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Steels for cold heading and cold extruding

Aciers pour refoulement et extrusion à froid

Reference number
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Contents

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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.

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 $\geqslant$ 6 mm and $\leqslant$ 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 d mm	Permissible depth of the partial (ferritic-pearlitic) decarburization in the condition[1]	
	C + AC or C + AC + LC mm	untreated or AC mm
$\leqslant 8$	$\leqslant 0{,}10$	$\leqslant 0{,}12$
$> 8 \leqslant 12$	$\leqslant 0{,}12$	$\leqslant 0{,}15$
$> 12 \leqslant 17$	$\leqslant 0{,}16$	$\leqslant 0{,}20$
$> 17 \leqslant 23$	$\leqslant 0{,}20$	$\leqslant 0{,}25$
$> 23 \leqslant 27$	$\leqslant 0{,}24$	$\leqslant 0{,}29$
> 27	$\leqslant (0{,}007 \times d) + 0{,}05$	$\leqslant (0{,}009 \times d) + 0{,}05$

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 tolerances 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 $\geqslant$ 6 mm and $\leqslant$ 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 $h_o = 1{,}5 \times d_o$ (d_o = 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 temperature, 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.

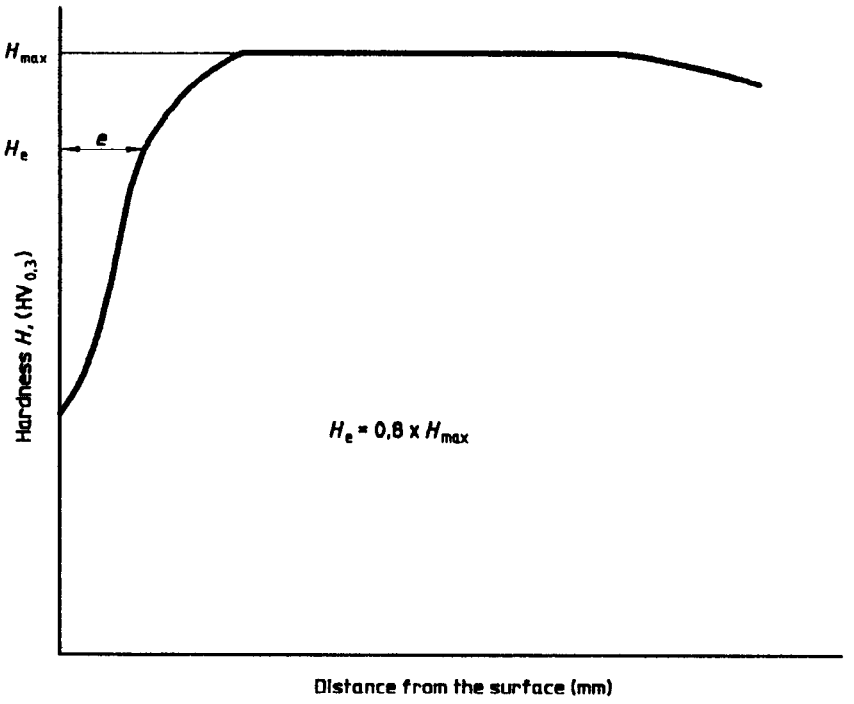

Figure 1 — Determination of the depth of the decarburized zone

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.

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)
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)

Type of steel			Chemical composition [% (m/m)] [1]					
Designation[2]			C	Si	Mn	P	S	Others
No.	Name	according to ISO 4954:1979				max.	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.

Table 6 — Permissible deviations between specified analysis and product analysis for the aluminium or silicon killed steels

Element	Permissible maximum content according to cast analysis % (*m/m*)	Permissible deviations[1) 2)] % (*m/m*)
C	⩽ 0,23	± 0,02
Si	⩽ 0,35	+ 0,02 [3)]
Mn	⩽ 0,60	± 0,04
P	⩽ 0,040	+ 0,005
S	⩽ 0,040	+ 0,005

1) For rimming and rimming equivalent steels (grades CC 4 X, CC 8 X, CC 11 X and CC 15 X), the permissible deviations shall, where required, be specified at the time of enquiry and order.

2) ± means that in one cast the deviation may occur over the upper value or under the lower value of the specified range given in table 5, but not both at the same time.

3) For steel types CC 15 K and CC 21 K, ± 0,03 % (*m/m*) Si.

Table 7 — Mechanical properties in the usual treatment condition for cold heading or cold extruding (the values are for guidance)

Type of steel	Treatment condition [as rolled (U) or as rolled and peeled (P)]	
	$R_{m,max}$ N/mm²	Z_{min} %
CC 4 X CC 4 A	420 440	60
CC 8 X CC 8 A	450 470	60
CC 11 X CC 11 A	470 490	55
CC 15 X CC 15 K CC 15 A	530	50
CC 21 K CC 21 A	580	45

R_m : Tensile strength

Z : Reduction of area after fracture

Section 3: Specific requirements for cold-heading and cold-extruding case-hardening steels

3.1 Scope

This section covers the specific requirements for the cold-heading and cold-extruding case-hardening steels. It applies for diameters from 2 mm to 100 mm.

3.2 Requirements

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

Table 8 gives a survey of combinations of usual treatment conditions on delivery, product forms and requirements regarding chemical composition, mechanical properties and hardenability.

3.2.2 Chemical composition

3.2.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 9.

3.2.2.2 The permissible deviations between the values specified in table 9 and the product analysis are indicated in table 10.

3.2.3 Hardenability and mechanical properties

3.2.3.1 Where the steel is not ordered according to hardenability requirements, i.e. where the steel type designations of tables 9 and 11 and not the designations given in table 12 or 13 are applied (besides the requirements for chemical composition), the requirements for mechanical properties given in table 8, column 6.2, apply for the particular heat-treatment condition. In this case, the values of hardenability given in table 12 are for guidance purposes only.

3.2.3.2 Where the steel is, by using the designations given in table 12 or 13, ordered according to normal (see table 12) or to narrowed (see table 13) hardenability requirements, the values of hardenability given in table 12 or 13 respectively apply in addition to the requirements given in table 8, column 6 (see footnote 2 to table 9).

3.2.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 8.

Table 8 — Combinations of usual treatment conditions on delivery, product forms and requirements according to tables 9 to 13 for case-hardening steels

1	2		3	4	5	6		7		
1	Heat-treatment condition on delivery	Symbol	"x" indicates applicable to			Applicable requirements, if the steel is ordered with the designation given in				
			hot-rolled bars	wire rod	drawn products	table 9 or 11		table 12 or 13		
						6.1	6.2	7.1	7.2	7.3
2	Untreated	None or U	x	x	—	Chemical composition according to tables 9 and 10	—	As in column 6		Hardenability values according to table 12 or 13
3	Annealed to achieve a spheroidization of the carbides	AC	x	x	—		Mechanical properties according to table 11, column 2			
4	Annealed to achieve a spheroidization of the carbides and peeled	AC + P	x	—	—					
5	Cold drawn and annealed to achieve a spheroidization of the carbides	C + AC	—	—	x		Mechanical properties according to table 11, column 3			
6	Cold drawn and annealed to achieve a spheroidization of the carbides, and lightly cold reduced (e.g. with a reduction of 5 %)	C + AC + LC	—	—	x		Mechanical properties according to table 11, column 4			
7	Others	Other treatment conditions may be agreed upon at the time of enquiry and order.								

Table 9 — Types of steel and chemical composition (applicable to cast analysis)

Type of steel Designation[3]			Chemical composition [% (*m*/*m*)] [1) 2)]							
No.	Name	according to ISO 4954:1979	C	Si max.	Mn	P max.	S max.	Cr	Mo	Ni
21	CE 10	B 1	0,07 to 0,13	0,40	0,30 to 0,60	0,035	0,035	—	—	—
22	CE 15 E4	B 2	0,12 to 0,18	0,40	0,30 to 0,60	0,035	0,035	—	—	—
23	CE 16 E4	B 3	0,12 to 0,18	0,40	0,60 to 0,90	0,035	0,035	—	—	—
24	CE 20 E4	—	0,17 to 0,23	0,40	0,30 to 0,60	0,035	0,035	—	—	—
25	20 Cr 4 E	B 10	0,17 to 0,23	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	—	—
26	16 MnCr 5 E	B 11	0,13 to 0,19	0,40	1,00 to 1,30	0,035	0,035	0,80 to 1,10	—	—
27	18 CrMo 4 E	B 30	0,15 to 0,21	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	0,15 to 0,25	—
28	20 NiCrMo 2 E	B 41	0,17 to 0,23	0,40	0,65 to 0,95	0,035	0,035	0,30 to 0,65	0,15 to 0,25	0,40 to 0,70

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 the hardenability, mechanical properties and applicability.

2) In the case of grades with specified hardenability requirements (see tables 12 and 13), except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. However, these deviations shall not exceed 0,01 % (*m*/*m*) in the case of carbon and, in all other cases, the values according to table 10.

3) 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.

Table 10 — Permissible deviations between specified analysis and product analysis

Element	Permissible maximum content according to cast analysis % (*m*/*m*)	Permissible deviations[1)] % (*m*/*m*)
C	⩽ 0,23	± 0,02
Si	⩽ 0,40	+ 0,03
Mn	⩽ 1,00 > 1,00 ⩽ 1,30	± 0,04 ± 0,06
P	⩽ 0,035	+ 0,005
S	⩽ 0,035	+ 0,005
Cr	⩽ 1,20	± 0,05
Mo	⩽ 0,25	± 0,03
Ni	⩽ 0,70	± 0,03

1) ± means that in one cast the deviation may occur over the upper value or under the lower value of the specified range given in table 9, but not both at the same time.

Table 11 — Mechanical properties in the usual treatment condition for cold heading or cold extruding

1	2		3		4	
Type of steel	Treatment condition[1]					
	AC or AC + P		C + AC		C + AC + LC	
	$R_{m,max}$ N/mm²	Z_{min} %	$R_{m,max}$ N/mm²	Z_{min} %	$R_{m,max}$ N/mm²	Z_{min} [2] %
CE 10	450	65	430	68	460	65
CE 15 E4	470	64	450	67	490	64
CE 16 E4	490	64	470	67	510	64
CE 20 E4	490	63	470	66	510	63
20 Cr 4 E	560	60	540	62	570	62
16 MnCr 5 E	550	60	530	62	570	62
18 CrMo 4 E	560	60	540	62	570	62
20 NiCrMo 2 E	590	60	570	62	600	62

R_m = Tensile strength

Z = Reduction of area after fracture

1) See table 8.

2) For diameters ⩽ 12 mm, the reduction of area may be 2 % lower.

Table 12 — Hardness limits for steel types with specified (normal) hardenability: H-grades (see 3.2.3.2)

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
20 Cr 4 E H	900 ± 5	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
		min.	41	38	31	26	23	21	—	—	—	—	—	—	—
16 MnCr 5 E H	900 ± 5	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
		min.	39	36	31	28	24	21	—	—	—	—	—	—	—
18 CrMo 4 E H	900 ± 5	max.	47	46	45	42	39	37	35	34	31	29	28	27	26
		min.	39	37	34	30	27	24	22	21	—	—	—	—	—
20 NiCrMo 2 E H	900 ± 5	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—

1) Time for austenitizing, as a guide: 0,5 h minimum.

Table 13 — Hardness limits for steel types with narrowed hardenability scatterbands: HH and HL-grades

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
20 Cr 4 E HH	900 ± 5	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
		min.	44	41	36	31	28	26	24	22	—	—	—	—	—
20 Cr 4 E HL	900 ± 5	max.	46	45	41	37	33	31	29	27	24	22	21	—	—
		min.	41	38	31	26	23	21	—	—	—	—	—	—	—
16 MnCr 5 E HH	900 ± 5	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
		min.	42	39	35	32	29	26	24	22	20	—	—	—	—
16 MnCr 5 E HL	900 ± 5	max.	44	43	40	37	34	32	30	28	26	25	24	23	22
		min.	39	36	31	28	24	21	—	—	—	—	—	—	—
18 CrMo 4 E HH	900 ± 5	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	—	—	—
18 CrMo 4 E HL	900 ± 5	max.	44	43	41	38	35	33	31	30	27	25	24	23	22
		min.	39	37	34	30	27	24	22	21	—	—	—	—	—
20 NiCrMo 2 E HH	900 ± 5	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
		min.	44	41	36	31	27	24	22	21	—	—	—	—	—
20 NiCrMo 2 E HL	900 ± 5	max.	46	44	40	36	31	29	27	26	23	21	20	20	—
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—

1) Time for austenitizing, as a guide: 0,5 h minimum.

Section 4: Specific requirements for cold-heading and cold-extruding steels for quenching and tempering (including boron-treated steels)

4.1 Scope

This section covers the specific requirements for the cold-heading and cold-extruding steels for quenching and tempering. It applies for diameters from 2 mm to 100 mm.

4.2 Requirements

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

Table 14 gives a survey of combinations of usual treatment conditions on delivery, product forms and requirements regarding chemical composition, mechanical properties and hardenability (end-quench test and core hardenability).

4.2.2 Chemical composition

4.2.2.1 The specified chemical composition of the steel according to the cast analysis is given in tables 15 and 16.

4.2.2.2 The permissible deviations between the values specified in tables 15 and 16 and the product analysis are indicated in table 17.

4.2.3 Hardenability and mechanical properties

4.2.3.1 Were the steel is not ordered according to hardenability requirements, i.e. where the steel type designations of tables 15, 16 and 18 and not the designations given in tables 19 to 24 are applied (besides the requirements for chemical composition), the requirements for mechanical properties given in table 14, column 6.2, apply for the particular heat-treatment condition. In this case, the values of hardenability in the end-quench test given in table 19 are for guidance purposes only.

4.2.3.2 Where the steel is, by using the designations given in tables 19 to 22, ordered according to normal (see tables 19 and 22) or to narrowed (see tables 20 and 21) end-quench hardenability requirements, the values of hardenability given in table 19, 20, 21 or 22 apply in addition to the requirements given in table 14, column 6 (see footnote 2 to tables 15 and 16).

4.2.3.3 Where the steel is, by using the designations given in table 23 or 24, ordered according to core hardenability requirements, the values of hardenability and maximum diameter given in table 23 or 24 apply in addition to the requirements given in table 14, column 6.

4.2.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 14.

Table 14 — Combinations of usual heat-treatment conditions on delivery, product forms and requirements according to tables 15 to 24 for steels for quenching and tempering

1	2		3	4	5	6		7			8		
1	Heat-treatment condition on delivery	Symbol	"x" indicates applicable to			Applicable requirements, if the steel is ordered with the designation given in							
			hot-rolled bars	wire rod	drawn products	table 15 or 16		table 19, 20, 21 or 22			table 23 or 24		
						6.1	6.2	7.1	7.2	7.3	8.1	8.2	8.3
2	Untreated	None or U	x	x	—		—						
3	Annealed to achieve a spheroidization of the carbides	AC	x	x	—		Mechanical properties according to table 18, column 2						
4	Annealed to achieve a spheroidization of the carbides and peeled	AC+P	x	—	—								
5	Cold drawn and annealed to achieve a spheroidization of the carbides	C+AC	—	—	x	Chemical composition according to tables 15 and 17 or tables 16 and 17	Mechanical properties according to table 18, column 3	As in column 6		Hardenability values according to table 19, 20, 21 or 22	As in column 6		Minimum core hardness and maximum diameter according to table 23 or 24
6	Cold drawn and annealed to achieve a spheroidization of the carbides, and lightly cold reduced (e.g. with a reduction of 5 %)	C+AC+LC	—	—	x		Mechanical properties according to table 18, column 4						
7	Others	Other treatment conditions, e.g. "AC+C+subcritically annealed", may be agreed upon at the time of enquiry and order.											

Table 15 — Types of steel and chemical composition (applicable to cast analysis)

Type of steel			Chemical composition [% (m/m)] [1) 2)]							
Designation[3)]			C	Si	Mn	P	S	Cr	Mo	Ni
No.	Name	according to ISO 4954:1979		max.		max.	max.			
31	CE 20 E4	—	0,17 to 0,23	0,40	0,30 to 0,60	0,035	0,035	—	—	—
32	CE 28 E4	C 2	0,25 to 0,32	0,40	0,60 to 0,90	0,035	0,035	—	—	—
33	CE 35 E4	C 3	0,32 to 0,39	0,40	0,50 to 0,80	0,035	0,035	—	—	—
34	CE 40 E4	—	0,37 to 0,44	0,40	0,50 to 0,80	0,035	0,035	—	—	—
35	CE 45 E4	C 6	0,42 to 0,50	0,40	0,50 to 0,80	0,035	0,035	—	—	—
36	42 Mn 6 E	—	0,39 to 0,46	0,40	1,30 to 1,65	0,035	0,035	—	—	—
37	37 Cr 2 E	C 12	0,34 to 0,41	0,40	0,50 to 0,80	0,035	0,035	0,40 to 0,60	—	—
38	46 Cr 2 E	C 13	0,42 to 0,50	0,40	0,50 to 0,80	0,035	0,035	0,40 to 0,60	—	—
39	34 Cr 4 E	C 14	0,30 to 0,37	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	—	—
40	37 Cr 4 E	C 15	0,34 to 0,41	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	—	—
41	41 Cr 4 E	C 16	0,38 to 0,45	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	—	—
42	36 Mo 3 E	C 22	0,33 to 0,40	0,40	0,70 to 1,00	0,035	0,035	—	0,20 to 0,30	—
43	25 CrMo 4 E	C 30	0,22 to 0,29	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	0,15 to 0,30	—
44	34 CrMo 4 E	C 31	0,30 to 0,37	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	0,15 to 0,30	—
45	42 CrMo 4 E	C 32	0,38 to 0,45	0,40	0,60 to 0,90	0,035	0,035	0,90 to 1,20	0,15 to 0,30	—
46	41 CrNiMo 2 E	C 40	0,37 to 0,44	0,40	0,70 to 1,00	0,035	0,035	0,40 to 0,60	0,15 to 0,30	0,40 to 0,70
47	41 NiCrMo 7 E	C 42	0,37 to 0,44	0,40	0,55 to 0,85	0,035	0,035	0,65 to 0,95	0,15 to 0,30	1,60 to 2,00
48	31 CrNiMo 8 E	C 43	0,27 to 0,34	0,40	0,30 to 0,60	0,035	0,035	1,80 to 2,20	0,30 to 0,50	1,80 to 2,20

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 the hardenability, mechanical properties and applicability.

2) In the case of grades with specified hardenability requirements (see tables 19 to 21) except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. However, these deviations shall not exceed 0,01 % (m/m) in the case of carbon and, in all other cases, the values according to table 17.

3) 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.

Table 16 — Types of steel and chemical composition (applicable to cast analysis)

Type of steel			Chemical composition [% (*m*/*m*)] [1) 2)]							
Designation[3)]			C	Si	Mn	P	S	Cr	B[4)]	Total Al[5)]
No.	Name	according to ISO 4954:1979		max.		max.	max.			
61	CE 20 B G1	E 1	0,17 to 0,24	0,40	0,50 to 0,80	0,035	0,035		0,000 8 to 0,005	⩾ 0,020
62	CE 20 B G2	E 2	0,17 to 0,24	0,40	0,80 to 1,20	0,035	0,035		0,000 8 to 0,005	⩾ 0,020
63	CE 28 B	E 4	0,25 to 0,32	0,40	0,60 to 0,90	0,035	0,035		0,000 8 to 0,005	⩾ 0,020
64	CE 35 B	E 5	0,32 to 0,39	0,40	0,50 to 0,80	0,035	0,035		0,000 8 to 0,005	⩾ 0,020
65	35 MnB 5E	E 7	0,32 to 0,39	0,40	1,10 to 1,40	0,035	0,035		0,000 8 to 0,005	⩾ 0,020
66	37 CrB 1 E	E 10	0,34 to 0,41	0,40	0,50 to 0,80	0,035	0,035	0,20 to 0,40	0,000 8 to 0,005	⩾ 0,020

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 the hardenability, mechanical properties and applicability.

2) In the case of grades with specified hardenability requirements (see table 22) except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. However, these deviations shall not exceed 0,01 % (*m*/*m*) in the case of carbon and, in all other cases, the values according to table 17.

3) 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.

4) Boron contents down to 0,000 5 % (*m*/*m*) are tolerated if the requirements for hardenability and mechanical properties are still obtained.

5) The determination of the soluble aluminium content shall be deemed to meet this requirement, provided that the soluble aluminium content value obtained is not less than 0,015 % (*m*/*m*).

Table 17 — Permissible deviations between specified analysis and product analysis

Element	Permissible maximum content according to cast analysis % (*m*/*m*)	Permissible deviations[1)] % (*m*/*m*)
C	⩽ 0,30 > 0,30 ⩽ 0,50	± 0,02 ± 0,03
Si	⩽ 0,40	+ 0,03
Mn	⩽ 1,00 > 1,00 ⩽ 1,65	± 0,04 ± 0,06
P	⩽ 0,035	+ 0,005
S	⩽ 0,035	+ 0,005
B	⩽ 0,005	± 0,000 3
Cr	⩽ 2,00 > 2,00 ⩽ 2,20	± 0,05 ± 0,10
Mo	⩽ 0,30 > 0,30 ⩽ 0,50	± 0,03 ± 0,04
Ni	⩽ 1,00 > 1,00 ⩽ 2,00 > 2,00 ⩽ 2,20	± 0,03 ± 0,05 ± 0,07

1) ± means that in one cast the deviation may occur over the upper value or under the lower value of the specified range given in table 15 or 16, but not both at the same time.

Table 18 — Mechanical properties in the usual treatment conditions for cold heading or cold extruding

1	2		3		4	
Type of steel	Treatment condition[1]					
	AC or AC + P		C + AC		C + AC + LC	
	$R_{m,max}$ N/mm²	Z_{min} %	$R_{m,max}$ N/mm²	Z_{min} %	$R_{m,max}$ N/mm²	Z_{min} [2] %
CE 20 E4	490	63	470	66	510	63
CE 28 E4	540	60	520	63	560	60
CE 35 E4	560	58	540	62	590	58
CE 40 E4	580	57	560	61	610	57
CE 45 E4	600	55	580	59	630	55
42 Mn 6 E	600	58	580	60	620	60
37 Cr 2 E	600	60	580	62	610	62
46 Cr 2 E	620	58	600	60	630	60
34 Cr 4 E	600	60	580	62	610	62
37 Cr 4 E	610	59	590	61	620	61
41 Cr 4 E	620	58	600	60	630	60
36 Mo 3 E	620	58	600	60	630	60
25 CrMo 4 E	580	60	560	62	590	62
34 CrMo 4 E	610	59	590	61	620	61
42 CrMo 4 E	630	58	610	60	640	60
41 CrNiMo 2 E	650	55	630	57	660	57
41 NiCrMo 7 E	680	55	660	57	690	57
31 CrNiMo 8 E	700	58	680	60	710	60
CE 20 B G1	500	64	480	66	510	66
CE 20 B G2	520	62	500	64	530	64
CE 28 B	530	62	510	64	540	64
CE 35 B	570	62	550	64	580	64
35 MnB 5 E	600	60	580	62	610	62
37 CrB 1 E	600	60	580	62	610	62

R_m = Tensile strength

Z = Reduction of area after fracture

1) See table 14.

2) For diameters $\leqslant$ 12 mm, the reduction of area may be 2 % lower.

Table 19 — Hardness limits for steel types with specified (normal) hardenability: H-grades (see 4.2.3.2)

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of															
			1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30
CE 35 E4 H2[2]	870 ± 5	max.	58	57	55	53	49	41	34	31	28	27	26	25	24	23	20	—
		min.	48	40	33	24	22	20	—	—	—	—	—	—	—	—	—	—
CE 40 E4 H2[2]	870 ± 5	max.	60	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	—	—	—	—	—	—
CE 45 E4 H2[2]	850 ± 5	max.	62	61	61	60	57	51	44	37	34	33	32	31	30	29	28	27
		min.	55	51	37	30	28	27	26	25	24	23	22	21	20	—	—	—

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of															
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50	
42 Mn 6 E H	845 ± 5	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	—	—	—	—	
37 Cr 2 E H	850 ± 5	max.	59	57	54	49	43	39	37	35	32	30	27	25	24	23	22	
		min.	51	46	37	29	25	22	20	—	—	—	—	—	—	—	—	
46 Cr 2 E H	850 ± 5	max.	61	59	56	51	45	41	39	37	33	31	29	27	26	25	24	
		min.	52	47	39	31	27	24	22	20	—	—	—	—	—	—	—	
34 Cr 4 E H	850 ± 5	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	—	—	—	—	
37 Cr 4 E H	845 ± 5	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	—	—	—	
41 Cr 4 E H	840 ± 5	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	—	—	—	
36 Mo 3 E H	845 ± 5	max.	59	57	54	48	39	34	31	30	27	25	25	25	24	24	23	
		min.	52	49	40	33	27	24	22	21	—	—	—	—	—	—	—	
25 CrMo 4 E H	860 ± 5	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	—	—	—	—	
34 CrMo 4 E H	850 ± 5	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	
42 CrMo 4 E H	840 ± 5	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	
41 CrNiMo 2 E H	845 ± 5	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	
41 NiCrMo 7 E H	835 ± 5	max.	60	59	58	58	58	58	58	58	57	57	57	57	57	56	56	
		min.	53	52	52	52	52	51	51	51	50	49	47	46	45	44	43	
31 CrNiMo 8 E H	845 ± 5	max.	56	56	56	56	55	55	55	55	55	54	54	54	54	54	54	
		min.	48	48	48	48	47	47	47	46	46	45	45	44	44	43	43	

1) Time for austenitizing, as a guide: 0,5 h minimum. For further quenching conditions, see ISO 642.

2) The hardenability values for the unalloyed steels are tentative and may be adjusted as more information becomes available. If the hardenability scatterband for the H-grade of the relevant steel of a manufacturer falls outside the limits given in this table, the manufacturer has to inform the purchaser accordingly at the time of enquiry and order.

Table 20 — Tentative hardness limits for unalloyed steel types with narrowed hardenability scatterbands: HH and HL-grades

Type of steel	Quenching temperature[1] °C	Tentative values of hardness (HRC) at a distance (in mm) from the quenched end of the test piece of	
		1	4
CE 35 E4 HH4	870 ± 5	—	34 to 53
CE 35 E4 HH14		51 to 58	34 to 53
CE 35 E4 HL4	870 ± 5	—	24 to 43
CE 35 E4 HL14		48 to 55	24 to 43
CE 40 E4 HH4	870 ± 5	—	38 to 57
CE 40 E4 HH14		54 to 60	38 to 57
CE 40 E4 HL4	870 ± 5	—	27 to 46
CE 40 E4 HL14		51 to 57	27 to 46
CE 45 E4 HH4	850 ± 5	—	41 to 60
CE 45 E4 HH14		57 to 62	41 to 60
CE 45 E4 HL4	850 ± 5	—	30 to 49
CE 45 E4 HL14		55 to 60	30 to 49

1) Time for austenitizing, as a guide: 0,5 h minimum. For further quenching conditions, see ISO 642.

Table 21 — Hardness limits for alloyed steel types with narrowed hardenability scatterbands: HH and HL-grades

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of														
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
42 Mn 6 E HH	845 ± 5	max.	62	61	60	59	57	54	50	45	37	34	32	31	30	29	28
		min.	57	56	53	46	41	37	35	32	28	26	24	23	22	21	20
42 Mn 6 E HL	845 ± 5	max.	60	58	56	52	49	46	42	39	32	30	28	27	26	25	24
		min.	55	53	49	39	33	29	27	26	23	22	20	—	—	—	—
37 Cr 2 E HH	850 ± 5	max.	59	57	54	49	43	39	37	35	32	30	27	25	24	23	22
		min.	54	50	43	36	31	28	26	24	21	—	—	—	—	—	—
37 Cr 2 E HL	850 ± 5	max.	56	53	48	42	37	33	31	29	26	24	21	—	—	—	—
		min.	51	46	37	29	25	22	20	—	—	—	—	—	—	—	—
46 Cr 2 E HH	850 ± 5	max.	61	59	56	51	45	41	39	37	33	31	29	27	26	25	24
		min.	55	51	45	38	33	30	28	26	22	20	—	—	—	—	—
46 Cr 2 E HL	850 ± 5	max.	58	55	50	44	39	35	33	31	27	25	23	21	20	—	—
		min.	52	47	39	31	27	24	22	20	—	—	—	—	—	—	—
34 Cr 4 E HH	850 ± 5	max.	57	57	56	54	52	49	46	44	39	37	35	34	33	32	31
		min.	52	51	49	45	41	38	35	33	28	26	25	24	23	22	21
34 Cr 4 E HL	850 ± 5	max.	54	54	52	50	46	43	40	38	34	32	30	29	28	27	26
		min.	49	48	45	41	35	32	29	27	23	21	20	—	—	—	—
37 Cr 4 E HH	845 ± 5	max.	59	59	58	57	55	52	50	48	42	39	37	36	35	34	33
		min.	54	53	51	48	44	41	39	37	31	29	27	25	24	23	22
37 Cr 4 E HL	845 ± 5	max.	56	56	55	53	50	47	44	42	37	34	32	31	30	29	28
		min.	51	50	48	44	39	36	33	31	26	24	22	20	—	—	—
41 Cr 4 E HH	840 ± 5	max.	61	61	60	59	58	56	54	52	46	42	40	38	37	36	35
		min.	56	55	53	51	47	43	41	39	35	31	29	27	26	25	24
41 Cr 4 E HL	840 ± 5	max.	58	58	57	55	52	50	47	45	40	37	34	32	31	30	29
		min.	53	52	50	47	41	37	34	32	29	26	23	21	—	—	—
36 Mo 3 E HH	845 ± 5	max.	59	57	54	48	39	34	31	30	27	25	25	25	24	24	23
		min.	54	52	45	38	31	27	25	24	21	—	—	—	—	—	—
36 Mo 3 E HL	845 ± 5	max.	57	54	49	43	35	31	28	27	24	22	22	22	21	21	20
		min.	52	49	40	33	27	24	22	21	—	—	—	—	—	—	—
25 CrMo 4 E HH	860 ± 5	max.	52	52	51	50	48	46	43	41	37	35	33	32	31	31	31
		min.	47	46	44	41	39	37	34	32	28	26	24	23	22	22	22
25 CrMo 4 E HL	860 ± 5	max.	49	49	47	46	43	41	38	36	32	30	29	28	27	27	27
		min.	44	43	40	37	34	32	29	27	23	21	20	—	—	—	—
34 CrMo 4 E HH	850 ± 5	max.	57	57	57	56	55	54	53	52	48	45	43	41	40	40	39
		min.	52	52	51	49	46	44	42	40	36	34	32	31	30	29	29

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness (HRC) at a distance (in mm) from the quenched end of the test piece of														
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
34 CrMo 4 E HL	850 ± 5	max.	54	54	54	52	51	49	47	46	42	39	38	36	35	35	34
		min.	49	49	48	45	42	39	36	34	30	28	27	26	25	24	24
42 CrMo 4 E HH	840 ± 5	max.	61	61	61	60	60	59	59	58	56	53	51	48	47	46	45
		min.	56	56	55	54	52	48	46	44	41	39	38	36	36	35	34
42 CrMo 4 E HL	840 ± 5	max.	58	58	58	57	56	54	53	51	49	46	44	42	41	40	40
		min.	53	53	52	51	49	43	40	37	34	32	31	30	30	29	29
41 CrNiMo 2 E HH	845 ± 5	max.	60	60	60	59	58	57	55	54	48	42	40	38	37	37	36
		min.	55	55	55	53	51	47	44	41	36	33	31	29	28	28	27
41 CrNiMo 2 E HL	845 ± 5	max.	58	58	57	56	54	52	49	48	42	37	35	34	33	33	32
		min.	53	53	52	50	47	42	38	35	30	28	26	25	24	24	23
41 NiCrMo 7 E HH	835 ± 5	max.	60	59	58	58	58	58	58	58	57	57	57	57	57	56	56
		min.	55	54	54	54	54	53	53	53	52	52	50	50	49	48	47
41 NiCrMo 7 E HL	835 ± 5	max.	58	57	56	56	56	56	56	56	55	54	54	53	53	52	52
		min.	53	52	52	52	52	51	51	51	50	49	47	46	45	44	43
31 CrNiMo 8 E HH	845 ± 5	max.	56	56	56	56	55	55	55	55	55	54	54	54	54	54	54
		min.	51	51	51	51	50	50	50	49	49	48	48	47	47	47	47
31 CrNiMo 8 E HL	845 ± 5	max.	53	53	53	53	52	52	52	52	52	51	51	51	51	50	50
		min.	48	48	48	48	47	47	47	46	46	45	45	44	44	43	43

1) Time for austenitizing, as a guide: 0,5 h minimum. For further quenching conditions, see ISO 642.

Table 22 — Tentative hardness limits for specified hardenability of boron-treated steels

Type of steel	Quenching temperature[1] °C	Limits of range	Hardness HRC[2] [3] at a distance (in mm) from the quenched end of the test piece of														
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
CE 20 B G1 H	880 ± 5	max.	48	47	46	43	37	30	25	22	—	—	—	—	—	—	—
		min.	41	38	32	21	—	—	—	—	—	—	—	—	—	—	—
CE 20 B G2 H	880 ± 5	max.	48	48	47	45	41	35	30	27	22	—	—	—	—	—	—
		min.	41	40	37	28	20	—	—	—	—	—	—	—	—	—	—
CE 28 B H	850 ± 5	max.	53	52	51	48	44	38	32	27	20	—	—	—	—	—	—
		min.	45	42	35	27	22	—	—	—	—	—	—	—	—	—	—
CE 35 B H	850 ± 5	max.	58	58	57	55	52	46	38	33	26	25	—	—	—	—	—
		min.	51	49	43	30	24	21	—	—	—	—	—	—	—	—	—
35 MnB 5 E H	850 ± 5	max.	58	58	57	56	55	53	50	45	37	32	28	26	24	23	—
		min.	51	51	48	44	36	31	27	25	21	—	—	—	—	—	—
37 CrB 1 E H	850 ± 5	max.	59	59	58	56	54	50	45	41	34	30	27	25	24	—	—
		min.	52	50	46	37	30	26	24	22	—	—	—	—	—	—	—

1) Time for austenitizing, as a guide: 0,5 h minimum. For further quenching conditions, see ISO 642.

2) The hardness values are tentative and may be adjusted as more information becomes available.

3) By agreement between the purchaser and supplier, closer hardenability limits may be agreed upon.

Table 23 — Diameter up to which, after quenching in an oil of high quenching capacity, a hardness of 40, 45 or 48 HRC can be achieved for the core: CH-grades (see 4.2.3.3) (the values are for guidance)

Type of steel	Quenching temperature[1] °C	Hardness in the core HRC	Maximum diameter mm
CE 35 E4 CH	870 ± 5	40	8[2]
CE 40 E4 CH	870 ± 5	40	10[2]
CE 45 E4 CH	850 ± 5	40	12[2]
42 Mn 6 E CH	845 ± 5	40	20
37 Cr 2 E CH	850 ± 5	40	16[2]
46 Cr 2 E CH	850 ± 5	40	20[2]
34 Cr 4 E CH	850 ± 5	40	22
37 Cr 4 E CH	845 ± 5	40	24
41 Cr 4 E CH	840 ± 5	40	28
36 Mo 3 E CH	845 ± 5	40	20
25 CrMo 4 E CH	860 ± 5	40	20
34 CrMo 4 E CH	850 ± 5	45	20
42 CrMo 4 E CH	840 ± 5	48	28
41 CrNiMo 2 E CH	845 ± 5	48	21
41 NiCrMo 7 E CH	835 ± 5	48	34
31 CrNiMo 8 E CH	845 ± 5	45	60

1) Time for austenitizing, as a guide: 0,5 h minimum. For further quenching conditions, see 1.5.3.2.2 and 1.5.4.2.2.

2) These values apply only if the steel was not ordered as fine grain steel.

Table 24 — Diameter up to which, after quenching in an oil of high quenching capacity, a hardness of 40 HRC can be achieved for the core: CH-grades (see 4.2.3.3)

Type of steel	Quenching temperature[1] °C	Maximum diameter[2] mm
CE 20 B G1 CH	880 ± 5	9
CE 20 B G2 CH	880 ± 5	12
CE 28 B CH	850 ± 5	14
CE 35 B CH	850 ± 5	18
35 MnB 5 E CH	850 ± 5	26
37 CrB 1 E CH	850 ± 5	24

1) Time for austenitizing, as a guide: 0,5 h minimum.

2) The maximum diameters of the core hardening test given in this table do not necessarily indicate that the respective steels are suitable for all strength levels in these sizes.

Section 5: Specific requirements for cold-heading and cold-extruding stainless steels

5.1 Scope

This section covers the specific requirements for the cold-heading and cold-extruding stainless steels. It applies in the case of ferritic steels for diameters from 2 mm to 25 mm, in the case of martensitic steels for diameters from 2 mm to 100 mm and in the case of austenitic steels for diameters from 2 mm to 50 mm.

5.2 Requirements

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

Table 25 gives a survey of combinations of usual treatment conditions on delivery, product forms and requirements regarding chemical composition and mechanical properties.

5.2.2 Chemical composition

5.2.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 26.

5.2.2.2 The permissible deviations between the values specified in table 26 and the product analysis are indicated in table 27.

5.2.3 Mechanical properties

For all steels which were ordered in one of the treatment conditions indicated in table 25, the maximum values for the tensile strength and, for ferritic and martensitic steels, the minimum values for the reduction of area specified in table 28 apply.

5.2.4 Corrosion resistance

For the resistance against corrosion, the requirements may be agreed upon, e.g. for austenitic steels: intergranular corrosion tests according to ISO 3651-1[2] or ISO 3651-2[3].

5.2.5 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 25.

Table 25 — Combinations of usual heat-treatment conditions on delivery, product forms and requirements according to tables 26 to 28 for stainless steels

1	2		3		4	5	6	7	
1	Condition of delivery		Symbol for		"x" indicates applicable to			Applicable requirements	
	for ferritic and martensitic steels	for austenitic steels	ferritic and martensitic steels	austenitic steels	hot-rolled bars	wire rod	drawn products	7.1	7.2
2	Annealed	Quenched[1)]	AC	Q	x	x	—	Chemical composition according to tables 26 and 27	Mechanical properties according to table 28, column 2
3	Annealed and peeled	Quenched[1)] and peeled	AC+P	Q+P	x	—	—		
4	Cold drawn and annealed	Cold drawn and quenched[1)]	C+AC	C+Q	—	—	x		
5	Cold drawn and annealed, and lightly cold reduced (e.g. with a reduction of 5 %)	Cold drawn and quenched[1)], and lightly cold reduced (e.g. with a reduction of 5 %)	C+AC+LC	C+Q+LC	—	—	x		Mechanical properties according to table 28, column 3
6	Others		Other treatment conditions may be agreed upon at the time of enquiry and order.						

1) Instead of the term "quenched", the term "annealed" is often used for austenitic steels.

Table 26 — Types of steel and chemical composition (applicable to cast analysis)

Type of steel Designation[2]			Chemical composition [% (m/m)] [1]								
No.	Name	according to ISO 4954:1979	C	Si max.	Mn max.	P max.	S max.	Cr	Mo	Ni	Others
	Ferritic steels										
71	X 3 Cr 17 E	—	⩽ 0,04	1,00	1,00	0,040	0,030	16,0 to 18,0		⩽ 1,0	
72	X 6 Cr 17 E	D 1	⩽ 0,08	1,00	1,00	0,040	0,030	16,0 to 18,0		⩽ 1,0	
73	X 6 CrMo 17 1 E	D 2	⩽ 0,08	1,00	1,00	0,040	0,030	16,0 to 18,0	0,90 to 1,30	⩽ 1,0	
74	X 6 CrTi 12 E	—	⩽ 0,08	1,00	1,00	0,040	0,030	10,5 to 12,5		⩽ 0,50	Ti: 6 x % C ⩽ 1,0
75	X 6 CrNb 12 E	—	⩽ 0,08	1,00	1,00	0,040	0,030	10,5 to 12,5		⩽ 0,50	Nb: 6 x % C ⩽ 1,0
	Martensitic steels										
76	X 12 Cr 13 E	D 10	0,09 to 0,15	1,00	1,00	0,040	0,030	11,5 to 13,5		⩽ 1,0	
77	X 19 CrNi 16 2 E	D 12	0,14 to 0,23	1,00	1,00	0,040	0,030	15,0 to 17,5		1,5 to 2,5	
	Austenitic steels										
78	X 2 CrNi 18 10 E	D 20	⩽ 0,030	1,00	2,00	0,045	0,030	17,0 to 19,0		9,0 to 12,0	
79	X 5 CrNi 18 9 E	D 21	⩽ 0,07	1,00	2,00	0,045	0,030	17,0 to 19,0		8,0 to 11,0	
80	X 10 CrNi 18 9 E	D 22	⩽ 0,12	1,00	2,00	0,045	0,030	17,0 to 19,0		8,0 to 10,0	
81	X 5 CrNi 18 12 E	D 23	⩽ 0,07	1,00	2,00	0,045	0,030	17,0 to 19,0		11,0 to 13,0	
82	X 6 CrNi 18 16 E	D 25	⩽ 0,08	1,00	2,00	0,045	0,030	15,0 to 17,0		17,0 to 19,0	
83	X 6 CrNiTi 18 10 E	D 26	⩽ 0,08	1,00	2,00	0,045	0,030	17,0 to 19,0		9,0 to 12,0	Ti: 5 x % C ⩽ 0,80
84	X 5 CrNiMo 17 12 2 E	D 29	⩽ 0,07	1,00	2,00	0,045	0,030	16,5 to 18,5	2,0 to 2,5	10,5 to 13,5	
85	X 6 CrNiMoTi 17 12 2 E	D 30	⩽ 0,08	1,00	2,00	0,045	0,030	16,5 to 18,5	2,0 to 2,5	11,0 to 14,0	Ti: 5 x % C ⩽ 0,80
86	X 2 CrNiMo 17 13 3 E	—	⩽ 0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,5 to 3,0	11,5 to 14,5	
87	X 2 CrNiMoN 17 13 3 E	—	⩽ 0,030	1,00	2,00	0,045	0,030	16,5 to 18,5	2,5 to 3,0	11,5 to 14,5	N: 0,12 to 0,22
88	X 3 CrNiCu 18 9 3 E	D 32	⩽ 0,04	1,00	2,00	0,045	0,030	17,0 to 19,0		8,5 to 10,5	Cu: 3,00 to 4,00

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.

Table 27 — Product analysis — Permissible deviations from the specified cast analysis (see table 26)

Element	Cast analysis (specified limits) % (*m/m*)	Permissible deviations[1] from the specified composition % (*m/m*)
C	⩽ 0,030 > 0,030 < 0,20 ⩾ 0,20 ⩽ 0,23	+ 0,005 ± 0,01 ± 0,02
Si	⩽ 1,0	+ 0,05
Mn	⩽ 1,0 > 1,0 ⩽ 2,0	+ 0,03 + 0,04
P	⩽ 0,040 > 0,040 ⩽ 0,045	+ 0,005 + 0,010
S	⩽ 0,030	+ 0,005
Cr	⩾ 10,5 < 15,0 ⩾ 15,0 ⩽ 19,0	± 0,15 ± 0,20
Cu	⩽ 4,0	± 0,15
Mo	< 1,75 ⩾ 1,75 ⩽ 3,0	± 0,05 ± 0,10
Ni	⩽ 1,0 > 1,0 ⩽ 5,0 > 5,0 ⩽ 10,0 > 10,0 ⩽ 19,0	+ 0,03 ± 0,07 ± 0,10 ± 0,15
Nb	⩽ 1,0	± 0,05
N	⩽ 0,22	± 0,01
Ti	⩽ 1,00	± 0,05

1) ± means that in one cast, and in more than one product analysis, the deviation may occur over the upper value or under the lower value of the specified range given in table 26, but not both at the same time.

Table 28 — Mechanical properties in the usual treatment condition for cold heading or cold extruding

1	2		3	
Type of steel	Treatment condition[1] for the ferritic and martensitic steels			
	AC or AC + P or C + AC		C + AC + LC	
	Treatment condition[1] for the austenitic steels			
	Q or Q + P or C + Q		C + Q + LC	
	$R_{m,max}$ N/mm²	Z_{min} %	$R_{m,max}$ N/mm²	Z_{min} %
Ferritic steels				
X 3 Cr 17 E	500	65	540	63
X 6 Cr 17 E	560	65	600	63
X 6 CrMo 17 1 E	600	65	640	63
X 6 CrTi 12 E	530	65	570	63
X 6 CrNb 12 E	500	65	540	63
Martensitic steels				
X 12 Cr 13 E	600	62	640	60
X 19 CrNi 16 2 E	800	50	840	48
Austenitic steels				
X 2 CrNi 18 10 E	630		680	
X 5 CrNi 18 9 E	650		710	
X 10 CrNi 18 9 E	660		720	
X 5 CrNi 18 12 E	650		700	
X 6 NiCr 18 16 E	600		640	
X 6 CrNiTi 18 10 E	680		730	
X 5 CrNiMo 17 12 2 E	660		710	
X 6 CrNiMoTi 17 12 2 E	680		730	
X 2 CrNiMo 17 13 3 E	680		730	
X 2 CrNiMoN 17 13 3 E	780		840	
X 3 CrNiCu 18 9 3 E	590		620	

R_m = Tensile strength

Z = Reduction of area after fracture

1) See table 25.

Annex A
(informative)

Guide to property values after processing

A.1 Introduction

The property values contained in this International Standard are delivery requirements. The property values indicated in this annex are not delivery requirements because they are the result of processing after delivery. The data in this annex are provided only as a guide to the relative performance of the different steels enumerated in this International Standard. They are not intended for use in the purchase, design, development, manufacture or usage of any item. Users must assure themselves of the actual properties achieved in practice.

A.2 Tables A.1 to A.6 contain information on:

— mechanical properties for reference test bars in the simulated case-hardened condition (see table A.1);

— heat treating test bars and heat treatment of case-hardening steels (see table A.2);

— mechanical properties for quenched and tempered condition (see table A.3);

— conditions for heat treatment of steels for quenching and tempering (see table A.4);

— mechanical properties of martensitic stainless steels in the quenched and tempered condition (see table A.5);

— conditions for heat treatment of stainless steels (see table A.6).

NOTE 5 Austenitic steels are normally applied in the deformed condition. The properties can be very different and therefore cannot be standardized here. For the mechanical properties of ferritic and martensitic stainless steels in the annealed condition, see table 28.

Table A.1 — Mechanical properties for reference test bars in the simulated case-hardened condition
(see table A.2) (for guidance only)

Type of steel	Ø = 16 mm					Ø = 30 mm					Ø = 63 mm				
	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A 1) min. %	KU 2) min. J	KV 2) min. J	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A 1) min. %	KU 2) min. J	KV 2) min. J	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A 1) min. %	KU 2) min. J	KV 2) min. J
CE 10	270	450 to 800	14	35	3)	250	400 to 700	15	35	3)	—	—	—	—	—
CE 15 E4	300	500 to 850	13	30	3)	260	450 to 750	14	30	3)	—	—	—	—	—
CE 16 E4	340	550 to 900	11	25	3)	290	500 to 800	12	25	3)	—	—	—	—	—
CE 20 E4	370	570 to 920	10	25	3)	320	520 to 820	11	25	3)	—	—	—	—	—
20 Cr 4 E	550	820 to 1 170 4)	9	25	3)	490	750 to 1 100 4)	9	25	3)	450	670 to 1 020 4)	10	25	3)
16 MnCr 5 E	600	880 to 1 230 4)	9	25	3)	520	770 to 1 120 4)	10	25	3)	450	650 to 1 000 4)	11	25	3)
18 CrMo 4 E	600	920 to 1 270 4)	9	25	3)	540	820 to 1 170 4)	10	25	3)	480	710 to 1 060 4)	11	25	3)
20 NiCrMo 2 E	560	810 to 1 160 4)	9	25	3)	510	730 to 1 080 4)	10	30	3)	470	660 to 1 010 4)	11	30	3)

Ø = Diameter of test bar

R_m = Tensile strength

A = Percentage elongation after fracture ($L_o = 5\ d_o$, where L_o is the original length and d_o is the original diameter)

KU = Impact strength of ISO U-notch test pieces

KV = Impact strength of ISO V-notch test pieces

$R_{p0,2}$ = 0,2 % Proof stress (specified yield strength)

1) For the purposes of this International Standard, these values are only applicable for diameters ⩾ 4 mm. For products with diameters < 4 mm, if required, the values should be agreed upon at the time of enquiry and order.

2) Average of three individual values: no individual value shall be lower than 70 % of the minimum average value.

3) If testing of ISO V-notch impact test pieces is required, the minimum impact strength value is to be agreed upon.

4) The values given in this table are only based on a small amount of data. In addition, attempts were made to obtain some confirmation of the correctness of the values by calculation on the basis of Jominy values.

Table A.2 — Conditions for heat treating test bars and treatment of the steels

Type of steel	Carburizing temperature[1) 2) 3)] °C	Direct and simple hardening temperature[1)] °C	Double hardening		Quenching agent[4)]	Tempering[1) 5)] °C
			Core hardening[1) 3)] temperature °C	Case hardening[1)] temperature °C		
CE 10	880 to 980	830 to 870	880 to 920	780 to 820		150 to 200
CE 15 E4	880 to 980	830 to 870	880 to 920	780 to 820		150 to 200
CE 16 E4	880 to 980	830 to 870	880 to 920	780 to 820		150 to 200
CE 20 E4	880 to 980	830 to 870	880 to 920	780 to 820		150 to 200
20 Cr 4 E	880 to 980	820 to 860	860 to 900	780 to 820		150 to 200
16 MnCr 5 E	880 to 980	820 to 860	860 to 900	780 to 820		150 to 200
18 CrMo 4 E	880 to 980	820 to 860	860 to 900	780 to 820		150 to 200
20 NiCrMo 2 E	880 to 980	820 to 860	860 to 900	780 to 820		150 to 200

1) The temperatures given for carburizing, direct and simple hardening, core hardening, case hardening and tempering are for guidance only. The actual temperatures chosen should be those that will give the properties required.

2) The carburizing temperature will depend on the chemical composition of the steel, the mass of the product, and the carburizing medium. In general, if the steels are direct hardened, a temperature of 950 °C is not exceeded. Also, for special procedures e.g. under vacuum, higher temperatures, e.g. 1 020 °C to 1 050 °C, are not unusual.

3) If the steels are direct hardened and if there is a danger of distortion, they should be quenched from a temperature between the core-hardening and case-hardening temperatures.

4) The kind of quenching agent depends on, for example, the shape of the products, the cooling conditions and the quantity of furnace filling.

5) Time for tempering, as a guide: 1 h minimum.

Table A.3 — Mechanical properties for quenched and tempered condition

Type of steel	Ø ⩽ 16 mm					16 mm < Ø ⩽ 40 mm					40 mm < Ø ⩽ 100 mm				
	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A [1] min. %	KU [2] min. J	KV [2] min. J	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A [1] min. %	KU [2] min. J	KV [2] min. J	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A [1] min. %	KU [2] min. J	KV [2] min. J
CE 20 E4[3]	370	540 to 680	19	—	—	—	—	—	—	—	—	—	—	—	—
CE 28 E4	390	580 to 730	18	30	40	330	540 to 690	20	30	40	—	—	—	—	—
CE 35 E4	430	630 to 780	17	25	35	380	600 to 750	19	25	35	320	550 to 700	20	29	35
CE 40 E4	460	650 to 800	16	20	30	400	630 to 780	18	20	30	350	600 to 750	19	20	30
CE 45 E4	490	700 to 850	14	15	25	430	650 to 800	16	15	25	370	630 to 780	17	15	25
42 Mn 6 E	690	900 to 1 050	12	25	35	590	800 to 950	14	30	40	480	750 to 900	15	30	40
37 Cr 2 E	550	800 to 950	14	30	35	450	700 to 850	15	25	35	350	600 to 750	17	25	35
46 Cr 2 E	650	900 to 1 100	12	25	30	550	800 to 950	14	25	35	400	650 to 800	15	25	35
34 Cr 4 E	700	900 to 1 100	12	25	35	590	800 to 950	14	30	40	460	700 to 850	15	30	40
37 Cr 4 E	750	950 to 1 150	11	20	30	630	850 to 1 000	13	25	35	510	750 to 900	14	25	35
41 Cr 4 E	800	1 000 to 1 200	11	20	30	660	900 to 1 100	12	25	35	560	800 to 950	14	25	35
36 Mo 3 E	630	830 to 1 030	13	20	30	460	690 to 840	16	20	30	390	660 to 810	16	20	30
25 CrMo 4 E	700	900 to 1 100	12	30	45	600	800 to 950	14	35	50	450	700 to 850	15	35	50
34 CrMo 4 E	800	1 000 to 1 200	11	25	35	650	900 to 1 100	12	30	40	550	800 to 950	14	30	45
42 CrMo 4 E	900	1 100 to 1 300	10	20	30	750	1 000 to 1 200	11	25	35	650	900 to 1 100	12	25	35
41 CrNiMo 2 E	840	1 000 to 1 200	10	30	40	740	900 to 1 100	11	30	40	640	800 to 950	12	30	40
41 NiCrMo 7 E	1 000	1 200 to 1 400	9	25	35	900	1 100 to 1 300	10	25	35	800	1 000 to 1 200	11	30	40
31 CrNiMo 8 E G1	850	1 030 to 1 230	12	35	45	850	1 030 to 1 230	12	25	45	800	980 to 1 180	12	35	45
31 CrNiMo 8 E G2	1 050	1 250 to 1 450	9	20	30	1 050	1 250 to 1 450	9	20	30	900	1 100 to 1 300	10	25	35
CE 20 B G1	450	600 to 750	16	35	45	400	550 to 700	18	35	45	—	—	—	—	—
CE 20 B G2	550	700 to 850	14	30	40	500	650 to 800	16	30	40	—	—	—	—	—
CE 28 B	550	700 to 850	14	30	40	480	630 to 780	16	30	40	—	—	—	—	—
CE 35 B	600	750 to 900	14	30	40	500	650 to 800	16	30	40	—	—	—	—	—
35 MnB 5 E	750	900 to 1 050	12	20	30	650	800 to 950	14	20	30	510	680 to 830	15	30[4]	40[4]
37 CrB 1 E	700	850 to 1 000	12	25	35	600	750 to 900	14	25	35	480	630 to 780	16	30[4]	40[4]

Ø = Diameter
R_m = Tensile strength
A = Percentage elongation after fracture ($L_o = 5\ d_o$, where L_o is the original length and d_o is the original diameter)
KU = Impact strength of ISO U-notch test pieces
KV = Impact strength of ISO V-notch test pieces
$R_{p0,2}$ = 0,2 % Proof stress (specified yield strength)

NOTE — For the fastener industry, ISO 898-1[1] specifies minimum tempering temperatures of between 340 °C and 425 °C, for these types of steel resulting in differing mechanical properties.

1) For the purposes of this International Standard, these values are only applicable for diameters ⩾ 4 mm. For products with diameters < 4 mm, if required, the values should be agreed upon at the time of enquiry and order.

2) Average of three individual values: no individual value shall be lower than 70 % of the minimum average value. Unless otherwise agreed, the choice between ISO U-notch and ISO V-notch test pieces is left to the manufacturer.

3) The values for this steel type are only applicable for diameters up to 6 mm.

4) These impact values are tentative. They will, if necessary, be revised as soon as further data are available.

Table A.4 — Conditions for heat treatment (for guidance only)

Type of steel	Heat treatment of steel products			
	Normalizing temperature[1] °C	Quenching temperature[1][2] °C	Quenching agent[3]	Tempering temperature[4] [5] °C
CE 20 E4	890 to 930	870 to 910	Water	550 to 660
CE 28 E4	870 to 910	859 to 890	Water or oil	550 to 660
CE 35 E4	860 to 900	840 to 880	Water or oil	550 to 660
CE 40 E4	850 to 890	830 to 870	Water or oil	550 to 660
CE 45 E4	840 to 880	820 to 860	Water or oil	550 to 660
42 Mn 6 E	—	830 to 880	Oil	550 to 650
37 Cr 2 E	850 to 880	830 to 870	Water or oil	540 to 680
46 Cr 2 E	840 to 870	820 to 860	Water or oil	540 to 680
34 Cr 4 E	—	830 to 870	Water or oil	540 to 680
37 Cr 4 E	—	825 to 865	Oil or water	540 to 680
41 Cr 4 E	—	820 to 860	Oil or water	540 to 680
36 Mo 3 E	—	820 to 860	Oil	540 to 680
25 CrMo 4 E	—	840 to 880	Water or oil	540 to 680
34 CrMo 4 E	—	830 to 870	Oil or water	540 to 680
42 CrMo 4 E	—	820 to 860	Oil or water	540 to 680
41 CrNiMo 2 E	—	830 to 860	Oil or water	540 to 660
41 NiCrMo 7 E	—	820 to 850	Oil	540 to 660
31 CrNiMo 8 E G1	—	830 to 860	Oil	580 to 680
31 CrNiMo 8 E G2	—	830 to 860	Oil	540 to 640
CE 20 B G1	880 to 910	860 to 900	Water or oil	550 to 660
CE 20 B G2	880 to 910	860 to 900	Water or oil	550 to 660
CE 28 B	870 to 900	850 to 890	Water or oil	550 to 660
CE 35 B	860 to 890	840 to 880	Water or oil	550 to 660
35 MnB 5 E	860 to 890	840 to 880	Oil	550 to 660
37 CrB 1 E	855 to 885	835 to 875	Water or oil	550 to 660

1) Time for austenitizing, as a guide: 0,5 h minimum.

2) In the case where the quenching agents oil and water are indicated, the temperature at the lower end of the range should be used for water and that at the upper end for oil.

3) When choosing the quenching agent, the influence of other parameters, such as shape, dimensions, and quenching temperature, on properties and crack susceptibility should be taken into account. Other quenching agents such as synthetic quenchants may also be used.

4) Time for tempering, as a guide: 1 h minimum.

5) For the fastener industry, ISO 898-1[1] specifies minimum tempering temperatures of between 340 °C and 425 °C, for these types of steel resulting in differing mechanical properties.

Table A.5 — Mechanical properties of martensitic steels for the heat-treatment condition given in table A.6

Type of steel	$R_{p0,2}$ min. N/mm²	R_m N/mm²	A [1] min. %
X 12 Cr 13 E	400	600 to 800	16
X 19 CrNi 16 2 E	680	880 to 1 080	11

$R_{p0,2}$ = 0,2 % Proof stress (specified yield strength)

R_m = Tensile strength

A : Percentage elongation after fracture ($L_o = 5\ d_o$, where L_o is the original length and d_o is the original diameter)

1) For the purposes of this International Standard, these values are only applicable for diameters $\geqslant$ 4 mm. For products with diameters < 4 mm, if required, the values should be agreed upon at the time of enquiry and order.

Table A.6 — Heat treatment (for guidance only)

Type of steel	Symbol of heat-treatment[1]	Annealing or solution treatment temperature °C	Cooling medium	Tempering temperature °C
Ferritic steels				
X 3 Cr 17 E	A	750 to 850		
X 6 Cr 17 E	A	750 to 850	Air, water, furnace	
X 6 CrMo 17 1 E	A	750 to 850		
X 6 CrTi 12 E	A	750 à 850	Air, furnace	
X 6 CrNb 12 E	A	750 to 850		
Martensitic steels				
X 12 Cr 13 E	Q+T[2]	950 to 1 000	Oil, air	700 to 750
X 19 CrNi 16 2 E	Q+T[2]	980 to 1 030	Oil, air	600 to 700
Austenitic steels [3]				
X 2 CrNi 18 10 E	Q	1 000 to 1 100	Water, air[4]	
X 5 CrNi 18 9 E	Q	1 000 to 1 100	Water, air[4]	
X 10 CrNi 18 9 E	Q	1 000 to 1 100	Water, air[4]	
X 5 CrNi 18 12 E	Q	1 000 to 1 100	Water, air[4]	
X 6 NiCr 18 16 E	Q	1 020 to 1 120	Water, air[4]	
X 6 CrNiTi 18 10 E	Q	1 020 to 1 120	Water, air[4]	
X 5 CrNiMo 17 12 2 E	Q	1 020 to 1 120	Water, air[4]	
X 6 CrNiMoTi 17 12 2 E	Q	1 020 to 1 120	Water, air[4]	
X 2 CrNiMo 17 13 3 E	Q	1 020 to 1 120	Water, air[4]	
X 2 CrNiMoN 17 13 3 E	Q	1 020 to 1 120	Water, air[4]	
X 6 CrNiCu 17 9 3 E	Q	1 020 to 1 120	Water, air[4]	

1) A = annealing; Q = quenching; T = tempering.

2) If the steels are to be annealed, the following treatments are recommended:

— for type X 12 Cr 13 E: 700 °C to 780 °C/air cool or 700 °C to 870 °C/furnace cool;

— for type X 19 CrNi 16 2 E: 650 °C to 750 °C/air cool. Prior transformation to martensite may be necessary.

3) In the case of heat treatment in the course of processing after delivery, the lower part of the given solution temperature range is to be aimed for. If, in the course of heat treatment, the temperature was not below the specified lower limit of the solution temperature, the following temperatures are sufficient for repeat heat treatments:

980 °C in the case of Mo-free steels;

1 000 °C in the case of Mo-alloyed steels.

4) Cooling should be sufficiently rapid to prevent undesirable precipitations.

Annex B
(informative)

Bibliography

[1] ISO 898-1:1988, *Mechanical properties of fasteners — Part 1: Bolts, screws and studs.*

[2] ISO 3651-1:1976, *Austenitic stainless steels — Determination of resistance to intergranular corrosion — Part 1: Corrosion test in nitric acid medium by measurement of loss in mass (Huey test).*

[3] ISO 3651-2:1976, *Austenitic stainless steels — Determination of resistance to intergranular corrosion — Part 2: Corrosion test in a sulphuric acid/copper sulphate medium in the presence of copper turnings (Monypenny Strauss test).*

[4] ISO 4967:1979, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams.*

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Descriptors: steels, cold-working, extrusions, heading (forming), specifications, chemical composition, mechanical properties, hardenability, surface condition, tests.

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