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Heat-resistant steels

Aciers réfractaires

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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 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*

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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

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6 Classification of grades

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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 $d \leq 20$ mm — max. 0,01 d for $20 < d \leq 75$ mm — max. 0,75 mm for $d > 75$ mm	1 %
	Hexagons	— max. 0,3 mm for $d \leq 15$ mm — max. 0,02 d for $15 < d \leq 63$ mm	2 %
	Other bars	— max. 0,3 mm for $d \leq 15$ mm — max. 0,02 d for $15 < d \leq 63$ 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

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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

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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: <https://standards.iteh.ai/catalog/standards/sist/36430b2f-4666-4868-aeb2-bfd039eda507/iso-4955-2016>

- 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										
X6CrNiSiNcCe19-10	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	—
X7CrNiSiNcCe21-11	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
X6NiCrSiNcCe35-25	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 7,00	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 B25-23-3-3-2	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
<p>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.</p> <p>^a Maximum values unless otherwise indicated.</p> <p>^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).</p> <p>^c Tantalum determined as niobium.</p> <p>^d By agreement at the time of enquiry and order, this grade can also be delivered with Ti: 6 × C to 0,75.</p> <p>^e Patented grades.</p>										

Table 2 (continued)

Designation		% (mass fraction) ^a								
Name	ISO-number	C	Si	Mn	P	S	Cr	Ni	N	Others
X6Cr17	4016-430-00-1	0,08	1,00	1,00	0,040	0,030	16,0 to 18,0	1,00	—	—
X3CrTi17	4510-430-35-1	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	4521-444-00-1	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	4742-430-77-1	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	4762-445-72-1	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	4749-446-00-1	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										
X6NiCrTiMoVB2 5-15-2 ^e	4980-662-86-Xe	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	4668-077-18-1	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	4952-070-80-1	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 × C to 0,75.

^e Patented grades.