purchaser may choose stainless steel grades A2L or A4L, or stabilized stainless steels A3 or A5 including titanium or niobium. A8 is a highly alloyed austenitic stainless steel with corrosion resistance much higher than A1 to A5.

Austenitic steels in the annealed state are usually non-magnetic; however, cold working occurring during the fastener manufacture can create some residual magnetism; see Clause 10. Where low magnetic permeability is an important consideration, the advice of a stainless steel expert should be sought.

4.2.2 Grade A1

Stainless steels of grade A1 are specially designed for machining. Due to high sulfur content, this grade has lower resistance to corrosion than corresponding stainless steels with normal sulfur content. This grade is neither suitable for use in non-oxidizing acids and agents, nor in an environment with chloride (e.g. in swimming pools using chloride as a cleaning agent, or marine environments).

4.2.3 Grade A2

Stainless steels of grade A2 are the most frequently used stainless steel. This grade is not suitable for use in non-oxidizing acids and agents, or in an environment with chloride (e.g. in swimming pools using chloride as a cleaning agent, or marine environments).

4.2.4 Grade A3

Stainless steels of grade A3 have properties similar to grade A2, but with increased resistance to temperature (typically up to 350 °C). They are stabilized by addition of titanium or niobium that combines with carbon and nitrogen. This grade is neither suitable for use in non-oxidizing acids and agents, nor in an environment with chloride (e.g. in swimming pools using chloride as a cleaning agent, or marine environments).

4.2.5 Grade A4

Stainless steels of grade A4, often known as “acid proof steels”, are molybdenum alloyed which gives a considerably better resistance to corrosion. This grade may be used in some environments where chloride is present; however, it is still not suitable in swimming pools using chloride as a cleaning agent, or many marine environments.

4.2.6 Grade A5

Stainless steels of grade A5 are stabilized stainless steels with properties of grade A4, but with increased resistance to temperature (typically up to 350 °C). Stainless steels of grade A5 have properties similar to grade A4 and are resistant to many acids. They are stabilized by addition of titanium or niobium that combines with carbon and nitrogen. This grade may be used in some environments where chloride is present; however, it is still not suitable in swimming pools using chloride as a cleaning agent, or many marine environments.

4.2.7 Grade A8

Stainless steels of grade A8 are known as “6 % Mo” stainless steels. They have a high level of resistance to all forms of corrosion including pitting, crevice and stress corrosion cracking. They are suitable for use in swimming pools using chloride as a cleaning agent. However, there can be specific requirements and/or regulations for buildings and construction. Grade A8 is also suitable for applications in marine environments.

4.3 Stainless steel group C (martensitic structure)

4.3.1 General

Three grades of martensitic stainless steels (C1, C3 and C4) are included in the ISO 3506 series. They can be hardened by quenching and tempering. Mechanical properties increase when the carbon content rises, inducing the necessary rise of chromium content in order to achieve a suitable corrosion resistance.

Martensitic grades C1, C3 and C4 normally have a lower corrosion resistance than austenitic grades. However, other martensitic steels with improved corrosion resistance (see Table A.2) can also be used for special fasteners.

Caution should be taken when using martensitic stainless steels at sub-zero temperatures due to their poor impact strength and ductility.

Martensitic steel grades are always highly magnetic.

4.3.2 Grade C1

Stainless steels of grade C1 have limited resistance to corrosion.

4.3.3 Grade C3

Stainless steels of grade C3 have limited resistance to corrosion, though better resistance than C1.

4.3.4 Grade C4

Stainless steels of grade C4 are similar to grade C1 but with a lower resistance to corrosion due to their sulfur content. They are primarily intended for machining.

4.4 Stainless steel group F (ferritic structure) — Grade F1

One single ferritic stainless steel grade F1 is included in the ISO 3506 series. The steels within F1 can be hardened by work hardening (cold working); however, the cold working effect has a lower efficiency than for austenitic stainless steels. F1 steels are always magnetic.

When lower corrosion resistance than provided by grades A2 or A3 is suitable for the planned application, stainless steel grade F1 can be a good economical compromise. However, grade F1 should not be used at temperatures lower than –20 °C because ferritic stainless steels have poor impact strength and ductility.

4.5 Stainless steel group D (austenitic-ferritic structure)

4.5.1 General

Duplex stainless steel is a mixture of ferrite and austenite grains with a ferrite content typically 40 % to 60 % by volume.

In the solution annealed condition, the strength of duplex stainless steels is significantly higher than the strength of austenitic stainless steels and can be further increased by cold working, but ductility could then be lower.

Four grades of duplex stainless steels (D2, D4, D6 and D8) are included in the ISO 3506 series: the higher the digit in the grade, the better the corrosion resistance. Families of duplex stainless steel are usually described as follows:

— “lean-duplex” (D2 and D4) with lower alloying content (specifically nickel and molybdenum);

— “standard-duplex” (D6);

— “super-duplex” (D8) with higher alloying content.

Duplex stainless steels have much improved resistance to stress corrosion cracking when compared to austenitic stainless steels A1 to A5.

It is not recommended to use duplex stainless steels for application outside the temperature range of −40 °C to +280 °C.

4.5.2 Grades D2 and D4

D2 and D4 are “lean-duplex” characterized by their molybdenum content below 2 %, and even below 1 %.

With respect to pitting and crevice corrosion, D2 has at least an equivalent corrosion resistance compared to A2, and D4 has at least an equivalent corrosion resistance compared to A4.

4.5.3 Grades D6 and D8

D6 is a “standard-duplex” with molybdenum content above 2,5 %, which has improved corrosion resistance when compared to A1 to A5 and D4, particularly with respect to pitting and crevice corrosion.

D8 is a “super-duplex” and has a corrosion resistance comparable to A8.

4.6 Stainless steels and nickel alloys for elevated and high temperatures

Elevated temperatures refer to the temperature range of 300 °C to 550°C, and high temperatures refer to temperatures above 550 °C:

— for high temperature applications, fasteners require a sufficient resistance to oxidation and high temperature corrosion, as well as long-term creep resistance at the service temperature;

— for elevated temperature applications, time-dependent properties are generally not considered to be critical.

Stainless steels and nickel alloys for elevated and high temperature applications are dealt with in ISO 3506-5.

5 Chemical composition specifications for stainless steels and nickel alloys

Chemical composition for stainless steel fasteners is specified in ISO 3506-1 for bolts, screws and studs, ISO 3506-2 for nuts, ISO 3506-3 for set screws, ISO 3506-4 for tapping screws and ISO 3506-5 for special fasteners for high temperature applications. Tables 1 to 3 give the most widely used standardized materials, included in ISO 15510, EN 10269 and/or DIN 267-13.

Table 1 — Chemical composition of austenitic stainless steels (ISO 3506-1 to ISO 3506-4)

ISO number	Chemical composition [a] Cast analysis, mass fraction in % (maximum values unless stated otherwise)												Corresponding fastener grade/ symbol [b]
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	N	Nb	Ti	
Austenitic stainless steels													
4305-303-00-I	0,12	1,00	2,00	0,060	≥0,15	17,0 to 19,0	—	8,0 to 10,0	1,00	0,10	—	—	A1
4301-304-00-I	0,07	1,00	2,00	0,045	0,030	17,5 to 19,5	—	8,0 to 10,5	—	0,10	—	—	A2
4307-304-03-I	0,030	1,00	2,00	0,045	0,030	17,5 to 19,5	—	8,0 to 10,5	—	0,10	—	—	A2/A2L
4311-304-53-I	0,030	1,00	2,00	0,045	0,030	17,5 to 19,5	—	8,0 to 11,0	—	0,12 to 0,22	—	—	A2/A2L
4567-304-98-X	0,08	1,70	2,00	0,045	0,030	17,0 to 19,0	—	8,0 to 10,5	1,00 to 3,00	—	—	—	A2
4567-304-30-I	0,040	1,00	2,00	0,045	0,030	17,0 to 19,0	—	8,0 to 10,5	3,00 to 4,0	0,10	—	—	A2
4541-321-00-I	0,08	1,00	2,00	0,045	0,030	17,0 to 19,0	—	9,0 to 12,0	—	—	—	5 × C to 0,70	A3
4550-347-00-I	0,08	1,00	2,00	0,045	0,030	17,0 to 19,0	—	9,0 to 12,0	—	—	10 × C to 1,00	—	A3
4401-316-00-I	0,08	1,00	2,00	0,045	0,030	16,0 to 18,0	2,00 to 3,00	10,0 to 13,0	—	0,10	—	—	A4
4404-316-03-I	0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,00 to 3,00	10,0 to 13,0	—	0,10	—	—	A4/A4L
4406-316-53-I	0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,00 to 3,00	10,0 to 12,5	—	0,12 to 0,22	—	—	A4/A4L
4578-316-76-E	0,040	1,00	2,00	0,045	0,015	16,5 to 17,5	2,00 to 2,50	10,0 to 11,0	3,00 to 3,5	0,10	—	—	A4
4571-316-35-I	0,08	1,00	2,00	0,045	0,030	16,5 to 18,5	2,00 to 2,50	10,5 to 13,5	—	—	—	5 × C to 0,70	A5
4529-089-26-I	0,020	0,75	2,00	0,035	0,015	19,0 to 21,0	6,0 to 7,0	24,0 to 26,0	0,50 to 1,50	0,15 to 0,25	—	—	A8
4547-312-54-I	0,020	0,70	1,00	0,035	0,015	19,5 to 20,5	6,0 to 7,0	17,5 to 18,5	0,50 to 1,00	0,18 to 0,25	—	—	A8
4478-083-67-U	0,030	1,00	2,00	0,040	0,030	20,0 to 22,0	6,0 to 7,0	23,5 to 25,5	0,75	0,18 to 0,25	—	—	A8

[a] Elements not quoted shall not be intentionally added to the stainless steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition, from scrap or other material used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[b] The stainless steel grades are those which are nearest to the composition ranges specified in ISO 3506-1 and ISO 3506-2; however, inclusion in this table does not necessarily imply full conformance.

Table 2 — Chemical composition of martensitic, ferritic and duplex stainless steels (ISO 3506-1 to ISO 3506-4)

ISO number	Chemical composition [a] Cast analysis, mass fraction in % (maximum values unless stated otherwise)												Corresponding fastener grade/ symbol [b]
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	N	Nb	Ti	
Martensitic stainless steels													
4006-410-00-I	0,08 to 0,15	1,00	1,50	0,040	0,030	11,5 to 13,5	—	0,75	—	—	—	—	C1
4021-420-00-I	0,16 to 0,25	1,00	1,50	0,040	0,030	12,0 to 14,0	—	—	—	—	—	—	C1
4028-420-00-I	0,26 to 0,35	1,00	1,50	0,040	0,030	12,0 to 14,0	—	—	—	—	—	—	C1
4057-431-00-X	0,12 to 0,22	1,00	1,50	0,040	0,030	15,0 to 17,0	—	1,50 to 2,50	—	—	—	—	C3
4005-416-00-I	0,08 to 0,15	1,00	1,50	0,040	≥ 0,15	12,0 to 14,0	0,60	—	—	—	—	—	C4
Ferritic stainless steels													
4016-430-00-I	0,08	1,00	1,00	0,040	0,030	16,0 to 18,0	—	—	—	—	—	—	F1
Duplex stainless steels													
4482-320-01-X	0,030	1,00	4,0 to 6,0	0,035	0,030	19,5 to 21,5	0,10 to 0,60	1,50 to 3,5	1,00	0,05 to 0,20	—	—	D2 [c]
4362-323-04-I	0,030	1,00	2,00	0,035	0,015	22,0 to 24,5	0,10 to 0,60	3,5 to 5,5	0,10 to 0,60	0,05 to 0,20	—	—	D2 [c]
4062-322-02-U	0,030	1,00	2,00	0,040	0,010	21,5 to 24,0	0,45	1,00 to 2,90	—	0,16 to 0,28	—	—	D4
4162-321-01-E	0,040	1,00	4,0 to 6,0	0,040	0,015	21,0 to 22,0	0,10 to 0,80	1,35 to 1,90	0,10 to 0,80	0,20 to 0,25	—	—	D4
4662-824-41-X	0,030	0,70	2,50 to 4,0	0,035	0,005	23,0 to 25,0	1,00 to 2,00	3,00 to 4,5	0,10 to 0,80	0,20 to 0,30	—	—	D4
4462-318-03-I	0,030	1,00	2,00	0,035	0,015	21,0 to 23,0	2,50 to 3,5	4,5 to 6,5	—	0,10 to 0,22	—	—	D6
4481-312-60-J	0,030	1,00	1,50	0,040	0,030	24,0 to 26,0	2,50 to 3,5	5,5 to 7,5	—	0,08 to 0,30	—	—	D6
4410-327-50-I	0,030	1,00	2,00	0,035	0,015	24,0 to 26,0	3,00 to 4,5	6,0 to 8,0	—	0,24 to 0,35	—	—	D8
4501-327-60-I [d]	0,030	1,00	1,00	0,030	0,010	24,0 to 26,0	3,00 to 4,0	6,0 to 8,0	0,50 to 1,00	0,20 to 0,30	—	—	D8
4507-325-20-I	0,030	0,70	2,00	0,035	0,015	24,0 to 26,0	3,00 to 4,0	6,0 to 8,0	1,00 to 2,50	0,20 to 0,30	—	—	D8

[a] Elements not quoted shall not be intentionally added to the stainless steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition, from scrap or other material used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[b] The stainless steel grades are those which are nearest to the composition ranges specified in ISO 3506-1 and ISO 3506-2; however, inclusion in this table does not necessarily imply full conformance.

[c] Can be identified as D4 when wCr + 3,3wMo + 16wN > 24,0 in accordance with the ISO 3506 series, where w is the mass fraction expressed in %.

[d] Tungsten (W) content shall be 0,50 % to 1,00 %.

Table 3 — Chemical composition of stainless steels and nickel alloys for high temperature applications (ISO 3506-5)

ISO number	Chemical composition [a] Cast analysis, mass fraction in % (maximum values unless stated otherwise)												Corresponding fastener grade/ symbol [b]
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	N	Nb	Ti	
Martensitic stainless steels													
4021-420-00-I	0,16 to 0,25	1,00	1,50	0,040	0,030	12,0 to 14,0	—	—	—	—	—	—	CH0
4028-420-00-I	0,26 to 0,35	1,00	1,50	0,040	0,030	12,0 to 14,0	—	—	—	—	—	—	CH1
4057-431-00-X	0,12 to 0,22	1,00	1,50	0,040	0,030	15,0 to 17,0	—	1,50 to 2,50	—	—	—	—	CH2
4923-422-77-E [c]	0,18 to 0,24	0,50	0,40 to 0,90	0,025	0,015	11,0 to 12,5	0,80 to 1,20	0,30 to 0,80	—	—	—	—	V or VH
1.4913 [d]	0,17 to 0,23	0,50	0,40 to 0,90	0,025	0,015	10,0 to 11,5	0,50 to 0,80	0,20 to 0,60	—	0,05 to 0,10	0,25 to 0,55	—	VW
Austenitic precipitation hardening stainless steels and nickel alloys													
4980-662-86-X [e]	0,080	1,00	2,00	0,040	0,030	13,5 to 16,0	1,00 to 1,50	24,0 to 27,0	—	—	—	1,90 to 2,35	SD
2.4952 [f]	0,040 to 0,10	1,00	1,00	0,020	0,015	18,0 to 21,0	—	≥ 65	0,20	—	—	1,80 to 2,70	SB
2.4668 [g]	0,080	0,35	0,35	0,015	0,015	17,0 to 21,0	2,80 to 3,3	50 to 55	0,30	—	—	0,60 to 1,20	718

[a] Elements not quoted shall not be intentionally added to the stainless steel without the agreement of the purchaser, other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition, from scrap or other material used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[b] The stainless steel grades are those which are nearest to the composition ranges specified in ISO 3506-5; however, inclusion in this table does not necessarily imply full conformance.

[c] In addition, vanadium content shall be 0,25 % to 0,35 %.

[d] Chemical composition in accordance with EN 10269: in addition, aluminium content shall be ≤ 0,020 % and vanadium 0,10 % to 0,30 %, and boron ≤0,0015 %.

[e] In addition, aluminium content shall be ≤0,35 %, vanadium 0,10 % to 0,50 % and boron 0,0010 % to 0,010 %.

[f] Chemical composition in accordance with EN 10269: in addition, aluminium content shall be 1,00 % to 1,80 %, cobalt ≤1,00 %, iron ≤1,50 % and boron ≤0,0080 %.

[g] Chemical composition in accordance with EN 10269: in addition, aluminium content shall be 0,20 % to 0,80 %, cobalt ≤1,00 %, boron ≤0,0060 %, and niobium 4,7 % to 5,5 % (iron: balance).

Examples for other stainless steel chemical compositions, suitable for fasteners but not inclusively covered in the ISO 3506 series, are given in Annex A. For such materials, marking specified in the ISO 3506 series shall not be used.

6 Resistance to stress corrosion cracking

Austenitic grades A1 to A5 are susceptible to stress corrosion cracking.

Chloride induced stress corrosion can be significantly reduced by using duplex grades especially D6 and D8 or highly alloyed austenitic grade A8.

Ferritic grade F1 and martensitic grades have generally good resistance against stress corrosion cracking.

The specific case of stress corrosion cracking of stainless steel structural components in swimming pools is addressed in EN 13451-1: the only grades which are recommended unreservedly for this application and available as fasteners fall into the A8 grade.

7 Resistance to pitting and crevice corrosion

Pitting and crevice corrosion are localized forms of corrosion, which can occur as a result of exposure to specific environments, most notably those containing chlorides. In most structural applications, the extent of pitting is likely to be superficial and the reduction in section of a component is negligible. However, corrosion products can stain architectural features.

A less tolerant view of pitting should be adopted for services such as ducts, piping and containment structures. If there is a known pitting hazard, then a molybdenum containing stainless steel is required.

Pitting resistance equivalent numbers (PREN) are a theoretical way of comparing the pitting and crevice corrosion resistance of various types of stainless steels, based on their chemical compositions.

WARNING — The PREN (or PRE) numbers are useful for general ranking and comparing the different grades, but cannot be used to predict whether a particular grade will be suitable for a given application, where pitting corrosion may be a hazard.

Calculations usually take into account chromium, molybdenum and nitrogen. The most commonly used PREN Formula (1) is:

$$\text{PREN} = w\text{Cr} + 3{,}3w\text{Mo} + 16w\text{N} \tag{1}$$

where w is the mass fraction expressed in % (for example, if the stainless steel contains 18 'weight' percent of chromium, then wCr = 18).

When tungsten is also included in the molybdenum-rating factor to acknowledge its effect on pitting resistance in the tungsten containing super-duplex types, for example 1.4501, the following Formula (2) is then used:

$$\text{PREN} = w\text{Cr} + 3{,}3(w\text{Mo} + 0{,}5w\text{W}) + 16w\text{N} \tag{2}$$

where w is the mass fraction expressed in %.

NOTE Pitting resistance is strongly decreased with higher sulfur and phosphorus content.

8 Resistance to intergranular corrosion

Fasteners manufactured by hot forging (or if welding occurs) can be sensitive to intergranular corrosion. It can occur when the three following conditions are combined: inappropriate temperature condition during manufacturing, carbon content above 0,030 % and a wet or corrosive environment in service application.

When the risk of intergranular corrosion is present, the following stainless steel grades are recommended:

— A3 or A5, stabilized;

— A2 or A4 with carbon content not exceeding 0,030 %;

— A8;

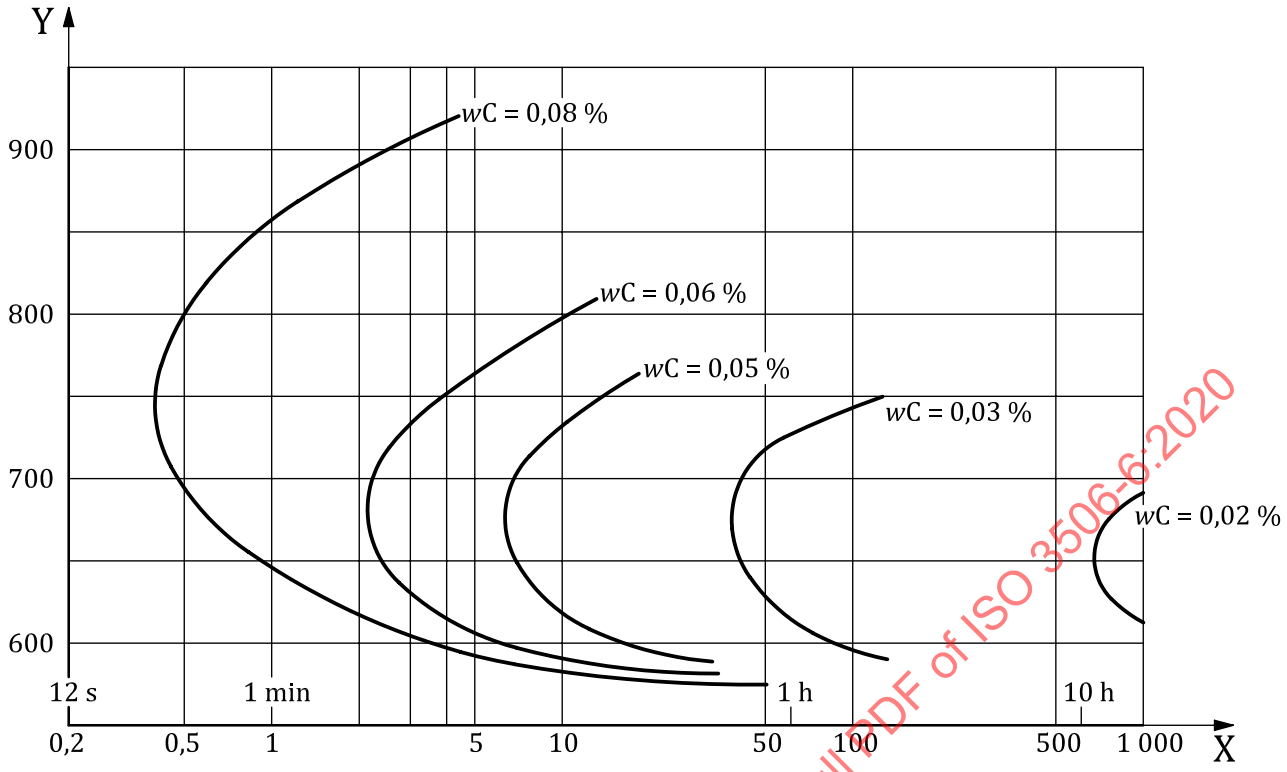
— all duplex (austenitic-ferritic) grades.

In such cases, testing in accordance with ISO 3651-1 or ISO 3651-2 can be performed.

Figure 1 gives the approximate exposure time for austenitic stainless steels of grade A2, with different carbon contents in the temperature range of 550 °C to 925 °C before risk of intergranular corrosion occurs.

With lower carbon contents, the resistance against intergranular corrosion is improved.

The risk of intergranular corrosion exists in the areas located at the right of the curves.



Key

X time, expressed in minutes

Y temperature, expressed in degrees Celsius

Figure 1 — Time-temperature diagram of intergranular corrosion in austenitic stainless steel grade A2

For example and according to Figure 1, a fastener of grade A2 with carbon content of 0,08 % and exposed at a temperature of 800 °C for 30 s can result in embrittlement (this can especially appear when welding operation occurs).

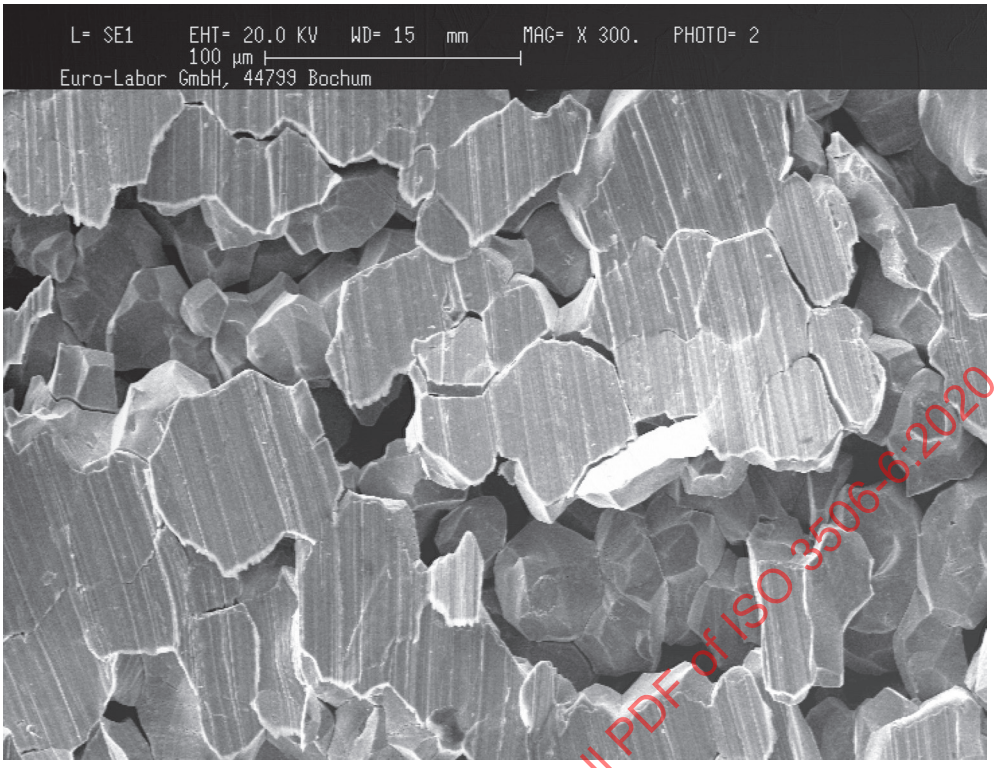


Figure 2 — Intergranular corrosion on a stainless steel 4301-304-00-I with 0,036 % C

Figure 2 shows intergranular corrosion of a stainless steel 4301-304-00-I with a carbon content of 0,036 %, tested according to ISO 3651-2 method A after annealing at 650 °C for 2 h.

9 Susceptibility to formation of intermetallic compounds

Duplex stainless steels are susceptible to the formation of compounds, such as carbides, nitrides, sigma and other intermetallic phases during exposures in the temperature range of 300 °C to 950 °C (575 °F to 1 750 °F). The presence of these phases can impair corrosion resistance and mechanical properties.

Correct heat treatment can minimize or avoid these detrimental phases. Rapid cooling of the product provides the maximum resistance to formation of detrimental phases by subsequent thermal exposure. Compliance with the chemical and mechanical requirements for the product does not necessarily indicate absence of detrimental phases.

Fasteners produced from these grades by hot forging may therefore be tested by one of the following methods to determine that these phases are not present in amounts which will cause impairment to their use:

— ISO 898-1 for impact Charpy V-notch test;

— ASTM A923 for test methods for detecting detrimental intermetallic phase in duplex austenitic/ferritic stainless steels;

— ASTM A1084 for test methods for detecting detrimental phases in lean duplex austenitic/ferritic stainless steels;

— ASTM G48 for test methods for pitting and crevice corrosion resistance of stainless steels and related alloys by use of ferric chloride solution.

10 Magnetic permeability properties of stainless steels

The magnetic permeability of materials relates to their ability to be attracted by a permanent magnet or influenced by a magnetic field.

Ferritic, martensitic, duplex and non-austenitic precipitation hardening stainless steels are usually classified as “magnetic” since they exhibit a strong response (or pull) to a magnetic field e.g. a hand-held magnet.

By comparison, austenitic stainless steels are classified as non-magnetic; however, cold working during fastener manufacture can induce some residual magnetism. This residual magnetism can then be lowered e.g. by a specific heat treatment process.

For some applications, it is necessary to use a stainless steel which has very low permeability. A limit is usually specified; the lowest relative magnetic permeability of a paramagnetic material would tend to 1,0 (i.e. the magnetic response of the material is the same as “free space” or a complete vacuum).

The best austenitic stainless steel types for low permeability applications are those with high austenite stability as these have low permeability in both the annealed or cold worked conditions. For example, the nitrogen containing steels such as 1.4311 (A2L) and 1.4406 (A4L) or the high nickel types such as 1.4845 (see Annex A) are considered suitable.

Where specific non-magnetic properties are necessary, the advice of a stainless steel materials expert should be sought before determining the specification and agreement between the purchaser and supplier established at the time of the order.

Annex A
(informative)

Common designations of stainless steels and nickel alloys used for fasteners

The ISO 3506 series specifies the composition ranges for the different stainless steel and nickel alloy grades used for fasteners in accordance with this document. These are broad and therefore all the variety of stainless steel and nickel alloy designations used for fastener applications are not fully covered in Table A.1 and Table A.2. The specific chemical compositions of most common grades are given in Tables 1 and 2.

Table A.1 for austenitic stainless steels and nickel alloys and Table A.2 for all other stainless steels of this annex give complementary information on the common steel designations in various international and national systems.

They also include stainless steels available as cold heading grades for special applications or proposed for high corrosion-resistant fasteners.

The grades already included in Tables 1 to 3 of this document are shown in **bold characters** in Table A.1 and Table A.2.

Table A.1 — Common designations [a] of main stainless steels used for fasteners and for cold heading applications — Austenitic grades

Type of grade	Symbol [b]	ISO 15510 Steel number [c]	European designation Steel number [c]	European designation Steel designation	Designation in ASTM standards UNS	USA common designation	ISO 3506 series	Grade included in reference standard
Resulfurized austenitic	A1	**4305-303-00-I**	1.4305	X8CrNiS18-9	S30300	303	Clause 4, Table 1	EN 10088-3, ISO 15510
	A1	4570-303-31-I	1.4570	X6CrNiCuS18-9-2	—	"303Cu"	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510
General purpose austenitic	A2L	**4307-304-03-I**	1.4307	X2CrNi18-9	S30403	304L	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A2L	4306-304-03-I	1.4306	X2CrNi19-11	S30403	304L	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510, EN 10263-5
	A2L	4311-304-53-I	1.4311	X2CrNiN18-9	S30453	304LN	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510
	A2	**4301-304-00-I**	1.4301	X5CrNi18-10	S30400	304	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A2	**4567-304-30-I**	1.4567 [d]	X3CrNiCu18-9-4	S30430	304Cu	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A2	—	1.4560	X3CrNiCu19-9-2	—	304Cu	ISO 3506-1, ISO 3506-2	EN 10088-3, EN 10263-5
	A2	4303-305-00-I	1.4303	X4CrNi18-12	S30500	305	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A3	**4550-347-00-I**	1.4550	X6CrNiNb18-10	S34700	347	Clause 4, Table 1	EN 10088-3, ISO 15510
	A3	**4541-321-00-I**	1.4541	X6CrNiTi18-10	S32100	321	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5
	[e]	**4615-201-75-E**	1.4615	X3CrMnNiCu15-8-5-3	—	201Cu	Clause 4, Table 2	EN 10088-3, ISO 15510
	[e]	4310-301-00-I	1.4310	X10CrNi18-8	S30100	301	—	EN 10088-3, ISO 15510, EN 10263-5

[a] There is not an exact correspondence between the compositions of various standards but strong overlap.

[b] Symbol in accordance with the ISO 3506 series.

[c] The grades already included in Table 1, 2 or 3 of this document are shown in **bold characters**.

[d] A minimum nickel content of 8 % is common and allowed according to EN 10263-5.

[e] Special grade: symbol not specified in ISO 3506-1 and ISO 3506-2 or in DIN 267-13.

[f] Symbol according to DIN 267-13.

[g] Symbol specified in ISO 3605-5.

Table A.1 *(continued)*

Type of grade	Symbol [b]	ISO 15510 Steel number [c]	European designation		Designation in ASTM standards	USA common designation	ISO 3506 series	Grade included in reference standard
			Steel number [c]	Steel designation	UNS			
Molybdenum containing austenitic	A4	**4401-316-00-I**	1.4401	X5CrNiMo17-12-2	S31600	316	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A4L	**4404-316-03-I**	1.4404	X2CrNiMo17-12-2	S31603	316L	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5, EN 10269
	A4L	**4406-316-53-I**	1.4406	X2CrNiMoN17-11-2	S31653	316LN	Clause 4, Table 1	EN 10088-3, ISO 15510
	A4L	4432-316-03-I	1.4432	X2CrNiMo17-12-3	S31603	316L	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510, EN 10263-5
	A4L	4435-316-91-I	1.4435	X2CrNiMo18-14-3	S31603	316L	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510
	A4	4436-316-00-I	1.4436	X3CrNiMo17-13-3	S31600	316	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510, EN 10263-5
	A4	4578-316-76-E	1.4578	X3CrNiCuMo17-11-3-2	—	—	ISO 3506-1, ISO 3506-2	EN 10088-3, ISO 15510, EN 10263-5
	A5	**4571-316-35-I**	1.4571	X6CrNiMoTi17-12-2	S31635	316Ti	Clause 4, Table 1	EN 10088-3, ISO 15510, EN 10263-5

[a] There is not an exact correspondence between the compositions of various standards but strong overlap.

[b] Symbol in accordance with the ISO 3506 series.

[c] The grades already included in Table 1, 2 or 3 of this document are shown in **bold characters**.

[d] A minimum nickel content of 8 % is common and allowed according to EN 10263-5.

[e] Special grade: symbol not specified in ISO 3506-1 and ISO 3506-2 or in DIN 267-13.

[f] Symbol according to DIN 267-13.

[g] Symbol specified in ISO 3605-5.

Table A.1 *(continued)*

Type of grade	Symbol [b]	ISO 15510 Steel number [c]	European designation		Designation in ASTM standards UNS	USA common designation	ISO 3506 series	Grade included in reference standard
			Steel number [c]	Steel designation				
High molybdenum super-austenitic	A8	**4478-083-67-U**	1.4478	X2NiCrMoN25-21-7	N08367	—	Clause 4, Table 1	ISO 15510
	A8	**4529-089-26-I**	1.4529	X1NiCrMoCuN25-20-7	N08926	"926"	Clause 4, Table 1	EN 10088-1, ISO 15510
	A8	**4547-312-54-I**	1.4547	X1CrNiMoCuN20-18-7	S31254	F44	Clause 4, Table 1	EN 10088-1, ISO 15510
Highly alloyed austenitic for special purposes	SD [f,g]	4980-662-86-X	1.4980	X6NiCrTiMoVB25-15-2	S66286	A286 Alloy 660	ISO 3506-5	EN 10088-3, ISO 15510, EN 10269, DIN 267-13
	S [f]	—	1.4986	X7CrNiMoBNb16-16	—	—	—	EN 10088-1, EN 10269, DIN 267-13
	e	4539-089-04-I	1.4539	X1NiCrMoCu25-20-5	N08904	904L	—	EN 10088-3, ISO 15510
	e	4841-314-00-E	1.4841	X15CrNiSi25-21	S31400	314	—	EN 10088-1, ISO 15510
	e	4828-305-09-I	1.4828	X15CrNiSi20-12	—	—	—	EN 10088-1, ISO 15510
	e	4845-310-08-E	1.4845	X8CrNi25-21	S31008	310S	—	EN 10088-1, ISO 15510
High manganese super-austenitic	e	4020-241-00-X	1.4020	X13CrMnNiN18-13-2	S24100	XM28	—	EN 10088-3, ISO 15510
	e	4378-240-00-X	1.4378	X6CrMnNiN18-13-3	S24000	XM29	—	EN 10088-3, ISO 15510
Nickel alloy	SB [f,g]	—	**2.4952**	NiCr20TiAl	N07080	Alloy 80A	ISO 3506-5	EN 10269, DIN 267-13
	718 [g]	—	**2.4668**	NiCr19NbMo	N07718	Alloy 718	ISO 3506-5	EN 10269

[a] There is not an exact correspondence between the compositions of various standards but strong overlap.

[b] Symbol in accordance with the ISO 3506 series.

[c] The grades already included in Table 1, 2 or 3 of this document are shown in **bold characters**.

[d] A minimum nickel content of 8 % is common and allowed according to EN 10263-5.

[e] Special grade: symbol not specified in ISO 3506-1 and ISO 3506-2 or in DIN 267-13.

[f] Symbol according to DIN 267-13.

[g] Symbol specified in ISO 3605-5.