International Standard 4954

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Steels for cold heading and cold extruding

Aciers pour refoulement et extrusion à froid

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4954 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in February 1978.

It has been approved by the member bodies of the following countries :

Austria	Iran	Romania
Belgium	Ireland	South Africa, Rep. of
Bulgaria	Italy	Spain
Canada	Japan	Sweden
Czechoslovakia	Korea, Dem. P. Rep. of	Switzerland
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Germany, F. R.	Netherlands	USSR
Hungary	Norway	
India	Poland	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Australia
Finland
New Zealand

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Steels for cold heading and cold extruding

1 Scope and field of application

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 or bars. It covers the following steel groups and diameter ranges :

a) steels not intended for heat treatment with diameters from 2 to 100 mm (see section two);

b) case hardening steels with diameters from 2 to 100 mm (see section three);

c) steels for quenching and tempering including boron treated steels, with diameters from 2 to 100 mm (see section four);

d) stainless steels with diameters of 2 mm up to 25 mm for ferritic and up to 100 mm for martensitic and austenitic steels (see section five).

1.2 This International Standard (except section two) is not applicable as regards 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.

NOTE — If stainless steels supplied to this International Standard are used for the manufacture of fasteners to the requirements of ISO 3506, Stainless steel and corrosion resistant steel fasteners — Specifications[1], see table 1 of ISO 3506, concerning the identification of steel type and strength as applied to cold headed/extruded fasteners.

2 References

ISO/R 79, *Brinell hardness test for steel.*

ISO/R 80, *Rockwell hardness test (B and C scales) for steel.*

ISO 82, *Steel — Tensile testing.*

ISO 83, *Steel — Charpy impact test (U-notch).*

ISO 89, *Steel — Tensile testing of wire.*

ISO 148, *Steel — Beam impact test (V-notch)*[1]

ISO/R 377, *Selection and preparation of samples and test pieces for wrought steel.*

ISO/R 404, *General technical delivery requirements for steel.*

ISO/R 642, *Hardenability test by end quenching steel (Jominy test).*

ISO/R 643, *Micrographic determination of the austenitic grain size of steels.*

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

1) At present at the stage of draft.

3 Ordering

3.1 The purchaser shall state in his enquiry and order

a) the dimensions and tolerances of the product (see 4.10);

b) the steel type (see tables 7, 11, 18, 19 and 29);

c) the treatment condition (see 4.9.1);

d) the surface coating treatment, if any (see 4.9.2);

e) the requirement class (see 4.3);

f) the required type of document (see 5.6).

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.

Table 1 — Permitted options in ordering

For steels of table	Permitted options	
7, 11, 18, 19, 29	g)	whether a product analysis is required (see 5.2.1);
7, 11, 18, 19, 29	h)	whether special specifications for the results and the testing conditions for the cold heading test and the surface inspection are required (see 4.7.2);
7	$i_{1)}$	whether cast separation is required (if no such statement is made, the manufacturer is permitted to supply the steel without cast separation; see 4.2);
	$i_{2)}$	whether the mechanical properties for the cold drawn condition are to be specified (see 8.3);
11, 18, 19, 29	j)	whether, for products with diameters < 4 mm in cases where the requirement classes 3r, 4r, 5r, 9r or 3v, 4v, 5v, 9v and 10v or 3w, 4w, 5w or 9w are specified, the elongation after fracture for a gauge length of 200 mm is required, in which case the values shall be agreed (see tables 14, 23 and 32, footnote 2);
11, 18, 19	k)	whether, in cases where impact values are specified for the relevant steel type and the requirement classes 3r, 4r, 5r, 9r or 3v, 4v, 5v, 9v or 3w, 4w, 5w, 9w are ordered and normal ISO U-notch test pieces (55 mm × 10 mm × 10 mm) can be prepared from the product, one impact test instead of three is sufficient (see table 6, footnote 6);
11, 18, 19	l)	whether impact properties are to be tested on ISO V-notch test pieces, in which case the values shall be agreed;
11, 18, 19	m)	whether, in cases where the requirement classes 7r, 8r or 9r or 7v, 8v and 9v or 7w, 8w or 9w are specified, coarse or fine grain steel is required (see 4.6.1);
11, 18, 19	n)	whether special specifications for testing the degree of spheroidization of the carbides are required (see 4.6.2);
14	o)	whether, in the case where simulated case hardening tests are required (requirement classes 5r, 9r, 5v, 9v, 5w, or 9w), a reference test bar of 16, 30 or 63 mm shall be used (see table 6, footnote 5);
18, 19, 29	p)	whether special specifications for the permissible depth of the ferritic-pearlitic decarburization are required (see 4.7.4.1);
29	q)	whether, in the case of a stainless steel, a test on corrosion resistance is required (see 4.8);
7, 11, 18, 19, 29	r)	whether, for products with diameters ⩾ 6 and ⩽ 30 mm, cold heading tests shall be carried out, in which case test conditions shall be agreed (see 4.7.2);
11, 18, 19	s)	whether a lower silicon content is required (see note 3 to tables 11 and 18 and note 4 to table 19).

Section one : General

4 Requirements

4.1 Manufacture of the steel and of the product

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.

4.1.2 The steels of table 7 with the suffix R in the designation shall be rimming, those with the suffix Si shall be silicon-killed and those with the suffix Al shall be killed with aluminium. The steels of tables 11, 18, 19 and 29 shall be killed.

4.2 Cast separation

The steels of tables 11, 18, 19 and 29 are delivered by casts. For the steels of table 7, cast separation, if required, must be especially agreed at the time of enquiry and order.

4.3 Requirement class

When a steel is ordered in accordance with this International Standard, one of the requirement classes indicated for the relevant steel type and treatment condition in 8.1, 10.1, 12.1 and 14.1 (see also table 4) shall be agreed at the time of enquiry and order.

NOTE — The requirement class indicates, as shown in table 5, the requirements to be observed. If, for example, the requirement class 2v is ordered (which according to table 4 is only applicable for the steel types B 10 to B 41, C 12 to C 43 and E 10 in a condition other than untreated), then, as marked by an "x" in column 3 of table 5, the delivery must fulfil the requirements given in lines 1, 2a, 3a, 6a, 6b and 6c of table 5.

4.4 Chemical composition

4.4.1 The chemical composition of the steels, as given by the cast analysis, shall be in accordance with the specifications in tables 7, 11, 18, 19 and 29 (see 4.4.3).

4.4.2 If ordered to the requirement classes 1r, 1v, 1w, 7r, 7v or 7w (see tables 4 and 5), the deviations between the values specified in tables 7 (not applicable to rimming steels), 11, 18, 19 and 29 and the product analysis shall be within the limits specified in tables 8, 12, 20, 21 or 30.

4.4.3 If ordered to other requirement classes than indicated under 4.4.2, the specified mechanical properties or hardenability values shall be regarded as the governing criteria for acceptance. In such cases the cast analysis may deviate slightly from the values shown in tables 7, 11, 18, 19 and 29.

4.5 Hardenability and mechanical properties

The products shall, as far as this is required by the agreed requirement class (see 8.3, 10.3, 12.3 and 14.3), fulfil the specifications of 8.3, 10.3, 12.3 and 14.3.

4.6 Structure

4.6.1 If, for the steels of section two or section three, a controlled austenitic grain size is required, as indicated by the requirement classes 7r, 8r, 9r, 21r, 7v, 8v, 9v, 21v, 7w, 8w, 9w or 21w (see tables 4 and 5), then the austenitic grain size of the steel determination in accordance with clause 5.3.5.1 shall be 5 and finer for fine grain steels and 5 and coarser for coarse grain steels. The portion of grains of other sizes in the micro-section shall be smaller than 30 %.

4.6.2 If, for the steels of sections two or three, the spheroidization of the carbides is required, as indicated by the requirement classes 1w to 9w, 20w and 21w, then the steels shall have a structure which is characterized by a high degree of spheroidization of the carbides.

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

4.7 Inner and outer soundness

4.7.1 The steel shall be free from inner and outer defects likely to have an adverse effect during cold heading or cold extruding and heat treatment. For the verification of the absence of these inner and outer defects, the requirements specified in 4.7.2 to 4.7.4 must be fulfilled.

4.7.2 If, at the time of enquiry and order, a cold heading test was agreed, test pieces subjected to a cold heading test under the conditions given in 5.3.6 and 5.4.6.1 shall not show any imperfections which are detrimental to the end product.

However, in the case of cold headed test pieces with a hot rolled surface, grooves which result from rolling scores, and also, in the case of the martensitic stainless steels (see table 29), shear cracks which are characterized by a declination angle of 45° between the crack plane and the axis of the test piece, are not to be considered as being cause for rejection.

4.7.3 The surface inspection shall reveal all defects which would lead to a rejection of the material when the cold heading test mentioned under 4.7.2 is applied. Bars and wire which according to the order were peeled or ground must be free from outer defects. Grooves originating from the machining operation are not to be considered as defects.

4.7.4 For the decarburization the following applies :

4.7.4.1 Bars and wire of the steels in tables 18 and 19 or of the martensitic stainless steels (see table 29) which are delivered in the hot rolled or cold drawn surface condition must, independent of their heat treatment condition, be free from completely ferritic decarburized zones.

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

Table 2 — Permissible depth of ferritic-pearlitic decarburization

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

1) See 10.4 and 12.4.

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

4.7.4.2 Bars and wire of the steels in tables 11, 18 or 19 or of the martensitic stainless steels of table 29 which, according to the order, were peeled or ground must be free from decarburization.

4.7.5 The general conditions given in ISO/R 404 for surface defects, rectification and internal defects are valid.

4.8 Corrosion resistance of the stainless steels

See 14.4.

4.9 Treatment condition at the time of delivery

4.9.1 The treatment and heat treatment condition (if any) at the time of delivery must comply with the condition agreed in the order and shall be one of the conditions indicated in 8.4, 10.4, 12.4 and 14.4.

4.9.2 Surface treatments which facilitate the cold heating and the 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 at the time of enquiry and order.

4.10 Dimensions, tolerances on dimensions and masses

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

If corresponding International Standard 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 the stainless steels) not applicable, then the dimensions and tolerances shall be agreed at the time of enquiry and order.

5 Acceptance testing

5.1 General

5.1.1 For all requirement classes acceptance tests can be agreed.

5.1.2 If acceptance tests have been agreed, the general conditions of ISO/R 404 regarding

- the place of acceptance,
- the submission for inspection,
- the rights of the inspector,
- the acceptance,

and, furthermore, the conditions given in 5.2 to 5.5 (as far as these are applicable according to the ordered requirement class) are to be observed.

5.2 Test unit and number of sample products and tests

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, for steels of table 7, no cast separation was agreed at the time of enquiry and order, then the product analysis shall be carried out separately for each steel type (see 4.4.2).

5.2.2 Hardenability, mechanical properties, structure, inner and outer soudness

If, according to the ordered requirement class (see tables 4 and 5) and the required type of document (see 5.6 and 5.1.2), the hardenability, the mechanical properties, the structure or the inner and outer soundness are to be verified, then the indications in table 6 apply for the test unit and the number of samples and test pieces.

5.3 Selection and preparation of samples and test pieces

5.3.1 General

5.3.1.1 The general conditions given in ISO/R 377 for the selection and the preparation of samples and test pieces shall apply.

5.3.1.2 In the case of coils, the samples shall be taken at least 300 mm from one of the ends of the coil. In cases of dispute, this distance shall be as indicated in table 3.

Table 3 — Minimum distance from one of the ends of the coil

Diameter mm	Minimum distance from one of the ends of the coil mm
⩽ 6,5	5 000
> 6,5 ⩽ 12,5	4 000
> 12,5 ⩽ 18	3 000
> 18 ⩽ 22,5	2 000
> 22,5 ⩽ 27	1 500
> 27	1 000

5.3.2 Product analysis

For product analysis, the selection and preparation of samples shall be carried out in conformity with the requirements of ISO/R 377.

5.3.3 Hardenability test

5.3.3.1 The bar from which the test piece for the end-quench hardenability test is machined shall be a forged or rolled round piece 32 or 30 mm in diameter, representing the full cross-section of the product. Larger cross-sections shall be rolled or forged to these dimensions. By special agreement, a cast test piece may be used instead of a rolled or forged test piece. The normalizing temperature must be 10 °C higher than the quenching temperature given for the end quench test in tables 16 or 28. Any other conditions to be observed when preparing the test pieces shall be as specified in ISO/R 642.

5.3.3.2 The test piece for evaluation of the core hardenability shall have, as far as possible, the maximum diameter given in tables 26 or 27. Test bars with diameters larger than those given in table 26 or 27 are to be rolled or forged to the maximum diameters of tables 26 or 27. The length of the test piece shall be at least four times its diameter.

5.3.4 Tensile and impact tests

Where reference test bars are required these are to be manufactured by hot forging the test sample to the diameter prescribed for the reference test bars (see under column 2 of table 6, lines Nos. 3b to 3e). These test bars shall then be heat treated as follows :

— case hardening steels, according to table 16;

— steels for quenching and tempering, including boron treated steels, according to table 28;

— stainless steels, according to table 33.

With the following two exceptions, the test pieces for tensile tests and ISO U-notch (or ISO V-notch) impact tests shall be taken according to figure 1 in the longitudinal direction of the products or the reference test bars.

Exception 1 : Test pieces for tensile tests in the usual condition for cold working (requirement 3a in table 6) shall be (as far as possible) tested with their original surface, i.e. without having been machined.

Exception 2 : The test pieces of simulated case hardened reference test bars with 30 mm diameters shall be taken as shown for diameters of < 25 mm in figure 1.

In cases of dispute, the tensile test pieces of products with > 4 mm diameter must have a gauge length of $L_o = 5\ d_o$. For products with a diameter < 4 mm, the gauge length shall be 200 mm.

Where three ISO U-notch (or ISO V-notch) impact test pieces are required, these should lie next to one another in the test sample or test bar. They must have the dimensions specified in ISO 83 (or ISO 148).

5.3.5 Structure

5.3.5.1 For the selection and preparation of the test pieces determined for the verification of the austenitic grain size, the indications in ISO/R 643 apply. If not otherwise agreed 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 three) are to be examined. In cases where steels for quenching and tempering (see section four) are to be examined, one of the other methods described in ISO/R 643 shall be applied and the austenitizing temperature shall correspond to the highest hardening temperature given in table 28 for the steel type concerned, and the holding time on this temperature shall be 1 h.

5.3.5.2 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.

5.3.6 Examination of the inner and outer soundness

5.3.6.1 The cold heading test applies only for products with a diameter > 6 and < 30 mm. If this test is required, and if not otherwise agreed at the time of enquiry and order, the cold heading test 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 without altering the original surface of the sample product (see 5.4.6.1). Samples from products, which have not been heat treated after hot rolling may be transformed into the heat treatment condition indicated in table 4 as the usual condition for cold heading and cold extruding.

5.3.6.2 In cases of dispute the surface inspection shall be carried out on the whole surface of the products to be tested. However, in normal cases the visual surface inspection of products with scaled surface can be restricted on samples of about 200 mm length, taken, in the case of coils, in accordance with 5.3.1.2, and pickled in an appropriate solution until the oxide layer has dissolved.

5.3.6.3 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 conditions as given in 5.4.2.2, observing all measures to prevent a 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.

5.4 Methods of test

5.4.1 Chemical analysis

In cases of dispute, the methods used for the chemical analysis shall be those established by the relevant International Standards. If no International Standards are available, the methods shall be agreed upon at the time of enquiry and order.

5.4.2 Hardenability test

5.4.2.1 The end quench hardenability test is to be carried out in conformity with ISO/R 642. The temperature for quenching must be in accordance with tables 16 or 28.

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 for the hardenability test in table 28, and maintained at this temperature until they are completely austenitized. They shall then be taken out of the furnace and promptly quenched down to complete temperature equalization, in a high-duty quenching oil, 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 temperature effect, so that the determination of the core hardness according to ISO/R 80 can be carried out.

5.4.3 Tensile test

The test shall be made in accordance with ISO 82 or ISO 89.

5.4.4 Impact test

The impact test shall be made in accordance with ISO 83. By special agreement between the purchaser and supplier the V-notch beam impact test according to ISO 148 may be carried out as an alternative test. In this case, the values to be guaranteed shall be agreed at the time of enquiry and order. Unless otherwise specified at the time of enquiry and order, the impact value shall be determined by taking the arithmetic mean of three test results.

5.4.5 Structure

5.4.5.1 The austenitic grain size shall be tested in accordance with ISO/R 643 on test pieces prepared in accordance with 5.3.5.1.

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

5.4.6 Examination of the inner and outer soundness

5.4.6.1 The test pieces for the cold heading 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 heading 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 at the time of enquiry and order.

5.4.6.2 Surface inspection on bars of the steel types of tables 7, 11, 18 and 19 and of the ferritic and martensitic steel types of table 29 may be carried out. The methods used are at the option of the manufacturer unless otherwise agreed at the time of enquiry and order.

If, at the time of enquiry and order, an agreement has been reached regarding the permissible depth of surface defects, any presumed defect shall be filled down until it disappears; the difference in the thickness before and after filling shall then be determined. Otherwise in cases of uncertainty with regard to the acceptability of the presumed defect a cold heading test according to 5.4.6.1 shall be carried out on a test piece containing the defect concerned or an equivalent defect.

5.4.6.3 When testing the products with regard to their decarburization (see ISO 3887), usually the depth of the ferritic completely decarburized zone and that of the ferritic-pearlitic partially decarburized zone are measured by microscope at a magnification of 100 X at the four ends of two diameters of the etched plane standing perpendicular to another. The inner starting point for the measurement of the depth of the ferritic-pearlitic decarburized 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 ferritic-pearlitic decarburized 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 3) shall be calculated. The single values e_1 to e_4 represent, according to figure 3, 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.

5.5 Retests

For retests ISO/R 404 shall apply.

5.6 Certification of the tests

ISO/R 404 is valid, acceptable documents being :

— statement of compliance with the order, or

— report based on quality control, or

— works certificate, or

— test certificate, or

— certificate of acceptance.

6 Complaints

6.1 The conditions for dealing with complaints laid down in ISO/R 404 shall apply.

6.2 Since it is not possible to detect, on coils, all surface imperfections which may be detrimental to cold heading or cold extruding, a certain portion of the length of the wire may have such imperfections. The maximum permissible percentage of length shall be agreed between the purchaser and supplier at the time of enquiry and order.

Table 4 — Types of requirement classes applicable (x) for the different steels and/or treatment conditions

Type of steel		Treatment conditions[1]	Types of requirement class[2]																													
according to table	No.		1r	2r	2cr	21r	3r	4r	5r	7r	8r	9r	1v	2v	20v	21v	3v	4v	5v	7v	8v	9v	10v	1w	2w	20w	21w	3w	4w	5w	7w	8w	9
7	A 1 R to A 5 A 1	U, P, C [3]	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	B 1 to B 3	U	x	-	-	-	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	x	-	x	-	x	-	-	-	-	-	x	x	-	x
	B 10 to B 41	U	x	x	-	-	-	-	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	x	x	x	x	-	x	x	-	-	-	-	x	x	x	x
18	C 1 to C 2	U	x	-	-	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	x	x	-	x	-	-	-	x	-	-	-	x	x	-	x	-	-
	C 3 to C 11	U	x	-	x	x	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	x	x	x	x	-	x	-	-	-	x	-	x	x	x	x	-	x	-	-
	C 12 to C 43	U	x	x	x	x	x	x	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	-	x	x	-	-	x	x	x	x	x	x	-	x	x	-
29	D 1 to D 12	AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
	D 20 to D 32	Q, Q + P, C + Q or C + Q + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
19	E 1 to E 7	U	x	-	x	x	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	-	x	x	x	x	-	x	-	-	-	x	-	x	x	x	x	-	x	-	-
	E 10	U	x	x	x	x	x	x	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		AC, AC + P, C + AC or C + AC + LC [3]	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	-	x	x	-	-	x	x	x	x	x	x	-	x	x	-

1) U = untreated (as rolled); P = peeled; AC = annealed in order to achieve a spheroidization of the carbides; LC = lightly cold reduced, for example with a reduction of 5 %; Q = quenched; C = cold reduced.

2) The numbers of the requirement classes should be regarded as provisional until a system for the types of requirement classes has been established.

3) Treatment conditions in which the products are usually cold headed or cold extruded.

Table 5 — Types of requirement classes and requirements specified by them

1	2	3																															4	5	6	7	8
Line No.	Quality requirement	Requirement class[1]																															Required results for				
		1r	2r	20r	21r	3r	4r	5r	7r	8r	9r	1v	2v	20v	21v	3v	4v	5v	7v	8v	9v	10v	1w	2w	20w	21w	3w	4w	5w	7w	8w	9w	steels not intended for heat treatment	case hardening steels	steel for quenching and tempering	stainless steels	boron treated steels for quenching and tempering
																																	See sub-clause . . ., or (table . . .)				
1	Chemical composition	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	8.2	10.2	12.2	14.2	12.2
2	Hardenability																																					
2a	End quench test	-	x	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-	x	-	-	-	x	-	-	-	-	-	-	x	-	—	(15)	(24)	—	(25)
2b	Core hardenability	-	-	x	x	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	—	—	(26)	—	(27)
3	Mechanical properties																																					
3a	in the usual condition for cold working[2]	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	(9)	(13)	(22)	(31)	(22)
3b	of simulated case hardened reference test bars of 16,30 or 63 mm diameter[3]	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	x	-	-	x	—	(14)	—	—	—
3c	of quenched and tempered reference test bars of 16 mm diameter	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	—	—	(23)	—	(23)
3d	of quenched and tempered reference test bars with the ruling section[4]	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	—	—	(23)	—	(23)
3e	of a reference test bar of stainless steel[5]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	—	—	—	(32)	—
		-	-	-	-																																
4	Austenitic grain size	-	-	-	x	-	-	-	x	x	x	-	-	-	x	-	-	-	x	x	x	-	-	-	-	x	-	-	x	x	x	-	—	4.6.1	4.6.1	—	4.6.1
5	Spheroidization	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	—	4.6.2	4.6.2	—	4.6.2
6	Inner and outer defects																																					
6a	Cold headability	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	4.7.2	4.7.2	4.7.2	4.7.2	4.7.2
6b	Surface quality	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	4.7.3	4.7.3	4.7.3	4.7.3	4.7.3
6c	Decarburization[6]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	—	—	4.7.4	4.7.4	4.7.4

1) The number of the requirement classes are to be regarded as provisional until a system for the type of requirement classes has been established.

2) See table 4, footnote 2.

3) The diameter for which the mechanical properties are required should be stated in the order. Otherwise, the manufacturer is permitted to use a sample having a diameter chosen from the three mentioned above. The chosen diameter shall be the smaller of those between which the diameter of the product lies.

4) In the selection of a steel, one of the most important considerations is whether the mechanical properties required can be obtained from the steel in the size and shape at the time of heat treatment. That portion, which is most important from the point of view of the mechanical properties obtained by heat treatment, is referred to as the ruling section, and the ruling section should always be expressed in terms of the diameter of an equivalent round bar (see figure 2).

5) In cases of dispute and if not otherwise stated in the order, the diameter of the reference test bar in the heat treatment condition given in table 33 shall be that of the product.

6) Only for the steels for quenching and tempering (see tables 18 and 19) and for the martensitic stainless steels (see table 29).

Table 6 — 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 5.2.1	see 5.2.1	see 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			
3a	in the usual condition for cold working[2]	C[3] + D[4] + T	2 per 10 t or broken 10 t	1
3b	of simulated case hardened reference test bars of 16, 30 or 63 mm diameter[5]	C	1 per cast	3 ISO U-notch[6] and
3c	of quenched and tempered reference test bars of 16 mm diameter	C	1 per cast	1 tensile test piece
3d	of quenched and tempered reference test bars with the ruling section[7]	C	1 per cast	1 tensile test piece
3e	of a reference test bar of stainless steel[8]	C	1 per cast	1 tensile test piece
4	Austenitic grain size	C	1 per cast	1
5	Spheroidization	C + D[4] + T	2 per 10 t or broken 10 t	1
6	Inner and outer defects			
6a	Cold headability	C[3] + D + T	To be agreed at the time of enquiry and order	1
6b	Surface quality	C[3] + D + T		
7	Decarburization[9]	C + D + T	2 per 10 t or part thereof	1

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

2) See footnote 2 of table 4.

3) If, for steels of table 7, no cast separation was agreed 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 or wire with cross sections which differ by not more than 3 : 1 these can be grouped into one test unit.

5) The diameter for which the mechanical properties are required should be stated in the order. Otherwise, the manufacturer is permitted to use a sample having a diameter chosen from the three mentioned above. The chosen diameter shall be the smaller of those between which the diameter of the product lies.

6) Where possible. If only one test piece was agreed at the time of enquiry and order, this requirement shall be modified accordingly.

7) In the selections of a steel, one of the most important considerations is whether the mechanical properties required can be obtained from the steel in the size and shape at the time of heat treatment. That portion which is most important from the point of view of the mechanical properties obtained by heat treatment, is referred to as the ruling section, and the ruling section should always be expressed in terms of the diameter of an equivalent round bar (see figure 2).

8) In cases of dispute and if not otherwise stated in the order, the diameter of the reference test bar in the heat treatment condition given in table 33 should be that of the product.

9) Only for the steels for quenching and tempering (see tables 18 and 19) and for the martensitic stainless steels (see table 29).

Dimensions in millimetres

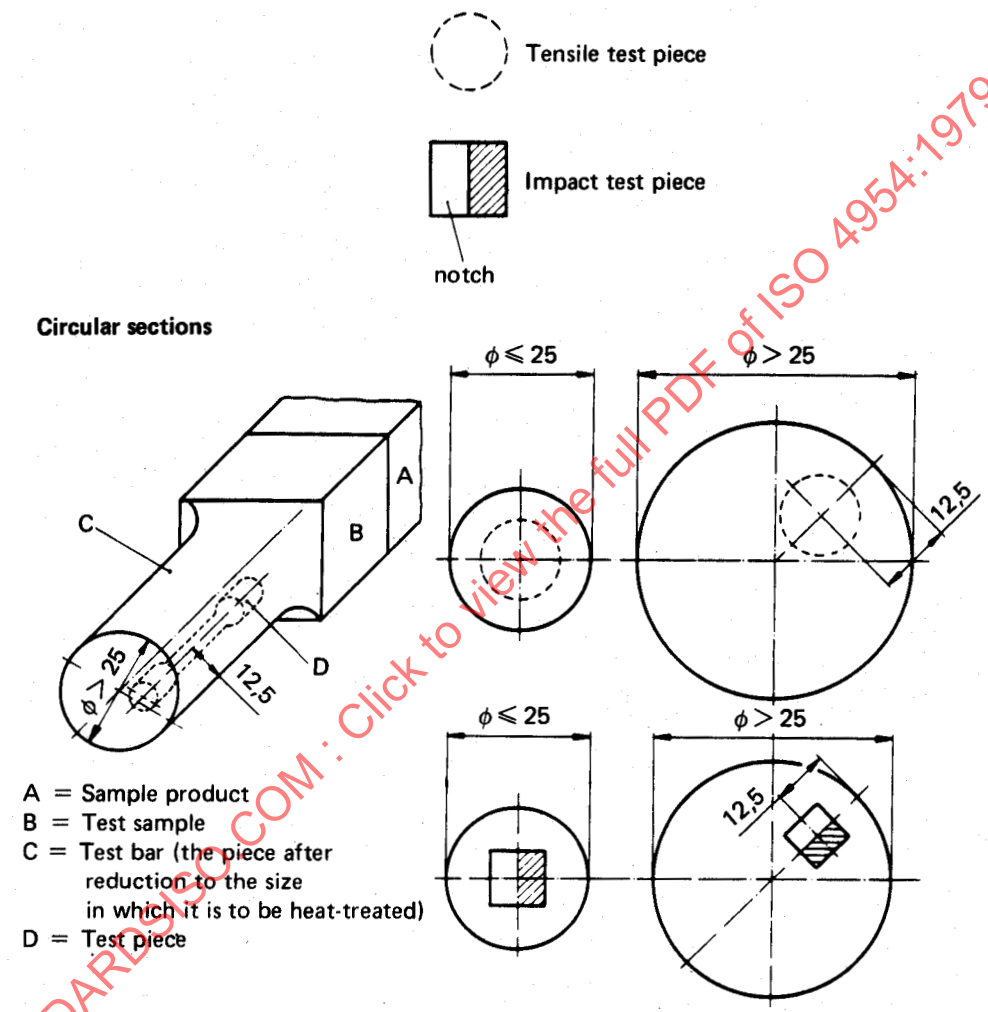

Figure 1 — Location of the tensile and impact test pieces in the products

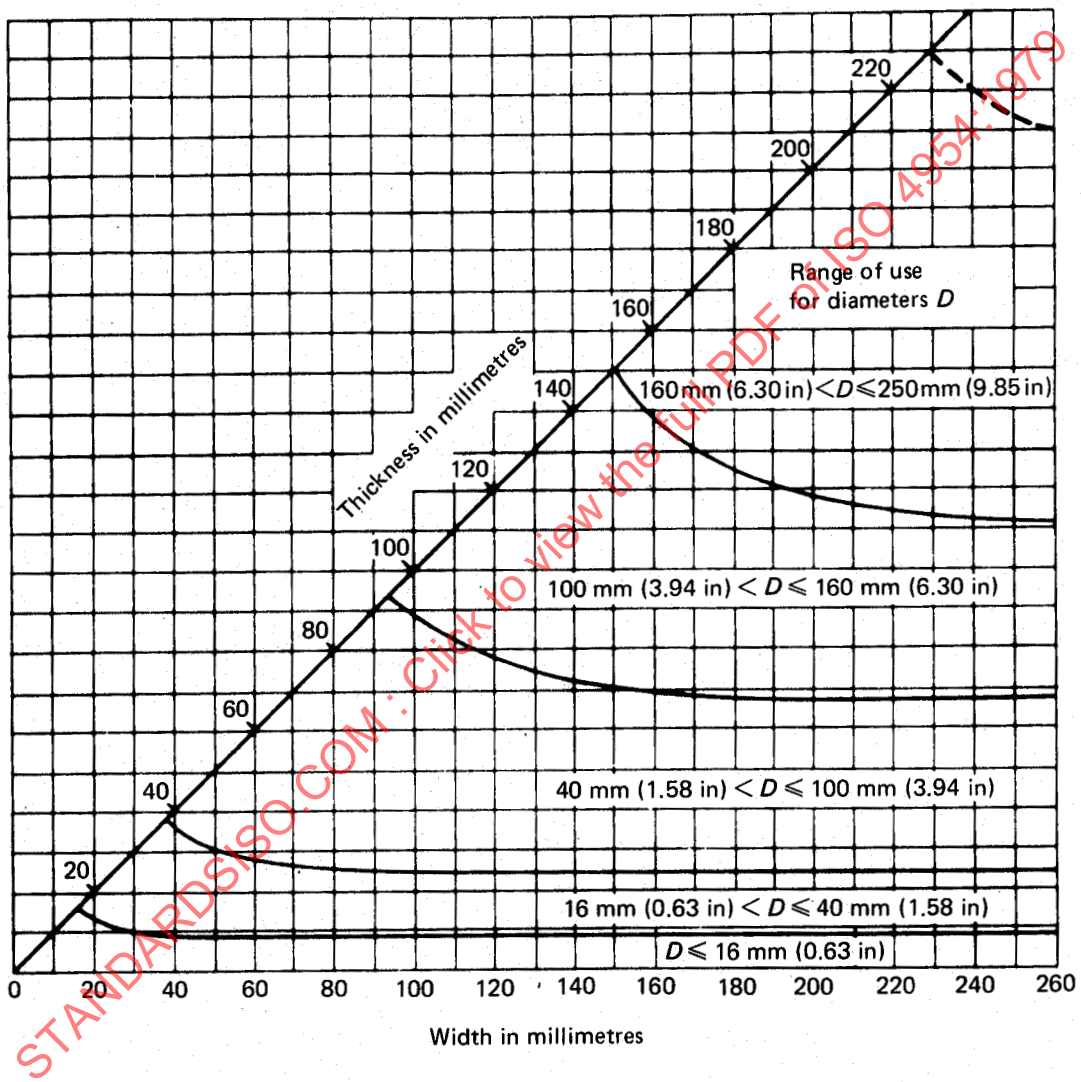

Figure 2 — Graph for converting rectangular sections into circular sections for the same mechanical properties

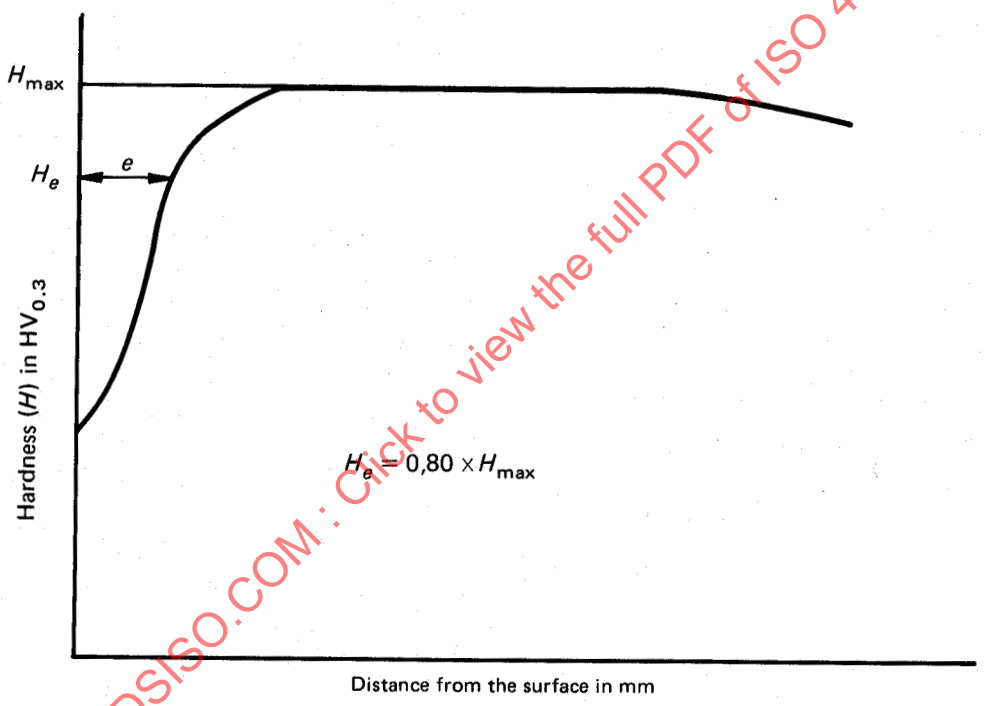

Figure 3 — Determination of the depth of the decarburized zone

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

7 Scope and field of application

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 to 100 mm.

8 Requirements

8.1 Requirement classes

When a steel is ordered in accordance with this International Standard, one of the following requirement classes shall be agreed at the time of enquiry and order : 1r or 1v (see tables 4 and 5).

8.2 Chemical composition

8.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 7.

8.2.2 For the silicon-killed and the aluminium-killed steels, the permissible deviations between the values specified in table 7 and the product analysis are indicated in table 8.

8.3 Mechanical properties

If ordered to the requirement class 1v in the untreated condition (U or P), the mechanical properties given in table 9 apply.

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

8.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the following treatment conditions :

Untreated with hot rolled surface	U	1)
Untreated with peeled surface	P	
Cold drawn	C	

Table 7 — Types of steel and chemical composition guaranteed (applicable to cast analysis)[1)]

Type of steel	C %	Si %	Mn %	P % max.	S % max.	Other %
A 1 R	⩽ 0,06	–	0,20/0,40	0,040	0,040	N ⩽ 0,008[2)]
A 1 Al	⩽ 0,06	⩽ 0,10	0,20/0,40	0,040	0,040	Al_{tot} ⩾ 0,020[3)]
A 2 R	0,05/0,10	–	0,30/0,60	0,040	0,040	N ⩽ 0,008[2)]
A 2 Al	0,05/0,10	⩽ 0,10	0,30/0,60	0,040	0,040	Al_{tot} ⩾ 0,020[3)]
A 3 R	0,08/0,13	–	0,30/0,60	0,040	0,040	N ⩽ 0,008[2)]
A 3 Al	0,08/0,13	⩽ 0,10	0,30/0,60	0,040	0,040	Al_{tot} ⩾ 0,020[3)]
A 4 Si[4)]	0,12/0,19	0,15/0,35	0,30/0,60	0,040	0,040	
A 4 Al	0,12/0,18	⩽ 0,10	0,30/0,60	0,040	0,040	Al_{tot} ⩾ 0,020[3)]
A 5 Si	0,18/0,23	0,15/0,35	0,30/0,60	0,040	0,040	
A 5 Al	0,18/0,23	⩽ 0,10	0,30/0,60	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 additions, from scrap or other materials used in manufacture, of such elements which affect mechanical properties and applicability.

2) The maximum nitrogen content does not apply to the steels manufactured by the electrical arc process.

3) or killed with a sufficient quantity of other elements having a similar effect such as e.g. V, Nb, Ti, Ca.

4) By agreement at the time of enquiry and order, rimming steel may be supplied. In that case, the nitrogen content should not exceed 0,008 % except where footnote 2 applies.

1) The symbols for the treatment condition are tentative.

Table 8 — Permissible deviations between specified analysis and product analysis for killed steels of table 7

Type of steel[1]	Permissible deviations[2]				
	C %	Si %	Mn %	P %	S %
A . . . Si	± 0,02	± 0,03	± 0,03	+ 0,005	+ 0,005
A . . . Al	± 0,02	+ 0,02	± 0,03	+ 0,005	+ 0,005

1) A . . . Si means for example that the given values apply to all types of table 7 which have the suffix Si.

2) ± 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 in table 7, but not both at the same time.

Table 9 — Mechanical properties[1] in the usual treatment condition for cold heading or cold extruding
(for guidance)

Type of steel	Treatment condition as rolled (U) or as rolled and peeled (P)	
	R_m max. N/mm^2	Z min.[2] %
A 1 R	420	60
A 1 Al	440	
A 2 R	450	60
A 2 Al	470	
A 3 R	470	60
A 3 Al	490	55
A 4 Si, A 4 Al	530	50
A 5 Si, A 5 Al	580	45

1) R_m = tensile strength
Z = reduction of area after fracture.

2) For machined test pieces the reduction may be 5 % lower, for example 50 % instead of 55 %.

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

9 Scope and field of application

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

10 Requirements

10.1 Requirement classes

When a steel is ordered in accordance with this International Standard one of the following requirement classes (see table 5) shall be agreed at the time of enquiry and order.

10.2 Chemical composition

10.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 11.

10.2.2 The permissible deviations between the values specified in table 11 and the product analysis are indicated in table 12.

10.3 Hardenability and mechanical properties

10.3.1 For all steels which were ordered in one of the treatment conditions indicated in 10.4, the maximum values for the tensile strength and the minimum values for the reduction of area specified in table 13 apply.

10.3.2 For steels which were ordered in accordance with the requirement classes 5r, 9r, 5v, 9v, 5w and 9w, the mechanical properties specified in table 14 apply for reference test pieces which were subjected to a simulated case hardening test in accordance with the corresponding heat treatment conditions in table 16.

10.3.3 For all steels which were ordered in accordance with the requirement classes 2r, 8r, 2v, 8v, 2w or 8w, the tentative hardness limits for end quench hardenability test pieces which were tested in accordance with 5.3.4.1 in table 15 apply.

10.4 Treatment condition of the delivery

The steels are usually delivered in one of the following treatment conditions :

annealed[1]	AC	2)
annealed[1] and peeled	AC + P	
cold drawn and annealed[1]	C + AC	
cold drawn and annealed[1] and lightly cold reduced (for example with a reduction of 5 %)	C + AC + LC	

The steels are also delivered in the untreated condition, mainly to drawing shops.

Table 10 — Requirement classes

Type of steel (see table 11)	Treatment condition	Requirement class[1]																	
		1r	2r	5r	7r	8r	9r	1v	2v	5v	7v	8v	9v	1w	2w	5w	7w	8w	9w
B 1 to B 3	untreated	x	-	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	x	-	x	x	-	x	x	-	x	x	-	x
B 10 to B 41	untreated	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x

1) The numbers for the requirement classes are to be regarded as provisional until a system for the types of requirement classes has been established.

2) See treatment conditions under 10.4.

1) The term "annealed" is applicable to an annealing employed to achieve a spheroidization of the carbides.

2) The symbols for the treatment condition are tentative.

Table 11 — Types of steel and chemical composition (applicable to cast analysis)[1)2)]

Type of steel	C %	Si %[3)]	Mn %	P % max.	S % max.	Cr %	Mo %	Ni %
B 1	0,07/0,13	0,15/0,40	0,30/0,60	0,035	0,035			
B 2	0,12/0,18	0,15/0,40	0,30/0,60	0,035	0,035			
B 3	0,12/0,18	0,15/0,40	0,60/0,90	0,035	0,035			
B 10	0,17/0,23	0,15/0,40	0,60/0,90	0,035	0,035	0,70/1,00		
B 11	0,13/0,19	0,15/0,40	1,0/1,3	0,035	0,035	0,80/1,10		
B 20	0,20/0,25	0,15/0,40	0,60/0,90	0,035	0,035		0,20/0,30	
B 30	0,15/0,21	0,15/0,40	0,60/0,90	0,035	0,035	0,85/1,15	0,15/0,25	
B 31	0,17/0,23	0,15/0,40	0,60/0,90	0,035	0,035	0,30/0,50	0,40/0,50	
B 40	0,12/0,18	0,15/0,40	0,60/0,90	0,035	0,035	0,35/0,65	0,15/0,25	0,40/0,70
B 41	0,17/0,23	0,15/0,40	0,60/0,90	0,035	0,035	0,35/0,65	0,15/0,25	0,40/0,70

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

2) If ordered to requirement classes other than 1r, 7r, 1v, 7v, 1w or 7w, the specified hardenability or the specified mechanical properties should be the governing criteria for acceptance. In such cases the cast analysis may deviate slightly from the figures shown in the above table.

3) A lower silicon content may be agreed at the time of enquiry and order; in this case the influence on mechanical properties should be taken into account.

Table 12 — Permissible deviations between specified analysis and product analysis

Type of steel	Permissible deviations[1)]							
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %
B 1	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	—	—	—
B 2	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	—	—	—
B 3	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	—	—	—
B 10	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		—
B 11	± 0,02	± 0,03	± 0,06	+ 0,005	+ 0,005	± 0,05	—	—
B 20	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	—	± 0,03	—
B 30	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	—
B 31	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,04	—
B 40	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,03
B 41	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,03

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 in table 11, but not both at the same time.

Table 13 — Mechanical properties[1] in the usual treatment conditions for cold heading or cold extruding

Type of steel	Treatment condition[2]			
	AC, AC + P or C + AC[3]		C + AC + LC	
	R_m max.	Z min.[4]	R_n max.	Z min.[4][5]
B 1	440	65	470	62
B 2	480	65	510	62
B 3	500	60	530	57
B 10	560	60	590	57
B 11	560	60	590	57
B 20	530	60	560	57
B 30	560	60	590	57
B 31	560	60	590	57
B 40	560	60	590	57
B 41	590	60	620	57

1) R_m = tensile strength
Z = reduction of area after fracture.

2) See 10.4.

3) In cases where increased formability is required, the material should be ordered in the treatment condition "C + AC" in which case the values of R_m max. may be reduced by about 20 N/mm^2 and the values of Z min. may be increased by about 2 %.

4) For machined test pieces the reduction of area may be 5 % lower, for example 60 % instead of 65 %.

5) For diameters ⩽ 12 mm the reduction of area may be 2 % lower; for diameters of > 12 ⩽ 25 mm it may be 1 % lower (for example 55 or 56 %, instead of 57 %).

Table 14 — Mechanical properties[1] for reference test bars in the simulated case hardened condition (see table 16)

Type of steel	ϕ = 16 mm				ϕ = 30 mm				ϕ = 63 mm			
	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	KU min.[3] J	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	KU min.[3] J	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	KU min.[3] J
B 1	270	440 to 770	14	35	250	390 to 690	15	35	–	–	–	–
B 2	300	520 to 840	13	30	260	440 to 740	14	30	–	–	–	–
B 3	340	560 to 880	11	25	290	490 to 790	12	25	–	–	–	–
B 10	460	730 to 1 050	11	25	390	590 to 890	13	25	290	490 to 740	16	25
B 11	570	870 to 1 190	9	25	490	780 to 1 080	10	25	440	680 to 930	12	25
B 20	530	810 to 1 130	11	25	440	700 to 950	12	25	350	500 to 750	13	25
B 30	620	950 to 1 270	9	25	540	830 to 1 130	10	25	490	730 to 1 030	11	25
B 31	560	820 to 1 150	10	25	490	730 to 1 030	11	25	440	610 to 890	13	25
B 40	520	780 to 1 100	10	25	470	700 to 1 000	11	25	380	580 to 830	13	25
B 41	570	850 to 1 180	10	25	490	730 to 1 030	11	30	440	640 to 890	13	30

1) R_m = Tensile strength
A = Percentage elongation after fracture ($L_o = 5\,d_o$)
KU = Impact energy of ISO U-notch test pieces

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

3) If three test pieces are tested (see table 6, footnote 6), than the specified values apply for the average of the three tests results. One single value may be lower, but not by more than 30 %.

Table 15 — Tentative hardness limits for specified hardenability[1)]

Distance from quenched end of test piece	Hardness, HRC, for steel type													
	B 10		B 11		B 20		B 30		B 31		B 40		B 41	
mm	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1,5	40	48	38	46	43	50	39	47	40	48	39	46	40	48
3	34	46	36	46	39	47	38	47	36	47	34	44	37	47
5	28	41	32	44	31	44	35	46	30	43	26	39	32	44
7	22	35	29	42	24	37	32	44	26	39	22	36	27	41
9	–	31	26	39	21	32	29	41	23	36	–	32	23	35
11	–	28	24	37	–	27	26	39	20	34	–	28	–	32
13	–	26	22	34	–	26	23	36	–	32	–	26	–	30
15	–	24	20	33	–	24	22	35	–	30	–	25	–	29
20	–	21	–		–	23	20	33	–	27	–	23	–	26
25	–	–	–	28	–	21	–	31	–	25	–	21	–	24
30	–	–	–	27	–	20	–	30	–	24	–	20	–	23
35	–	–	–	27	–	–	–	29	–	23	–	–	–	23
40	–	–	–	27	–	–	–	28	–	22	–	–	–	22
45	–	–	–	26	–	–	–	28	–	22	–	–	–	22
50	–	–	–	25	–	–	–	28	–	22	–	–	–	22

1) *The hardness values are tentative and may be adjusted as more information becomes available. The hardness values are based on steels having a grain size of 5 and finer, as defined in ISO/R 643.*

Table 16 — Conditions for heat treatment

Type of steel	End quench test	Simulated case hardening test			Heat treatment of steel products[3]				
	quenching temperature[1] °C	Quenching temperature[1] °C	Quenching medium	Tempering temperature[2] °C	Carburizing[4] temperature °C	Core hardening temperature[5] °C	Case hardening temperature °C	Quenching medium	Tempering temperature[2] °C
B 1	—	900 ± 10	Water	180 ± 10	880 to 950	880 to 920	770 to 810	Water	150 to 200
B 2	—	890 ± 10		180 ± 10	880 to 950	870 to 910	770 to 810		150 to 200
B 3	—	890 ± 10		180 ± 10	880 to 950	870 to 910	770 to 810	Water/Oil	150 to 200
B 10	900 ± 5	890 ± 10	Oil	180 ± 10	890 to 950	870 to 910	790 to 830	Oil	150 to 200
B 11	900 ± 5	880 ± 10		180 ± 10	880 to 950	860 to 900	800 to 840		150 to 200
B 20	900 ± 5	880 ± 10		180 ± 10	880 to 950	860 to 950	790 to 830		150 to 200
B 30	900 ± 5	880 ± 10		180 ± 10	880 to 950	860 to 900	800 to 840		150 to 200
B 31	900 ± 5	900 ± 10		180 ± 10	880 to 950	880 to 920	800 to 840		150 to 200
B 40	900 ± 5	800 ± 10		180 ± 10	880 to 950	860 to 900	800 to 840		150 to 200
B 41	900 ± 5	880 ± 10		180 ± 10	880 to 950	860 to 900	800 to 840		150 to 200

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

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

3) The given temperatures are for guidance, but the actual temperatures chosen should be those that will give the properties required.

4) The carburizing temperature will depend on the chemical composition of the steel, the mass of the product, and the carburizing medium.

5) If the steels are direct hardened, they should be quenched from a temperature between the core hardening and case hardening temperatures.

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

11 Scope and field of application

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

12 Requirements

12.1 Requirement classes

When a steel is ordered in accordance with this International Standard, one of the following requirement classes (see table 5) shall be agreed at the time of enquiry and order.

12.2 Chemical composition

12.2.1 The specified chemical composition of the steel according to the cast analysis is given in table 18.

12.2.2 The permissible deviations between the values specified in table 18 and the product analysis are indicated in table 20.

12.3 Hardenability and mechanical properties

12.3.1 For all steels which are ordered in one of the treatment conditions indicated in 12.4, the maximum values for the tensile strength and the minimum values for the reduction of area specified in table 22 apply.

12.3.2 For all steels which were ordered in accordance with the requirement classes 3r, 4r, 3v, 4v, 3w or 4w, the mechanical properties specified in table 23 apply for reference test pieces which were quenched and tempered in accordance with the heat treatment conditions given in table 28.

12.3.3 For all steels which were ordered in accordance with the requirement classes 2r, 8r, 2v, 8v, 2w or 8w, the tentative hardness limits for end quench hardenability test pieces which were tested in accordance with 5.3.3.1 in table 24 apply.

12.3.4 For all steels which were ordered in accordance with the requirement classes 20r, 21r, 20v, 21v, 20w or 21w, the core hardenability values in table 26 are given for guidance (see test conditions in 5.3.3.2).

Table 17 — Requirement classes

Type of steel (see table 18)	Treatment condition	Requirement class[1]																							
		1r	2r	20r	21r	3r	4r	7r	8r	1v	2v	20v	21v	3v	4v	7v	8v	1w	2w	20w	21w	3w	4w	7w	8w
C 1 to C 2	untreated	x	-	-	-	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	-	-	x	-	-	-	x	x	x	-	x	-	-	-	x	x	x	-
C 3 to C 11	untreated	x	-	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	-	-	x	-	x	x	x	x	x	-	-	x	-	x	x	x	x	-
C 12 to C 43	untreated	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
E 1 to E 7	untreated	x	-	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	-	-	x	-	x	x	x	x	x	-	x	-	x	x	x	x	x	-
E 10	untreated	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	treated[2]	-	-	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

1) The numbers for the requirement classes should be regarded as provisional until a system for the types of requirement classes has been established.

2) See treatment conditions under 12.4.

12.4 Treatment conditions of the delivery

The steels are usually delivered in one of the following treatment conditions :

annealed[1]	AC	2)
annealed[1] and peeled	AC + P	
cold drawn and annealed[1]	C + AC	
cold drawn and annealed[1] and lightly cold reduced (for example with a reduction of 5 %)	C + AC + LC	

The C type steels are also delivered in other treatment conditions than given above, for example in the conditions "AC + C + subcritically annealed" or mainly to drawing shops, in the untreated condition. In these cases the mechanical properties shall be agreed at the time of enquiry and order.

The E type steels are also delivered in the untreated condition, mainly to drawing shops.

Table 18 — Types of steel and chemical composition (applicable to cast analysis)[1)2)]

Type of steel	C %	Si %[3)]	Mn %	P % max.	S % max.	Cr %	Mo %	Ni %
C 1	0,17/0,23	0,15/0,40	0,60/0,90	0,035	0,035			
C 2	0,25/0,32	0,15/0,40	0,60/0,90	0,035	0,035			
C 3	0,32/0,39	0,15/0,40	0,50/0,80	0,035	0,035			
C 4	0,37/0,41	0,15/0,40	0,50/0,80	0,035	0,035			
C 5	0,40/0,46	0,15/0,40	0,60/0,90	0,035	0,035			
C 6	0,42/0,51	0,15/0,40	0,50/0,80	0,035	0,035			
C 10	0,34/0,41	0,15/0,40	0,50/0,80	0,035	0,035	0,20/0,40		
C 11	0,42/0,50	0,15/0,40	0,50/0,80	0,035	0,035	0,20/0,40		
C 12	0,34/0,41	0,15/0,40	0,50/0,80	0,035	0,035	0,40/0,60		
C 13	0,42/0,50	0,15/0,40	0,50/0,80	0,035	0,035	0,40/0,60		
C 14	0,30/0,37	0,15/0,40	0,60/0,90	0,035	0,035	0,90/1,20		
C 15	0,34/0,41	0,15/0,40	0,60/0,90	0,035	0,035	0,90/1,20		
C 16	0,38/0,45	0,15/0,40	0,60/0,90	0,035	0,035	0,90/1,20		
C 20	0,18/0,24	0,15/0,40	0,70/1,00	0,035	0,035		0,20/0,30	
C 21	0,25/0,32	0,15/0,40	0,70/1,00	0,035	0,035		0,20/0,30	
C 22	0,33/0,40	0,15/0,40	0,70/1,00	0,035	0,035		0,20/0,30	
C 30	0,22/0,29	0,15/0,40	0,50/0,80	0,035	0,035	0,90/1,20	0,15/0,30	
C 31	0,30/0,37	0,15/0,40	0,50/0,80	0,035	0,035	0,90/1,20	0,15/0,30	
C 32	0,38/0,45	0,15/0,40	0,50/1,00	0,035	0,035	0,90/1,20	0,15/0,30	
C 40	0,37/0,44	0,15/0,40	0,70/1,00	0,035	0,035	0,40/0,60	0,15/0,30	0,40/0,70
C 41	0,36/0,43	0,15/0,40	0,50/0,80	0,035	0,035	0,60/0,90	0,15/0,30	0,70/1,0
C 42	0,37/0,44	0,15/0,40	0,55/0,85	0,035	0,035	0,65/0,95	0,15/0,30	1,60/2,00
C 43	0,26/0,33	0,15/0,40	0,30/0,60	0,035	0,035	1,80/2,20	0,30/0,55	1,80/2,20

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

2) If ordered to requirement classes other than 1r, 7r, 1v, 7v, 1w or 7w, the specified hardenability or the specified mechanical properties should be the governing criteria for acceptance. In such cases the cast analysis may deviate slightly from the figures shown in the above table.

3) A lower silicon content may be agreed at the time of enquiry and order; in this case the influence on mechanical properties should be taken into account.

1) The term "annealed" is applicable to an annealing employed to achieve a spheroidization of the carbides.

2) The symbols for the treatment condition are tentative.

Table 19 — Types of steel and chemical composition (applicable to cast analysis[1)2)])

Type of steel	C %	Si %[3)]	Mn %	P % max.	S % max.	Cr %	B %	Total Al %[4)]
E 1	0,17/0,23	0,15/0,35	0,50/0,80	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 2	0,17/0,23	0,15/0,35	0,80/1,10	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 3	0,17/0,23	0,15/0,35	1,10/1,40	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 4	0,25/0,32	0,15/0,35	0,60/0,90	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 5	0,32/0,39	0,15/0,35	0,50/0,80	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 6	0,32/0,39	0,15/0,35	0,80/1,10	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 7	0,32/0,39	0,15/0,35	1,10/1,40	0,035	0,035		0,000 8/0,005	⩾ 0,020
E 10	0,34/0,41	0,15/0,35	0,50/0,80	0,035	0,035	0,20/0,40	0,000 8/0,005	⩾ 0,020

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

2) If ordered to requirement classes other than 1r, 7r, 1v, 7v, 1w or 7w, the specified hardenability or the specified mechanical properties should be the governing criteria for acceptance. In such cases the cast analysis may deviate slightly from the figures shown in the above table.

3) A lower silicon content may be agreed at the time of enquiry and order; in this case the influence of mechanical properties should be taken into account.

4) 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 %.

Table 20 — Permissible deviations between specified analysis and product analysis for C type steels

Type of steel	Permissible deviations[1]							
	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Mi %
C 1	± 0,02	± 0,03	± 0,04	± 0,005	± 0,005			
C 2	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005			
C 3	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005			
C 4	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005			
C 5	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005			
C 6	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005			
C 10	± 0,03	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 11	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 12	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 13	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 14	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 15	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 16	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05		
C 20	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005		± 0,03	
C 21	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005		± 0,03	
C 22	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005		± 0,03	
C 30	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	
C 31	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	
C 32	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	
C 40	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,03
C 41	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,03
C 42	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,05	± 0,03	± 0,05
C 43	± 0,02	± 0,03	± 0,04	+ 0,005	+ 0,005	± 0,10	± 0,04	± 0,07

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 in table 18, but not both at the same time.

Table 21 — Permissible deviations between specified analyses and product analyses for E type steels

Type of steel	Permissible deviation[1]						
	C %	Si %	Mn %	P %	S %	Cr %	B %
E 1	± 0,02	± 0,03	± 0,04	0,005	+ 0,005		± 0,000 3
E 2	± 0,02	± 0,03	± 0,06	0,005	+ 0,005		± 0,000 3
E 3	± 0,02	± 0,03	± 0,06	0,005	+ 0,005		± 0,000 3
E 4	± 0,03	± 0,03	± 0,04	0,005	+ 0,005		± 0,000 3
E 5	± 0,03	± 0,03	± 0,04	0,005	+ 0,005		± 0,000 3
E 6	± 0,03	± 0,03	± 0,06	0,005	+ 0,005		± 0,000 3
E 7	± 0,03	± 0,03	± 0,06	0,005	+ 0,005		± 0,000 3
E 10	± 0,03	± 0,03	± 0,04	0,005	+ 0,005	± 0,05	± 0,000 3

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 in table 19, but not both at the same time.

Table 22 — Mechanical properties[1] in the usual treatment conditions for cold heading or cold extruding

Type of steel	Treatment condition[2]			
	AC or AC + P or C + AC[5]		C + AC + LC	
	R_m max. N/mm^2	Z min.[3] %	R_m max. N/mm^2	Z min.[3][4] %
C 1	500	60	530	57
C 2	530	60	560	57
C 3	570	60	600	57
C 4	580	57	610	54
C 5	590	57	620	54
C 6	600	57	630	54
C 10	590	57	620	54
C 11	620	55	650	52
C 12	600		630	
C 13	630		660	
C 14	610		640	
C 15	620		650	
C 16	630		660	
C 20	580		610	
C 21	600		630	
C 22	620		650	
C 30	600		630	
C 31	620		650	
C 32	640		670	
C 40	650		680	
C 41	660		690	
C 42	680		710	
C 43	700		730	
E 1	500	60	530	57
E 2	520	60	550	57
E 3	550	60	580	57
E 4	530	60	560	57
E 5	570	60	600	57
E 6	590	57	620	54
E 7	600	57	630	54
E 10	590	57	620	54

1) R_m = tensile strength
Z = reduction of area after fracture

2) See 12.4.

3) For machined test pieces, the reduction of area may be 5 % lower, for example 50 % instead of 55 %.

4) For diameters of $\leqslant 12$ mm the reduction of area may be 2 % lower, and for diameters of $> 12 \leqslant 25$ mm it may be 1 % lower (for example 50 % or 51 % instead of 52 %).

5) In cases where increased formability is required, the material should be ordered in the treatment condition "C + AC", in which case the values of R_m max. may be reduced by about 20 N/mm^2 and the values of Z min. may be increased by about 2 %.

Table 23 — Mechanical properties[1] for the quenched and tempered condition

Type of steel	$\phi \leqslant 16$ mm			16 mm $< \phi \leqslant$ 40 mm				40 mm $< \phi \leqslant$ 100 mm			
	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	KU min.[3] J	Specified yield strength, min. N/mm²	R_m N/mm²	A min.[2] %	KU min.[3] J
C 1[4]	370	540 to 680	19	–	–	–	–	–	–	–	–
C 2	390	580 to 730	18	330	540 to 690	20	30				
C 3	420	620 to 770	17	360	580 to 730	19	25	320	540 to 690	20	25
C 4	450	660 to 810	16	390	620 to 770	18	20	340	580 to 730	19	20
C 5	460	690 to 840	16	380	620 to 760	18	20	340	580 to 720	19	20
C 6	480	700 to 850	14	410	660 to 810	16	15	370	620 to 770	17	15
C 10	470	690 to 840	15	380	620 to 770	16	25	330	560 to 710	18	25
C 11	550	800 to 950	13	460	710 to 860	15	20	390	640 to 790	16	20
C 12	540	780 to 930	14	440	690 to 840	15	25	340	590 to 740	17	25
C 13	640	880 to 1 080	12	540	780 to 930	14	25	440	690 to 840	14	25
C 14	700	900 to 1 100	12	600	800 to 950	14	30	470	700 to 850	15	30
C 15	750	950 to 1 150	11	640	840 to 1 000	13	25	520	750 to 900	14	25
C 16	800	1 000 to 1 200	11	680	900 to 1 100	12	25	570	800 to 950	14	25
C 20	480	690 to 840	16	360	580 to 720	19	25	320	560 to 680	20	25
C 21	580	780 to 980	13	410	650 to 800	15	20	370	620 to 760	16	20
C 22	630	830 to 1 030	13	460	690 to 840	16	20	390	660 to 810	16	20
C 30	700	900 to 1 100	12	600	800 to 950	14	35	470	700 to 850	15	35
C 31	800	1 000 to 1 200	11	680	900 to 1 100	12	30	570	800 to 950	14	30
C 32	900	1 100 to 1 300	10	780	1 000 to 1 200	11	25	650	900 to 1 100	12	25
C 40	850	1 050 to 1 250	10	750	950 to 1 150	11	30	650	850 to 1 000	12	30
C 41	850	1 050 to 1 250	10	800	1 000 to 1 200	11	30	700	900 to 1 100	12	30
C 42	1 000	1 200 to 1 400	9	900	1 100 to 1 300	10	25	800	1 000 to 1 200	11	30
C 43	1 050	1 250 to 1 450	9	1 050	1 250 to 1 450	9	20	900	1 100 to 1 300	10	25
E 1	450	600 to 750	16	400	550 to 700	18	35	–	–	–	–
E 2	550	700 to 850	14	500	650 to 800	16	30	–	–	–	–
E 3	600	750 to 900	14	550	700 to 850	15	25	–	–	–	–
E 4	550	700 to 850	14	480	630 to 780	16	30	–	–	–	–
E 5	600	750 to 900	14	500	650 to 800	16	30	–	–	–	–
E 6	700	850 to 1 000	12	600	750 to 900	14	25	–	–	–	–
E 7	750	900 to 1 050	12	650	800 to 950	14	20	510	680 to 830	15	30[5]
E 10	700	850 to 1 000	12	600	750 to 900	14	25	480	630 to 780	16	30[5]

1) R_m = tensile strength
A = percentage elongation after fracture $(L_o - 5\,d_o)$
KU = impact energy of ISO U-notch test pieces

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

3) If three test pieces are tested (see table 6, footnote 6) than the specified values apply for the average of the three test results. One single value may be lower, but not by more than 30 %.

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

5) These KU values for the E type steels are tentative; they will, if necessary, be revised as soon as further data are available.

Table 24 — Tentative hardness limit for specified hardenability[1)]

Distance from quenched end of test piece	Hardness HRC for steel type																											
	C 12		C 13		C 14		C 15		C 16		C 20		C 21		C 22		C 30		C 31		C 32		C 40		C 41		C 42		C 43	
mm	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1,5	51	59	52	61	49	57	51	59	53	61	41	48	45	52	52	59	43	52	49	57	53	61	53	60	52	61	53	60	49	57
3	46	57	47	59	48	57	50	59	52	61	39	47	40	50	49	57	42	52	49	57	53	61	53	60	51	60	52	59	49	57
5	37	54	39	56	45	56	48	58	50	60	31	44	28	45	40	54	38	51	48	57	53	61	53	60	50	59	52	58	49	57
7	29	49	31	51	41	54	44	57	47	59	24	37	23	36	33	48	35	50	45	56	51	60	50	59	49	58	52	58	49	57
9	25	43	27	45	35	52	39	55	44	58	21	32	20	30	27	39	32	48	42	55	50	60	47	58	48	58	52	58	48	56
11	22	39	24	41	32	49	36	52	40	56	–	27	–	27	24	34	29	46	39	54	48	59	42	57	46	57	51	58	48	56
13	20	37	22	39	29	46	33	50	37	54	–	26	–	25	22	31	26	43	36	53	45	59	38	55	44	57	51	58	48	56
15		35	20	37	27	44	31	48	35	52	–	24	–	23	21	30	24	41	34	52	43	58	35	54	43	56	51	58	47	56
20		32		33	23	39	26	42	30	46	–	23	–	22		27	20	37	30	48	38	56	30	48	39	55	50	57	47	56
25		30		31	21	37	24	39	27	42	–	21	–	21		25	18	35	28	45	35	53	28	42	36	53	49	57	46	55
30		27		29	20	35	22	37	25	40	–	20	–	20		25	17	33	27	43	34	51	26	40	34	51	47	57	46	55
35		25		27	–	34	20	36	23	38						25		32	26	41	33	48	25	38	33	49	46	57	45	55
40		24		26	–	33	–	35	22	37						24		31	25	40	32	47	24	37	32	48	45	57	45	55
45		23		25	–	32	–	34	21	36						24		31	24	40	32	46	24	37	31	46	44	56	44	55
50		22		24	–	31	–	33	20	35						23		31	24	39	32	45	23	36	30	45	43	56	44	55

1) The hardness values are tentative and may be adjusted as more information becomes available. The hardness values for the steel types C 14 to C 43 are based primarily on steels having a grain size of 5 and finer as defined in ISO/R 643.

Table 25 — Tentative hardness limits for specified hardenability[1)2)]

Distance from quenched end of test piece	Hardness HRC, for steel type															
	E 1		E 2		E 3		E 4		E 5		E 6		E 7		E 10	
mm	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1,5	41	48	41	48	41	48	45	53	51	58	51	58	51	58	52	59
3	38	47	40	48	41	48	42	52	49	58	51	58	51	58	50	59
5	32	46	37	47	39	48	35	51	43	57	48	57	48	57	46	58
7	21	43	28	45	35	47	27	48	30	55	42	56	44	56	37	56
9	–	37	20	41	26	46	22	44	24	52	32	55	36	55	30	54
11	–	30	–	35	21	44	–	38	21	46	26	51	31	53	26	50
13	–	25	–	30	–	40	–	32	–	38	22	46	27	50	24	45
15	–	22	–	27	–	36	–	27	–	33	20	40	25	45	22	41
20			–	22	–	29	–	20	–	26	–	32	21	37	–	34
25					–	25			–	25	–	29	–	32	–	30
30														28	–	27
35														26	–	25
40														24	–	24
45														23		
50																

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

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

Table 26 — 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
(the values are for guidance)

Type of steel	Hardness in the core HRC	Maximum diameter mm	
C 3	40	8	1)
C 4	40	10	
C 5	40	12	
C 6	40	12	
C 10	40	12	1)
C 11	40	16	
C 12	40	16	
C 13	40	20	
C 14	40	22	
C 15	40	24	
C 16	40	28	
C 20	40	12	
C 21	40	16	
C 22	40	20	
C 30	40	20	
C 31	45	20	
C 32	48	28	
C 40	48	21	
C 41	48	30	
C 42	48	34	
C 43	45	60	

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

Table 27 — Diameter up to which, after quenching in an oil of high quenching capacity, a hardness of 40 HRC can be achieved for the core

Type of steel	Maximum diameter[1] mm
E 1	9
E 2	12
E 3	14
E 4	14
E 5	18
E 6	22
E 7	26
E 10	24

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