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Steels for cold heading and cold extruding

Aciers pour refoulement et extrusion à froid

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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.

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

International Standard ISO 4954 was prepared by Technical Committee ISO/TC 17, *Steel*, Sub-Committee SC 4, *Heat treatable and alloy steels*.

This second edition cancels and replaces the first edition (ISO 4954:1979), of which it constitutes a technical revision.

Annexes A and B of this International Standard are for information only.

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Steels for cold heading and cold extruding

Section 1: General

1.1 Scope

1.1.1 This International Standard applies to wrought unalloyed and alloyed steels which are intended for cold heading or cold extruding and are delivered as wire rods, wire or bars. It contains five sections covering the following topics:

Section 1 — general requirements common to all sections.

Section 2 — steels not intended for heat treatment with diameters from 2 mm to 100 mm.

Section 3 — case-hardening steels with diameters from 2 mm to 100 mm.

Section 4 — steels for quenching and tempering including boron treated steels, with diameters from 2 mm to 100 mm.

Section 5 — stainless steels with diameters of 2 mm up to 25 mm for ferritic, up to 100 mm for martensitic, and up to 50 mm for austenitic steels.

1.1.2 This International Standard (except section 2) is not applicable to the properties of cold-headed or cold-extruded parts which have not been subjected to a subsequent heat treatment. As the properties of the parts in the cold headed or cold extruded and subsequently not-heat-treated condition are largely dependent on the applied cold-heading or cold-extruding conditions, these should, if necessary, be a matter of agreement between the purchaser and the manufacturer of the parts.

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

1.2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 377-1:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 1: Samples and test pieces for mechanical test.*

ISO 377-2:1989, *Selection and preparation of samples and test pieces of wrought steels — Part 2: Samples for the determination of the chemical composition.*

ISO 404:1992, *Steel and steel products — General technical delivery requirements.*

ISO 642:1979, *Steel — Hardenability test by end quenching (Jominy test).*

ISO 643:1983, *Steels — Micrographic determination of the ferritic or austenitic grain size.*

ISO 3887:1976, *Steel, non-alloy and low-alloy — Determination of depth of decarburization.*

ISO 6508:1986, *Metallic materials — Hardness test — Rockwell test (scales A - B - C - D - E - F - G - H - K).*

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO 9443:1991, *Heat-treatable and alloy steels — Surface quality classes for hot-rolled round bars and wire rods — Technical delivery conditions.*

ISO/TR 9769:1991, *Steel and iron — Review of available methods of analysis.*

ISO 10474:1991, *Steel and steel products — Inspection documents.*

1.3 Ordering

1.3.1 The purchaser shall state in his enquiry and order

- a) the dimensions and tolerances of the product (see 1.4.11);
- b) the steel type (see tables 5, 9, 12, 13, 15, 16, 19 to 24 and 26);
- c) the treatment condition (see 1.4.3.1);
- d) the surface coating treatment, if any (see 1.4.3.2);
- e) the required type of document (see 1.5.1).

1.3.2 Certain options in ordering are permitted by this International Standard and the purchaser may also state in his enquiry and order his related requirements, as shown in table 1.

1.4 Requirements

1.4.1 Manufacture of the steel and the product

1.4.1.1 Unless otherwise agreed in the order, the process used in making the steel and the product are left to the discretion of the manufacturer. When he so requests, the user shall be informed what steelmaking process is being used.

1.4.1.2 The steels of table 5 with the suffix X in the designation may be rimmed or rimming equivalent, those with the suffix K shall be silicon-killed and those with the suffix A shall be aluminium-killed. The steels of tables 9, 15, 16 and 26 shall be killed.

1.4.2 Cast separation

The steels of tables 9, 15, 16 and 26 are delivered by casts. For the steels of table 5, cast separation, if required, must be especially agreed upon at the time of enquiry and order.

Table 1 — Permitted options in ordering

For steels of table	Permitted options
5, 9, 15, 16, 26	f) whether a product analysis is required (see 1.5.2.1);
5, 9, 15, 16, 26	g1) the choice of the surface quality class selected from ISO 9443 (see 1.4.8.1.1); g2) whether special specifications for the results and the testing conditions for the cold-compression test and the surface inspection are required (see 1.4.8.1.1);
5	h1) whether cast separation is required (if no such statement is made, the manufacturer is permitted to supply the steel without cast separation; see 1.4.2); h2) whether the mechanical properties for the cold-drawn condition are to be specified (see table 4, footnote 1);
9, 15, 16	i) whether, explicitly, coarse or fine grain steel is required (see 1.4.7.1);
9, 15, 16	j) whether special specifications for testing the degree of spheroidization of the carbides are required (see 1.4.7.2);
9, 15, 16	k) whether the microscopically determined non-metallic inclusion content shall be within agreed limits (see 1.4.9.2);
15, 16	l) whether special specifications for the permissible depth of the ferritic-pearlitic decarburization are required (see 1.4.8.2.1);
26	m) whether, in the case of a stainless steel, a corrosion resistance test is required (see 1.4.10);
5, 9, 15, 16	n) whether, for products with diameters ≥ 6 mm and ≤ 30 mm, cold-compression tests shall be carried out, in which case test conditions shall be agreed upon (see 1.4.8.1.1).

1.4.3 Treatment condition at the time of delivery

1.4.3.1 The treatment and heat-treatment condition (if any) at the time of delivery must comply with the condition agreed upon in the order and shall be one of the conditions indicated in tables 4, 8, 14 and 25.

1.4.3.2 Surface treatments which facilitate the cold-heading or cold-extruding operation and which, in part, may also delay the formation of rust, such as descaling, copper coating, liming, phosphate

coating, greasing or oiling etc., shall, if required, be agreed upon at the time of enquiry and order.

1.4.4 Survey of combinations of usual treatment conditions on delivery, product forms and requirements

Tables 4, 8, 14 and 25 give a survey of combinations of usual treatment conditions on delivery, product forms and requirements regarding chemical composition, mechanical properties and hardenability.

1.4.5 Chemical composition

1.4.5.1 The chemical composition of the steels, as given by the cast analysis, shall be in accordance with the specifications in tables 5, 9, 15, 16 and 26 (see 1.4.5.3).

1.4.5.2 The permissible deviations between the values specified in tables 5, 9, 15, 16 and 26 and the product analyses are given in tables 6, 10, 17 and 27.

1.4.5.3 If case-hardening or direct-hardening steels are ordered by using the designations given in table 12, 13, 19, 20, 21 or 22 to hardenability requirements for Jominy test pieces, the hardenability values shall be regarded as the governing criteria for acceptance. In such cases, the cast analysis may deviate from the values shown in tables 9, 15 and 16 by the values given in footnote 2 to these tables.

1.4.6 Hardenability and mechanical properties

The products shall fulfil the specifications of 2.2.3, 3.2.3, 4.2.3 and 5.2.3.

1.4.7 Structure

1.4.7.1 If, for the steels of section 3 or 4, a controlled austenitic grain size is required, then the austenitic grain size of the steel determined in accordance with 1.5.4.4.1 shall be 5 or finer for fine grain steels and 1 to 5 for coarse grain steels. The grain structure shall be considered satisfactory if 70 % is within the specified limits.

1.4.7.2 If, for the steels of section 3 or 4, the spheroidization of the carbides is required, then the steels shall have a structure which is characterized by a high degree of spheroidization of the carbides.

NOTE 1 It should be taken into account that the spheroidization of the cementite is more difficult for steels with lower carbon contents.

1.4.8 Outer soundness

1.4.8.1 Surface quality

1.4.8.1.1 For products in the hot-rolled or cold-drawn surface condition, the required surface quality shall be agreed upon at the time of enquiry and order, either by reference to ISO 9443 or by specifying that, when material is subjected to the cold-compression tests described in 1.5.3.6.2 and 1.5.4.6.1, no imperfections shall appear.

NOTES

2 The cold-compression test is normally not applicable for stainless steel products.

3 In the case of cold-compression tests on test pieces with hot-rolled surfaces, grooves which result from rolling scores are not to be considered as being a cause for rejection.

1.4.8.1.2 Products which, according to the order, were peeled or ground must be free from outer defects. Grooves originating from machining operations are not to be considered as defects.

1.4.8.2 Decarburization

1.4.8.2.1 Bars, wire rods and wire of the steels in tables 15 and 16 which are delivered in the hot-rolled or cold-drawn surface condition must, independent of their heat-treatment conditions, be free from completely ferritic decarburized zones.

For such products, the values given in table 2 apply for the permissible depth of the partial (ferritic-pearlitic) decarburization.

If, in special cases, other values for the permissible depth of the partial (ferritic-pearlitic) decarburization are required, these shall be specially agreed upon at the time of enquiry and order.

1.4.8.2.2 Bars, wire rods and wire of the steels in table 9, 15 or 16 which, according to the order, were peeled or ground must be free from decarburization.

1.4.9 Internal soundness

1.4.9.1 The steel shall be free from internal defects likely to have an adverse effect during its further processing or use.

Table 2 — Permissible depth of the partial (ferritic-pearlitic) decarburization

Diameter <i>d</i>	Permissible depth of the partial (ferritic-pearlitic) decarburization in the condition ¹⁾	
	C + AC or C + AC + LC	untreated or AC
mm	mm	mm
≤ 8	≤ 0,10	≤ 0,12
> 8 ≤ 12	≤ 0,12	≤ 0,15
> 12 ≤ 17	≤ 0,16	≤ 0,20
> 17 ≤ 23	≤ 0,20	≤ 0,25
> 23 ≤ 27	≤ 0,24	≤ 0,29
> 27	≤ (0,007 × <i>d</i>) + 0,05	≤ (0,009 × <i>d</i>) + 0,05

1) See table 14.

1.4.9.2 Where appropriate, exact criteria for the compliance of the steel with the general requirement in 1.4.9.1 shall be agreed upon at the time of enquiry and order.

NOTE 4 Where, in accordance with 1.4.8.1.1, cold-compression tests were agreed upon, the requirement in 1.4.9.1 shall be regarded as complied with when, after the test, the test piece does not show defects originating from internal imperfections.

For the steels of sections 3 and 4, agreements on the non-metallic inclusion content may be made, for example on the basis of ISO 4967 or other suitable methods.

1.4.10 Corrosion resistance of the stainless steels

See 5.2.4.

1.4.11 Dimensions, tolerances on dimensions and masses

The products shall, if possible, be ordered in accordance with existing International Standards for dimensions and tolerances on dimensions and masses.

If corresponding International Standards for dimensions and tolerances are not yet available or if the tolerances given in the corresponding International Standard are (for example in the case of stainless steels) not applicable, then the dimensions and tol-

erances shall be agreed upon at the time of enquiry and order.

1.5 Testing

1.5.1 Agreement on tests and documents

1.5.1.1 For each delivery, the issue of any document according to ISO 10474 may be agreed upon at the time of enquiry and other.

1.5.1.2 If, in accordance with such an agreement, a specific inspection is to be carried out, the specifications given in 1.5.2 to 1.5.5 shall be observed.

1.5.2 Test unit and number of sample products and tests

1.5.2.1 Chemical composition

The cast analysis, if called for in the order, shall be provided by the manufacturer.

If a product analysis is required by the purchaser, and if not otherwise agreed at the time of enquiry and order, one sample product shall be taken from each cast.

If no cast separation is required by this International Standard or was agreed upon in the order, then one sample for product analysis shall be taken from the total delivery, independent of the number of casts contained in it.

1.5.2.2 Hardenability, mechanical properties, structure, inner and outer soundness

If, according to the ordered requirements (see tables 4, 8, 14 and 25) and the required type of document (see 1.5.1), the hardenability, the mechanical properties, the structure or the inner and outer soundness are to be verified, then the indications in table 3 apply for the test unit and the number of samples and test pieces.

1.5.3 Selection and preparation of samples and test pieces

1.5.3.1 General

The general conditions given in ISO 377-1 and ISO 377-2 for the selection and preparation of samples and test pieces shall apply.

1.5.3.2 Hardenability test

1.5.3.2.1 In cases of dispute, for the end-quench hardenability test, if possible the sampling method given in 5.1 a) or 5.1 b1) of ISO 642 shall be applied.

Table 3 — Test unit and number of samples and test pieces

Line No.	Quality requirement	Test unit ¹⁾	Number of sample products	Number of test pieces per sample product
1	Chemical composition	See 1.5.2.1	See 1.5.2.1	See 1.5.2.1
2	Hardenability			
2a	end quench test	C	1 per cast	1
2b	core hardenability	C	1 per cast	1
3	Mechanical properties in the usual condition for cold working ²⁾	C ³⁾ + D ⁴⁾ + T	2 per 10 t or part thereof	1
4	Austenitic grain size	C	1 per cast	1
5	Spheroidization	C + D ⁴⁾ + T	2 per 10 t or part thereof	1
6	Inner and outer soundness			
6a	Cold headability	C ³⁾ + D + T	To be agreed upon at the time of enquiry and order	1
6b	Surface quality	C ³⁾ + D + T		
6c	Non-metallic inclusion content	C + D		
7	Decarburization ⁵⁾	C + D + T	2 per 10 t or part thereof	1

1) The test shall be carried out separately for each cast (symbol C), or, for each cast and each dimension (symbol C + D), or, for each cast, each dimension and each treatment (symbol C + D + T).

2) See tables 7, 11, 18 and 28.

3) If, for the steels of table 5, no cast separation was agreed upon at the time of enquiry and order, then the tests shall be carried out separately for each steel type.

4) If the consignment consists of bars, wire rods or wire with cross-sections which differ by not more than 3:1, these can be grouped into one test unit.

5) Only for the steels for quenching and tempering (see tables 15 and 16).

1.5.3.2.2 The test piece for evaluation of the core hardenability shall have, as far as possible, the maximum diameter given in table 23 or 24. Test bars with diameters larger than those given in table 23 or 24 are to be rolled or forged to the maximum diameters of table 23 or 24. The length of the test piece shall be at least four times its diameter.

1.5.3.3 Tensile test

Test pieces for tensile tests in the usual condition for cold working (requirement 3 in table 3) shall be, as far as possible, tested with their original surface, i.e. without having been machined.

1.5.3.4 Structure

1.5.3.4.1 For the selection and preparation of the test pieces used for the verification of the austenitic grain size, the indications in ISO 643 apply. If not otherwise agreed upon at the time of enquiry and

order, in cases of dispute the indications for the McQuaid-Ehn method shall be observed, if case-hardening steels (see section 3) are to be examined. In cases where steels for quenching and tempering (see section 4) are to be examined, one of the other methods described in ISO 643 shall be applied and the austenitizing temperature shall correspond to the highest hardening temperature given in table A.4 for the steel type concerned, and this temperature shall be maintained for 1 h.

1.5.3.4.2 For the examination of the spheroidization of the carbides, polished transverse micro-sections shall be prepared and these shall be etched in an appropriate solution.

1.5.3.5 Internal soundness

For the selection and preparation of the test pieces used for the verification of the non-metallic inclusion content, the indications in ISO 4967 or other agreed standards apply.

1.5.3.6 Outer soundness

1.5.3.6.1 For the verification of surface quality see ISO 9443.

1.5.3.6.2 The cold-compression test applies only for products with a diameter ≥ 6 mm and ≤ 30 mm. If this test is required, and if not otherwise agreed at the time of enquiry and order, straight test pieces with parallel-cut end faces and an initial height of $h_0 = 1,5 \times d_0$ (d_0 = diameter of the test piece) are to be prepared for the cold-compression test, without altering the original surface of the sample product (see 1.5.4.6.1). Samples from products, which have not been heat treated after hot rolling may be treated as indicated in table 11, 18 or 28 as the usual condition for cold heading and cold extruding.

1.5.3.7 Decarburization

Etched transverse micro-sections with sharp edges shall be prepared for a microscopic examination of decarburization.

In cases of dispute, however, the micro-section shall be hardened under the conditions given in 1.5.4.2.2, while observing all measures to prevent decarburization or carburization. After hardening, the micro-sections shall be prepared for micro-hardness measurements by grinding and polishing. In all cases the requirements of ISO 3887 shall be observed.

1.5.4 Methods of test

1.5.4.1 Chemical analysis

The chemical composition shall be determined in accordance with the appropriate International Standards listed in ISO/TR 9769.

1.5.4.2 Hardenability test

1.5.4.2.1 The end-quench hardenability test is to be carried out in conformity with ISO 642. The quenching temperature must be in accordance with table 12, 13, 19, 20, 21 or 22.

1.5.4.2.2 The test pieces for the core hardening test shall be heated, in a neutral or reducing furnace atmosphere, up to the hardening temperatures given in table 23 or 24, and maintained at these temperatures until they are completely austenitized. They shall then be taken out of the furnace and promptly quenched in a high-duty quenching oil to complete temperature equalization, at a bath temperature of 50 °C and with a speed of immersion of approximately 0,25 m/s. The samples shall then be centrally notched transverse to their longitudinal axis and broken. The fracture surface must be ground under conditions which do not lead to a rise in tempera-

ture, so that the determination of the core hardness according to ISO 6508 can be carried out.

1.5.4.3 Tensile test

The test shall be made in accordance with ISO 6892.

1.5.4.4 Structure

1.5.4.4.1 The austenitic grain size shall be tested in accordance with ISO 643 on test pieces prepared in accordance with 1.5.3.4.1.

1.5.4.4.2 For testing the degree of spheroidization of the cementite, the micro-sections are usually examined at a magnification of $\times 500$ and, if required, they shall be evaluated according to rating charts agreed upon at the time of enquiry and order.

1.5.4.5 Internal soundness

For determining the microscopic non-metallic inclusion content, the procedure is to be agreed upon at the time of enquiry and order (for example see ISO 4967).

1.5.4.6 Other soundness

1.5.4.6.1 The test pieces for the cold-compression test shall be headed, at ambient temperature, to one-third of their initial height. The frequency and severity of imperfection that would justify rejection shall be determined at the time of enquiry and order.

If, because of over-large sample diameters or presses of insufficient power, the compression test cannot be carried out at ambient temperature, it should be carried out, after agreement, at approximately 500 °C. Where necessary, other requirements and test conditions can be agreed upon at the time of enquiry and order.

1.5.4.6.2 If, at the time of enquiry and order, an agreement has been reached regarding surface quality classes, the verification shall be in accordance with ISO 9443.

1.5.4.7 Decarburization

When testing the products with regard to their decarburization (see ISO 3887), the depth of the completely decarburized ferritic zone and that of the partially decarburized ferritic-pearlitic zone are usually measured using microscope at a magnification of $\times 100$ at the four ends of two diameters of the etched plane which are perpendicular to each other. The inner starting point for the measurement of the depth of the decarburized ferritic-pearlitic zone shall be the point at which a marked decrease of the pearlite content begins. (This is usually at about two-thirds of the total depth of the

decarburized ferritic-pearlitic zone.) The average of the four single values obtained in this way is to be calculated.

In cases of dispute, the decarburization shall be checked by micro-hardness measurements (HV 0,3) along the two diameters. For the depth of the decarburized zone, the average of the distances e_1 , e_2 , e_3 and e_4 (see figure 1) shall be calculated. The single values e_1 to e_4 represent, according to

figure 1, the distance between the surface and the next point of the corresponding diameter, where the hardness is 80 % of the maximum hardness, which, in the case of a decarburization, is measured in the outer zone of the micro-section.

1.5.5 Retests

Retests shall be made in accordance with ISO 404.

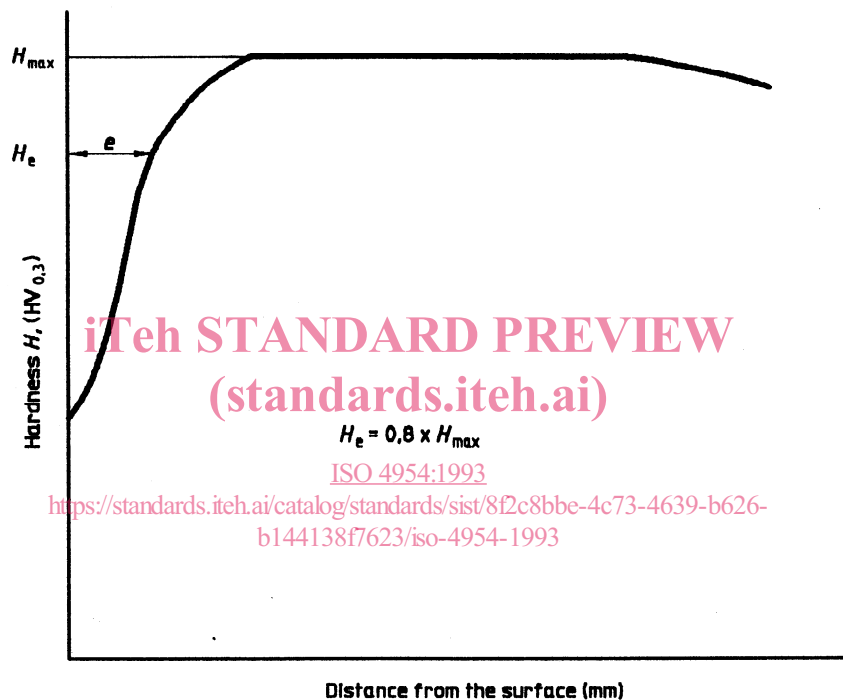


Figure 1 — Determination of the depth of the decarburized zone

Section 2: Specific requirements for cold-heading and cold-extruding steels not intended for heat treatment

2.1 Scope

This section covers the specific requirements for those cold-heading and cold-extruding steels which are not intended for heat treatment. It applies to diameters from 2 mm to 100 mm.

2.2 Requirements

2.2.1 Survey of combinations of usual treatment conditions on delivery, product forms and requirements

Table 4 gives a survey of combinations of usual treatment conditions on delivery, product forms and requirements regarding chemical composition and mechanical properties.

2.2.2 Chemical composition

2.2.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 5.

2.2.2.2 The permissible deviations between the values specified in table 5 and the product analysis are indicated in table 6.

2.2.3 Mechanical properties

For the untreated condition (U or P), the mechanical properties given in table 7 apply.

For the cold-drawn delivery condition, the mechanical properties shall, if necessary, be agreed upon at the time of enquiry and order.

2.2.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 4.

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Table 4 — Combinations of usual treatment conditions on delivery, product forms and requirements according to tables 5 to 7 for steels not intended for heat treatment

1	2		3		4	5	6	
1	Treatment condition on delivery	Symbol	"x" indicates applicable to			Applicable requirements		
			hot-rolled bars	wire rod	drawn products	6.1	6.2	
2	Untreated with hot-rolled surface	None or U	x	x	—	Chemical composition according to tables 5 and 6	Mechanical properties according to table 7	
3	Untreated with peeled surface	P	x	—	—			
4	Cold drawn	C	—	—	x			
1) The mechanical properties shall, if necessary, be agreed upon at the time of enquiry and order.								

Table 5 — Types of steel and chemical composition (applicable to cast analysis)

No.	Type of steel Designation ²⁾		Chemical composition [% (m/m)] ¹⁾					Others
	Name	according to ISO 4954:1979	C	Si	Mn	P max.	S max.	
1	CC 4 X	A 1 R	≤ 0,06	≤ 0,10	0,20 to 0,40	0,040	0,040	Al _{tot} ≤ 0,020
2	CC 4 A	A 1 Al	≤ 0,06	≤ 0,10	0,20 to 0,40	0,040	0,040	Al _{tot} ≥ 0,020 ³⁾
3	CC 8 X	A 2 R	0,05 to 0,10	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≤ 0,020
4	CC 8 A	A 2 Al	0,05 to 0,10	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≥ 0,020 ³⁾
5	CC 11 X	A 3 R	0,08 to 0,13	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≤ 0,020
6	CC 11 A	A 3 Al	0,08 to 0,13	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≥ 0,020 ³⁾
7	CC 15 X	—	0,12 to 0,19	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≤ 0,020
8	CC 15 K	A 4 Si	0,12 to 0,19	0,15 to 0,35	0,30 to 0,60	0,040	0,040	
9	CC 15 A	A 4 Al	0,12 to 0,18	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≥ 0,020 ³⁾
10	CC 21 K	A 5 Si	0,18 to 0,23	0,15 to 0,35	0,30 to 0,60	0,040	0,040	
11	CC 21 A	A 5 Al	0,18 to 0,23	≤ 0,10	0,30 to 0,60	0,040	0,040	Al _{tot} ≥ 0,020 ³⁾

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

2) The designations given in the first column are consecutive numbers. The designations given in the second column are in accordance with the system proposed by ISO/TC 17/SC 2. The designations given in the third column represent the antiquated numbers of ISO 4954:1979.

3) Otherwise, by agreement with the purchaser, treated with sufficient additions of other elements having a similar effect, for example V, Nb, Ti, Ca.