INTERNATIONAL STANDARD

ISO 4955

Fourth edition
2016-05-01

Heat-resistant steels

Aciers réfractaires

Reference number
ISO 4955:2016(E)

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Contents

Page

Foreword ... **iv**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms and definitions ... **2**

4 Designation ... **2**

5 Information to be supplied by the purchaser ... **2**

6 Classification of grades ... **3**

7 Requirements ... **3**
7.1 Manufacturing process ... 3
7.2 Delivery condition ... 3
7.3 Chemical composition ... 4
7.4 Mechanical properties ... 4
7.4.1 Mechanical properties at room temperature ... 4
7.4.2 Mechanical properties at elevated temperatures ... 4
7.5 Surface quality ... 4
7.6 Internal soundness ... 5
7.7 Dimensions and tolerances on dimensions and shape ... 5

8 Inspection, testing and conformance of products ... **5**
8.1 General ... 5
8.2 Inspection procedures and types of inspection documents ... 6
8.3 Specific inspection and testing ... 6
8.3.1 Extent of testing ... 6
8.3.2 Selection and preparation of samples and test pieces ... 6
8.4 Test methods ... 6
8.5 Retest ... 7

9 Marking ... **7**

Annex A (informative) **Technical information on heat- and creep-resistant steels** ... **21**

Annex B (informative) **Data for creep strength to 1 % plastic strain and creep rupture strength** ... **28**

Annex C (informative) **Designations of the steels given in Table 2 and of comparable grades covered in various designation systems** ... **33**

Annex D (informative) **Applicable dimensional International Standards** ... **36**

Bibliography ... **37**

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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This fourth edition cancels and replaces the third edition (ISO 4955:2005), which has been technically revised.

Heat-resistant steels

1 Scope

This International Standard specifies requirements for the grades listed in Table 2, which are usually employed for products for which the resistance to the effects of hot gases and the products of combustion at temperatures in the region above 550°C and/or to long-term mechanical stress is the main requirement.

NOTE 1 Grades mentioned in this International Standard may also be used for corrosion and creep resistant purposes.

This International Standard is applicable to the following:

— flat products;

— bars, sections, rod, semi-finished products and forgings.

NOTE 2 Hammer-forged semi-finished products (blooms, billets, slabs, etc.), seamless rolled rings and hammer-forged bars are in the following, covered under semi-finished products or bars and not under the term "forgings".

NOTE 3 Not all of the grades included in this International Standard are necessarily available in all product forms.

NOTE 4 In Table 2, two alloys are listed in addition to the steels since they belong to the heat resistant grades.

NOTE 5 Heat resistant wire in the cold worked condition is covered by ISO 16143-3.

NOTE 6 Corrosion resistant stainless steels for which resistance to corrosion is of primary importance are covered by ISO 16143-1 and ISO 16143-2.

NOTE 7 Heat-resistant steels for valves are covered by ISO 683-15.

In addition to this International Standard, the general technical delivery requirements of ISO 404 are applicable.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 4885, *Ferrous products — Heat treatments — Vocabulary*

ISO/TS 4949, *Steel names based on letter symbols*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1:2009, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6929, *Steel products — Vocabulary*

ISO 9443, *Heat-treatable and alloy steels — Surface quality classes for hot-rolled round bars and wire rods — Technical delivery conditions*

ISO/TR 9769, *Steel and iron — Review of available methods of analysis*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO 15510, *Stainless steels — Chemical composition*

ISO 20723, *Structural steels — Surface condition of hot-rolled sections — Delivery requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 377, ISO 404, ISO 4885, ISO 6929, ISO 14284 and the following apply.

3.1
heat resistant steels
heat resistant steels of this International Standard are used at above 550°C (wustite point) due to their excellent resistance to the effects of hot gases and products of combustion, as well as their resistance to the influence of molten salts and molten metals but also showing good mechanical properties during short and long-term stressing

3.2
creep resistant grades
steels, nickel- or cobalt-alloys with a minimum of 8 % chromium, which are characterised by good mechanical behaviour at temperatures above 500 °C under long-range service conditions, i.e. primarily by creep strength to 1 % plastic strain or creep rupture strength during long-time stressing

4 Designation

For the steel grades covered by this International Standard, the steel names as given in the tables are allocated in accordance with ISO/TS 4949.

For the steel grades covered by this International Standard, the steel numbers as given in the tables are allocated in accordance with ISO 15510.

5 Information to be supplied by the purchaser

It shall be the responsibility of the purchaser to specify all requirements that are necessary for products under this specification. Such requirements to be considered include, in the order listed, but not limited to, the following:

— the desired quantity;

— the product form;

— the number of the appropriate dimensional standard (see Annex A), the nominal dimensions, plus any choice of requirements;

— the type of material (grade);

— the number of this International Standard (ISO 4955);

— the name or number of the steel grade;

— if, for the relevant steel in Tables 6 and 7 for the mechanical properties, more than one treatment condition is covered, the symbol for the desired heat treatment;

— the desired process route, including surface finish (see 7.2, 7.5 and Table 4, footnote d);

— if a verification of internal soundness is required, the requirements have to be agreed at the time of enquiry and order;

— any further optional test agreed between the manufacturer and purchaser at the time of enquiry and order;

— the type of inspection document and its designation in accordance with ISO 10474 (see 8.2).

EXAMPLE 1 ton of plates according to ISO 9444-2 with a specified thickness of 5,0 mm, a specified width of 1 200 mm, with trimmed edges (T) and a specified length of 2 500 mm made of a steel grade with the name X8NiCrAlTi32–21 (4876–088–00-I) as specified in ISO 4955, in process route 1U and inspection certificate 3.1 as specified in ISO 10474:

1 t plate ISO 9444-2 — 5,0 × 1200T × 2500

Steel ISO 4955 — X8NiCrAlTi32–21 + 1U

ISO 10474 — 3.1

or

1 t plate ISO 9444-2 — 5,0 × 1200T × 2500

Steel ISO 4955 — 4876-088-00-I + 1U

ISO 10474 — 3.1

6 Classification of grades

Heat-resistant steels covered in this International Standard are classified according to their structure into the following:

— austenitic grades;

— ferritic grades;

— martensitic grades;

— precipitation hardening grades.

7 Requirements

7.1 Manufacturing process

Unless a special steelmaking process is agreed when ordering, the steelmaking process shall be at the discretion of the manufacturer. When he so requests, the purchaser shall be informed what steelmaking process is being used.

7.2 Delivery condition

The products shall be supplied in the delivery condition agreed in the order by reference to the process route given in Tables 4 and 5 (see also Annex A) and where different alternatives exist to the treatment conditions given in Tables 6 and 7.

7.3 Chemical composition

7.3.1 The chemical composition requirements given in Table 2 apply with respect to the chemical composition of the cast analysis.

7.3.2 The product analysis may deviate from the limiting values for the cast analysis given in Table 2 by values listed in Table 3.

7.4 Mechanical properties

7.4.1 Mechanical properties at room temperature

The mechanical properties at room temperature as specified in Tables 6 and 7 apply for the relevant specified heat treatment condition. This does not apply to the process route 1U (hot rolled, not heat-treated, not descaled). If, by agreement at the time of ordering, the products are to be supplied in a non-heat-treated condition, the mechanical properties specified in Tables 6 and 7 shall be obtainable from reference test pieces which have received the appropriate heat treatment (simulated heat treatment).

7.4.2 Mechanical properties at elevated temperatures

The mechanical properties at elevated temperature as specified in Table 8 apply for each specified heat treatment condition. This does not apply to the process route 1U (hot rolled, not heat-treated, not descaled) and to semi-finished products.

The tensile test at elevated temperature shall be carried out at temperature of interest only when agreed at the time of enquiry and order.

If, by agreement at the time of ordering, the products are to be supplied in a non-heat-treated condition, the mechanical properties specified in Table 8 shall be obtainable from reference test pieces which have received the appropriate heat treatment (simulated heat treatment).

7.5 Surface quality

Availability, and the determination of the types of process route and surface finish (for flat products, see Table 4 and for long products, see Table 5) most suited to a particular case, should be discussed with the manufacturer.

The general surface appearance with respect to soundness and surface finish shall be consistent with good production practice, for the grade and quality ordered, as determined by visual inspection.

When flat products are delivered in coil form, the degree and extent of imperfections may be expected to be higher, due to the impracticability of removing short lengths of coil.

Flat products delivered with hot-rolled or cold-rolled finishes (see Table 4) shall, unless otherwise agreed, be supplied with only one surface inspected to the required finish (the prime surface). In such instances, the manufacturer should indicate the prime surface, by marking the material or the packaging, or by some other agreed method. The default method is to mark the prime surface, and to make this surface the top surface of plates, sheets and cut lengths, or the outside surface of coiled products.

For long products, the available surface finishes are given in Table 5. Slight surface imperfections, inherent to the production process, are permitted. Exact requirements concerning the maximum depth of acceptable discontinuities for bars, rods and sections in the relevant conditions are given in Table 1.

Table 1 — Maximum depth of acceptable discontinuities for bars, rods and sections

Conditions	Product forms	Permissible depth of discontinuities[a]	Max. % of delivered weight in excess of permissible depth of discontinuities
1U, 1C, 1E, 1D	Sections	To be agreed upon at the time of enquiry and order on the basis of ISO 20723.	
1U, 1C, 1E, 1D	Rounds and rod	Specified at the time of enquiry and order, otherwise ISO 9443 class 1 za2.	
1X[b]	Rounds	— max. 0,2 mm for d ≤ 20 mm — max. 0,01 d for 20 < d ≤ 75 mm — max. 0,75 mm for d > 75 mm	1 %
	Hexagons	— max. 0,3 mm for d ≤ 15 mm — max. 0,02 d for 15 < d ≤ 63 mm	2 %
	Other bars	— max. 0,3 mm for d ≤ 15 mm — max. 0,02 d for 15 < d ≤ 63 mm	4 %
1G	Rounds	Technically defect free by manufacture.	0,2 %

[a] Depth of discontinuities is understood as being the distance, measured normally to the surface, between the bottom of the discontinuities and that surface.

[b] At the time of enquiry and order, it may be agreed that the product shall be delivered with a surface that is technically defect free by manufacture. In this case, also the maximum % of delivered weight in excess of permissible depth of discontinuities shall be agreed.

7.6 Internal soundness

For the internal soundness, where appropriate, requirements together with the conditions for their verification may be agreed at the time of enquiry and order, if possible, with reference to other International Standards (e.g. ISO 17577 for flat products of thickness equal to or greater than 6 mm).

7.7 Dimensions and tolerances on dimensions and shape

7.7.1 The dimensions and the tolerances on dimensions and shape are to be agreed at the time of enquiry and order, as far as possible with reference to the dimensional International Standards listed in Annex D. The ordered dimensions shall, where applicable, include the minimum machining allowances.

7.7.2 If none of the International Standards listed in Annex D is applicable, then the dimensions and tolerances should be agreed at the time of enquiry and order on the basis of regional or national standards.

8 Inspection, testing and conformance of products

8.1 General

The manufacturer shall carry out appropriate process control, inspection and testing to ensure that the delivery complies with the requirements of the order.

This includes the following:

— a suitable frequency of verification of the dimensions of the products;

— an adequate intensity of visual examination of the surface quality of the products;

— an appropriate frequency and type of test to ensure that the correct grade of steel is delivered.

The nature and frequency of these verifications, examinations and tests are determined by the manufacturer, based on the degree of consistency that has been determined by the evidence of his quality system. In view of this, verifications by specific tests for these requirements are not necessary unless otherwise agreed upon.

8.2 Inspection procedures and types of inspection documents

8.2.1 Products complying with this International Standard shall be ordered and delivered with one of the inspection documents as specified in ISO 10474. The type of document shall be agreed upon at the time of enquiry and order. If the order does not contain any specification of this type, a test report 2.2 shall be issued.

8.2.2 If, in accordance with the agreements made at the time of enquiry and order, a test report is to be provided, this shall cover the following:

a) a statement that the material complies with the requirements of the order;

b) the results of the cast analysis for all elements specified for the type of steel supplied.

8.2.3 If, in accordance with the agreements in the order, an inspection certificate 3.1 or 3.2 is to be provided, the specific inspections and tests described in 8.3 shall be carried out and their results shall be certified in the document.

In addition to the details in 8.2.2, the document shall cover the following:

a) the results of the mandatory tests marked in the second column of Tables 9 and 10 by an "m";

b) the results of any optional test or inspection agreed when ordering.

8.3 Specific inspection and testing

8.3.1 Extent of testing

The tests to be carried out, either mandatorily (m) or by agreement (o) and the composition and size of the test units, and the number of sample products, samples and test pieces to be taken are given in Tables 9 and 10.

8.3.2 Selection and preparation of samples and test pieces

8.3.2.1 The general conditions for selection and preparation of samples and test pieces shall be in accordance with ISO 377 and ISO 14284.

8.3.2.2 The samples for the tensile test shall be taken in accordance with Figures 1 to 3. Samples from flat products shall be taken in such a way that they are located halfway between the centre and a longitudinal edge.

The samples shall be taken from products in the delivery condition. If agreed, the samples may be taken from flat products before flattening or from bars before straightening.

For samples to be given a simulated heat treatment, the conditions for annealing shall be agreed.

8.3.2.3 Samples for the hardness test, where requested, shall be taken from the same locations as those for the tensile test.

8.4 Test methods

8.4.1 Unless otherwise agreed when ordering, the choice of a suitable physical or chemical method of analysis to determine the product analysis is at the discretion of the manufacturer. In cases of dispute, the analysis shall be carried out by a laboratory approved by the two parties. In these cases, the reference method of analysis shall be agreed, where possible, with reference to ISO/TR 9769.

8.4.2 The tensile test at room temperature shall be carried out in accordance with ISO 6892-1, taking into account for flat products the additional or deviating conditions specified in Figure 3, footnote a. It shall be performed under controlled conditions in accordance with ISO 6892-1:2009, Clause 5.

Unless otherwise agreed, the tensile strength and elongation after fracture shall be determined and, in addition, for ferritic, martensitic, precipitation-hardening, austenitic free-cutting and austenitic-ferritic steels, the 0,2 % proof strength, and for austenitic steels, the 0,2 % and 1 % proof strength.

8.4.3 The Brinell hardness test shall be carried out in accordance with ISO 6506-1.

8.4.4 Dimensions and dimensional tolerances of the products shall be tested in accordance with the requirements of the relevant dimensional International Standards given in Annex D.

8.5 Retest

See ISO 404.

9 Marking

9.1 The products shall be marked with the manufacturer's trademark or symbol and the steel name or number. The product shall also be marked with the cast number, thickness or dimension (and if an inspection, certificate is requested) an identification number related to the inspection certificate.

9.2 Unless otherwise agreed, the method of marking and the material of marking shall be at the option of the manufacturer. Its quality shall be such that it shall be durable for at least one year, can withstand normal handling and can be stored in unheated storage under cover. The corrosion resistance of the product shall not be impaired by the marking.

9.3 Each unit shall be marked:

— for flat products as an alternative, for items that are wrapped, bundled or boxed, or where the surface is ground or polished, the marking may be applied to the packaging or to a tag securely attached to it;

— for semi-finished products, bars, sections and forgings by means of labels attached to the bundle or, by agreement at the time of enquiry and order, by inking, adhesive labels, electrolytic etching or stamping;

— for rods, by means of a label attached to the coil.

Table 2 — Chemical composition (cast analysis)

Designation		% (mass fraction)[a]								
Name	ISO-number	C	Si	Mn	P	S	Cr	Ni	N	Others
Austenitic steels for heat resistant applications										
X6CrNiSiNCe19–10	4818–304–15-E	0,04 to 0,08	1,00 to 2,00	1,00	0,045	0,015	18,0 to 20,0	9,0 to 11,0	0,12 to 0,20	Ce: 0,03 to 0,08
X15CrNiSi20–12	4828–305–09-I	0,20	1,50 to 2,50	2,00	0,045	0,030	19,0 to 21,0	11,0 to 13,0	0,10	—
X7CrNiSiNCe21–11	4835–308–15-U	0,05 to 0,10	1,40 to 2,00	0,80	0,040	0,030	20,0 to 22,0	10,0 to 12,0	0,14 to 0,20	Ce: 0,03 to 0,08
X18CrNi23–13	4833–309–08-I	0,20	1,00	2,00	0,045	0,030	22,0 to 24,0	12,0 to 15,0	0,10	—
X8CrNi25–21	4845–310–08-E	0,10	1,50	2,00	0,045	0,015	24,0 to 26,0	19,0 to 22,0	0,10	—
X15CrNiSi25–21	4841–314–00-E	0,20	1,50 to 2,50	2,00	0,045	0,015	24,0 to 26,0	19,0 to 22,0	0,10	—
X8NiCrAlTi32–21	4876–088–00-I	0,05 to 0,10	1,00	1,50	0,015	0,015	19,0 to 23,0	30,0 to 34,0	—	Al: 0,15 to 0,60 Ti: 0,15 to 0,60 Cu: 0,70
X6NiCrSiNCe35–25	4854–353–15-E	0,04 to 0,08	1,20 to 2,00	2,00	0,040	0,015	24,0 to 26,0	34,0 to 36,0	0,12 to 0,20	Ce: 0,03 to 0,08
Austenitic steels for creep resistant applications										
X10CrNiMoMnNbV B15–10–1	4982–215–00-E	0,06 to 0,15	0,20 to 1,00	5,50 to 7,0	0,035	0,015	14,0 to 16,0	9,0 to 11,0	0,10	Mo: 0,80 to 1,20 V: 0,15 to 0,40 Nb: 0,75 to 1,25 B: 0,003 to 0,009
X7CrNi18–9	4948–304–09-I	0,04 to 0,10	1,00	2,00	0,045	0,030	17,0 to 19,0	8,0 to 11,0	—	—
X7CrNiTi18–10	4940–321–09-I	0,04 to 0,10	1,00	2,00	0,045	0,030	17,0 to 19,0	9,0 to 12,0	—	Ti: 5 × C to 0,80
X7CrNiNb18–10	4912–347–09-I	0,04 to 0,10	1,00	2,00	0,045	0,030	17,0 to 19,0	9,0 to 12,0	—	Nb: 10 × C to 1,20[c]
X8CrNiNb16–13	4961–347–77-E	0,04 to 0,10	0,30 to 0,60	1,50	0,035	0,015	15,0 to 17,0	12,0 to 14,0	—	Nb: 10 × C to 1,20
X6CrNiMo17–13–2	4918–316–09-E	0,04 to 0,08	0,75	2,00	0,035	0,015	16,0 to 18,0	12,0 to 14,0	0,10	Mo: 2,00 to 2,50
X7NiCrWCuCoNbN B25–23–3–3–3-2	4990–310–35-U	0,04 to 0,10	0,40	0,60	0,025	0,015	21,5 to 23,5	23,5 to 26,5	0,20 to 0,30	Co: 1,0 to 2,0 Cu: 2,5 to 3,5 Nb: 0,40 to 0,60 W: 3,0 to 4,0 B: 0,002 to 0,008
Ferritic steels for heat resistant applications										
X10CrAlSi7	4713–503–72-E	0,12	0,50 to 1,00	1,00	0,040	0,0150	6,0 to 8,0	—	—	Al: 0,50 to 1,00
X2CrTi12	4512–409–10-I	0,03	1,00	1,00	0,040	0,015	10,5 to 12,5	—	—	Ti: 6 × (C+N) to 0,65[d]
X6Cr13	4000–410–08-I	0,08	1,00	1,00	0,040	0,030	12,0 to 14,0	1,00	—	—
X10CrAlSi13	4724–405–77-I	0,12	0,70 to 1,40	1,00	0,040	0,015	12,0 to 14,0	1,00	—	Al: 0,70 to 1,20

Elements not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, except for finishing the cast. All appropriate precautions shall be taken to avoid the addition of such elements from scrap or other materials used in production, which would impair mechanical properties and the suitability of the steel.

[a] Maximum values unless otherwise indicated.

[b] The stabilization may be by use of titanium and/or niobium and/or zirconium. According to the atomic mass of these elements and the content of carbon and nitrogen, the equivalence shall be the following: Nb (% by mass) = Zr (% by mass) = 7/4 Ti (% by mass).

[c] Tantalum determined as niobium.

[d] By agreement at the time of enquiry and order, this grade can also be delivered with Ti: 6 x C to 0,75.

[e] Patented grades.

Table 2 *(continued)*

Designation		% (mass fraction)[a]								
Name	ISO-number	C	Si	Mn	P	S	Cr	Ni	N	Others
X6Cr17	4016–430–00-I	0,08	1,00	1,00	0,040	0,030	16,0 to 18,0	1,00	—	—
X3CrTi17	4510–430–35-I	0,05	1,00	1,00	0,040	0,015	16,0 to 18,0	—	—	Ti: [4 × (C+N) + 0,15] to 0,80[b]
X2CrTiNb18	4509–439–40-X	0,03	1,00	1,00	0,040	0,015	17,5 to 18,5	—	—	Ti: 0,10 to 0,60 Nb: (3 × C + 0,30) to 1,00[c]
X2CrMoTi18–2	4521–444–00-I	0,025	1,00	1,00	0,040	0,015	17,0 to 20,0	—	0,030	Mo: 1,75 to 2,50 Ti: ≥4 × (C+N) + 0,15 to 0,80[b]
X10CrAlSi18	4742–430–77-I	0,12	0,70 to 1,40	1,00	0,040	0,015	17,0 to 19,0	1,00	—	Al: 0,70 to 1,20
X10CrAlSi25	4762–445–72-I	0,12	0,70 to 1,40	1,00	0,040	0,015	23,0 to 26,0	1,00	—	Al: 1,20 to 1,70
X15CrN26	4749–446–00-I	0,20	1,00	1,00	0,040	0,030	24,0 to 28,0	1,00	0,15 to 0,25	—
Martensitic steels for creep resistant applications										
X18CrMnMoNbVN12	4916–600–77-J	0,15 to 0,20	0,50	0,50 to 1,00	0,040	0,030	10,0 to 13,0	0,60	0,05 to 0,10	Mo: 0,30 to 0,90 Nb: 0,20 to 0,60 V: 0,10 to 0,40
X22CrMoV12–1	4923–422–77-E	0,18 to 0,24	0,50	0,40 to 0,90	0,025	0,015	11,0 to 12,5	0,30 to 0,80	—	Mo: 0,80 to 1,20 V: 0,25 to 0,35
Precipitation hardening grades for creep resistant applications										
X6NiCrTiMoVB25–15–2 [e]	4980–662–86-X[e]	0,08	1,00	2,00	0,040	0,030	13,5 to 16,0	24,0 to 27,0	—	Mo: 1,00 to 1,50 Ti: 1,90 to 2,35 Al: 0,35 V: 0,10 to 0,50 B: 0,001 to 0,010
NiCr19Fe19Nb5Mo3	4668–077–18-I	0,020 to 0,08	0,35	0,35	0,015	0,015	17,0 to 21,0	50,0 to 55,0	—	Al: 0,30 to 0,70 Co: 1,00, Cu:0,30 Mo: 2,80 to 3,3 Nb + Ta: 4,7 to 5,5 Ti: 0,60 to 1,20 B: 0,002 to 0,006
NiCr20TiAl	4952–070–80-I	0,04 to 0,10	1,00	1,00	0,020	0,015	18,0 to 21,0	≥65,0	—	Al: 1,00 to 1,80 Co: 1,00, Cu:0,20 Fe: 1,50 Ti: 1,80 to 2,70 B: 0,008

Elements not quoted in this table shall not be intentionally added to the steel without the agreement of the purchaser, except for finishing the cast. All appropriate precautions shall be taken to avoid the addition of such elements from scrap or other materials used in production, which would impair mechanical properties and the suitability of the steel.

[a] Maximum values unless otherwise indicated.

[b] The stabilization may be by use of titanium and/or niobium and/or zirconium. According to the atomic mass of these elements and the content of carbon and nitrogen, the equivalence shall be the following: Nb (% by mass) = Zr (% by mass) = 7/4 Ti (% by mass).

[c] Tantalum determined as niobium.

[d] By agreement at the time of enquiry and order, this grade can also be delivered with Ti: 6 x C to 0,75.

[e] Patented grades.

Table 3 — Permissible deviations between the product analysis and the limiting values given in Table 2 for the cast analysis

Element	Specified limits, cast analysis % by mass		Permissible deviation[a] % by mass
Carbon		≤0,030	+0,005
	>0,030	≤0,20	±0,01
	>0,20	≤0,60	±0,02
Silicon		≤1,00	±0,05
	>1,00	≤3,00	±0,10
Manganese		≤1,00	±0,03
	>1,00	≤2,00	±0,04
	>2,00	≤15,0	±0,10
Phosphorus		≤0,045	+0,005
Sulfur		≤0,015	+0,003
	>0,015	≤0,030	±0,005
Chromium		≤15,0	±0,15
	>15,0	≤20,0	±0,20
	>20,0	≤35,0	±0,25
Nickel		≤1,00	±0,03
	>1,00	≤5,0	±0,07
	>5,0	≤10,0	±0,10
	>10,0	≤20,0	±0,15
	>20,0	≤38,0	±0,20
	>38,0		±0,50
Nitrogen		≤0,10	+ 0,01
	≥0,10	≤0,60	±0,02
Aluminium		≤0,30	±0,05
	>0,30	≤2,00	±0,10
Boron		≤0,010	±0,000 5
Cerium		≤0,08	±0,01
Cobalt		≤2,00	±0,10
Copper		≤1,00	+0,04
	>1,00	≤5,0	±0,10
Molybdenum		≤ 0,60	±0,03
	>0,60	≤1,75	±0,05
	>1,75	≤3,50	±0,10
Niobium		≤1,50	+0,05
Titanium		≤1,00	+0,05
	>1,00	≤3,0	±0,07
Tungsten		≤4,0	±0,07
Vanadium		≤0,85	±0,03

[a] ± means that in one cast, the deviation may occur over the upper value or under the lower value of the specified range in Table 2, but not both at the same time.

Table 4 — Type of process route and surface finish of heat-resistant flat steel products[a]

	Abbreviation[b]	Type of process route	Surface finish	Notes
Hot rolled	1U	Hot rolled, not heat-treated, not descaled	Covered with the rolling scale	Suitable for products which are to be further worked, e.g. strip for rerolling.
	1C	Hot rolled, heat-treated, not descaled	Covered with the rolling scale	Suitable for parts which will be descaled or machined in subsequent production or for certain heat-resistant applications.
	1E	Hot rolled, heat-treated, mechanically descaled	Free of scale	The type of mechanical descaling, e.g. coarse grinding or shot blasting, depends on the steel grade and the product, and is left to the manufacturer's discretion, unless otherwise agreed upon.
	1D	Hot rolled, heat-treated, pickled	Free of scale	Usually standard for most steel types to ensure good corrosion resistance; also common finish for further processing. It is permissible for grinding marks to be present. Not as smooth as 2D or 2B.
Cold rolled	2C	Cold rolled, heat-treated, not descaled	Smooth with scale from heat treatment	Suitable for parts which will be descaled or machined in subsequent production or for certain heat-resistant applications.
	2E	Cold rolled, heat-treated, mechanically descaled	Free of scale, see footnote f.	Usually applied to steels with scale that is very resistant to pickling solutions. May be followed by pickling.
	2D	Cold rolled, heat-treated, pickled	Smooth	Finish for good ductility, but not as smooth as 2B or 2R.
	2B	Cold rolled, heat-treated, pickled, skin passed	Smoother than 2D	Most common finish for most steel types to ensure good corrosion resistance, smoothness and flatness. Also common finish for further processing. Tension levelling may be used as an alternative to skin passing.
	2A	Cold rolled, heat-treated, bright-pickled, skin passed	Smoother and more reflective than 2B	Typical finish for ferritic grades when high reflectivity is desired.
	2R	Cold rolled, bright annealed[c]	Smooth, bright, reflective	Smoother and brighter than 2B. Also common finish for further processing.
Special finishes	1G or 2G	Ground[d]	See footnote e.	Grade of grit or surface roughness can be specified. Undirectional texture, not very reflective.

[a] Not all process routes and surface finishes are available for all steels.

[b] First digit, 1 = hot rolled, 2 = cold rolled.

[c] May be skin passed.

[d] One surface only, unless specifically agreed upon at the time of enquiry and order.

[e] Within each finish description, the surface characteristics can vary, and more specific requirements may need to be agreed upon between manufacturer and purchaser (e.g. grade of grit or surface roughness).

[f] Different methods of mechanical descaling can be used. Shot blasting will result in a rough and dull surface while brushing can result in a smooth surface.

Table 5 — Type of process route and surface finish of heat-resistant long steel products[a]

Condition	Abbreviation[b]	Type of process route	Surface finish	Product form				Notes
				Rods	Bars, sections	Semi-finished	Forgings	
Hot formed	1U	Hot formed, not heat-treated, not descaled	Covered with scale (spot ground if necessary)	X	X	X	—	Suitable for products to be further hot formed. For semi-finished products, ground on all sides can be specified
	1C	Hot formed, heat-treated,[c] not descaled	Covered with scale (spot ground if necessary)	X	X	X	X	Suitable for products to be further processed. For semi-finished products, ground on all sides can be specified
	1E	Hot formed, heat-treated,[c] mechanically descaled	Largely free of scale (but some black spots may remain)	X	X	X	X	The type of mechanical descaling, e.g. grinding, peeling or shot blasting, is left to the manufacturer's discretion unless otherwise agreed. Suitable for products to be further processed
	1D	Hot formed, heat-treated,[c] pickled	Free of scale	X	X	—	X	Tolerance ≥ IT 14[d,e]
	1X	Hot formed, heat-treated,[c] rough machined	Metallically clean	—	X	—	X	Tolerance ≥ IT 12[d,e]
Special finishing process	1G	Centreless ground	Uniform finish. Type and degree of grinding to be agreed	—	X	—	—	Surface roughness can be specified. Finish for close ISO-tolerances. Normally obtained from material in finishes 1E, 1D, 2H or 2B. Tolerance ≤ IT 8[d,e]
	1P	Polished	Smoother and brighter than finish 1G or 2G. Type and degree of polishing to be agreed	—	X	—	—	Surface roughness can be specified. Finish for close ISO-tolerances. Normally obtained from material in finishes 1E, 1D, 2B, 1G or 2H. Tolerance ≤ IT 11[d,e]

[a] Not all process routes and surface finishes are available for all steels.

[b] First digit, 1 = hot formed, 2 = cold processed.

[c] On ferritic and austenitic grades, the heat treatment may be omitted if the conditions for hot forming and subsequent cooling are such that the requirements for the mechanical properties of the product are obtained.

[d] For information: IT = international tolerance, as defined in ISO 286-1, and in other dimensional tolerance standards.

[e] Specific tolerance within the ranges shall be agreed upon at the time of enquiry and order.

Table 6 — Mechanical properties for flat products in the usual delivery condition

Designation		Thickness[a]	Heat treatment[b]	Hardness[c,d]	Proof strength		Tensile strength	Elongation after fracture[e]		
Name	ISO-number	t		*HBW*	$R_{p0,2}$	$R_{p1,0}$	R_m	A_{80}	A	
		flat products mm			MPa[f]		MPa[f]	$0,5 \le t < 3$ %	$3 \le t$ %	
		max.		max.	min.			min.	min.	
								(lg. + tr.)	lg.	tr.
Austenitic steels for heat resistant applications										
X6CrNiSiNCe19–10	4818–304–15–E	$0,5 \le t \le 75$	+AT	210	290	330	600 to 800	30	40	40
X15CrNiSi20–12	4828–305–09–I	$0,5 \le t \le 75$	+AT	223	230	270	550 to 750	28	30	30
X7CrNiSiNCe21–11	4835–308–15–U	$0,5 \le t \le 75$	+AT	210	310	345	650 to 850	37	40	40
X18CrNi23–13	4833–309–08–I	$0,5 \le t \le 75$	+AT	192	210	250	500 to 700	33	35	35
X8CrNi25–21	4845–310–08–E	$0,5 \le t \le 75$	+AT	192	210	250	500 to 700	33	35	35
X15CrNiSi25–21	4841–314–00–E	$0,5 \le t \le 75$	+AT	223	230	270	550 to 750	28	30	30
X8NiCrAlTi32–21	4876–088–00–I	$0,5 \le t \le 75$	+AT	192	170	210	450 to 680	28	30	30
X6NiCrSiNCe35–25	4854–353–15–E	$0,5 \le t \le 75$	+AT	210	300	340	650 to 850	40	40	40
Austenitic steels for creep resistant applications										
X10CrNiMoMnNbV B15–10–1	4982–215–00–E	—	—	—	—	—	—	—	—	—
X7CrNi18–9	4948–304–09–I	$0,5 \le t \le 75$	+AT	192	195	230	500 to 700	37	40	40
X7CrNiTi18–10	4940–321–09–I	$0,5 \le t \le 75$	+AT	215	190	230	500 to 720	40	40	40
X7CrNiNb18–10	4912–347–09–I	$0,5 \le t \le 75$	+AT	192	205	240	510 to 710	28	30	30
X8CrNiNb16–13	4961–347–77–E	$0,5 \le t \le 75$	+AT	—	200	240	500 to 750	30	30	35
X6CrNiMo17–13–2	4918–316–09–E	—	—	—	—	—	—	—	—	—
X7NiCrWCuCoNbN B25–23–3–3–3–2	4990–310–35–U	—	—	—	—	—	—	—	—	—
Ferritic steels for heat resistant applications										
X10CrAlSi7	4713–503–72–E	$0,5 \le t \le 12$	+A	192	220	—	420 to 620	—	20	15
X2CrTi12	4512–409–10–I	$0,5 \le t \le 12$	+A	—	210	—	380 to 560	25	25	25
X6Cr13	4000–410–08–I	$0,5 \le t \le 12$	+A	197	230	—	400 to 630	18	20	18
X10CrAlSi13	4724–405–77–I	$0,5 \le t \le 12$	+A	192	250	—	450 to 650	13	15	15
X6Cr17	4016–430–00–I	$0,5 \le t \le 12$	+A	197	250	—	430 to 630	18	20	18
X3CrTi17	4510–430–35–I	$0,5 \le t \le 12$	+A	—	230	—	420 to 600	23	23	23
X2CrTiNb18	4509–439–40–X	$0,5 \le t \le 12$	+A	—	230	—	430 to 630	18	18	18
X2CrMoTi18–2	4521–444–00–I	$0,5 \le t \le 12$	+A	—	280	300	420 to 620	20	20	20
X10CrAlSi18	4742–430–77–I	$0,5 \le t \le 12$	+A	212	270	—	500 to 700	13	15	15
X10CrAlSi25	4762–445–72–I	$0,5 \le t \le 12$	+A	223	280	—	520 to 720	13	15	15
X15CrN26	4749–446–00–I	$0,5 \le t \le 12$	+A	212	280	—	500 to 700	13	15	15
Martensitic steels for creep resistant applications										
X18CrMnMoNbV N12	4916–600–77–J	$0,5 \le t \le 75$	—	—	—	—	—	—	—	
X22CrMoV12–1	4923–422–77–E	$0,5 \le t \le 75$	+QT	—	600	—	800 to 950	—	14	
Precipitation hardening grades for creep resistant applications										

[a] For other thicknesses, the mechanical properties shall be negotiated.

[b] +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened (see also Table B.1).

[c] For guidance only.

[d] For thin materials, the *HRB* or *HV* hardness test may be used, by agreement between purchaser and manufacturer, where it is not practicable to use the *HBW* test.

[e] In the case of ferritic and austenitic steels, the values for flat products having a thickness $t \ge 3$ mm are valid for a gauge length of $L_0 = 5,65\sqrt{S_0}$; for flat products of thickness with $0,5 \le t < 3$ mm, the values are valid for both test pieces specified in ISO 6892-1.

[f] 1 MPa = 1 N/mm^2.

Table 6 *(continued)*

Designation		Thickness[a]	Heat treatment[b]	Hardness[c,d]	Proof strength		Tensile strength	Elongation after fracture[e]	
Name	ISO-number	t		*HBW*	$R_{p0,2}$	$R_{p1,0}$	R_m	A_{80}	A
		flat products mm			MPa[f]		MPa[f]	$0,5 \le t < 3$ %	$3 \le t$ %
		max.		max.	min.			min.	min.
								(lg. + tr.)	lg. tr.
X6NiCrTiMoV B25–15–2	4980–662–86-X	$0,5 \le t \le 75$	+P	—	590	—	900 to 1 150	—	15
NiCr19Fe19Nb5 Mo3	4668–077–18-I	$0,5 \le t \le 20$	+P	—	1 030	—	≥1 230	—	12
NiCr20TiAl	4952–070–80-I	$0,5 \le t \le 20$	+P	—	600	—	≥1 000	—	18

[a] For other thicknesses, the mechanical properties shall be negotiated.

[b] +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened (see also Table B.1).

[c] For guidance only.

[d] For thin materials, the *HRB* or *HV* hardness test may be used, by agreement between purchaser and manufacturer, where it is not practicable to use the *HBW* test.

[e] In the case of ferritic and austenitic steels, the values for flat products having a thickness $t \ge 3$ mm are valid for a gauge length of $L_0 = 5,65\sqrt{S_0}$; for flat products of thickness with $0,5 \le t < 3$ mm, the values are valid for both test pieces specified in ISO 6892-1.

[f] 1 MPa = 1 N/mm^2.

Table 7 — Mechanical properties for long products in the usual delivery condition

Designation		Thickness[a] product form			Heat treatment[b]	Hardness[c,d,e,f]	Proof strength[f]		Tensile strength[e]	Elongation after fracture[g]
Name	ISO-number	Bars	Rods and sections	forgings		*HBW*	$R_{p0,2}$	$R_{p1,0}$		*A*
		d	*d*	*d*						
		mm max.	mm max.	mm max.		max.	MPa min.	MPa min.	MPa	% min.
Austenitic steels for heat resistant applications										
X6CrNiSiNCe19–10	4818–304–15-E	5 ≤ *d* ≤ 160	1,5 ≤ *d* ≤ 25	*d* ≤ 100	+AT	210	290	330	600 to 800	40[e]
X15CrNiSi20–12	4828–305–09-I				+AT	223	230	270	550 to 750	30[e]
X7CrNiSiNCe21–11	4835–308–15-U				+AT	210	310	345	650 to 850	40[e]
X18CrNi23–13	4833–309–08-I				+AT	192	210	250	500 to 700	35[e]
X8CrNi25–21	4845–310–08-E				+AT	192	210	250	500 to 700	35[e]
X15CrNiSi25–21	4841–314–00-E				+AT	223	230	270	550 to 750	30[e]
X8NiCrAlTi32–21	4876–088–00-I				+AT	192	170	210	450 to 680	30[e]
X6NiCrSiNCe35–25	4854–353–15-E				+AT	210	300	340	650 to 850	40[e]
Austenitic steels steels for creep resistant applications										
X10CrNiMoMnNbVB15–10–1	4982–215–00-E	5 ≤ *d* ≤ 100	—	—	+AT	—	510	—	650 to 850	25
X7CrNi18–9	4948–304–09-I	5 ≤ *d* ≤ 160	1,5 ≤ *d* ≤ 25	*d* ≤ 100	+AT	192	195	230	500 to 700	40
X7CrNiTi18–10	4940–321–09-I				+AT	215	190	230	500 to 720	40
X7CrNiNb18–10	4912–347–09-I				+AT	192	205	240	510 to 710	30
X8CrNiNb16–13	4961–347–77-E	5 ≤ *d* ≤ 100	—	—	+AT	—	205	245	510 to 690	30
X6CrNiMo17–13–2	4918–316–09-E	5 ≤ *d* ≤ 160	1,5 ≤ *d* ≤ 25	*d* ≤ 100	+AT	—	205	245	490 to 690	30
X7NiCrWCuCoNbNB25–23–3-3–3-2	4990–310–35-U	—	3,0 ≤ *d* ≤ 14	—	+AT	185	310	355	650 to 850	35

a For other dimensions, the mechanical properties shall be negotiated.

b +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened (see also Table A.1).

c For guidance only.

d For thin materials, the HRB or HV hardness test may be used, by agreement between user and manufacturer, where it is not practicable to use the HBW test.

e The maximum HBW values may be raised by 100 units or the maximum tensile strength value may be raised by 200 MPa and the minimum elongation value be lowered to 20 % for sections and bars of ≤35 mm thickness having a final cold deformation.

f For rods, only the tensile strength values apply.

g For diameters of ≥3 mm, the values are valid for a gauge length of $L_0 = 5{,}65\sqrt{S_0}$.

Table 7 *(continued)*

Designation		Thickness[a] product form			Heat treatment[b]	Hardness[c,d,e,f]	Proof strength[f]		Tensile strength[e]	Elongation after fracture[g]
Name	ISO-number	Bars *d* mm max.	Rods and sections *d* mm max.	forgings *d* mm max.		*HBW* max.	$R_{p0,2}$ MPa min.	$R_{p1,0}$ MPa min.	MPa	*A* % min.
Ferritic steels for heat resistant applications										
X10CrAlSi7	4713–503–72-E	$5 \le d \le 25$	$1,5 \le d \le 25$	$5 \le d \le 15$	+A	192	220	—	420 to 620	20
X2CrTi12	4512–409–10-I				+A	—	210	—	380 to 560	—
X6Cr13	4000–410–08-I				+A	197	230	—	400 to 630	20
X10CrAlSi13	4724–405–77-I				+A	192	250	—	450 to 650	15
X6Cr17	4016–430–00-I				+A	197	250	—	430 to 630	20
X3CrTi17	4510–430–35-I				+A	—	230	—	420 to 600	—
X2CrTiNb18	4509–439–40-X				+A	—	230	—	430 to 630	18
X2CrMoTi18–2	4521–444–00-I				+A	—	280	—	420 to 620	20
X10CrAlSi18	4742–430–77-I				+A	212	270	—	500 to 700	15
X10CrAlSi25	4762–445–72-I				+A	223	280	—	520 to 720	10
X15CrN26	4749–446–00-I				+A	212	280	—	500 to 700	15
Martensitic steels for creep resistant applications										
X18CrMnMoNbVN12	4916–600–77-J	$5 \le d \le 160$	—	—	-+QT	—	685	—	≥830	12
X22CrMoV12–1	4923–422–77-E	$5 \le d \le 160$	—	—	+QT	—	600	—	800 to 950	14
Precipitation hardening grades for creep resistant applications										
X6NiCrTiMoVB25–15–2	4980–662–86-X	$5 \le d \le 160$	—	—	+P	—	590	—	900 to 1 150	15
NiCr19Fe19Nb5Mo3	4668–077–18-I	$5 \le d \le 160$	—	—	+P	—	1 030	—	≥1 230	12
NiCr20TiAl	4952–070–80-I	$5 \le d \le 160$	—	—	+P	—	600	—	≥1 000	18

[a] For other dimensions, the mechanical properties shall be negotiated.

[b] +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened (see also Table A.1).

[c] For guidance only.

[d] For thin materials, the HRB or HV hardness test may be used, by agreement between user and manufacturer, where it is not practicable to use the HBW test.

[e] The maximum HBW values may be raised by 100 units or the maximum tensile strength value may be raised by 200 MPa and the minimum elongation value be lowered to 20 % for sections and bars of ≤35 mm thickness having a final cold deformation.

[f] For rods, only the tensile strength values apply.

[g] For diameters of ≥3 mm, the values are valid for a gauge length of $L_0 = 5,65\sqrt{S_0}$.

Table 8 — Minimum 0,2 %-proof strength values at elevated temperatures in the usual delivery condition

Designation		Heat treatment[a]	Minimum 0,2 %-proof strength, MPa at a temperature (in °C) of															
Name	Number		50	100	150	200	250	300	350	400	450	500	550	600	650	700	750 800	850 900
Austenitic steels for creep resistant applications																		
X8CrNiNb16–13	4961–347–77-E	+AT	197	175	166	157	147	137	132	128	123	118	118	113	—	—	—	—
X7NiCrWCuCoNbN 25–23–3-3–2	4990–310–35-U	+AT	285	250	235	225	215	210	205	200	197	195	185	180	180	180	180	—
Ferritic steels for heat resistant applications																		
X2CrTi12	4512–409–10-I	+A	—	200	195	190	185	180	160	—	—	—	—	—	—	—	—	—
X6Cr13	4000–410–08-I	+A	—	220	215	210	205	200	195	190	—	—	—	—	—	—	—	—
X6Cr17	4016–430–00-I	+A	—	220	215	210	206	200	195	190	—	—	—	—	—	—	—	—
X3CrTi17	4510–430–35-I	+A	—	195	190	185	175	165	155	—	—	—	—	—	—	—	—	—
X2CrTiNb18	4509–439–40-X	+A	—	230	220	210	205	200	180	—	—	—	—	—	—	—	—	—
X2CrMoTi18–2	4521–444–00-I	+A	—	250	240	230	220	210	205	200	—	—	—	—	—	—	—	—
Martensitic steels for creep resistant applications																		
X18CrMnMoNbV N12	4916–600–77-J	+QT	726[b]	701	676	651	643	627	610	577	544	495	412	305	—	—	—	—
X22CrMoV12–1	4923–422–77-E	+QT	585[b]	560	545[b]	530	505[b]	480	450[b]	420	380	335	280	—	—	—	—	—
Precipitation hardening grades for creep resistant applications																		
X6NiCrTiMoV B25–15–2	4980–662–86-X	+P	592[b]	580	570	560	550	530	520	510	500	490	460	430	380	295	200 —	— —
NiCr19Fe19Nb5 Mo3	4668–077–18-I	+P	—	—	—	—	—	880	—	865		860	—	860	—	800	— 615	— —
NiCr20TiAl	4952–070–80-I	+P	595[b]	586[b]	577[b]	568	564	560	550	540	530	520	510	500	480	—	—	—

[a] +AT = solution annealed; +A = soft annealed; +QT = quenched and tempered; +*P* = precipitation hardened.

[b] Values calculated by linear interpolation.

Table 9 — Tests to be carried out, test units and extent of testing in specific testing for heat resistant flat steel products

Test	[a]	Test unit	Product form			Number of test pieces per test sample
			Strip, sheet and cut length cut from strip in rolling width		Rolled plate (P)	
			<600 mm	≥600 mm		
Chemical analysis	m	Cast	The cast analysis is given by the manufacturer[b]			
Tensile test at room temperature	m	same cast, same nominal thickness ±10 %, same final treatment condition (i.e. same heat treatment and/or same degree of cold deformation)	The extent of testing shall be agreed at the time of ordering.	One test sample from each coil	a) Plates processed under identical conditions may be collected into a batch with a maximum total weight of 30 000 kg comprising no more than 40 plates. One test sample per batch shall be taken from heat-treated plates up to 15 m in length. One test sample shall be taken from each end of the longest plate in the batch where heat-treated plates are longer than 15 m. b) If the plate cannot be tested in batches, one test sample shall be taken from one end from heat-treated plates up to 15 m long and one test sample shall be taken from each end of heat-treated plates longer than 15 m.	1

[a] Tests marked with a "m" (mandatory) shall be carried out as specific tests. In all cases optional tests shall be carried out as specific tests only if agreed at the time of ordering.

[b] A product analysis may be agreed at the time of ordering; the extent of testing shall be specified at the same time.

Table 10 — Tests to be carried out, test units and extent of testing in specific testing for heat resistant long steel products

Test	[a]	Test unit	Product form Rods, bars and sections	Number of test pieces per sample
Chemical analysis	m	Cast	The cast analysis is given by the manufacturer.[b]	—
Tensile test at room temperature	m	Batch[c]	One sample per 25 t; maximum of two per test unit.	1

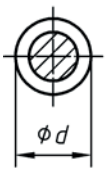
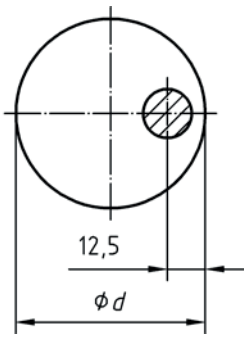
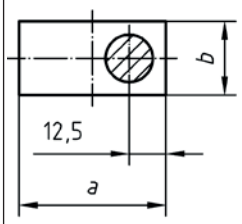
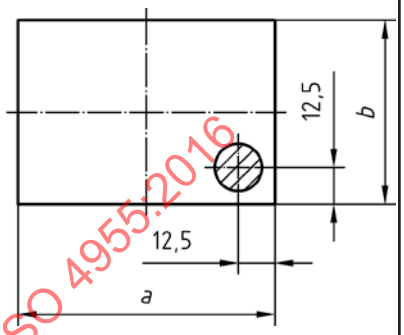
[a] Tests marked with an "m" (mandatory) shall be carried out as specific tests. In all cases, optional tests shall be carried out as specific tests only if agreed at the time of ordering.

[b] A product analysis may be agreed at the time of ordering; the extent of testing shall be specified at the same time.

[c] Each batch consists of products coming from the same cast. The products must have been subject to the same heat treatment cycle in the same furnace. In the case of a continuous furnace, or in process annealing, a batch is the lot heat-treated without intermission with the same process parameters.

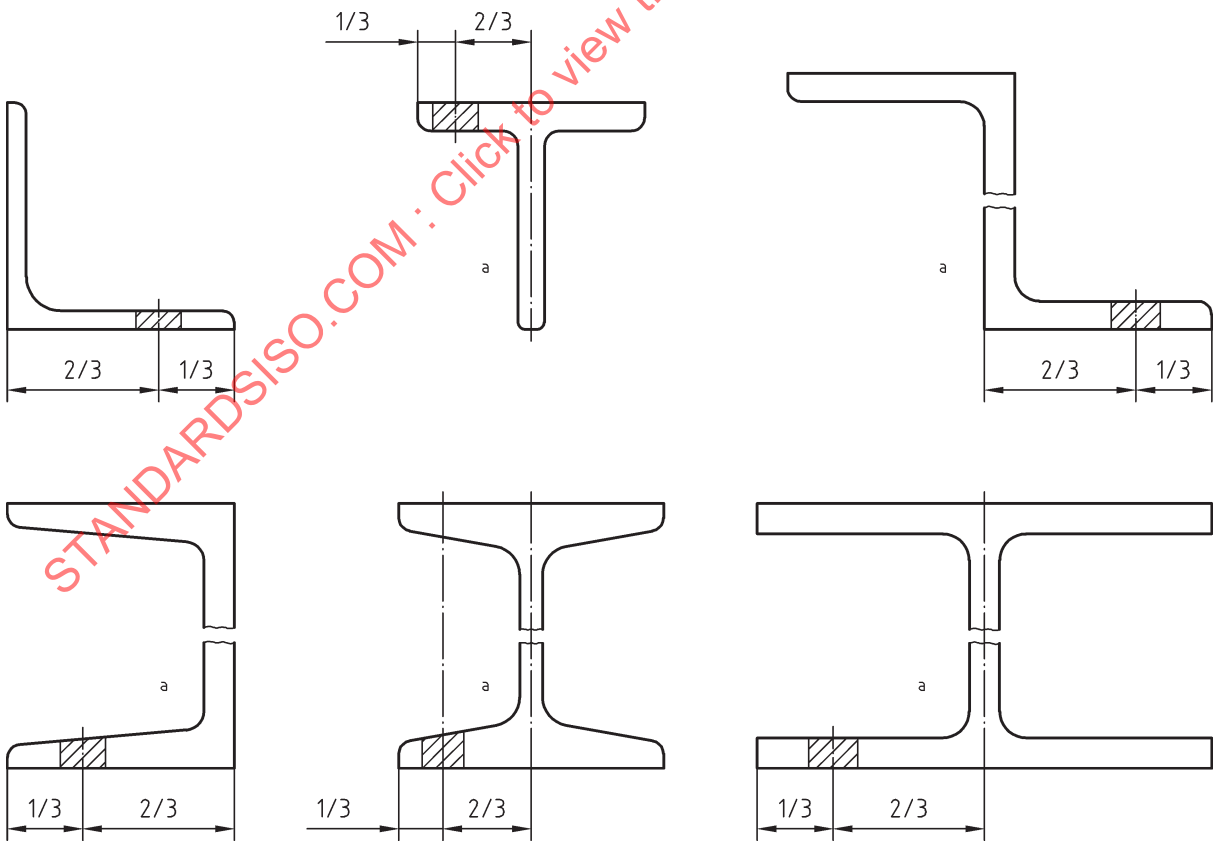
The shape and size of cross sections of products in a single batch may be different providing that the ratio of the largest to the smallest areas shall be equal to or less than three.

Dimensions in millimetres

Type of test	Round cross-section products		Rectangular cross-section products	
Tensile	$d \leq 25$ [a]	$25 < d \leq 160$	$b \leq 25$ $a \geq b$	$25 < b \leq 160$ $a \geq b$
				

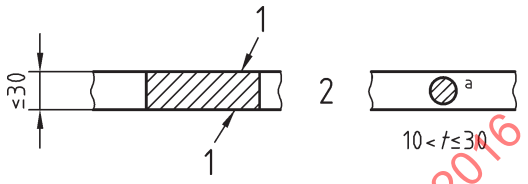
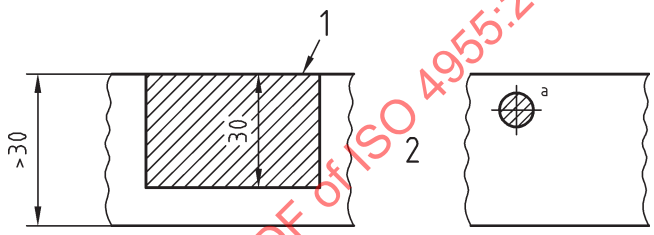
[a] Samples of product may alternatively be tested unmachined.

Figure 1 — Location of test pieces for steel bars, rods and wire ≤160 mm diameter or thickness (longitudinal test pieces)



[a] By agreement, the sample can be taken from the web, at a quarter of the total height.

Figure 2 — Location of test pieces for beams, channels, angles, T-sections and Z-sections

Type of test piece	Product thickness	Direction of the longitudinal axis of the test piece in relation to the principal direction of rolling at a product width of:		Distance of the test piece from the rolled surface
	mm	<300 mm	≥300 mm	mm
Tensile[a]	≤30	Longitudinal	Transverse	
	>30			

Key

1 rolled surface

2 flat or round test piece may be used

For products <3 mm thickness, non-proportional test pieces with a gauge length of 80 mm and a width of 20 mm shall be used, but test pieces with a gauge length of 50 mm and a width of 12,5 mm may also be applied. For products with a thickness of 3 mm to 10 mm, flat proportional test pieces with two rolled surfaces and a maximum width of 30 mm shall be used. For products with thickness >10 mm, one of the following proportional test pieces may be used:

— either a flat test piece with a maximum thickness of 30 mm; the thickness may be reduced to 10 mm by machining, but one rolled surface must be preserved;

— or a round test piece with a diameter of ≥5 mm the axis of which shall be located as near as possible to a plane in the outer third of half the product thickness.

a In case of doubt or dispute the gauge length shall be $L_0 = 5{,}65\sqrt{S_0}$ for test pieces from products ≥3 mm.

Figure 3 — Location of test pieces in sheet, strip or plate

Annex A
(informative)

Technical information on heat- and creep-resistant steels

A.1 General

The property values contained in the preceding specification are delivery requirements. The property values indicated in this Annex are not delivery requirements. The data given in this Annex are provided only as a guide for the heat treatment and for the relative performance of the different steels. Users should ensure themselves of the actual properties achieved in practice.

A.2 Groups of heat- and creep resistant steels

Several groups of material may be distinguished as follows:

— heat-resistant austenitic steels;

— heat resistant ferritic steels;

— tempered martensitic creep-resistant chromium steels with 8 % to 12 % Cr and special carbide- and nitride-formers suitable for service temperatures up to 600 °C (650 °C).

As the austenitic structure is basic for high temperature creep resistance above 550 °C to 600 °C reference is given to the following:

— solution-annealed steels and nickel- or cobalt-alloys, strengthened by solid-solution hardening, occasionally stress relieved (800 °C to 950 °C),

— thermomechanically worked, and

— precipitation-hardened austenitic steels and alloys containing Al plus Ti to form γ'- phase, i.e. face-centred cubic Ni_3 (Al, Ti), and partially alloyed with Nb which forms γ"-phase, also known as body-centred tetragonal Ni_3Nb.

The strongest alloys are the so-called superalloys. They require special metallurgical practices, e.g. vacuum induction melting and consumable remelting, primarily in order to obtain microstructural cleanliness and to avoid or minimize segregations.

A.3 Heat treatment

For information on heat-treatment, see Table A.1.

A.4 Heat resistance

The heat resistant steels given in Table 2 have, by virtue of their alloy content, an increased resistance to attack by hot gases and combustion products. This resistance and, consequently, the maximum service temperature of the materials is, however, largely dependent on the conditions of attack. For use in clean air under conditions where the mechanical stresses (see Table A.2) are unimportant with regard to service life, the maximum service temperature indicated in Table A.2 can be taken as a guide.

A warning is given that where a heat resistant steel is to be used in atmospheres other than clean air, then the values in Table A.2 should not be taken as applicable for the maximum temperature of use. In such cases, the rate of oxidation of the steels can be significantly increased, depending on their chemical

composition, so that as a consequence, the maximum temperature of use can be considerably reduced and could be, for example, several hundred degrees lower than the temperatures in Table A.2.

A.5 Creep resistance

The creep resistant steels and alloys given in Table 2 contain sufficient chromium for resistance to oxidation and hot corrosion at elevated temperature; otherwise, the surface must be shielded. In general, steels and alloys may be used up to the highest temperature indicated in Table B.1.

In Table B.1, the mean creep strength to 1 % plastic strain ($R_{p1,0/t/T}$) and creep rupture strength ($R_{u/t/T}$) after durations of 1 000 h, 10 000 h and 100 000 h are given for guidance only. These strength values in relation to time are the main limiting factors during operation at high temperatures, provided the environment is sufficiently mild regarding corrosivity. In addition, the interactions between total stressing and oxidation behaviour may be taken into account. The maximum service temperature of the materials is, however, largely dependent on the conditions of exposure.

A.6 Physical properties

In Tables A.3 and A.4, the physical properties of the steels are given for guidance.

A.7 Technological properties

A.7.1 The steels are suitable for hot working. The optimum hot-working conditions shall, where necessary, be requested from the manufacturer.

A.7.2 The steels are suitable for cold forming. It is, however, recommended that ferritic steels be annealed before working. Furthermore, the marked tendency of austenitic steels to work-harden should be noted.

A.7.3 The steels may generally be welded by the usual welding processes. It is, however, recommended that users who have not had experience in welding these materials should consult the manufacturer regarding appropriate welding conditions. Additionally, the tendency of ferritic steels to grain growth when being welded should be taken into account.

A.7.4 The long-time properties of steels and alloys may be adversely affected by cold-forming and welding. Therefore, customers should ask for appropriate advice concerning fabrication.

Table A.1 — Heat treatment (for guidance only)

Designation		Heat treatment			
Name	ISO number	Symbol[a]	Temperature[b] °C	Cooling[c]	Tempering or precipitation treatment temperature (and time) °C
Austenitic steels for heat resistant applications					
X6CrNiSiNCe19–10	4818–304–15–E	+AT	1 070 ± 50	w, a[e]	—
X15CrNiSi20–12	4828–305–09–I	+AT	1 100 ± 50	w, (a)	—
X7CrNiSiNCe21–11	4835–308–15–U	+AT	1 070 ± 50	w, a	—
X18CrNi23–13	4833–309–08–I	+AT	1 100 ± 50	w, a[e]	—
X8CrNi25–21	4845–310–08–E	+AT	1 100 ± 50	w, a[e]	—
X15CrNiSi25–21	4841–314–00–E	+AT	1 100 ± 50	w, a[e]	—
X8NiCrAlTi32–21	4876–088–00–I	+AT	1 150 ± 50[f]	w, a	—
X6NiCrSiNCe35–25	4854–353–15–E	+AT	1 125 ± 25	w, a[e]	—
Austenitic steels for creep resistant applications					
X10CrNiMoMnNbV B15–10–1	4982–215–00–E	+AT	1 050 ± 50	—	—
X7CrNi18–9	4948–304–09–I	+AT	1 050 ± 50	w, a[e]	—
X7CrNiTi18–10	4940–321–09–I	+AT	1 070 ± 50	w, a[e]	—
X7CrNiNb18–10	4912–347–09–I	+AT	1 070 ± 50	w, a[e]	—
X8CrNiNb16–13	4961–347–77–E	+AT	1 100 ± 50	w, a[e]	—
X6CrNiMo17–13–2	4918–316–09–E	+AT	—	—	—
X7NiCrWCuCoNbN B25–23–3–3–3–2	4990–310–35–U	+AT	1 215 ± 35	w, a[e]	—

[a] +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened.

[b] In the case where the heat treatment is performed in a continuous furnace, the upper part of the given temperature range, or even a temperature in excess of it, is normally preferred.

[c] a = air; f = furnace; w = water; o = oil.

[d] In special cases, furnace cooling is also permitted.

[e] Cooling sufficiently rapid.

[f] A grain size of 0 to 5 after heat treatment is recommended.

[g] Recommended time.

Table A.1 *(continued)*

Designation		Heat treatment			
Name	ISO number	Symbol[a]	Temperature[b] °C	Cooling[c]	Tempering or precipitation treatment temperature (and time) °C
Ferritic steels for heat resistant applications					
X10CrAlSi7	4713–503–72-E	+A	810 ± 30	a, (w)[d]	—
X2CrTi12	4512–409–10-I	+A	800 ± 30	a, w	—
X6Cr13	4000–410–08-I	+A	775 ± 25	a[f]	—
X10CrAlSi13	4724–405–77-I	+A	825 ± 25	a, (w)[d]	—
X6Cr17	4016–430–00-I	+A	800 ± 50	a, w[f]	—
X3CrTi17	4510–430–35-I	+A	800 ± 30	a, w	—
X2CrTiNb18	4509–439–40-X	+A	900 ± 25	a, w	—
X2CrMoTi18–2	4521–444–00-I	+A	900 ± 100	a, w	—
X10CrAlSi18	4742–430–77-I	+A	825 ± 25	a, (w)[d]	—
X10CrAlSi25	4762–445–72-I	+A	825 ± 25	a, (w)[d]	—
X15CrN26	4749–446–00-I	+A	825 ± 25	a, (w)[d]	—
Martensitic steels for creep resistant applications					
X18CrMnMoNbVN12	4916–600–77-J	+QT	1 115 ± 15	a, o	670 to 720 (min 2 h)
X22CrMoV12–1	4923–422–77-E	+QT	1 045 ± 25	a, o	680 to 740 (min 2 h)
Precipitation hardening grades for creep resistant applications					
X6NiCrTiMoVB25–15–2	4980–662–86-X	+P	980 ± 10	a, w	710 to 730 (16 h)[g]
NiCr19Fe19Nb5Mo3	4668–077–18-I	+P	980 ± 30	a[e]	710 to 730 for 8 h[g] furnace cooling down to 610 to 630, hold at 610 to 630. Total treatment time min. 18 h[g]
NiCr20TiAl	4952–070–80-I	+P	1 065 ± 15	a	840 to 860 for 24 h[g], air cool + 690 to 710 for 16 h[g], air cool

[a] +A = annealed; +AT = solution annealed; +QT quenched and tempered; +P precipitation hardened.

[b] In the case where the heat treatment is performed in a continuous furnace, the upper part of the given temperature range, or even a temperature in excess of it, is normally preferred.

[c] a = air; f = furnace; w = water; o = oil.

[d] In special cases, furnace cooling is also permitted.

[e] Cooling sufficiently rapid.

[f] A grain size of 0 to 5 after heat treatment is recommended.

[g] Recommended time.

Table A.2 — Maximum application temperature T_a for air (for guidance only)

Designation		T_a max. °C
Name	ISO-number	
Austenitic steels for heat resistant applications		
X6CrNiSiNCe19–10	4818–304–15-E	1 050
X15CrNiSi20–12	4828–305–09-I	1 000
X7CrNiSiNCe21–11	4835–308–15-U	1 150
X18CrNi23–13	4833–309–08-I	1 000
X8CrNi25–21	4845–310–08-E	1 050
X15CrNiSi25–21	4841–314–00-E	1 150
X8NiCrAlTi32–21	4876–088–00-I	1 100
X6NiCrSiNCe35–25	4854–353–15-E	1 170
Austenitic steels for creep resistant applications		
X10CrNiMoMnNbVB15–10–1	4982–215–00-E	—
X7CrNi18–9	4948–304–09-I	800
X7CrNiTi18–10	4940–321–09-I	850
X7CrNiNb18–10	4912–347–09-I	850
X8CrNiNb16–13	4961–347–77-E	—
X6CrNiMo17–13–2	4918–316–09-E	—
X7NiCrWCuCoNbNB25–23–3-3–3-2	4990–310–35-U	750
Ferritic steels for heat resistant applications		
X10CrAlSi7	4713–503–72-E	800
X2CrTi12	4512–409–10-I	650
X6Cr13	4000–410–08-I	800
X10CrAlSi13	4724–405–77-I	750
X6Cr17	4016–430–00-I	850
X3CrTi17	4510–430–35-I	900
X2CrTiNb18	4509–439–40-X	900
X2CrMoTi18–2	4521–444–00-I	1 000
X10CrAlSi18	4742–430–77-I	850
X10CrAlSi25	4762–445–72-I	1 000
X15CrN26	4749–446–00-I	1 150
Martensitic steels for creep resistant applications		
X18CrMnMoNbVN12	4916–600–77-J	—
X22CrMoV12–1	4923–422–77-E	—
Precipitation hardening grades for creep resistant applications		
X6NiCrTiMoVB25–15–2	4980–662–86-X	—
NiCr19Fe19Nb5Mo3	4668–077–18-I	—
NiCr20TiAl	4952–070–80-I	—
NOTE See A.4.		

Table A.3 — Physical properties (for guidance only)

Designation		Density kg/dm³	Linear expansion coefficient 10^{-6} K^{-1} between 20 °C and					Thermal conductivity W/(m K)		Specific heat capacity kJ/(kg K)	Resistivity Ω mm²/m	Magnetizability
Name	ISO-number		200 °C	400 °C	600 °C	800 °C	1 000 °C	at 20 °C	at 500 °C	at 20 °C	at 20 °C	
Austenitic steels for heat resistant applications												
X6CrNiSiNCe19-10	4818-304-15-E	7,8	16,5	18,0	18,5	19,0	20,0	15	21	0,50	0,85	no[a]
X15CrNiSi20-12	4828-305-09-I	7,9	16,5	17,5	18,0	18,5	19,5	15	21	0,50	0,85	no[a]
X7CrNiSiNCe21-11	4835-308-15-U	7,9	17,0	18,0	18,5	19,0	19,5	15	21	0,50	0,85	no[a]
X18CrNi23-13	4833-309-08-I	7,9	16,0	17,5	18,0	18,5	19,5	15	19	0,50	0,78	no[a]
X8CrNi25-21	4845-310-08-E	7,9	15,5	17,0	17,5	18,5	19,0	15	19	0,50	0,85	no[a]
X15CrNiSi25-21	4841-314-00-E	7,9	15,5	17,0	17,5	18,5	19,0	15	—	0,50	0,90	no[a]
X8NiCrAlTi32-21	4876-088-00-I	8,0	15,0	16,0	17,0	17,5	18,5	12	17	0,55	1,0	no[a]
X6NiCrSiNCe35-25	4854-353-15-E	7,9	15,5	16,0	17,0	17,5	18,0	11	18,5	0,45	1,0	no[a]
Austenitic steels for creep resistant applications												
X10CrNiMoMnNbVB15-10-1	4982-215-00-E	7,9	—	—	—	—	—	—	—	—	—	no[a]
X7CrNi18-9	4948-304-09-I	7,9	17,0	18,0	18,5	19,0	—	15	21	0,50	0,73	no[a]
X7CrNiTi18-10	4940-321-09-I	7,9	17,0	18,0	18,5	19,0	—	15	—	0,50	0,73	no[a]
X7CrNiNb18-10	4912-347-09-I	7,9	17,0	18,0	18,5	19,0	—	15	—	0,50	0,73	no[a]
X8CrNiNb16-13	4961-347-77-E	7,9	16,9	17,6	18,5	—	—	16	—	0,45	0,78	no[a]
X6CrNiMo17-13-2	4918-316-09-E	7,9	—	—	—	—	—	—	—	—	—	no[a]
X7NiCrWCuCoNbNB25-23-3-3-3-2	4990-310-35-U	8,1	15,5	16	16,5	17	18	12	20	0,47	0,98	no[a]
Ferritic steels for heat resistant applications												
X10CrAlSi7	4713-503-72-E	7,7	11,5	12,0	12,5	13,0	—	23	—	0,45	0,70	yes
X2CrTi12	4512-409-10-I	7,7	11,0	12,0	—	—	—	25	—	0,46	0,60	yes
X6Cr13	4000-410-08-I	7,7	11,0	11,5	12,0	12,5	—	25	28	0,50	0,60	yes
X10CrAlSi13	4724-405-77-I	7,7	10,5	11,5	12,0	12,5	—	21	23	0,50	0,75	yes
X6Cr17	4016-430-00-I	7,7	10,0	11,0	11,5	12,5	—	21	21	0,50	0,60	yes
X3CrTi17	4510-430-35-I	7,7	10,0	10,5	—	—	—	25	—	0,46	0,60	yes
X2CrTiNb18	4509-439-40-X	7,7	10,0	10,5	—	—	—	25	—	0,46	0,60	yes
X2CrMoTi18-2	4521-444-00-I	7,7	10,8	11,0	11,4	11,9	12,9	20	23	0,43	0,80	yes
X10CrAlSi18	4742-430-77-I	7,7	10,5	11,5	12,0	12,5	13,5	19	25	0,50	0,93	yes
X10CrAlSi25	4762-445-72-I	7,7	10,0	11,5	12,0	12,5	13,5	17	23	0,50	1,1	yes
X15CrN26	4749-446-00-I	7,7	10,5	11,0	11,5	12,0	13,0	17	23	0,50	0,70	yes
Martensitic steels for creep resistant applications												
X18CrMnMoN-bVN12	4916-600-77-J	7,7	11	12	12,5	—	—	24	29	0,46	—	yes
X22CrMoV12-1	4923-422-77-E	7,7	11	12	12,5	—	—	24	29	0,46	0,60	yes
Precipitation hardening grades for creep resistant applications												
X6NiCrTiMoVB25-15-2	4980-662-86-X	8,0	17,4	18	18,5	—	—	13	21	0,49	0,91	no[a]
NiCr19Fe19Nb5Mo3	4668-077-18-I	8,2	13,4	14,1	14,7	16,4	—	13	19	0,44	1,23	no[a]
NiCr20TiAl	4952-070-80-I	8,2	12,6	13,5	14,0	—	—	11,4	18,5	0,46	1,24	no[a]

[a] Slightly magnetic when cold worked.

Table A.4 — Values for the modulus of elasticity of creep resistant grades[a] (for guidance only)

Designation		Modulus of elasticity, E dyn, GPa at a temperature (in °C) of														
Name	Number	20	100	200	300	400	450	500	550	600	650	700	800	900	1 000	1 100
Austenitic steels for creep resistant applications																
X10CrNiMoMnNbVB15-10-1	4982-215-00-E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X7CrNi18-9	4948-304-09-I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X7CrNiTi18-10	4940-321-09-I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X7CrNiNb18-10	4912-347-09-I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X8CrNiNb16-13	4961-347-77-E	200	190	185	175	170	—	160	—	155	—	145	—	—	—	—
X6CrNiMo17-13-2	4918-316-09-E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
X7NiCrWCuCoNbN25-23-3-3-2	4990-310-35-U	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Martensitic steels for creep resistant applications																
X19CrMoNbVN11-1	4916-600-77-J	(216)	(209)	(200)	(190)	(179)	(175)	(167)	(157)	(127)	—	—	—	—	—	—
X22CrMoV12-1	4923-422-77-E	(216)	(209)	(200)	(190)	(179)	(175)	(167)	(157)	(127)	—	—	—	—	—	—
Precipitation hardening grades for creep resistant applications																
X6NiCrTiMoVB25-15-2	4980-662-86-X	211	206	200	192	183	—	173	—	162	152	—	—	—	—	—
NiCr19FeNb5Mo3	4668-077-18-I	199	195	190	185	179	—	174	167	—	163	149	134	120	100	—
NiCr20TiAl	4952-070-80-I	216 (212)	212 (207)	208 (202)	202 (195)	196 (188)	—	189 (180)	179 (168)	(160)	161 (148)	130 (115)	—	—	—	—

NOTE The dynamic modulus of elasticity can differ from the static modulus of elasticity (determined by tensile testing), especially at higher temperatures. The deviation between single values is about ±4 %.

[a] Values in brackets indicate values for the static modulus of elasticity.

Annex B
(informative)

Data for creep strength to 1 % plastic strain and creep rupture strength

In Table B.1, the average creep strength to 1 % plastic strain elongation ($R_{p1,0}$) and creep rupture (R_m) after durations of 1 000 h, 10 000 h and 100 000 h (200 000 h) are given for guidance only (see Table B.1, footnote b).

Table B.1 — Creep rupture properties (for guidance only

Designation[a]		Temperature °C	Estimated average creep strength[b,c]						
			Creep strength to 1 % plastic strain for[d]			Creep rupture strength for[e]			
Name	Number		1 000 h MPa	10 000 h MPa	100 000 h MPa	1 000 h MPa	10 000 h MPa	100 000 h MPa	200 000 h MPa
Austenitic steels for heat resistant applications									
X6CrNiSiNCe-19–10–1	4818–304–15-E	500	—	—	—	—	—	—	—
		600	147	126	80	238	157	88	—
		700	61	42	26	105	63	35	—
		800	25	15	9	46	25	14	—
		900	9	8	3	18	10	5	—
		1 000	(2,5)	(1,7)	(1,0)	(7)	(4)	(1,5)	—
X15CrNiSi20–12	4828–305–09-I	500	—	—	—	—	—	—	—
		600	120	80	—	190	120	65	—
		700	50	25	—	75	36	16	—
		800	20	10	—	35	18	7,5	—
		900	8	4	—	15	8,5	3	—
		1 000	—	—	—	—	—	—	—
X7CrNiSiNCe21–11	4835–308–15-U	500	—	—	—	—	—	—	—
		600	170	126	80	238	157	88	—
		700	66	45	26	105	63	35	—
		800	31	19	11	50	27	15	—
		900	15,5	10	6	24	13	8	—
		1 000	(8)	(5)	(3)	(12)	(7)	(4)	—
X12CrNi23–13	4833–309–08-I	500	—	—	—	—	—	—	—
		600	100	70	—	190	120	65	—
		700	40	25	—	75	36	16	—
		800	18	10	—	35	18	7,5	—
		900	8	5	—	15	8,5	3	—
		1 000	—	—	—	—	—	—	—
X8CrNi25–21	4845–310–08-E	500	—	—	—	—	—	—	—
		600	100	90	—	170	130	80	—
		700	45	30	—	80	40	18	—
		800	18	10	—	35	18	7	—
		900	10	4	—	15	8,5	3	—
		1 000	—	—	—	—	—	—	—

Table B.1 *(continued)*

Designation[a]		Temperature °C	Estimated average creep strength[b,c]						
			Creep strength to 1 % plastic strain for[d]			Creep rupture strength for[e]			
Name	Number		1 000 h MPa	10 000 h MPa	100 000 h MPa	1 000 h MPa	10 000 h MPa	100 000 h MPa	200 000 h MPa
X15CrNiSi25–21	4841–314–00-E	500	—	—	—	—	—	—	—
		600	105	95	—	170	130	80	—
		700	50	35	—	90	40	18	—
		800	23	10	—	40	20	7	—
		900	10	4	—	20	10	3	—
		1 000	3	—	—	5	—	—	—
Austenitic steels for creep resistant applications									
X10NiCrAlTi32–31	4876–088–00-I	500	—	—	—	—	—	—	—
		600	130	90	—	200	152	114	—
		700	70	40	—	90	68	48	—
		800	30	15	—	45	30	21	—
		900	13	5	—	20	10	8	—
		1 000	—	—	—	—	—	—	—
X6NiCrSiNCe35–25	4854–353–15-E	500	—	—	—	—	—	—	—
		600	150	88	52	200	127	80	—
		700	60	34	21	84	56	36	—
		800	26	15	9,7	41	28	18	—
		900	12,5	8	5,1	22	15	9,2	—
		1 000	6,5	4,5	3,0	12	8	4,8	—
X10CrNiMoMnNbV B15–10–1	4982–215–00-E	500	—	—	—	—	—	—	—
		600	—	—	—	—	—	—	—
		700	—	—	—	—	—	—	—
		800	—	—	—	—	—	—	—
		900	—	—	—	—	—	—	—
X7CrNi18–9	4948–304–09-I	500	—	—	—	—	—	—	—
		600	100	80	—	178	122	—	—
		700	45	30	—	83	48	—	—
		800	15	—	—	—	—	—	—
		900	—	—	—	—	—	—	—
X8CrNiTi18–10	4940–321–09-I	500	—	—	—	—	—	—	—
		600	110	85	—	200	142	—	—
		700	45	30	—	88	48	—	—
		800	15	10	—	30	15	—	—
		900	—	—	—	—	—	—	—
X7CrNiNb18–10	4912–347–09-I	500	—	—	—	—	—	—	—
		600	140	110	—	210	159	—	—
		700	65	45	—	110	61	—	—
		800	25	—	—	—		—	—
		900	—	—	—	—	—	—	—