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ISO 4954-1

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Steels for cold heading and cold extruding — Technical delivery conditions —

Part 1: Non-alloy and alloy steels

Aciers pour transformation à froid et extrusion à froid — Conditions techniques de livraison —

Partie 1: Aciers non alliés et faiblement alliés

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Foreword

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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 document 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).

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

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This first edition of ISO 4954-1, together with ISO 4954-2, cancels and replaces ISO 4954:2022, which has been technically revised.

The main changes are as follows:

— the following steel grades were added: 15B2, 20MnCr5, 42Mn6, 40MnB6

— Annex D.4 was extended to method K of SEP 1571-2.

A list of all parts in the ISO 4954 series can be found on the ISO website.

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

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Steels for cold heading and cold extruding — Technical delivery conditions —

Part 1: Non-alloy and alloy steels

1 Scope

This document specifies requirements for non-alloy and alloy steels that are intended for cold heading or cold extruding and are delivered as wire rods, wire or bars. It also lists the specific requirements for:

— steels not intended for heat treatment, with diameters from 2 mm to 100 mm (see Annex A);

— case-hardening steels with diameters from 2 mm to 100 mm (see Annex B);

— steels for quenching and tempering, including boron-alloyed steels, with diameters from 2 mm to 100 mm (see Annex C).

This document (except Annex A) also applies to the properties of cold-headed or cold-extruded parts which have been subjected to a subsequent heat treatment.

NOTE Stainless steels for cold heading and cold extruding are covered by ISO 4954-2.

2 Normative references

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

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

ISO 643, *Steels — Micrographic determination of the apparent grain size*

ISO 683-1, *Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Non-alloy steels for quenching and tempering*

ISO 683-2, *Heat-treatable steels, alloy steels and free-cutting steels — Part 2: Alloy steels for quenching and tempering*

ISO 683-3, *Heat-treatable steels, alloy steels and free-cutting steels — Part 3: Case-hardening steels*

ISO 683-7, *Heat-treatable steels, alloy steels and free-cutting steels — Part 7: Bright products of non-alloy and alloy steels*

ISO 1035-1, *Hot-rolled steel bars — Part 1: Dimensions of round bars*

ISO 1035-2, *Hot-rolled steel bars — Part 2: Dimensions of square bars*

ISO 1035-3, *Hot-rolled steel bars — Part 3: Dimensions of flat bars*

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ISO 1035-4, *Hot-rolled steel bars — Part 4: Tolerances*

ISO 3887, *Steels — Determination of the depth of decarburization*

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

ISO 4948-1, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 4948-2, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

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

ISO 4967:2013, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

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

ISO 6929, *Steel products — Vocabulary*

ISO 9443, *Surface quality classes for hot-rolled bars and wire rod*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

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 15549, *Non-destructive testing — Eddy current testing — General principles*

ISO 16124, *Steel wire rod — Dimensions and tolerances*

ISO 22034-2, *Steel wire and wire products — Part 2: Tolerances on wire dimensions*

JIS G 0555:2015, *Microscopic testing method for the non-metallic inclusions in steel*

SEP 1571-1, *Evaluation of inclusions in special steels based on their surface areas – Part 1: Basics*

SEP 1571-2, *Evaluation of inclusions in special steels based on their surface areas – Part 2: Methods K and M*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 377, ISO 683-1, ISO 683-2, ISO 683-3, ISO 683-7, ISO 4885, ISO 4948-1, ISO 4948-2, ISO 6929, ISO 14284 and the following apply.

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

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

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

3.1
bright steel product
drawn or peeled/turned bar with smoother surface quality and better dimensional accuracy in comparison with a hot-rolled bar

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3.2
drawn product
product of various cross-sectional shapes obtained, after descaling, by cold drawing of hot-rolled bars or wire rod, on a drawing bench (cold deformation without removing material)

Note 1 to entry: This operation gives the product special features with respect to shape, dimensional accuracy and surface finish. Products in lengths are delivered straightened, products of small cross-section may also be supplied in coils.

3.3
peeled/turned bar
steel bar of circular cross-section having the same features as *drawn products* (3.2) concerning shape, dimensional accuracy and bright surface finish but without work hardening

Note 1 to entry: They are produced by peeling on a peeling machine usually followed by straightening and by polishing. The removal of metal by peeling is carried out in such a way that the bright product is generally free from surface defects and decarburization coming from the hot-rolling process.

4 Classification and designation

4.1 Classification

The classification of the relevant steel grades shall be in accordance with ISO 4948-1 and ISO 4948-2.

All steel grades mentioned in this document are special steels in accordance with ISO 4948-2.

The steels not intended for heat treatment after cold forming (see Annex A) are non-alloy steels.

The case-hardening steel grades (see Annex B) are alloy steels, except steel grades C10E2C to C20E2C.

The steels for quenching and tempering (see Annex C) are alloy steels, except steel grades C30EC to C45RC and 42Mn6.

4.2 Designation

For the steel grades covered by this document, the steel names as given in the relevant tables shall be allocated in accordance with ISO/TS 4949.

Annex E provides a list of steels given in Annexes A, B and C and the comparable grades covered in various designation systems.

5 Information to be supplied by the purchaser

5.1 Mandatory information

The manufacturer shall obtain the following information from the purchaser at the time of enquiry and order:

a) the quantity to be delivered (mass, length);

b) the product form (e.g.: round bars, wire rod, wire);

c) the nominal diameter and the tolerances on dimensions and shape of the product with reference to the relevant International Standard;

d) for bars, the length; and for wire rod and wire, the dimensions, e.g. inner diameter etc., and mass of the coils;

e) a reference to this document, i.e. ISO 4954-1;

f) the designation of the steel grade given in Tables A.2, B.2, C.2 and C.3;

g) if applicable, the symbol for the required heat-treatment condition, see Tables A.3, B.3 to B.7 and C.4 to C.10;

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h) standard designation for a test report 2.2 or, if required, any other type of inspection document in accordance with ISO 10474 or another comparable national standard.

5.2 Options and/or supplementary or special requirements

A number of options are specified in this document and listed below. If the purchaser does not indicate a wish to implement any of these options, the products shall at least be supplied in accordance with the basic specifications of this document (see 5.1):

a) any requirement for the hardenability (+H, +HH, +HL) of case-hardening steels of Annex B and of steels for quenching and tempering of Annex C and for the core hardening (+CH) of steels for quenching and tempering of Annex C, see 7.1.4;

b) verification of hardenability and, if agreed, information about the calculation of the hardenability for case-hardening steels of Annex B and for steels for quenching and tempering of Annex C, see 10.3.1;

c) verification of core hardness for steels for quenching and tempering of Annex C, see 10.3.2;

d) if another surface condition than hot-rolled or a special surface quality is required, for the surface condition, see Table 1, and for the surface quality E for wire rod and bars, see 7.7.2 and 7.7.3;

e) any requirement for the verification of the surface quality, see 7.7.5;

f) any requirement relating to the removal of surface defects, see 7.7.6;

g) any requirement for a product analysis, see 7.1.2.2;

h) any requirement for the verification of the fine grain structure, see D.2, of case-hardening steels of Annex B and of steels for quenching and tempering of Annex C;

i) carbide spheroidization, see 7.3, and any requirement for the verification of the carbide spheroidization, see D.3;

j) any requirement for the verification of the non-metallic inclusions of case-hardening steels of Annex B and of steels for quenching and tempering of Annex C, see 7.4 and D.4;

k) internal soundness and any requirements for non-destructive testing, see 7.5 and 10.4;

l) verification of aptitude to cold forming, see 7.6 and 10.5;

m) any requirement concerning non-destructive testing of the surface, see 7.7.6 and 10.4;

n) depth of decarburization, see 7.8, and any requirements for testing the depth of decarburization, see D.5;

o) any requirement concerning surface treatment and temporary corrosion protection, see 11.1;

p) any special requirements concerning special or additional marking, see 11.2;

q) any special requirements concerning packaging, see 11.3;

r) statistical evaluation, see 6.5.

5.3 Ordering example

EXAMPLE 50 t round bars with a nominal diameter of 40 mm and a nominal length of 6 000 mm with diameter tolerance according to class S and with length tolerance according to class L2 of ISO 1035-4 made of steel grade ISO 4954-1, 42CrMo4 in the heat-treatment condition +AC+PE (see Table C.5), with hardenability requirement +H (see Table C.7) and product analysis with an inspection certificate 3.1 in accordance with ISO 10474.

50 t round bars ISO 1035-4 – 40,0S × 6 000L2

ISO 4954-1, 42CrMo4+AC+PE+H – product analysis

ISO 10474 – 3.1

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6 Manufacturing process

6.1 General

The manufacturing process of the steel and of the products is, with the restrictions given by the requirements in 6.2 to 6.4, left to the discretion of the manufacturer.

6.2 Deoxidation

All steels shall be fully deoxidized.

Besides silicon and aluminium other suitable elements having a similar effect may also be used.

The deoxidation practice should be agreed at the time of enquiry and order.

NOTE Concerning the effect of aluminium on the fine grain structure, see 7.2 and D.2.

6.3 Heat-treatment condition and surface condition at delivery

6.3.1 Heat-treatment condition

Treatment and heat-treatment condition shall conform to one of the conditions indicated in Tables A.1, B.1 and C.1.

Bright steel products in cold drawn or peeled/turned condition are coated with a light film of grease from processing. For bright steel products in a finally heat-treated condition, the manufacturer chooses the rust protection after heat treatment.

The usual light application of ordinary grease or oil does not afford positive protection against rusting, particularly in the presence of condensation water. Any surface treatment that can facilitate subsequent cold heading and cold extrusion or partially delay any formation of rust shall, if required, be agreed at the time of enquiry and order, see 11.1.

6.3.2 Particular surface conditions

If so agreed at the time of enquiry and order, the products shall be delivered in one of the particular surface conditions given in Table 1.

Table 1 — Surface condition at delivery

Surface condition at delivery		Symbol	Bar	Wire rod	Wire
Unless otherwise agreed	as-rolled	none or +AR	x	x	—
Particular surface conditions supplied by agreement	cold drawn	+C	x	—	x
	skin passed	+LC	x	—	x
	peeled	+PE	x	x	x

6.4 Traceability of the cast

Each product shall be traceable to the cast, see 11.2.

6.5 Statistical evaluation

Suppliers are responsible, using the means they think fit, for inspecting their product in accordance with various quality criteria specified. In view of the practical difficulties in inspecting a coil of wire rod along its entire length, it cannot be proved that no value greater than the specified limits occur in the coil as a whole. Statistical evaluation of performances applicable to all coils may be agreed between the purchaser and the manufacturer at the time of ordering.

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7 Requirements

7.1 Chemical composition, mechanical properties and hardenability

7.1.1 General

Wire rod, bars and wire shall be supplied in one of the delivery conditions as indicated in Tables A.1, B.1, and C.1 as agreed at the time of enquiry and order. These tables show the combinations of usual heat-treatment conditions at delivery, product forms and applicable requirements.

In addition to this document, the general technical delivery requirements of ISO 404 shall apply.

7.1.2 Chemical composition

7.1.2.1 The chemical composition determined by cast analysis shall conform to the values in Tables A.2, B.2, C.2 and C.3.

In cases where steels for case hardening or for quenching and tempering are ordered with hardenability requirements in accordance with Tables B.6, B.7, C.7, C.8 and C.9, a deviation of the cast analysis with respect to the values indicated in Tables B.2, C.2 and C.3 is admissible, taking into account the prescriptions given in footnote b) of those tables. In any case, however, the deviations in the product analysis in relation to the specified limits of cast analysis shall not exceed the values indicated in Table 2.

7.1.2.2 Permissible deviations between the limiting values for cast analysis and the values for product analysis are given in Tables 2. The product analysis shall be carried out when specified at the time of the enquiry and order.

Table 2 — Permissible deviations between product analysis and the limiting values of the cast analysis specified in Tables A.2, B.2, C.2 and C.3

Elements	Limiting values of the cast (heat) analysis % mass fraction	Permissible deviation for the product analysis % mass fraction[a]
C	≤0,50	±0,02
Si	≤0,30	±0,03
Mn	≤1,00	±0,04
	>1,00 ≤ 1,65	±0,06
P	≤0,025	+0,005
S	≤0,040	+0,005[b]
Cr	≤1,70	±0,05
Ni	≤1,00	±0,03
	>1,00 ≤ 2,00	±0,05
Mo	≤0,30	±0,03
	>0,30 ≤ 0,50	±0,04
Al	≤0,060	±0,005
B	≤0,005 0	±0,000 3
Cu	≤0,25	+0,03

[a] ± means that in one heat the deviation of the product analysis for a given element may occur over the upper value or under the lower value of the specified range of the cast analysis, but not both at the same time.

[b] For steels with a specified sulfur range (0,020 % to 0,035 % or 0,040 %) according to cast analysis, the permissible deviation is ±0,005 %.

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7.1.3 Mechanical properties

The mechanical properties of the products, to be determined by the tensile test (and, as an option, either by end quench test hardenability requirements or by core hardening requirements for steels of Annexes B and C) and by consideration of the delivery conditions of Tables A.1, B.1 and C.1 and of the surface condition of Table 1, shall conform to Tables A.3, B.3, B.4, B.5, C.4, C.5 and C.6.

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 are, if necessary, subject to agreement between the purchaser and the manufacturer of the parts.

7.1.4 Hardenability (only applicable to steel grades of Annexes B and C)

7.1.4.1 Where the steel is not ordered with hardenability or core hardening requirements, the requirements for mechanical properties apply as given in Tables B.3, B.4, B.5, C.4, C.5 and C.6. In this case, the hardenability values given in Tables B.6, B.7, C.7, C.8 and C.9 and the core hardness values in Table C.10 are for guidance purposes only.

7.1.4.2 In the case of products ordered with standard requirements regarding hardenability, that is, when the steel names or numbers are supplemented by the symbol "+H", the hardness values obtained in the end quench test (Jominy test) shall conform to the values given in Tables B.6, C.7 and C.8.

In the case of products ordered with restricted requirements regarding the scatter bands of the hardness values obtained by the Jominy test, that is, when the steel name or number is supplemented by the symbols "+HH" or "+HL", the above hardness values shall conform to the values given in Tables B.7 and C.9.

NOTE 1 The symbol "+HH" denotes that the upper limit of the scatter band coincides with the upper limit for the corresponding steel "+H".

NOTE 2 The symbol "+HL" denotes that the lower limit of the scatter band coincides with the lower limit for the corresponding steel "+H".

NOTE 3 For hardenability by calculation and for verification of hardenability, see 10.3.

The austenizing temperatures for the Jominy test are given in Tables B.6, B.7, C.7, C.8 and C.9.

7.1.4.3 In the case of steels for quenching and tempering (see Annex C) ordered with core hardening requirements, that is, when the steel names or numbers are supplemented by the symbol "+CH", the minimum core hardness shall conform to the values given in Table C.10.

At least 90 % of the structure shall be martensite, even in the core.

7.2 Grain size

Steels of Annexes B and C shall have a fine grain structure with an austenite grain size number of 5 or finer. For verification, see D.2.

For steels of Annex A, the austenitic grain size is left to the manufacturer's discretion unless otherwise agreed.

7.3 Carbide spheroidization

If carbide spheroidization is requested, reference shall be made to D.3.

7.4 Non-metallic inclusions

7.4.1 Microscopic inclusions

The special steels of Annexes B and C shall have a certain degree of cleanness. However, verification of the non-metallic inclusion content requires a special agreement. For such an agreement, see D.4.

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For steels of Annex A, the cleanness is left to the manufacturer's discretion unless otherwise agreed at the time of enquiry and order.

7.4.2 Macroscopic inclusions

This requirement is applicable to the verification of the macroscopic inclusions in special steels. If verification is agreed, the method and acceptance limits shall be agreed at the time of enquiry and order.

7.5 Internal soundness

Wire rod, bars and wire shall be free from internal defects, which can cause an adverse effect on products during cold heading or cold extrusion or during heat treatment.

Where appropriate, non-destructive testing relating to the internal soundness of the products shall be agreed at the time of enquiry and order, see 10.4.

7.6 Aptitude to cold forming

A test for verification of the aptitude of products to cold forming shall be carried out if agreed at the time of enquiry and order with reference to 10.5

7.7 Surface quality

7.7.1 General

All products shall have a smooth surface finish appropriate to the manufacturing process applied. For hot-rolled products, minor surface imperfections, which can occur also under normal manufacturing conditions, such as prints originating from rolled-in scale, shall not be regarded as defects. It is more difficult to detect and eliminate surface discontinuities from coiled products than from cut lengths. This should be taken into account when agreements on surface quality are made.

7.7.2 Wire rod

Wire rod shall meet surface quality requirements in accordance with ISO 9443 quality class D. For certain higher applications, quality class E in accordance with ISO 9443 is appropriate and may be agreed at the time of enquiry and order.

7.7.3 Bars

Bars shall meet surface quality requirements in accordance with ISO 9443 quality class D. Conformity to surface quality in accordance with ISO 9443 quality class E may be agreed at the time of enquiry and order. When the diameter of the product is greater than the maximum diameter specified in ISO 9443 for the surface quality class concerned, the maximum permissible depth of surface defects on the product shall not be greater than that specified for this maximum diameter.

7.7.4 Bright products and wire

For wire, the permissible depth of surface discontinuities shall be in proportion to the reduction of the diameter during cold drawing. Depending on the starting material for cold drawn products, the same requirements apply as specified in 7.7.2.

Cold drawn bars shall be delivered with the surface quality class 1 and peeled/turned bars shall be delivered with surface quality class 3 in accordance with ISO 683-7.

7.7.5 Removal of surface discontinuities

Removal of surface defects and imperfections shall only be done after approval from the purchaser.

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7.7.6 Non-destructive testing of the surface

The surface shall be non-destructive inspected with magnetic particles if agreed at the time of enquiry and order, see 10.4.

7.8 Decarburization

7.8.1 Decarburization applicable for steels of Annexes B and C

Bars and wire rod with as-rolled surface of steels specified in Tables B.2, C.2 and C.3 and wire, independent of the heat-treatment condition, shall be free from complete decarburization.

For bars and wire rod with as-rolled surface and wire partial decarburization (ferrite-pearlite) E is permitted, provided that it does not exceed the following limits. For diameters $d \leq 10$ mm, the maximum permissible depth of decarburization is $E = 0{,}07$ mm. For diameters greater than 10 mm, the maximum permissible depth of decarburization is $E = 0{,}007\ d$.

For cold drawn products with diameters greater than 5 mm, the limits of partial decarburization shall be the same as those for hot-rolled products. For cold drawn products with diameter less than 5 mm, the permissible depth of partial decarburization shall be reduced in function of the reduction of the diameter during the cold drawing.

Peeled/turned bars, wire rod and wire shall be free of decarburization.

If, in special cases, the purchaser requests other values (e.g. bars annealed in an atmosphere that is not controlled the depth of decarburization) for partial decarburization, those values shall be agreed at the time of enquiry and order in accordance with D.5. Testing for decarburization should also be done according to D.5.

7.8.2 Decarburization applicable for steels of Annex A

For steels of Annex A, requirements for decarburization only apply if agreed at the time of enquiry and order.

7.9 Shape, dimensions and tolerances

The shape, dimensions and tolerances of the products shall conform to the requirements agreed at the time of enquiry and order. The agreements shall be based on corresponding International Standards: ISO 683-7, ISO 1035-1, ISO 1035-2, ISO 1035-3, ISO 1035-4, ISO 16124 and ISO 22034-2, or on other suitable regional standards.

8 Inspection

8.1 Testing procedures and types of documents

8.1.1 Products conforming to this document shall be ordered and delivered with one of the inspection documents as specified in ISO 10474 or another comparable national standard. 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.

NOTE Other comparable national standards, such as EN 10204, JIS G0415 or GB/T 18253, can be used.

8.1.2 If, in accordance with the agreements made at the time of enquiry and order, a test report 2.2 shall be provided, this shall cover the following information:

a) confirmation that the material conforms to the requirements of the order;

b) results of the cast analysis for all elements specified in Tables A.2, B.2, C.2 and C.3 for the steel grade concerned.

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8.1.3 If, in accordance with the agreements in the order, an inspection certificate 3.1 or 3.2, must be provided, the specific inspections and tests described in 8.2 and Clause 10 shall be carried out and the results shall be confirmed in the inspection certificate.

In addition, the inspection certificate shall cover:

a) confirmation that the material conforms to the requirements of the order;

b) results of the cast analysis for all elements specified in Tables A.2, B.2, C.2 and C.3 for the steel grade concerned;

c) results of all mandatory and optional inspections and tests (see Table 3);

d) the symbol, letters or numbers relating the inspection certificate, test pieces and products to each other.

8.2 Summary of specific inspection and frequency of testing

The requirements for specific inspection and frequency of testing for steels for cold heading and cold extrusion shall be as given in Table 3.

9 Preparation of samples and test pieces

9.1 Selection and preparation of samples for product analysis

Samples for product analysis shall be taken from the test pieces or samples for mechanical testing or from the same location as the mechanical test samples in accordance with ISO 14284.

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Table 3 — Specific inspection and frequency of inspection of steels for cold heading and cold extrusion

Inspection requirements				Frequency of testing			Applicable for steels in accordance with Annex [d]		
Type of test			Clause/ subclause reference	Test unit [a]	Number of samples per test unit	Number of test pieces per sample	A	B	C
Mandatory tests	1	Cast analysis	7.1.2 and 10.1	C	the cast analysis is given by the manufacturer		m	m	m
	2	Tensile test	7.1.3 and 10.2	C + D + T	1 for each 15 t with a maximum of 3	1	m	m	m
	3	Surface condition and dimensions	Clause 7 and 10.6	C + D + T	at the manufacturer's discretion		m	m	m
Optional tests	4	Verification of hardenability or of core hardness	7.1.4 and 10.3	C	1 per cast	1	o	o	o
	5	Product analysis	7.1.2, 9.1, 10.1	C	1 per cast	1	o	o	o
	6	Fine grain structure	7.2 and D.2	C	1 per cast	1	o	o	o
	7	Carbide spheroidization	7.3 and D.3	C + D + T	1 for each 15 t with a maximum of 3	1	o	o	o
	8	Non-metallic inclusions	7.4 and D.4	C[c]	[b]	[b]	o	o	o
	9	NDT-testing	7.5, 7.7.6 and 10.4	C[c]	[b]	[b]	o	o	o
	10	Aptitude to cold forming	7.6 and 10.5	C[c]	[b]	[b]	o	o	o
	11	Decarburization	7.8 and D.5	C + D + T	1 for each 15 t with a maximum of 3	1	o	o	o

[a] The tests shall be carried out separately for each cast as indicated by "C", — for each dimension as indicated by "D" — and for each treatment batch as indicated by "T". Wire rod, bars and wire for which the ratio of nominal section does not exceed 3:1 may be grouped in a single test unit. In cases where heat treatment is performed as a continuous process the symbol "T" denotes that the tests are to be carried out for each 25 t or fraction thereof.

[b] Shall be agreed upon at the time of enquiry and order.

[c] The test unit may be agreed at the time of enquiry and order.

[d] m = mandatory (to be carried out in every case), o = optional, (to be carried out if agreed at the time of enquiry and order), – = is not carried out.

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9.2 Selection and preparation of samples and test pieces for the mechanical test

Samples and test pieces shall be taken in accordance with the general requirements of ISO 377. The test piece shall be prepared in accordance with ISO 6892-1.

— For products with $d > 25$ mm: The test piece for the tensile test shall be taken to conform to the indication given in Figure 1 c).

— For products with $d \leq 25$ mm**:** The test piece for the tensile test shall be submitted to test without preliminary machining, see Figure 1 a). If test equipment does not allow this, the test piece may be prepared by machining, as shown in Figure 1 b).

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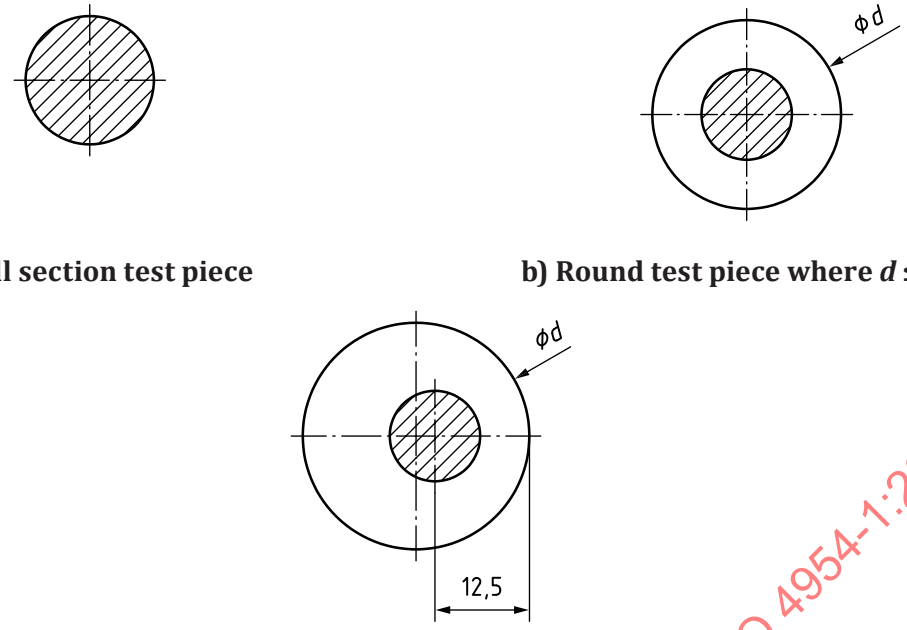

a) Full section test piece

b) Round test piece where $d \leq 25$ mm

c) Round test piece where $d > 25$ mm

Figure 1 — Location of test piece for the tensile test

The test piece for the Jominy test (hardenability test) shall be obtained by machining from the samples with $d \leq 40$ mm. Depending on the agreements made at the time of ordering, the samples shall be taken from the product concerned, or the billet or bloom originating from the same cast. In the absence of such agreements, the origin of the sample is left to the manufacturer's discretion. The sample shall be obtained by hot rolling or hot forging.

The test piece for evaluation of the core hardening test shall have, as far as possible, the maximum diameter indicated in Table C.10. Test bars with diameters larger than those given in Table C.10 are to be rolled or forged to the maximum diameters of Table C.10. Sampling and sample preparation is left to the manufacturer's discretion, taking into account the indications concerning the test piece for the End Quench test (Jominy test), see ISO 642. The length of the test piece shall be at least four times its diameter.

10 Test methods

10.1 Chemical analysis

The choice of a suitable physical or chemical analytical method for the analysis shall be at the discretion of the manufacturer. In cases of dispute, the method for product analysis used shall be agreed taking into account the relevant existing International Standards.

NOTE The list of available International Standards on chemical analysis is given in ISO/TR 9769.

10.2 Mechanical tests

The tensile test shall be carried out in accordance with ISO 6892-1.

For the specified yield strength in the tables on mechanical properties in this document, the upper yield strength, R_{eH}, shall be determined.

If a yield phenomenon is not present, the 0,2 % proof strength, $R_{p0,2}$, shall be determined.

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10.3 Hardenability and core hardness tests

10.3.1 Verification of hardenability

As far as available, the manufacturer has the option to verify the hardenability by calculation. The calculation method is left to the discretion of the manufacturer. If agreed at the time of enquiry and order, the manufacturer shall give sufficient information about the calculation for the customer to confirm the result.

If a calculation formula is not available or in the case of dispute, an end quench hardenability test shall be carried out in accordance with ISO 642. The temperature for austenitizing shall conform to the relevant tables of Annexes B and C. The hardness values shall be determined in accordance with ISO 6508-1, scale C.

10.3.2 Verification of core hardness

The test piece shall be heated in a furnace with a neutral or reducing atmosphere up to the temperatures indicated in Table C.10. It shall be maintained at that temperature until complete austenitizing takes place.

It shall then be removed from the furnace and quenched immediately in a quenching oil with high cooling capacity until a full equilibrium of temperature is reached, the temperature of the quenching bath being about 50 °C and the rate of movement of the test piece being about 0,25 m/s. The test piece shall then be notched at its midpoint in a direction perpendicular to its longitudinal axis and then broken. One of the fracture surfaces shall be polished (care should be taken to prevent excessive local heating).

The Rockwell hardness at the centre of the fracture surface shall then be determined in accordance with ISO 6508-1, scale C.

10.4 Non-destructive testing

Concerning the internal soundness, the products shall be non-destructively tested, preferably with an ultrasonic test and under acceptance criteria to be agreed at the time of enquiry and order.

Concerning the surface of the products, the eddy current test in accordance with ISO 15549 or the magnetic particle test in accordance with ISO 9934-1 shall be performed. The descaling of the test pieces is not requested unless otherwise agreed at the time of enquiry and order. The absence of detectable cracks on the test piece after it has been submitted to magnetic particle inspection shall be considered as evidence that the product concerned is free from surface defects.

10.5 Aptitude to cold forming — Upsetting test

The surfaces of the end sections of the above test pieces shall be flat and parallel to each other and their initial length (height) shall be $h = 1{,}5 * d$, where d is the test piece diameter. During the test, the length (height) of the test piece shall be reduced to one third of its initial value.

Supplementary for treated condition “AC” and diameter less than 25 mm ($d < 25$ mm), the following may be agreed between the manufacturer and the customer. The surfaces of the end sections of the above test pieces shall be flat and parallel to each other and their initial length (height) shall be $h = 2{,}0 * d$, where d is the test piece diameter. During the test, the length (height) of the test piece shall be reduced to one quarter of its initial value.

The tests shall be carried out at room temperature. The absence of cracks on the specimen, after the upsetting test has been carried out, is to be taken as evidence that the product in question is free from longitudinal surface defects. Non propagating notches on the sample resulting from indentations or scratches shall not be considered as defects. The details of the assessment and acceptance criteria shall also be agreed at the time of enquiry and order.

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10.6 Visual and dimensional tests

A sufficient number of products shall be inspected to ensure conformity to the specification. The corresponding International Standards are ISO 683-7, ISO 1035-1, ISO 1035-2, ISO 1035-3, ISO 1035-4, ISO 16124 and ISO 22034-2.

10.7 Retests

Retests shall be as specified in ISO 404.

11 Surface treatment, marking and packaging

11.1 Surface treatment and temporary corrosion protection

Surface treatment can facilitate subsequent cold heading and cold extrusion or partially delay any formation of rust. This treatment can include, e.g. descaling, treatment with lime and/or phosphate and/or adequate protection during transport and storage, and shall be subject to an agreement at the time of enquiry and order.

11.2 Marking

The manufacturer shall mark the products or the bundles or boxes containing the products in a suitable way, so that the identification of the cast, the steel type and the origin of the delivery is possible.

Further requirements to special marking of the products shall be agreed at the time of enquiry and order.

11.3 Packaging

A special method of packaging of the product to be delivered shall be agreed at the time of enquiry and order.

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Annex A
(normative)

Specific requirements for cold heading and cold extruding steels not intended for heat treatment after cold working

Table A.1 — Combinations of heat-treatment conditions at delivery, product forms and applicable requirements

Delivery condition		Symbols	Product form[a]			Applicable requirements		
			Wire rod	Bar	Wire			
Untreated	(as hot-rolled)	+AR	X	X	—	Chemical composition as specified in Table A.2	Mechanical properties as specified in Table A.3	Supplementary or special requirements as specified in Annex D[b]
Untreated +	peeled	+AR+PE	X	X	—			
	cold drawn	+AR+C	—	X	X			
	cold drawn + spheroidized	+AR+C+AC	—	X	X			
	cold drawn + spheroidized + skin passed	+AR+C+AC+LC	—	X	X			
Annealed to achieve spheroidized carbides +	as treated or peeled	+AC or AC+PE	X	X	—			
	cold drawn	+AC+C	—	X	X			
Other			Other delivery conditions may be agreed at the time of ordering					

[a] X = applicable, — = not applicable.

[b] If agreed at the time of enquiry and order.

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Table A.2 — Chemical composition (applicable to cast analysis) of steels not intended for heat treatment after cold working[a]

Steel name	% mass fraction[a]										
	C	Si	Mn	P	S	Cr	Ni	Mo	Al[b]	Cu	Cr + Ni + Mo
Non-alloy steel grades											
C2C	0,03	0,10	0,20 to 0,40[d]	0,020	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C4C	0,02 to 0,06	0,10	0,25 to 0,40	0,020	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C8C	0,06 to 0,10	0,10	0,25 to 0,45	0,020	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C10C	0,08 to 0,12	0,10	0,30 to 0,50	0,025	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C10GC	0,08 to 0,12	0,15 to 0,25[c]	0,30 to 0,50	0,025	0,025	0,30	0,30	0,10	—[c]	0,30	0,50
C15C	0,13 to 0,17	0,10	0,35 to 0,60	0,025	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C15GC	0,13 to 0,17	0,15 to 0,25[c]	0,35 to 0,60	0,025	0,025	0,30	0,30	0,10	—[c]	0,30	0,50
C17C	0,15 to 0,19	0,10	0,65 to 0,85	0,025	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C17GC	0,15 to 0,19	0,15 to 0,25[c]	0,65 to 0,85	0,025	0,025	0,30	0,30	0,10	—[c]	0,30	0,50
C20C	0,18 to 0,22	0,10	0,70 to 0,90[d]	0,025	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C20GC	0,18 to 0,22	0,15 to 0,25[c]	0,70 to 0,90[d]	0,025	0,025	0,30	0,30	0,10	—[c]	0,30	0,50
C25C	0,23 to 0,27	0,10	0,80 to 1,00[d]	0,025	0,025	0,30	0,30	0,10	0,020 to 0,060	0,30	0,50
C25GC	0,23 to 0,27	0,15 to 0,25[c]	0,80 to 1,00[d]	0,025	0,025	0,30	0,30	0,10	—[c]	0,30	0,50

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of elements from scrap or other material used in the production process. However, residual elements may be present, provided that they do not affect the mechanical properties and applicability.

[a] Maximum values unless otherwise indicated.

[b] Aluminium may be replaced by another element or elements having a similar effect on deoxidation and on grain size.

[c] Grades C10GC, C15GC, C17GC, C20GC and C25GC can be delivered in two qualities: a) with an aluminium content of Al max. 0,015 %, or b) without aluminium and a silicon content of 0,15 % to 0,25 % for hot dip zinc coating.

[d] For grades C2C, C20C, C20GC and C25C, a lower manganese content may be specified with a range of 0,20 %.

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Table A.3 — Mechanical properties of wire rod, bars and wire not intended for heat treatment after cold working

Steel name	Diameter		Delivery Condition											
			+AR or +AR+PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
	above mm	up to mm	R_m max. MPa	Z^a min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %
C2C	≥ 2	5	—	—	—	—	—	—	310	80	350	75	—	—
	5	10	360	75	—	—	450	70	300	80	340	75	—	—
	10	40	360	75	—	—	440	70	300	80	340	75	—	—
	40	100	360	75	—	—	440	68	300	80	340	75	—	—
C4C	≥ 2	5	—	—			—	—	320	77	360	73	—	—
	5	10	390	70	330	75	470	66	310	77	350	73	410	70
	10	40	390	70	330	75	460	66	300	77	350	73	400	70
	40	100	390	70	330	75	—	—	—	—	—	—	—	—
C8C	≥ 2	5	—	—	—	—	—	—	350	72	390	68	—	—
	5	10	410	65	360	70	490	63	340	72	380	68	450	65
	10	40	410	65	360	70	480	63	340	72	380	68	440	65
	40	100	410	65	360	70	—	—	—	—	—	—	—	—
C10C C10GC	≥ 2	5	—	—	—	—	—	—	370	72	410	68	—	—
	5	10	430	60	380	70	520	58	360	72	400	68	470	63
	10	40	430	60	380	70	510	58	360	72	400	68	460	63
	40	100	430	60	380	70	—	—	—	—	—	—	—	—
C15C C15GC	≥ 2	5	—	—	—	—	—	—	390	70	430	66	—	—
	5	10	460	58	400	68	550	56	380	70	420	66	490	63
	10	40	460	58	400	68	540	56	380	70	420	66	480	63
	40	100	460	58	400	68	—	—	—	—	—	—	—	—
C17C C17GC	≥ 2	5	—	—	—	—	—	—	430	67	470	63	—	—
	5	10	520	58	440	65	610	56	420	67	460	63	530	60
	10	40	520	58	440	65	600	56	420	67	460	63	520	60
	40	100	520	58	440	65	—	—	—	—	—	—	—	—

[a] The values are given only for information.

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Table A.3 *(continued)*

Steel name	Diameter		Delivery Condition											
			+AR or +AR+PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
	above mm	up to mm	R_m max. MPa	Z[a] min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %	R_m max. MPa	Z min. %
C20C C20GC	≥ 2	5	—	—	—	—	—	—	470	67	510	63	—	—
	5	10	560	55	480	65	650	53	460	67	500	63	570	60
	10	40	560	55	480	65	640	53	460	67	500	63	560	60
	40	100	560	55	480	65	—	—	—	—	—	—	—	—
C25C	≥ 2	5	—	—	—	—	—	—	500	65	540	60	—	—
	5	10	590	50	510	60	680	50	490	65	530	60	600	55
	10	40	590	50	510	60	670	50	490	65	530	60	590	55
	40	100	590	50	510	60	—	—	—	—	—	—	—	—
C25GC	≥ 2	5	—	—	—	—	570	45	—	—	440	55	—	—
	5	10	590	50	—	—	470	45	—	—	440	55	440	55
	10	40	590	50	—	—	470	45	—	—	440	55	440	55
	40	100	590	50	—	—	—	—	—	—	—	—	—	—

[a] The values are given only for information.

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Annex B
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Specific requirements for cold heading and cold extruding case-hardening steels

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Table B.1 — Combinations of heat-treatment conditions at delivery, product forms and applicable requirements

Heat-treatment condition at delivery	Symbol	Products form[a]			Applicable requirements in cases where the steel concerned has been ordered with reference to the steel names indicated in					
		Wire rod	Bar	Wire	Tables B.2, B.3, B.4 or B.5		Tables B.2, B.3, B.4, B.5, B.6 or B.7			Optional
As hot-rolled or peeled	+AR or +PE	X	X	X	Chemical composition as specified in Table B.2	Mechanical properties as specified in Tables B.3, B.4 and B.5	Chemical composition as specified in Table B.2	Mechanical properties as specified in Tables B.3, B.4 and B.5	Values for hardenability according to Tables B.6 and B.7	Supplementary or special requirements as specified in Annex D[b]
Cold drawn	+AR +C	—	X	X						
Cold drawn + spheroidized	+AR +C +AC	—	X	X						
Cold drawn + spheroidized + skin passed	+AR +C +AC + LC	—	X	X						
Spheroidized or spheroidized + peeled	+AC or +AC +PE	X	X	X						
Spheroidized + cold drawn	+AC + C	—	X	X						
Treated to ferrite-pearlite structure and hardness range	+FP	—	X	—						
Others	Other delivery conditions may be agreed at the time of ordering									

[a] X = applicable, — = not applicable.

[b] If agreed at the time of the enquiry and order.

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Table B.2 — Chemical composition (applicable to cast analysis) of steels for case hardening

Steel name[b]	% mass fraction[a]									
	C	Si[c]	Mn	P	S	Cr	Ni	Mo	B [d]	Cu
Non-alloy steel grades										
C10E2C	0,08 to 0,12	0,30	0,30 to 0,60	0,025	0,025	—	—	—	—	0,25
C15E2C	0,13 to 0,17	0,30	0,30 to 0,60	0,025	0,025	—	—	—	—	0,25
C17E2C	0,15 to 0,19	0,30	0,60 to 0,90	0,025	0,025	—	—	—	—	0,25
C20E2C	0,18 to 0,22	0,30	0,30 to 0,60	0,025	0,025	—	—	—	—	0,25
Alloy steel grades										
15B2	0,13 to 0,16	0,30	0,60 to 0,90	0,025	0,025	—	—	—	0,000 8 to 0,005 0	0,25
18MnB4	0,16 to 0,20	0,30	0,90 to 1,20	0,025	0,025	—	—	—	0,000 8 to 0,005 0	0,25
22MnB4	0,20 to 0,24	0,30	0,90 to 1,20	0,025	0,025	—	—	—	0,000 8 to 0,005 0	0,25
17Cr3	0,12 to 0,20	0,30	0,60 to 0,90	0,025	0,025	0,70 to 1,25	—	—	—	0,25
17CrS3	0,12 to 0,20	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,70 to 1,25	—	—	—	0,25
20Cr4	0,17 to 0,23	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	—	—	0,25
20CrS4	0,17 to 0,23	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,90 to 1,20	—	—	—	0,25
16MnCr5	0,14 to 0,19	0,30	1,00 to 1,30	0,025	0,025	0,80 to 1,10	—	—	—	0,25
16MnCrS5	0,14 to 0,19	0,30	1,00 to 1,30	0,025	0,020 to 0,040	0,80 to 1,10	—	—	—	0,25
16MnCrB5	0,14 to 0,19	0,30	1,00 to 1,30	0,025	0,025	0,80 to 1,10	—	—	0,000 8 to 0,005 0	0,25
20MnCr5	0,17 to 0,22	0,30	1,10 to 1,40	0,025	0,025	1,00 to 1,30	—	—	—	0,25
20MnCrS5	0,17 to 0,22	0,30	1,10 to 1,40	0,025	0,020 to 0,040	1,00 to 1,30	—	—	—	0,25
12CrMo4	0,10 to 0,15	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,25	—	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max. Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Tables B.6 and B.7), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] A lower silicon content or a specific silicon range may be agreed at the time of ordering.

[d] Non-effective boron is detrimental to toughness and should be avoided. Boron should be in solution in order to guarantee the hardening, i.e. 90 % martensite in the core.

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Table B.2 *(continued)*

Steel name[b]	% mass fraction[a]									
	C	Si[c]	Mn	P	S	Cr	Ni	Mo	B [d]	Cu
18CrMo4	0,15 to 0,21	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,25	—	0,25
18CrMoS4	0,15 to 0,21	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,90 to 1,20	—	0,15 to 0,25	—	0,25
20MoCr4	0,17 to 0,23	0,30	0,70 to 1,00	0,025	0,025	0,30 to 0,60	—	0,40 to 0,50	—	0,25
20MoCrS4	0,17 to 0,23	0,30	0,70 to 1,00	0,025	0,020 to 0,040	0,30 to 0,60	—	0,40 to 0,50	—	0,25
10NiCr5-4	0,07 to 0,12	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	1,20 to 1,50	—	—	0,25
12NiCr3-2	0,09 to 0,15	0,30	0,30 to 0,60	0,025	0,025	0,40 to 0,70	0,50 to 0,80	—	—	0,25
17CrNi6-6	0,14 to 0,20	0,30	0,50 to 0,90	0,025	0,025	1,40 to 1,70	1,40 to 1,70	—	—	0,25
20NiCrMo2-2	0,17 to 0,23	0,30	0,65 to 0,95	0,025	0,025	0,35 to 0,70	0,40 to 0,70	0,15 to 0,25	—	0,25
20NiCrMoS2-2	0,17 to 0,23	0,30	0,65 to 0,95	0,025	0,020 to 0,040	0,35 to 0,70	0,40 to 0,70	0,15 to 0,25	—	0,25
20NiCrMo7	0,17 to 0,23	0,30	0,40 to 0,70	0,025	0,025	0,35 to 0,65	1,60 to 2,00	0,20 to 0,30	—	0,25
20NiCrMoS6-4	0,16 to 0,23	0,30	0,50 to 0,90	0,025	0,020 to 0,040	0,60 to 0,90	1,40 to 1,70	0,25 to 0,35	—	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max. Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Tables B.6 and B.7), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] A lower silicon content or a specific silicon range may be agreed at the time of ordering.

[d] Non-effective boron is detrimental to toughness and should be avoided. Boron should be in solution in order to guarantee the hardening, i.e. 90 % martensite in the core.

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Table B.3 — Mechanical properties of non-alloy steel grades

Steel name	Diameter		Delivery condition											
			+AR or +PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
	above	up to	R_m max.	Z[a] min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%
C10E2C	≥ 2	5	—	—	—	—	—	—	390	67	430	65	—	—
	5	10	450	58	400	65	540	56	380	67	420	65	490	62
	10	40	450	58	400	65	530	56	380	67	420	65	480	62
	40	100	450	58	400	65	—	—	—	—	—	—	—	—
C15E2C	≥ 2	5	—	—	—	—	—	—	420	67	460	65	—	—
	5	10	480	58	430	65	570	56	410	67	450	65	520	62
	10	40	480	58	430	65	560	56	410	67	450	65	510	62
	40	100	480	58	430	65	—	—	—	—	—	—	—	—
C17E2C	≥ 2	5	—	—	—	—	—	—	440	67	480	65	—	—
	5	10	530	58	450	65	630	56	430	67	470	65	550	62
	10	40	530	58	450	65	620	56	430	67	470	65	540	62
	40	100	530	58	450	65	—	—	—	—	—	—	—	—
C20E2C	≥ 2	5	—	—	—	—	—	—	460	67	500	65	—	—
	5	10	530	58	470	65	640	56	450	67	490	65	580	62
	10	40	530	58	470	65	630	56	450	67	490	65	570	62
	40	100	530	58	470	65	—	—	—	—	—	—	—	—

[a] The values are given only for information.

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Table B.4 — Mechanical properties of boron-alloyed steel grades

Steel name	Diameter		Delivery condition											
			+AR		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
	above	up to	R_m max.	Z[a] min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%
15B2	≥ 2	5	—	—	—	—	—	—	440	67	480	65	—	—
	5	10	500	58	450	65	590	56	430	67	470	65	540	62
	10	40	500	58	450	65	580	56	430	67	470	65	530	62
18MnB4	≥ 2	5	—	—	—	—	—	—	500	64	540	62	—	—
	5	10	580	55	500	64	680	53	480	64	520	62	600	59
	10	40	580	55	500	64	670	53	480	64	520	62	590	59
22MnB4	≥ 2	5	—	—	—	—	—	—	520	64	560	62	—	—
	5	10	600	55	520	62	720	53	500	64	540	62	630	59
	10	40	600	55	520	62	710	53	500	64	540	62	620	59

[a] The values are given only for information.

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Table B.5 — Mechanical properties of alloy steel grades

Steel name	Diameter		Delivery condition									
			+AC		+FP		+AR+C+AC		+AR+C+AC+LC		+AC+C	
			Mechanical properties									
	above	up to	R_m max.	Z min.	HB min.	HB max.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%			MPa	%	MPa	%	MPa	%
17Cr3 17CrS3	≥ 2	5	—	—	—	—	520	62	560	60	—	—
	5	10	520	60	140	187	500	62	540	60	630	57
	10	40	520	60	140	187	500	62	540	60	620	57
20Cr4 20CrS4	≥ 2	5	—	—	—	—	—	—	—	—	—	—
	5	10	—	—	—	—	540	60	580	60	640	55
	10	40	640	60	—	—	540	60	580	60	640	55
16MnCr5 16MnCrS5 16MnCrB5	≥ 2	5	—	—	—	—	550	64	590	62	—	—
	5	10	550	62	140	187	530	64	570	62	660	59
	10	40	550	62	140	187	530	64	570	62	650	59
20MnCr5 20MnCrS5	≥ 2	5	—	—	—	—	570	62	610	60	—	—
	5	10	570	60	152	201	550	62	590	60	680	57
	10	40	570	60	152	201	550	62	590	60	670	57
12CrMo4	≥ 2	5	—	—	—	—	500	—	—	—	—	—
	5	10	500	62	135	185	480	64	520	62	—	—
	10	40	500	62	135	185	480	64	520	62	—	—
18CrMo4 18CrMoS4	≥ 2	5	—	—	—	—	550	62	590	60	—	—
	5	10	550	60	140	187	530	62	570	60	660	57
	10	40	550	60	140	187	530	62	570	60	650	57
20MoCr4 20MoCrS4	≥ 2	5	—	—	—	—	560	62	600	60	—	—
	5	10	560	60	140	187	540	62	580	60	670	57
	10	40	560	60	140	187	540	62	580	60	660	57
10NiCr5-4	≥ 2	5	—	—	—	—	520	64	560	62	—	—
	5	10	520	62	137	187	500	64	540	62	640	59
	10	40	520	62	137	187	500	64	540	62	630	59

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Table B.5 *(continued)*

Steel name	Diameter		Delivery condition									
			+AC		+FP		+AR+C+AC		+AR+C+AC+LC		+AC+C	
			Mechanical properties									
	above	up to	R_m max.	Z min.	HB min.	HB max.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%			MPa	%	MPa	%	MPa	%
12NiCr3-2	≥ 2	5	—	—	—	—	500	64	540	62	—	—
	5	10	500	62	130	180	480	64	520	62	620	59
	10	40	500	62	130	180	480	64	520	62	610	59
17CrNi6-6	≥ 2	5	—	—	—	—	600	62	640	60	—	—
	5	10	600	60	156	207	580	62	620	60	720	57
	10	40	600	60	156	207	580	62	620	60	710	57
20NiCrMo2-2 20NiCrMoS2-2	≥ 2	5	—	—	—	—	590	62	630	60	—	—
	5	10	590	60	149	194	570	62	610	60	720	57
	10	40	590	60	149	194	570	62	610	60	710	57
20NiCrMo7	≥ 2	5	—	—	—	—	—	—	—	—	—	—
	5	10	—	—	—	—	680	60	—	—	700	55
	10	25	—	—	—	—	680	60	—	—	700	55
20NiCrMoS6-4	≥ 2	5	—	—	—	—	610	60	650	58	—	—
	5	10	610	58	149	201	590	60	630	58	730	55
	10	25	610	58	149	201	590	60	630	58	720	55

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Table B.6 — Hardness limits for steel grades with standard hardenability (+H grades)

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of												
				1,5	3	5	7	9	11	13	15	20	25	30	35	40
18MnB4	+H	890	max.	46	45	44	41	39	35	32	28	21	—	—	—	—
			min.	40	38	37	30	21	—	—	—	—	—	—	—	—
22MnB4	+H	880	max.	49	48	47	45	42	39	35	32	24	20	—	—	—
			min.	43	41	40	32	23	—	—	—	—	—	—	—	—
17Cr3 17CrS3	+H	880	max.	47	44	40	33	29	27	25	24	23	21	—	—	—
			min.	39	35	25	20	—	—	—	—	—	—	—	—	—
20Cr4 20CrS4	+H	900	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
			min.	41	38	31	26	23	21-	—	—	—	—	—	—	—
16MnCr5 16MnCrS5	+H	870	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
			min.	39	36	31	28	24	21	—	—	—	—	—	—	—
16MnCrB5	+H	870	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
			min.	39	36	31	28	24	21	—	—	—	—	—	—	—
20MnCr5 20MnCrS5	+H	870	max.	49	49	48	46	43	42	41	39	37	35	34	33	32
			min.	41	39	36	33	30	28	26	25	23	21	—	—	—
12CrMo4	+H	870	max.	44	43	41	38	34	30	28	27	23	21	—	—	—
			min.	36	34	30	26	22	—	—	—	—	—	—	—	—
18CrMo4 18CrMoS4	+H	880	max.	47	46	45	42	39	37	35	34	31	29	28	27	26
			min.	39	37	34	30	27	24	22	21	—	—	—	—	—
20MoCr4 20MoCrS4	+H	910	max.	49	47	44	41	38	35	33	31	28	26	25	24	24
			min.	41	37	31	27	24	22	—	—	—	—	—	—	—
10NiCr5	+H	880	max.	41	39	37	34	32	30	—	—	—	—	—	—	—
			min.	32	27	24	22	—	—	—	—	—	—	—	—	—
12NiCr3-2	+H	870	max.	43	40	35	26	21	—	—	—	—	—	—	—	—
			min.	37	32	25	—	—	—	—	—	—	—	—	—	—
17CrNi6-6	+H	870	max.	47	47	46	45	43	42	41	39	37	35	34	34	33
			min.	39	38	36	35	32	30	28	26	24	22	21	20	20
20NiCrMo2-2 20NiCrMoS2-2	+H	880	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
			min.	41	37	31	25	22	20	—	—	—	—	—	—	—

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Table B.6 *(continued)*

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of												
				1,5	3	5	7	9	11	13	15	20	25	30	35	40
20NiCrMo7	+H	900	max.	48	47	45	42	39	36	34	32	29	26	25	24	24
			min.	40	38	34	30	27	25	23	22	20	—	—	—	—
20NiCrMoS6-4	+H	880	max.	49	49	48	48	47	47	46	44	41	39	38	37	36
			min.	41	40	39	36	33	30	28	26	23	21	—	—	—

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Table B.7 — Hardness limits for steel grades with restricted hardenability scatter bands (+HH and +HL grades)

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of												
				1,5	3	5	7	9	11	13	15	20	25	30	35	40
17Cr3 17CrS3	+HH	880	max.	47	44	40	33	29	27	25	24	23	21	—	—	—
			min.	42	38	30	24	20	—	—	—	—	—	—	—	—
	+HL		max.	44	41	35	29	25	23	21	20	—	—	—	—	—
			min.	39	35	25	20	—	—	—	—	—	—	—	—	—
20Cr4 20CrS4	+HH	900	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
			min.	44	41	36	31	28	26	24	22	—	—	—	—	—
	+HL		max.	46	45	41	37	33	31	29	27	24	22	21	—	—
			min.	41	38	31	26	23	21-	—	—	—	—	—	—	—
16MnCr5 16MnCrS5	+HH	870	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
			min.	42	39	35	32	29	26	24	22	20	—	—	—	—
	+HL		max.	44	43	40	37	34	32	30	28	26	25	24	23	22
			min.	39	36	31	28	24	21	—	—	—	—	—	—	—
16MnCrB5	+HH	870	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
			min.	42	39	35	32	29	26	24	22	20	—	—	—	—
	+HL		max.	44	43	40	37	34	32	30	28	26	25	24	23	22
			min.	39	36	31	28	24	21	—	—	—	—	—	—	—
20MnCr5 20MnCrS5	+HH	870	max.	49	49	48	46	43	42	41	39	37	35	34	33	32
			min.	44	42	40	37	34	33	31	30	28	26	25	24	23
	+HL		max.	46	46	44	42	39	37	36	34	32	30	29	28	27
			min.	41	39	36	33	30	28	26	25	23	21	—	—	—
12CrMo4	+HH	870	max.	44	43	41	38	34	30	28	27	23	21	—	—	—
			min.	39	37	34	30	26	21	—	—	—	—	—	—	—
	+HL		max.	41	40	37	34	30	26	23	20	—	—	—	—	—
			min.	36	34	30	26	22	—	—	—	—	—	—	—	—
18CrMo4 18CrMoS4	+HH	880	max.	47	46	45	42	39	37	35	34	31	29	28	27	26
			min.	42	40	38	34	31	28	26	25	22	20	—	—	—
	+HL		max.	44	43	41	38	35	33	31	30	27	25	24	23	22
			min.	39	37	34	30	27	24	22	21	—	—	—	—	—

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Table B.7 *(continued)*

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of												
				1,5	3	5	7	9	11	13	15	20	25	30	35	40
20MoCr4 20MoCrS4	+HH	910	max.	49	47	44	41	38	35	33	31	28	26	25	24	24
			min.	44	40	35	32	29	26	24	22	—	—	—	—	—
	+HL		max.	46	44	40	36	33	31	29	27	24	22	21	20	20
			min.	41	37	31	27	24	22	—	—	—	—	—	—	—
10NiCr5-4	+HH	880	max.	41	39	37	34	32	30	—	—	—	—	—	—	—
			min.	33	29	26	24	21	20	—	—	—	—	—	—	—
	+HL		max.	38	35	32	30	27	25	—	—	—	—	—	—	—
			min.	32	27	24	22	—	—	—	—	—	—	—	—	—
17CrNi6-6	+HH	870	max.	47	47	46	45	43	42	41	39	37	35	34	34	33
			min	42	41	39	38	36	34	32	30	28	26	25	25	24
	+HL		max.	44	44	43	42	39	38	37	35	33	31	30	29	29
			min	39	38	36	35	32	30	28	26	24	22	21	20	20
20NiCrMo2-2 20NiCrMoS2-2	+HH	880	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
			min.	44	41	36	31	27	24	22	21	—	—	—	—	—
	+HL		max.	46	44	40	36	31	29	27	26	23	21	20	20	—
			min.	41	37	31	25	22	20	—	—	—	—	—	—	—
20NiCrMoS6-4	+HH	880	max.	49	49	48	48	47	47	46	44	41	39	38	37	36
			min.	44	43	42	40	38	36	34	32	29	27	26	25	24
	+HL		max.	46	46	45	44	42	41	40	38	35	33	32	31	30
			min.	41	40	39	36	33	30	28	26	23	21	—	—	—

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Annex C
(normative)

Specific requirements for cold heading and cold extruding steels for quenching and tempering

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Table C.1 — Combinations of heat-treatment conditions at delivery, product forms and applicable requirements

Heat-treatment condition at delivery	Symbol	Products form[a]			Applicable requirements in cases where the steel concerned has been ordered with reference to the steel names indicated in								
		Wire rod	Bar	Wire	Tables C.2, C.3, C.4, C.5 or C.6		Tables C.2, C.3, C.4, C.5, C.6, C.7, C.8 or C.9			Tables C.2, C.3, C.4, C.5, C.6 or C.10			Optional
As hot-rolled or peeled	+AR or +PE	X	X	X	Chemical composition as specified in Tables C.2 and C.3	Mechanical properties as specified in Tables C.4, C.5 and C.6	Chemical composition as specified in Tables C.2 and C.3	Mechanical properties as specified in Tables C.4, C.5 and C.6	Values for hardenability according to Tables C.7, C.8 and C.9	Chemical composition as specified in Tables C.2 and C.3	Mechanical properties as specified in Tables C.4, C.5 and C.6	Minimum core hardness and maximum diameter according to Table C.10	Supplementary or special requirements as specified in Annex D[b]
Cold drawn	+AR +C	—	X	X									
Cold drawn + spheroidized	+AR +C + AC	—	X	X									
Cold drawn + spheroidized + skin passed	+AR +C +AC +LC	—	X	X									
Spheroidized or spheroidized + peeled	+AC or +AC +PE	X	X	X									
Spheroidized + cold drawn	+AC + C	—	X	X									
Spheroidized + cold drawn + spheroidized	+AC + C + AC	—	X	X									
Spheroidized + cold drawn +spheroidized +skin passed	+AC + C + AC + LC	—	X	X									
Others	Other delivery conditions may be agreed at the time of ordering												

[a] X = applicable, — = not applicable.

[b] If agreed at the time of the enquiry and order.

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Table C.2 — Chemical composition (applicable to cast analysis) of steel without boron for quenching and tempering

Steel name[b]	% mass fraction[a]								
	C[c]	Si[d]	Mn	P	S	Cr	Ni	Mo	Cu
C30EC	0,27 to 0,33	0,30	0,50 to 0,80	0,025	0,025	—	—	—	0,25
C30RC	0,27 to 0,33	0,30	0,50 to 0,80	0,025	0,020 to 0,035	—	—	—	0,25
C35EC	0,32 to 0,39	0,30	0,50 to 0,80	0,025	0,025	—	—	—	0,25
C35RC	0,32 to 0,39	0,30	0,50 to 0,80	0,025	0,020 to 0,035	—	—	—	0,25
C45EC	0,42 to 0,50	0,30	0,50 to 0,80	0,025	0,025	—	—	—	0,25
C45RC	0,42 to 0,50	0,30	0,50 to 0,80	0,025	0,020 to 0,035	—	—	—	0,25
42Mn6	0,36 to 0,46	0,30	1,30 to 1,65	0,025	0,025	—	—	—	0,25
37Mo2	0,35 to 0,40	0,30	0,60 to 0,90	0,025	0,025	—	—	0,20 to 0,30	0,25
38Cr2	0,35 to 0,42	0,30	0,50 to 0,80	0,025	0,025	0,40 to 0,60	—	—	0,25
46Cr2	0,42 to 0,50	0,30	0,50 to 0,80	0,025	0,025	0,40 to 0,60	—	—	0,25
34Cr4	0,30 to 0,37	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	—	0,25
37Cr4	0,34 to 0,41	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	—	0,25
41Cr4	0,38 to 0,45	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	—	0,25
41CrS4	0,38 to 0,45	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,90 to 1,20	—	—	0,25
25CrMo4	0,22 to 0,29	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,30	0,25
25CrMoS4	0,22 to 0,29	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,90 to 1,20	—	0,15 to 0,30	0,25
34CrMo4	0,30 to 0,37	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,30	0,25
37CrMo4	0,35 to 0,40	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,30	0,25
42CrMo4	0,38 to 0,45	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,15 to 0,30	0,25
42CrMoS4	0,38 to 0,45	0,30	0,60 to 0,90	0,025	0,020 to 0,040	0,90 to 1,20	—	0,15 to 0,30	0,25
41CrNiMo2	0,37 to 0,44	0,30	0,70 to 1,00	0,025	0,025	0,40 to 0,60	0,40 to 0,70	0,15 to 0,30	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max. Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Tables C.7 and C.9), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] A carbon range of 0,04 % (e.g. 0,33 % to 0,37 %) may be agreed at the time of enquiry and order.

[d] Lower silicon contents may be agreed at the time of ordering, in which case due consideration should be given to the effects that could result for what concerns the specified properties such as, for example, hardenability.

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Table C.2 *(continued)*

Steel name[b]	% mass fraction[a]								
	C[c]	Si[d]	Mn	P	S	Cr	Ni	Mo	Cu
41CrNiMoS2	0,37 to 0,44	0,30	0,70 to 1,00	0,025	0,020 to 0,040	0,40 to 0,60	0,40 to 0,70	0,15 to 0,30	0,25
34CrNiMo6	0,30 to 0,38	0,30	0,50 to 0,80	0,025	0,025	1,30 to 1,70	1,30 to 1,70	0,15 to 0,30	0,25
41NiCrMo7-3-2	0,38 to 0,44	0,30	0,60 to 0,90	0,025	0,025	0,70 to 0,90	1,65 to 2,00	0,15 to 0,30	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max. Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Tables C.7 and C.9), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] A carbon range of 0,04 % (e.g. 0,33 % to 0,37 %) may be agreed at the time of enquiry and order.

[d] Lower silicon contents may be agreed at the time of ordering, in which case due consideration should be given to the effects that could result for what concerns the specified properties such as, for example, hardenability.

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Table C.3 — Chemical composition (applicable to cast analysis) of boron-alloyed steel grades for quenching and tempering

Steel name[b]	% mass fraction[a]								
	C	SI[c]	Mn	P	S	Cr[d]	Mo	B [e]	Cu
17B2	0,15 to 0,20	0,30	0,60 to 0,90	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
23B2	0,20 to 0,25	0,30	0,60 to 0,90	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
28B2	0,25 to 0,30	0,30	0,60 to 0,90	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
33B2	0,30 to 0,35	0,30	0,60 to 0,90	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
38B2	0,35 to 0,40	0,30	0,60 to 0,90	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
23MnB3	0,21 to 0,25	0,15	0,80 to 1,00	0,015	0,015	0,25 to 0,35	—	0,000 8 to 0,005 0	0,25
17MnB4	0,15 to 0,20	0,30	0,90 to 1,20	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
20MnB4	0,18 to 0,23	0,30	0,90 to 1,20	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
23MnB4	0,20 to 0,25	0,30	0,90 to 1,20	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
27MnB4	0,25 to 0,30	0,30	0,90 to 1,20	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
30MnB4	0,27 to 0,32	0,30	0,80 to 1,10	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
36MnB4	0,33 to 0,38	0,30	0,80 to 1,10	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
20MnB5	0,17 to 0,23	0,30	1,10 to 1,40	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
23MnB5	0,20 to 0,26	0,30	1,10 to 1,40	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
26MnB5	0,23 to 0,29	0,30	1,20 to 1,50	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
34MnB5	0,31 to 0,37	0,30	1,20 to 1,50	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
37MnB5	0,35 to 0,40	0,30	1,15 to 1,45	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25
40MnB6	0,36 to 0,44	0,30	1,35 to 1,65	0,025	0,025	0,30	—	0,000 8 to 0,005 0	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max, Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Table C.8), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] Lower silicon contents may be agreed at the time of ordering, in which case due consideration should be given to the effects that could result for what concerns the specified properties such as, for example, hardenability.

[d] Where a maximum chromium content of 0,30 % is specified, a minimum level may also be agreed at the time of enquiry and order.

[e] Non-effective boron is detrimental to toughness and should be avoided. Boron should be in solution in order to guarantee the hardening, i.e. 90 % martensite in the core.

[f] In order to obtain a core hardening for the steel grade 30MoB1, the lower limit of Cr shall be 0,15 % and may be agreed at the time of enquiry and order. For certain applications, the higher limit for Cr may also be lowered by agreement at time of enquiry and order.

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Table C.3 *(continued)*

Steel name[b]	% mass fraction[a]								
	C	SI[c]	Mn	P	S	Cr[d]	Mo	B [e]	Cu
30MoB1	0,28 to 0,32	0,30	0,80 to 1,00	0,025	0,025	0,30 [f]	0,08 to 0,12	0,000 8 to 0,005 0	0,25
32CrB4	0,30 to 0,34	0,30	0,60 to 0,90	0,025	0,025	0,90 to 1,20	—	0,000 8 to 0,005 0	0,25
36CrB4	0,34 to 0,38	0,30	0,70 to 1,00	0,025	0,025	0,90 to 1,20	—	0,000 8 to 0,005 0	0,25
31CrMoB2-1	0,28 to 0,33	0,30	0,90 to 1,20	0,025	0,025	0,40 to 0,55	0,10 to 0,15	0,000 8 to 0,005 0	0,25

Elements not quoted in this table should not be intentionally added to the steel without the agreement of the purchaser, except those intended for finishing the heat. All reasonable precautions shall be taken in order to prevent the addition of such elements from scrap or other materials used in the production process, which can affect the hardenability, mechanical properties and applicability.

To improve the performance of cold heading, it is possible to add max, Al: 0,050 %.

[a] Maximum values unless otherwise indicated.

[b] In the case of steels with hardenability requirements (see Table C.8), minor deviations from the specified limits are permitted (with the exception of sulfur and phosphorus), provided that they do not exceed 0,01 % for carbon and the values indicated in Table 2 for the other elements.

[c] Lower silicon contents may be agreed at the time of ordering, in which case due consideration should be given to the effects that could result for what concerns the specified properties such as, for example, hardenability.

[d] Where a maximum chromium content of 0,30 % is specified, a minimum level may also be agreed at the time of enquiry and order.

[e] Non-effective boron is detrimental to toughness and should be avoided. Boron should be in solution in order to guarantee the hardening, i.e. 90 % martensite in the core.

[f] In order to obtain a core hardening for the steel grade 30MoB1, the lower limit of Cr shall be 0,15 % and may be agreed at the time of enquiry and order. For certain applications, the higher limit for Cr may also be lowered by agreement at time of enquiry and order.

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Table C.4 — Mechanical properties for non-alloy steel grades without boron

Steel name	Diameter		Delivery condition							
			+AC or +AC+PE		+AR+C+AC		+AR+C+AC+LC		+AC+C	
	above	up to	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%
C30EC C30RC	≥ 2	5	—	—	—	—	620	55	—	—
	5	10	—	—	—	—	620	55	620	55
	10	40	590	—	—	—	620	55	620	55
C35EC C35RC	≥ 2	5	—	—	550	62	590	60	—	—
	5	10	560	60	540	62	580	60	670	—
	10	40	560	60	540	62	580	60	660	—
C45EC C45RC	≥ 2	5	—	—	590	62	630	60	—	—
	5	10	600	60	580	62	620	60	720	—
	10	40	600	60	580	62	620	60	710	—
42Mn6 [a]	≥ 2	5	—	—	590	60	650	60	—	—
	5	10	600	60	580	60	640	60	720	—
	10	40	600	60	580	660	640	60	710	—

[a] Preliminary data, mechanical properties for 42Mn6 to be agreed at the time of enquiry and order

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Table C.5 — Mechanical properties for alloy steel grades without boron

Steel name	Diameter		Delivery condition					
			+AC or +AC+PE		+AC+C+AC		+AC+C+AC+LC	
	above	up to	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%
37Mo2	≥ 2	5	—	—	560	61	600	59
	5	40	570	59	550	61	590	59
38Cr2	≥ 2	5	—	—	590	62	630	60
	5	40	600	60	580	62	620	60
46Cr2	≥ 2	5	—	—	610	60	650	58
	5	40	620	58	600	60	640	58
34Cr4	≥ 2	5	—	—	570	64	610	62
	5	40	580	62	560	64	600	62
37Cr4	≥ 2	5	—	—	580	62	620	60
	5	40	590	60	570	62	610	60
41Cr4 41CrS4	≥ 2	5	—	—	610	60	650	58
	5	40	620	58	600	60	640	58
25CrMo4 25CrMoS4	2	5	—	—	570	62	610	60
	5	40	580	60	560	62	600	60
34CrMo4	≥ 2	5	—	—	590	62	630	60
	5	40	600	60	580	62	620	60
37CrMo4	≥ 2	5	—	—	610	62	650	60
	5	40	620	60	600	62	640	60
42CrMo4 42CrMoS4	≥ 2	5	—	—	620	60	660	58
	5	40	630	58	610	60	650	58
41CrNiMo2 41CrNiMoS2	≥ 2	5	—	—	640	60	680	55
	5	40	—	—	640	60	680	55
34CrNiMo6	≥ 2	5	—	—	710	60	750	58
	5	40	720	58	700	60	740	58
41NiCrMo7-3-2	≥ 2	5	—	—	710	60	750	58
	5	40	720	58	700	60	740	58

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Table C.6 — Mechanical properties for boron-alloyed steel grades

Steel name	Diameter		Delivery condition											
			+AR or +PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
			Mechanical properties											
	above	up to	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%
17B2	≥ 2	5	—	—	—	—	—	—	450	70	490	68	—	—
	5	10	540	60	460	68	630	55	440	70	480	68	550	63
	10	25	540	60	460	68	620	55	440	70	480	68	540	63
23B2	≥ 2	5	—	—	—	—	—	—	480	68	520	66	—	—
	5	10	600	60	490	66	690	55	470	68	510	66	580	61
	10	25	600	60	490	66	680	55	470	68	510	66	570	61
28B2	≥ 2	5	—	—	—	—	—	—	510	66	550	64	—	—
	5	10	630	60	520	64	720	55	500	66	540	64	610	59
	10	25	630	60	520	64	710	55	500	66	540	64	600	59
33B2	≥ 2	5	—	—	—	—	—	—	540	64	580	62	—	—
	5	10	—	—	550	62	—	—	530	64	570	62	640	57
	10	40	—	—	550	62	—	—	530	64	570	62	630	57
38B2	≥ 2	5	—	—	—	—	—	—	560	64	600	62	—	—
	5	10	—	—	570	62	—	—	550	64	590	62	660	57
	10	40	—	—	570	62	—	—	550	64	590	62	650	57
23MnB3	≥ 2	5	—	—	—	—	—	—	510	66	550	64	—	—
	5	10	600	60	520	64	700	55	500	66	540	64	620	59
	10	25	600	60	520	64	690	55	500	66	540	64	610	59
17MnB4	≥ 2	5	—	—	—	—	—	—	470	69	510	67	—	—
	5	10	570	60	480	67	660	55	460	69	500	67	570	62
	10	25	570	60	480	67	650	55	460	69	500	67	560	62
20MnB4	≥ 2	5	—	—	—	—	—	—	490	68	530	66	—	—
	5	10	580	60	500	66	680	55	480	68	520	66	600	61
	10	25	580	60	500	66	670	55	480	68	520	66	590	61

It should be recognized in the +AR condition that the tensile strength values are not compatible with the whole range of composition given in Table C.3 for a steel grade. Care should be taken that, depending on diameter and composition supplied, the tensile strength values are compatible with the hardenability requirements.

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Table C.6 *(continued)*

Steel name	Diameter		Delivery condition											
			+AR or +PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
			Mechanical properties											
	above	up to	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%
23MnB4	≥ 2	5	—	—	—	—	—	—	510	66	550	64	—	—
	5	10	600	60	520	64	700	55	500	66	540	64	620	59
	10	25	600	60	520	64	690	55	500	66	540	64	610	59
27MnB4	≥ 2	5	—	—	—	—	—	—	530	65	570	63	—	—
	5	40	—	—	540	63	—	—	520	65	560	63	640	58
30MnB4	≥ 2	5	—	—	—	—	—	—	560	65	600	63	—	—
	5	40	—	—	570	63	—	—	550	65	590	63	670	58
36MnB4	≥ 2	5	—	—	—	—	—	—	590	64	630	62	—	—
	5	40	—	—	600	62	—	—	580	64	620	62	700	57
20MnB5	≥ 2	5	—	—	—	—	—	—	—	—	630	55	—	—
	5	40	—	—	—	—	—	—	—	—	630	55	630	55
23MnB5	≥ 2	5	—	—	—	—	—	—	—	—	640	55	—	—
	5	40	—	—	—	—	—	—	—	—	640	55	640	55
26MnB5	≥ 2	5	—	—	—	—	—	—	—	—	650	55	—	—
	5	40	—	—	—	—	—	—	—	—	650	55	650	55
34MnB5	≥ 2	5	—	—	—	—	—	—	—	—	680	55	—	—
	5	40	—	—	—	—	—	—	—	—	680	55	680	55
37MnB5	≥ 2	5	—	—	—	—	—	—	610	64	650	62	—	—
	5	40	—	—	620	62	—	—	600	64	640	62	720	57
42MnB6	≥ 2	5	—	—	—	—	—	—	610	60	650	60	—	—
	5	40	—	—	620	60	—	—	600	60	640	60	720	—
30MoB1	≥ 2	5	—	—	—	—	—	—	530	64	570	62	—	—
	5	40	—	—	530	62	—	—	510	64	550	62	630	57

It should be recognized in the +AR condition that the tensile strength values are not compatible with the whole range of composition given in Table C.3 for a steel grade. Care should be taken that, depending on diameter and composition supplied, the tensile strength values are compatible with the hardenability requirements.

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Table C.6 *(continued)*

Steel name	Diameter		Delivery condition											
			+AR or +PE		+AC or +AC+PE		+AR+C		+AR+C+AC		+AR+C+AC+LC		+AC+C	
			Mechanical properties											
	above	up to	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.	R_m max.	Z min.
	mm	mm	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%	MPa	%
32CrB4	≥ 2	5	—	—	—	—	—	—	550	64	590	62	—	—
	5	40	—	—	550	62	—	—	530	64	570	62	670	57
36CrB4	≥ 2	5	—	—	—	—	—	—	570	63	610	61	—	—
	5	40	—	—	570	61	—	—	550	63	590	61	690	56
31CrMoB2-1	≥ 2	5	—	—	—	—	—	—	570	63	610	61	—	—
	5	40	—	—	570	61	—	—	550	63	590	61	690	56
It should be recognized in the +AR condition that the tensile strength values are not compatible with the whole range of composition given in Table C.3 for a steel grade. Care should be taken that, depending on diameter and composition supplied, the tensile strength values are compatible with the hardenability requirements.														

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Table C.7 — Hardness limits for steel grades without boron with specified (normal) hardenability (+H grades)

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of															
				1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30
C35EC C35RC	+H	870	max.	58	57	55	53	49	41	34	31	28	27	26	25	24	23	20	—
			min.	48	40	33	24	22	20	—	—	—	—	—	—	—	—	—	—
C45EC C45RC	+H	850	max.	61	60	59	57	53	47	39	34	31	30	29	28	27	26	25	24
			min.	51	46	35	27	25	24	23	22	21	20	—	—	—	—	—	—
				at a distance from quenched end of test piece (in mm) of															
				1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50	—
42Mn6	+H	850	max.	62	61	60	59	57	54	50	45	37	34	32	31	30	29	28	—
			min.	55	53	49	39	33	29	27	26	23	22	20	—	—	—	—	—
37Mo2	+H	850	max.	59	57	53	47	41	36	32	29	27	25	—	—	—	—	—	—
			min.	51	48	41	33	27	26	22	20	—	—	—	—	—	—	—	—
38Cr2	+H	850	max.	59	57	54	49	43	39	37	35	32	30	27	25	24	23	22	—
			min.	51	46	37	29	25	22	20	—	—	—	—	—	—	—	—	—
46Cr2	+H	850	max.	63	61	57	52	46	42	40	38	35	33	31	29	28	27	26	—
			min.	54	49	40	32	28	25	23	22	20	—	—	—	—	—	—	—
34Cr4	+H	850	max.	57	57	56	54	52	49	46	44	39	37	35	34	33	32	31	—
			min.	49	48	45	41	35	32	29	27	23	21	20	—	—	—	—	—
37Cr4	+H	850	max.	59	59	58	57	55	52	50	48	42	39	37	36	35	34	33	—
			min.	51	50	48	44	39	36	33	31	26	24	22	20	—	—	—	—
41Cr4 41CrS4	+H	850	max.	61	61	60	59	58	56	54	52	46	42	40	38	37	36	35	—
			min.	53	52	50	47	41	37	34	32	29	26	23	21	—	—	—	—
25CrMo4 25CrMoS4	+H	850	max.	52	52	51	50	48	46	43	41	37	35	33	32	31	31	31	—
			min.	44	43	40	37	34	32	29	27	23	21	20	—	—	—	—	—
34CrMo4	+H	850	max.	57	57	57	56	55	54	53	52	48	45	43	41	40	40	39	—
			min.	49	49	48	45	42	39	36	34	30	28	27	26	25	24	24	—
37CrMo4	+H	850	max.	60	60	60	59	58	56	55	54	51	48	46	45	—	—	—	—
			min.	52	50	49	47	45	43	40	37	34	32	31	30	—	—	—	—
42CrMo4 42CrMoS4	+H	850	max.	61	61	61	60	60	59	59	58	56	53	51	48	47	46	45	—
			min.	53	53	52	51	49	43	40	37	34	32	31	30	30	29	29	—

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Table C.7 *(continued)*

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of															
				1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30
41CrNiMo2 41CrNiMoS2	+H	850	max.	60	60	60	59	58	57	55	54	48	42	40	38	37	37	36	—
			min.	53	53	52	50	47	42	38	35	30	28	26	25	24	24	23	—
34CrNiMo6	+H	850	max.	58	58	58	58	57	57	57	57	57	57	57	57	57	57	57	—
			min.	50	50	50	50	49	48	48	48	48	47	47	47	46	45	44	—
41NiCrMo7-3-2	+H	860	max.	60	60	60	60	60	60	60	59	59	58	58	57	57	—	—	—
			min.	54	54	54	54	54	54	54	54	53	52	52	51	50	—	—	—

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Table C.8 — Hardness limits for boron-alloyed steel grades with standard hardenability (+H grades)

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of															
				1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50	
17B2	+H	900	max.	46	45	45	41	35	—	—	—	—	—	—	—	—	—	—	
			min.	39	34	30	20	—	—	—	—	—	—	—	—	—	—	—	
23B2	+H	890	max.	49	48	47	45	39	—	—	—	—	—	—	—	—	—	—	
			min.	41	39	37	21	—	—	—	—	—	—	—	—	—	—	—	
28B2	+H	880	max.	53	51	51	49	45	39	29	24	20	—	—	—	—	—	—	
			min.	46	42	39	23	—	—	—	—	—	—	—	—	—	—	—	
33B2	+H	870	max.	55	55	54	52	49	43	—	—	—	—	—	—	—	—	—	
			min.	49	45	43	27	20	—	—	—	—	—	—	—	—	—	—	
38B2	+H	860	max.	58	57	56	55	51	49	44	—	—	—	—	—	—	—	—	
			min.	51	49	47	36	25	20	—	—	—	—	—	—	—	—	—	
23MnB3	+H	880	max.	49	48	47	47	45	41	—	—	—	—	—	—	—	—	—	
			min.	43	41	40	32	23	—	—	—	—	—	—	—	—	—	—	
17MnB4	+H	890	max.	47	46	46	44	41	36	—	—	—	—	—	—	—	—	—	
			min.	40	38	37	30	20	—	—	—	—	—	—	—	—	—	—	
20MnB4	+H	880	max.	48	48	47	46	44	39	—	—	—	—	—	—	—	—	—	
			min.	41	40	38	30	20	—	—	—	—	—	—	—	—	—	—	
23MnB4	+H	880	max.	49	48	47	47	45	41	—	—	—	—	—	—	—	—	—	
			min.	43	41	40	32	23	—	—	—	—	—	—	—	—	—	—	
27MnB4	+H	870	max.	53	52	51	50	48	45	41	—	—	—	—	—	—	—	—	
			min.	46	44	43	36	27	21	—	—	—	—	—	—	—	—	—	
30MnB4	+H	860	max.	54	53	53	53	51	46	42	—	—	—	—	—	—	—	—	
			min.	48	46	44	36	25	20	—	—	—	—	—	—	—	—	—	
36MnB4	+H	850	max.	58	57	57	56	54	52	48	43	—	—	—	—	—	—	—	
			min.	51	49	48	43	31	25	20	—	—	—	—	—	—	—	—	
20MnB5	+H	925	max.	48	48	48	47	46	44	40	36	29	25	21	—	—	—	—	
			min.	40	39	37	30	22	—	—	—	—	—	—	—	—	—	—	
23MnB5	+H	870	max.	50	50	49	48	48	46	44	41	30	22	—	—	—	—	—	
			min.	42	41	39	35	27	20	—	—	—	—	—	—	—	—	—	

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Table C.8 *(continued)*

Steel name	Symbol	Austenitizing temperature °C ± 5 °C	Limits of range	Hardness HRC at a distance from quenched end of test piece (in mm) of														
				1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
26MnB5	+H	870	max.	52	52	52	51	50	49	48	45	36	27	23	20	—	—	—
			min.	44	43	42	40	34	27	23	20	—	—	—	—	—	—	—
34MnB5	+H	845	max.	57	56	56	55	55	54	53	51	43	33	28	25	22	20	—
			min.	49	48	47	45	43	37	31	26	20	—	—	—	—	—	—
37MnB5	+H	850	max.	60	60	59	58	57	57	55	53	48	—	—	—	—	—	—
			min.	52	51	50	48	43	37	32	29	—	—	—	—	—	—	—
40MnB6	+H	850	max.	60	59	58	57	55	54	52	50	49	36	—	—	—	—	—
			min.	52	52	51	49	44	32	26	25	22	20	—	—	—	—	—
30MoB1	+H	870	max.	53	52	52	51	49	48	46	43	34	—	—	—	—	—	—
			min.	47	46	45	39	30	24	21	—	—	—	—	—	—	—	—
32CrB4	+H	860	max.	56	56	55	55	55	54	53	53	51	49	45	42	40	38	—
			min.	49	48	47	46	46	45	—	—	—	—	—	—	—	—	—
36CrB4	+H	850	max.	58	58	57	56	56	55	55	55	53	51	48	46	—	—	—
			min.	50	49	48	48	47	46	46	45	34	30	27	—	—	—	—
31CrMoB2-1	+H	860	max.	54	54	54	53	53	52	51	51	48	43	41	—	—	—	—
			min.	48	48	47	47	45	45	41	39	31	27	25	—	—	—	—

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