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Mechanical properties of corrosion-resistant stainless-steel fasteners —

Part 4: Tapping screws

Caractéristiques mécaniques des éléments de fixation en acier inoxydable résistant à la corrosion —

Partie 4: Vis à tôle

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 3506-4 was prepared by Technical Committee ISO/TC 2, *Fasteners*, Subcommittee SC 1, *Mechanical properties of fasteners*.

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

— *Part 1: Bolts, screws and studs*

— *Part 2: Nuts*

— *Part 3: Set screws and similar fasteners not under tensile stress*

— *Part 4: Tapping screws*

Introduction

In the preparation of this part of ISO 3506 special attention has been given to the fundamentally different property characteristics of stainless steel fastener grades compared with those of carbon steel and low-alloy steel fasteners. Ferritic and austenitic stainless steels are strengthened only by cold working and consequently the components do not have as homogeneous a condition as hardened and tempered parts. These special features have been recognized in the elaboration of property classes and the test procedures for mechanical properties.

The primary objective of this part of ISO 3506 is to ensure that corrosion-resistant austenitic, martensitic and ferritic stainless steel tapping screws will form mating threads in materials such as aluminium into which they are normally driven without deforming their own thread and without breaking during assembly or service. Selection of the steel group should be based on the intended application.

Mechanical properties of corrosion-resistant stainless-steel fasteners —

Part 4: Tapping screws

1 Scope

This part of ISO 3506 specifies the mechanical properties of tapping screws made from austenitic, martensitic and ferritic grades of corrosion-resistant stainless steels when tested at an ambient temperature range of 15 °C to 25 °C. Properties vary between higher and lower temperatures.

It applies to tapping screws with threads from ST2,2 up to and including ST8 in accordance with ISO 1478.

It does not apply to screws with special properties such as weldability.

This part of ISO 3506 does not define corrosion or oxidation resistance in particular environments, however some information on materials for particular environments is given in Annex D. Regarding definitions of corrosion and corrosion resistance see ISO 8044.

The aim of this part of ISO 3506 is a classification into property classes of corrosion-resistant stainless-steel fasteners.

Corrosion and oxidation performances and mechanical properties for use at elevated or sub-zero temperatures should be agreed between user and manufacturer in each particular case. Annex C shows how the risk of intergranular corrosion at elevated temperatures depends on the carbon content.

All austenitic stainless-steel fasteners are normally non-magnetic in the annealed condition; after cold working, some magnetic properties may be evident (see Annex E).

2 Normative references

The following referenced documents are indispensable for the application 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 1478:1999, *Tapping screws thread*

ISO 3651-1:1998, *Determination of resistance to intergranular corrosion of stainless steels — Part 1: Austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in nitric acid medium by measurement of loss in mass (Huey test)*

ISO 3651-2:1998, *Determination of resistance to intergranular corrosion of stainless steels — Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in media containing sulfuric acid*

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 16048:2003 , *Passivation of corrosion-resistant stainless-steel fasteners*

3 Designation, marking and finish

3.1 Designation

The designation system for stainless-steel grades and property classes for tapping screws is shown in Figure 1. The designation of the material consists of two blocks which are separated by a hyphen. The first block designates the steel grade, the second block the property class.

The designation of the steel grade (first block) consists of the letter

— **A** for austenitic steels,

— **C** for martensitic steels,

— **F** for ferritic steels,

which indicate the group of steel and a digit which indicates a range of chemical compositions within this steel group, see Table 2.

The designation of the property class (second block) consists of two digits representing 1/10 of the minimum Vickers hardness and the letter H referring to hardness, see Table 1.

Table 1 — Designations of property classes in relation to Vickers hardness

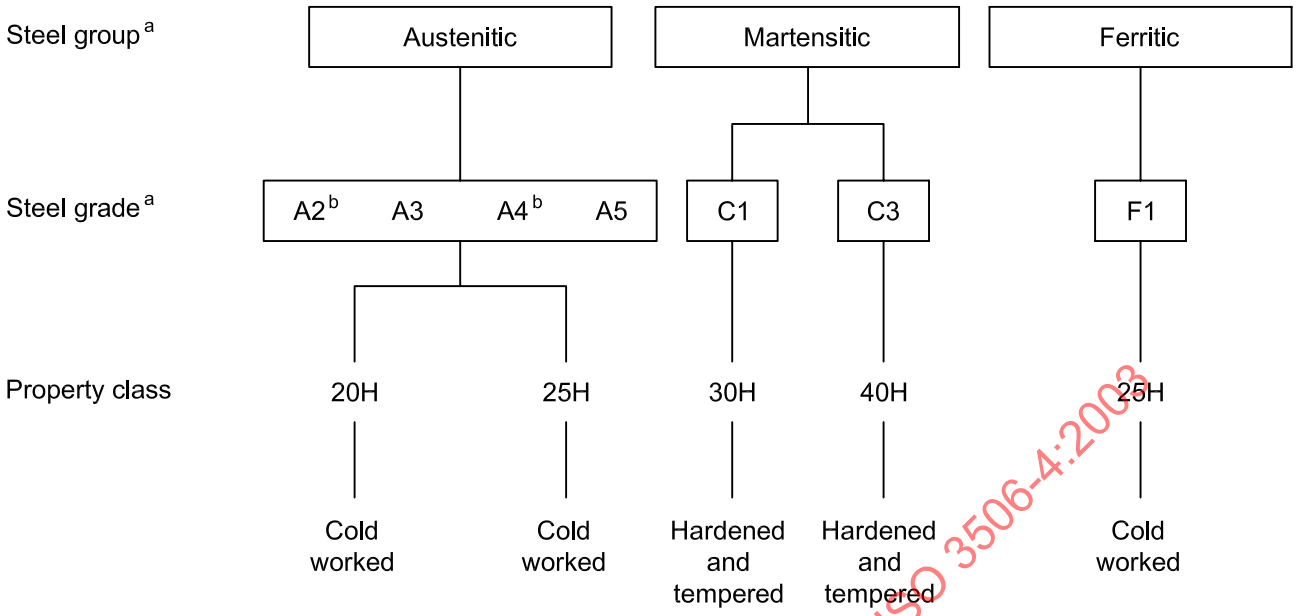
Property class	20H	25H	30H	40H
Vickers hardness, HV min.	200	250	300	400

EXAMPLE 1 A4-25H indicates:

Austenitic steel, cold worked, minimum hardness 250 HV.

EXAMPLE 2 C3-40H indicates:

Martensitic steel, hardened and tempered, minimum hardness 400 HV.



a The steel groups and steel grades classified in Figure 1 are described in Annex A and specified by chemical composition given in Table 2.

b Low carbon austenitic stainless steels with a carbon content not exceeding 0,03 % may additionally be marked with an L.

EXAMPLE A4L-25H.

Figure 1 — Designation system for stainless-steel grades and property classes for tapping screws

3.2 Marking

3.2.1 Tapping screws

Marking of tapping screws is not mandatory.

If tapping screws are to be marked, they shall be marked and/or described according to the designation system described in 3.1, only if all requirements in this part of ISO 3506 are fulfilled.

3.2.2 Packages and containers

Marking with the steel grade and property class according to 3.1 and the manufacturer's identification mark is mandatory on all packages of all sizes.

3.3 Finish

Unless otherwise specified, tapping screws in accordance with this part of ISO 3506 shall be supplied clean and bright. For maximum corrosion resistance passivation is recommended. When passivation is required it shall be performed in accordance with ISO 16048.

4 Chemical composition

The chemical compositions of stainless steels suitable for tapping screws in accordance with this part of ISO 3506 are given in Table 2.

NOTE Table 2 corresponds with the chemical compositions in ISO 3506-1 for the relevant steel grades.

The final choice of the chemical composition within the specified steel grade is at the discretion of the manufacturer unless by prior agreement between the purchaser and the manufacturer.

In applications where risk of inter-granular corrosion is present, testing in accordance with ISO 3651-1 or ISO 3651-2 is recommended. In such cases, stabilized stainless steels A3 and A5 or stainless steels A2 and A4 with a carbon content not exceeding 0,03 % are recommended.

Table 2 — Stainless steel grades — Chemical composition

Group	Grade	Chemical composition mass fraction % [a]									Notes
		C	Si	Mn	P	S	Cr	Mo	Ni	Cu	
Austenitic	A2	0,1	1	2	0,050	0,03	15 to 20	[b]	8 to 19	4	[c, d]
	A3	0,08	1	2	0,045	0,03	17 to 19	[b]	9 to 12	1	[e]
	A4	0,08	1	2	0,045	0,03	16,0 to 18,5	2 to 3	10 to 15	1	[d, f]
	A5	0,08	1	2	0,045	0,03	16,0 to 18,5	2 to 3	10,5 to 14	1	[e, f]
Martensitic	C1	0,09 to 0,15	1	1	0,050	0,03	11,5 to 14	—	1	—	[f]
	C3	0,17 to 0,25	1	1	0,040	0,03	16 to 18	—	1,5 to 2,5	—	
Ferritic	F1	0,12	1	1	0,040	0,03	15 to 18	[g]	1	—	[h, i]

NOTE 1 A description of the groups and grades of stainless steels also entering into their specific properties and applications is given in Annex A.

NOTE 2 Examples for stainless steels which are standardized in ISO 4954 are given in Annex B.

NOTE 3 Certain materials for specific applications are given in Annex D.

[a] Values are maximum unless otherwise indicated.

[b] Molybdenum may be present at the discretion of the manufacturer. However, if for some applications limiting of the molybdenum content is essential, this shall be stated at the time of ordering by the purchaser.

[c] If the chromium content is below 17 %, the minimum nickel content shall be 12 %.

[d] For austenitic stainless steels having a maximum carbon content of 0,03 %, nitrogen may be present to a maximum of 0,22 %.

[e] Shall contain titanium $\geqslant 5 \times C$ up to a 0,8 % maximum for stabilization, or shall contain niobium (columbium) and/or tantalum $\geqslant 10 \times C$ up to a 1 % maximum for stabilization.

[f] At the discretion of the manufacturer the carbon content may be higher where required in order to obtain the specified mechanical properties at larger diameters, but shall not exceed 0,12 % for austenitic steels.

[g] Molybdenum may be present at the discretion of the manufacturer.

[h] May contain titanium $\geqslant 5 \times C$ up to a 0,8 % maximum.

[i] May contain niobium (columbium) and/or tantalum $\geqslant 10 \times C$ up to a 1 % maximum.

5 Mechanical properties and performance

5.1 General

For acceptance purposes the mechanical properties and performance characteristics specified in 5.2 and 5.3 apply and shall be tested in accordance with 6.1 to 6.4.

In cases where screws are plated subsequent to delivery to the purchaser (or where plating of screws is otherwise under the control of the purchaser), the manufacturer is not responsible for failure due to plating. In such cases, the screw manufacturer can only be held responsible if it is proved that the failure is not due to any post-treatment. Screws from which the plating has been stripped off cannot be considered as samples.

5.2 Mechanical properties

5.2.1 Surface hardness

Screws of martensitic steel grades shall conform to the surface hardness requirements given in Table 3 when tested in accordance with 6.1.

Table 3 — Surface hardness

Steel group	Steel grade	Property class	Surface hardness, HV min.
Martensitic	C1	30H	300
	C3	40H	400

5.2.2 Core hardness

Screws of austenitic and ferritic steel grades shall conform to the core hardness requirements given in Table 4 when tested in accordance with 6.2. In case of dispute the requirements for performance characteristics in accordance with 5.3 shall be used to determine product acceptance.

Table 4 — Core hardness

Steel group	Steel grade	Property class	Core hardness, HV[a] min.
Austenitic	A2, A3, A4, A5	20H	200
		25H	250
Ferritic	F1	25H	250

[a] For threads ⩽ ST3,9 HV 5 shall be used;
for threads > ST3,9 HV 10 shall be used.

5.2.3 Torsional strength

Stainless-steel tapping screws shall have a torsional strength such that the torque necessary to cause failure, when tested in accordance with 6.3, shall equal or exceed the minimum torque values given in Table 5 for the applicable property class.

5.3 Thread forming capability

Stainless-steel tapping screws shall form mating threads without deforming their own thread when driven into a test plate in accordance with 6.4.

6 Test methods

6.1 Surface hardness test

This test is valid for screws of martensitic steel grades.

Vickers hardness testing shall be carried out in accordance with ISO 6507-1.

The indentation of the pyramid shall be made on a flat surface, preferably on the head of the screw.

6.2 Core hardness test

This test is valid for screws of austenitic and ferritic steel grades.

Vickers core hardness testing shall be carried out in accordance with ISO 6507-1 at the mid-radius of a transverse section through the screw taken at a distance sufficiently behind the point of the screw to be through the full minor diameter.

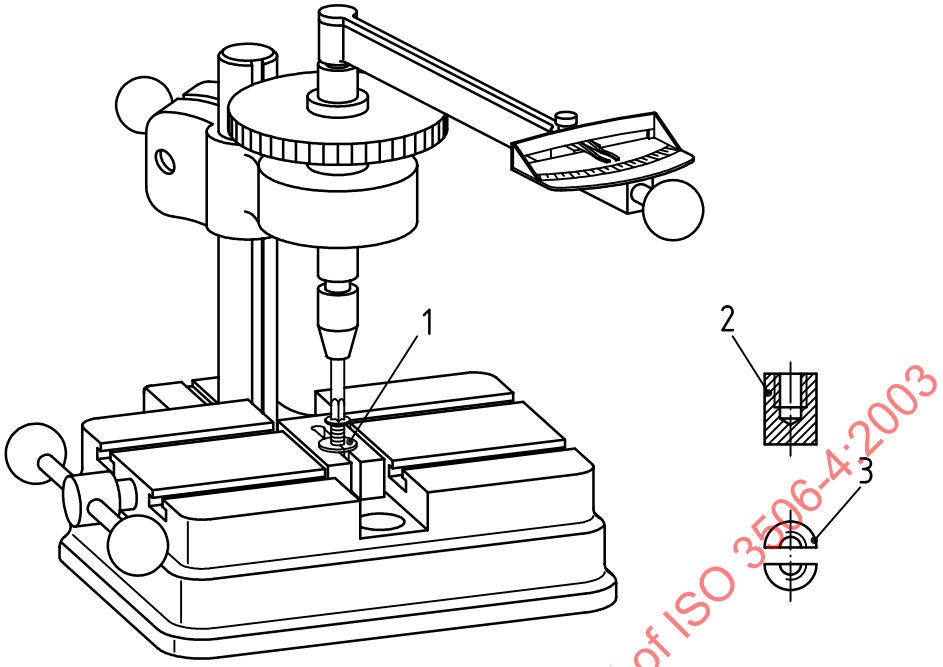
6.3 Torsional strength test

The thread of the as-received sample screw (coated or uncoated) shall be clamped in a mating split threaded die or other device so that the clamped portion of the screw is not damaged and at least two full threads project above the clamping device and at least two full-form threads exclusive of point are held within the clamping device. A threaded insert with a blind hole may be used in place of the clamping device (see Figure 2) provided that the hole depth is such as to ensure that breakage will occur in the fully-threaded portion.

The torque shall be applied to the screw until failure occurs. The torque-measuring device shall have an accuracy of at least ± 7 % of the minimum torque values specified in Table 5. The screw shall meet the minimum breaking torque specified in Table 5.

Table 5 — Minimum breaking torque

Thread	Breaking torque, M_B min. Nm			
	Property class			
	20H	25H	30H	40H
ST2,2	0,38	0,48	0,54	0,6
ST2,6	0,64	0,8	0,9	1
ST2,9	1	1,2	1,4	1,5
ST3,3	1,3	1,6	1,8	2
ST3,5	1,7	2,2	2,4	2,7
ST3,9	2,3	2,9	3,3	3,6
ST4,2	2,8	3,5	3,9	4,4
ST4,8	4,4	5,5	6,2	6,9
ST5,5	6,9	8,7	9,7	10,8
ST6,3	11,4	14,2	15,9	17,7
ST8	23,5	29,4	32,9	36,5



Key

1 threaded die or insert
2 threaded insert with a blind hole
3 split threaded die

Figure 2 — Apparatus for determination of breaking torque, M_B (see 6.3)

6.4 Drive test

The sample screw as received (coated or uncoated) shall be driven into a test plate until one thread of full diameter is completely through the test plate.

For the drive test of screws of austenitic and ferritic steel grades, a test plate made from aluminium alloy and with a hardness of 80 HV 30 to 120 HV 30 shall be used.

For the drive test of screws of martensitic steel grades, a test plate made from low carbon steel with a carbon content not exceeding 0,23 % shall be used. The hardness of the plate shall be 125 HV 30 to 165 HV 30 when measured in accordance with ISO 6507-1.

The thickness of the test plates shall conform to the values given in Table 6.

The test hole shall be drilled, or punched and drilled, or punched and reamed, to the hole diameter specified in Table 6.

Table 6 — Test plate thickness and hole size

Thread	Test plate thickness mm		Hole diameter mm	
	min.	max.	min.	max.
ST2,2	1,17	1,30	1,905	1,955
ST2,6	1,17	1,30	2,185	2,235
ST2,9	1,17	1,30	2,415	2,465
ST3,3	1,17	1,30	2,680	2,730
ST3,5	1,85	2,06	2,920	2,970
ST3,9	1,85	2,06	3,240	3,290
ST4,2	1,85	2,06	3,430	3,480
ST4,8	3,10	3,23	4,015	4,065
ST5,5	3,10	3,23	4,735	4,785
ST6,3	4,67	5,05	5,475	5,525
ST8	4,67	5,05	6,885	6,935

Annex A
(informative)

Description of groups and grades of stainless steels

A.1 General

In ISO 3506 reference is made to steel grades A1 to A5, C1, C3, C4 and F1 covering steels of the following steel groups:

— Austenitic steel A1 to A5

— Martensitic steel C1, C3 and C4

— Ferritic steel F1

In this annex the characteristics of the above mentioned steel groups and grades are described.

This annex also gives some information on the non-standardized steel group FA. Steels of this group have a ferritic-austenitic structure.

A.2 Steel group A (austenitic structure)

A.2.1 General

Five main grades of austenitic steels, A1 to A5, are included in ISO 3506. They cannot be hardened and are usually non-magnetic. In order to reduce the susceptability to work-hardening copper may be added to steel grades A1 to A5 as specified in Table 2.

For non-stabilized steel grades A2 and A4, the following applies.

As chromic oxide makes steel resistant to corrosion, low carbon content is of great importance to non-stabilized steels. Due to the high affinity of chrome to carbon, chrome carbide is obtained instead of chromic oxide which is more likely at elevated temperature (see Annex C.)

For stabilized steel grades A3 and A5, the following applies.

The elements Ti, Nb or Ta affect the carbon and chromic oxide is produced to its full extent.

For offshore or similar applications, steels with Cr and Ni contents of about 20 % and Mo content of 4,5 % to 6,5 % are required.

When risk of corrosion is high, experts should be consulted.

A.2.2 Steel grade A1

Steel grade A1 is especially designed for machining. Due to high sulfur content the steels within this grade have lower resistance to corrosion than corresponding steels with normal sulfur content.

A.2.3 Steel grade A2

Steels of grade A2 are the most frequently used stainless steels. They are used for kitchen equipment and apparatus for the chemical industry. Steels within this grade are not suitable in non-oxidizing acid and agents with chloride content, i.e. swimming pools and sea water.

A.2.4 Steel grade A3

Steels of grade A3 are stabilized “stainless steels” with properties of the steels in grade A2.

A.2.5 Steel grade A4

Steels of grade A4 are “acid proof steels”, which are Mo-alloyed and give a considerably better resistance to corrosion. A4 is used to a great extent by the cellulose industry as this steel grade is developed for boiling sulfuric acid (thus given the name “acid proof”) and is, to a certain extent, also suitable in an environment with chloride content. A4 is also frequently used by the food industry and by the ship-building industry.

A.2.6 Steel grade A5

Steels of grade A5 are stabilized “acid proof steels” with properties of the steels in grade A4.

A.3 Steel group F (ferritic structure)

One ferritic steel grade (F1) is included in ISO 3506. The steels within grade F1 cannot be hardened normally and should not be hardened even if possible in certain cases. The F1 steels are magnetic.

Steel grade F1 is normally used for simpler equipment with the exception of the superferrites which have extremely low C and N contents. The steels within grade F1 can, if need be, replace steels of the grades A2 and A3 and be used at higher chloride content.

A.4 Steel group C (martensitic structure)

A.4.1 General

Three types of martensitic steel grades, C1, C3 and C4, are included in ISO 3506. They can be hardened to an excellent strength and are magnetic.

A.4.2 Steel grade C1

Steels within grade C1 have limited resistance to corrosion. They are used in turbines, pumps and for knives.

A.4.3 Steel grade C3

Steels within grade C3 have limited resistance to corrosion though better resistance than C1. They are used in pumps and valves.

A.4.4 Steel grade C4

Steels within grade C4 have limited resistance to corrosion. They are intended for machining, otherwise they are similar to steels of grade C1.

A.5 Steel group FA (ferritic-austenitic structure)

The steel group FA is not included in ISO 3506 but will most probably be included in the future.

Steels of this steel group are so-called duplex steels. The first FA steels to be developed had some drawbacks that have been eliminated in the recently developed steels. The FA steels have better properties than steels of the types A4 and A5 especially as far as strength is concerned. They also exhibit superior resistance to pitting and crack corrosion.

Examples of composition are shown in Table A.1.

Table A.1 — Ferritic-austenitic steels — Chemical composition

Group	Chemical composition mass fraction %						
	C max.	**Si**	**Mn**	**Cr**	**Ni**	**Mo**	**N**
Ferritic-austenitic	0,03	1,7	1,5	18,5	5	2,7	0,07
	0,03	< 1	< 2	22	5,5	3	0,14

Annex B
(informative)

Stainless steels for cold heading and extruding
(Extract from ISO 4954:1993)

Table B.1

Type of steel			Chemical composition[b] mass fraction %									Fastener grade identification[c]
No.	Name	Designation[a] in accordance with ISO 4954:1993	C	Si max.	Mn max.	P max.	S max.	Cr	Mo	Ni	Other	
	Ferritic											
71	X 3 Cr 17 E	—	⩽ 0,04	1,00	1,00	0,040	0,030	16,0 to 18,0		⩽ 1,0		F1
72	X 6 Cr 17 E	D 1	⩽ 0,08	1,00	1,00	0,040	0,030	16,0 to 18,0		⩽ 1,0		F1
73	X 6 CrMo 17 1 E	D 2	⩽ 0,08	1,00	1,00	0,040	0,030	16,0 to 18,0	0,90 to 1,30	⩽ 1,0		F1
74	X 6 CrTi 12 E	—	⩽ 0,08	1,00	1,00	0,040	0,030	10,5 to 12,5		⩽ 0,50	Ti: $6 \times \%\ C \leqslant 1,0$	F1
75	X 6 CrNb 12 E	—	⩽ 0,08	1,00	1,00	0,040	0,030	10,5 to 12,5		⩽ 0,50	Nb: $6 \times \%\ C \leqslant 1,0$	F1
	Martensitic											
76	X 12 Cr 13 E	D 10	0,90 to 0,15	1,00	1,00	0,040	0,030	11,5 to 13,5		⩽ 1,0		C1
77	X 19 CrNi 16 2 E	D 12	0,14 to 0,23	1,00	1,00	0,040	0,030	15,0 to 17,5		1,5 to 2,5		C3
	Austenitic											
78	X 2 CrNi 18 10 E	D 20	⩽ 0,030	1,00	2,00	0,045	0,030	17,0 to 19,0		9,0 to 12,0		A2[d]
79	X 5 CrNi 18 9 E	D 21	⩽ 0,07	1,00	2,00	0,045	0,030	17,0 to 19,0		8,0 to 11,0		A2
80	X 10 CrNi 18 9 E	D 22	⩽ 0,12	1,00	2,00	0,045	0,030	17,0 to 19,0		8,0 to 10,0		A2
81	X 5 CrNi 18 12 E	D 23	⩽ 0,07	1,00	2,00	0,045	0,030	17,0 to 19,0		11,0 to 13,0		A2
82	X 6 CrNi 18 16 E	D 25	⩽ 0,08	1,00	2,00	0,045	0,030	15,0 to 17,0		17,0 to 19,0		A2
83	X 6 CrNiTi 18 10 E	D 26	⩽ 0,08	1,00	2,00	0,045	0,030	17,0 to 19,0		9,0 to 12,0	Ti: $5 \times \%\ C \leqslant 0,80$	A3[d]
84	X 5 CrNiMo 17 12 2 E	D 29	⩽ 0,07	1,00	2,00	0,045	0,030	16,5 to 18,5	2,0 to 2,5	10,5 to 13,5		A4
85	X 6 CrNiMoTi 17 12 2 E	D 30	⩽ 0,08	1,00	2,00	0,045	0,030	16,5 to 18,5	2,0 to 2,5	11,0 to 14,0	Ti: $5 \times \%\ C \leqslant 0,80$	A5[d]
86	X 2 CrNiMo 17 13 3 E	—	⩽ 0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,5 to 3,0	11,5 to 14,5		A4[e]
87	X 2 CrNiMoN 17 13 3 E	—	⩽ 0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,5 to 3,0	11,5 to 14,5	N: 0,12 to 0,22	A4[e]
88	X 3 CrNiCu 18 9 3 E	D 32	⩽ 0,04	1,00	2,00	0,045	0,030	17,0 to 19,0		8,5 to 10,5	Cu: 3,00 to 4,00	A2

[a] The designations given in the first column are consecutive numbers. The designations given in the second column are in accordance with the system proposed by ISO/TC 17/SC 2. The designations given in the third column represent the antiquated numbers of ISO 4954:1993.

[b] Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, other than for finishing the heat. All reasonable precautions should be taken to prevent the addition, from scrap or other materials used in manufacture, of elements which affect mechanical properties and applicability.

[c] Not part of ISO 4954.

[d] Stabilized steels.

[e] Excellent resistance to intergranular corrosion.