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Heat-treatable steels, alloy steels and free-cutting steels —

Part 18:

Bright products of unalloyed and low alloy
steels

*Aciers pour traitement thermique, aciers alliés et aciers pour
décolletage —*

Partie 18: Produits blancs en aciers non alliés et faiblement alliés



Reference number
ISO 683-18:1996(E)

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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 683-18 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels*.

This second edition cancels and replaces the first edition (ISO 683-18:1976), of which it constitutes a technical revision.

ISO 683 consists of the following parts, under the general title *Heat-treatable steels, alloy steels and free-cutting steels*:

- Part 1: *Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products*
- Part 9: *Wrought free-cutting steels*
- Part 10: *Wrought nitriding steels*
- Part 11: *Wrought case-hardening steels*
- Part 13: *Wrought stainless steels*
- Part 14: *Hot-rolled steels for quenched and tempered springs*
- Part 15: *Valve steels for internal combustion engines*
- Part 16: *Precipitation hardening stainless steels*
- Part 17: *Ball and roller bearing steels*
- Part 18: *Bright products of unalloyed and low alloy steels*

Annexes A and B of this part of ISO 683 are for information only.

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Heat-treatable steels, alloy steels and free-cutting steels —

Part 18:

Bright products of unalloyed and low alloy steels

1 Scope

1.1 This part of ISO 683 applies to wrought unalloyed and alloyed steels in the form of bright products which are intended for mechanical purposes, for example for machine parts. It is subdivided as follows:

- a) clauses 5 and 6: general requirements and tests;
- b) clause 7: Case-hardening steels;
- c) clause 8: steels for quenching and tempering.

1.2 In addition to this part of ISO 683, the general technical delivery requirements of ISO 404 are applicable.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 683. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 683 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 83:1976, *Steel — Charpy impact test (U-notch)*.

ISO 148:1983, *Steel — Charpy impact test (V-notch)*.

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 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 4948-1:1982, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*.

ISO 4948-2:1981, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*.

ISO 6506:1981, *Metallic materials — Hardness test — Brinell test*.

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

ISO 6929:1987, *Steel products — Definitions and classification*.

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*.

ISO 14284:1996, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*.

3 Definitions

For the purposes of this part of ISO 683, the relevant definitions given in ISO 4948-1, ISO 4948-2 and ISO 6929, and also the definition given in 3.4, apply.

3.1 Bright products

For definition of drawn products, turned (or peeled) products and ground products, see ISO 6929.

3.2 Unalloyed and alloyed steel

See ISO 4948-1.

3.3 Special steel

See ISO 4948-2.

3.4 Thickness

Thickness is considered to be the nominal dimension of the product, that means:

- the diameter in the case of rounds;
- the lateral length in the case of squares;
- the width over flats in the case of hexagons;
- the shorter lateral length in the case of flats.

4 Ordering

4.1 The purchaser shall state in this enquiry and order

- a) the dimensions and tolerances of the product (see 5.10);
- b) the steel type (see tables 3, 7, 8, 11, 15, 16 and 17);
- c) the treatment condition (see 5.3.1);
- d) the surface-coating treatment, if any (see 5.3.2);
- e) the required type of document (see 6.1).

4.2 Certain options in ordering are permitted by this part of ISO 683. 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 tables	Permitted options
3, 11	f) whether a product analysis is required (see 6.2.1);
3, 11	g1) the choice of the surface quality class selected from ISO 9443 (see 5.8.1.5); g2) whether special specifications for the limits of surface defects are required (see 5.8.1.6);
3, 11	h) whether, specifically, coarse or fine grain steel is required (see 5.7);
3, 11	i) whether, for special steels, the microscopically determined non-metallic inclusion content shall be within agreed limits (see 5.9.2);
11	j) whether, for drawn products, special specifications for the permissible depth of the ferritic-pearlitic decarburization are required (see 5.8.2.1).

5 General requirements

5.1 Manufacture of the steel and of the product

5.1.1 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.

5.1.2 The steels shall be killed.

5.2 Cast separation

The steels are delivered by casts.

5.3 Treatment condition at the time of delivery

5.3.1 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 table 2 or 10. (See also 5.8.1.)

5.3.2 Bright steel is supplied commercially with a light coating of grease, provided that nothing to the contrary is laid down in the regulations of the freighter regarding unpacked piece goods.

The usual light application of ordinary grease does not afford positive protection against rusting, particularly in the presence of water due to condensation. The use of a selected rust inhibitor or a special type of packing shall, if required, be agreed upon at the time of enquiry and order.

5.4 Survey of combinations of usual treatment conditions on delivery and requirements

Tables 2 and 10 give a survey of combinations of usual treatment conditions on delivery and requirements concerning chemical composition, mechanical properties and hardenability.

5.5 Chemical composition

5.5.1 The chemical composition of the steels, determined by the cast analysis, shall be in accordance with the specifications in tables 3 and 11 (see 5.5.3).

5.5.2 Tables 4 and 12 give the permissible deviations between the values given in tables 3 and 11 and those from the product analysis.

5.5.3 If case-hardening or direct-hardening steels are ordered by using the designations given in tables 7, 8, 15, 16 or 17 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 3 and 11 by the values given in footnote 1) to table 3 and footnote 3) to table 11.

5.6 Hardenability and mechanical properties

The products shall fulfil the specifications of 7.2.3 and 8.2.3.

5.7 Structure

If a controlled austenitic grain size is required, the austenitic grain size of the steel determined in accordance with 6.3.4 shall be 5 and 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.

5.8 Outer soundness

5.8.1 Surface quality

5.8.1.1 In the case of hexagons, squares, flats and special sections, the achievement of a light bright surface is precluded by the manufacturing methods used; the surface is darker than that of bright rounds.

5.8.1.2 Heat treatment (e.g. stress relieving, soft annealing, normalizing, quenching and tempering) applied after drawing, centreless turning, grinding or polishing makes the surface darker and rougher.

5.8.1.3 Pitting, scars and grooves are permitted on a localized scale; in the case of rounds, their depth shall not be greater than ISO tolerance zone h11.

In the case of bright products with different shapes, comparative samples may be agreed upon at the time of enquiry and order.

5.8.1.4 If a surface quality that is superior to that obtained from the usual method of drawing once only or by centreless turning is required, an additional treatment (e.g. redrawing, grinding or polishing) may be agreed upon at the time of enquiry and order.

This is in particular necessary for a light bright and very smooth surface which may be needed for electrolytic surface coating.

5.8.1.5 Longitudinal surface defects cannot be completely avoided when rolling and they are retained when drawing. Therefore, in the case of drawn products, agreements may be made concerning the permissible depth of such defects and their examination.

In the case of rounds, these agreements shall be based on ISO 9443.

5.8.1.6 If special requirements concerning the limits of surface defects exist, the products shall be centreless-turned in a suitable way, and shall also be ground to improve the surface microstructure of rounds. Such requirements shall be agreed upon, if necessary, at the time of enquiry and order.

5.8.2 Decarburization

5.8.2.1 Drawn products of the steels in table 11 shall, independent of their heat-treatment conditions, be free from completely ferritic decarburized zones.

For such products, values for the permissible depth of the partial (ferritic-pearlitic) decarburization may be agreed upon at the time of enquiry and order.

5.8.2.2 Bright products of the steels in tables 3 or 11 which, according to the order, were peeled or ground or polished shall be free from decarburization.

5.9 Internal soundness

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

5.9.2 Where appropriate, exact criteria for the compliance of the steel with the general requirement in 5.9.1 shall be agreed upon at the time of enquiry and order.

Agreements on the content of non-metallic inclusions, for example in accordance with ISO 4967 or other suitable methods, may be made for special steels.

5.10 Dimensions, tolerances on dimensions and masses

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

If corresponding International Standards for dimensions and tolerances are not yet available, the dimensions and tolerances shall be agreed upon at the time of enquiry and order.

6 Testing

6.1 Agreement of tests and documents

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

6.1.2 If, in accordance with such an agreement, specific inspection is to be carried out, the specifications in 6.2 to 6.5 shall be observed.

6.2 Test unit and number of sample products and tests

6.2.1 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.

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

If, according to the ordered requirements (see tables 2 and 10) and the required type of document (see 6.1), the hardenability, mechanical properties, structure or inner and outer soundness are to be verified, then the indications in table 9 or 18 apply for the test unit and the number of samples and test pieces.

6.3 Selection and preparation of samples and test pieces

6.3.1 General

The general conditions given in ISO 377-1 and ISO 14284 for the selection and preparation of samples and test pieces shall apply.

6.3.2 Hardenability test

In cases of dispute, for the end-quench hardenability test, if possible the sampling method given in ISO 642:1979 [5.1 a) or b1)] shall be applied.

6.3.3 Tensile test and impact test

6.3.3.1 Test pieces for tensile tests shall be tested (as far as possible) with their original surface (see figure 1).

6.3.3.2 Impact test pieces shall be taken in accordance with figure 1 and be prepared in accordance with ISO 83 or ISO 148.

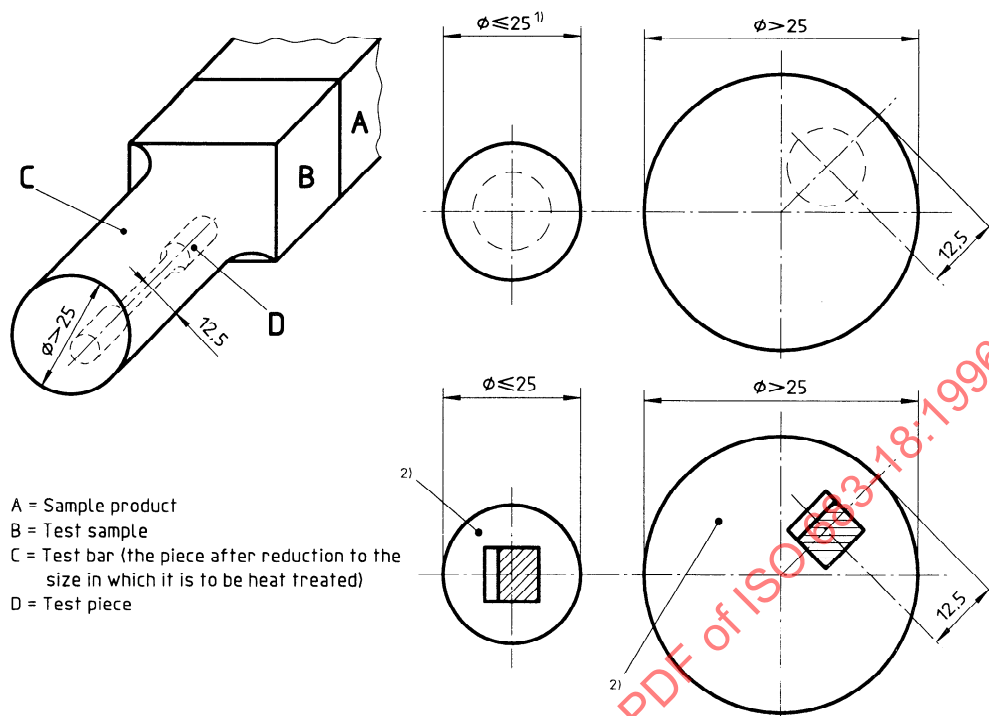
6.3.4 Structure

For the selection and preparation of the test pieces for the verification of the austenitic grain size, the indications in ISO 643 apply. In cases of dispute, if not otherwise agreed at the time of enquiry and order, the indications for the McQuaid-Ehn method shall be observed, if case-hardening steels (see clause 7) are to be examined. In cases where steels for quenching and tempering (see clause 8) 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 (see table A.3) for the steel type concerned, and this temperature shall be maintained for 1 h.

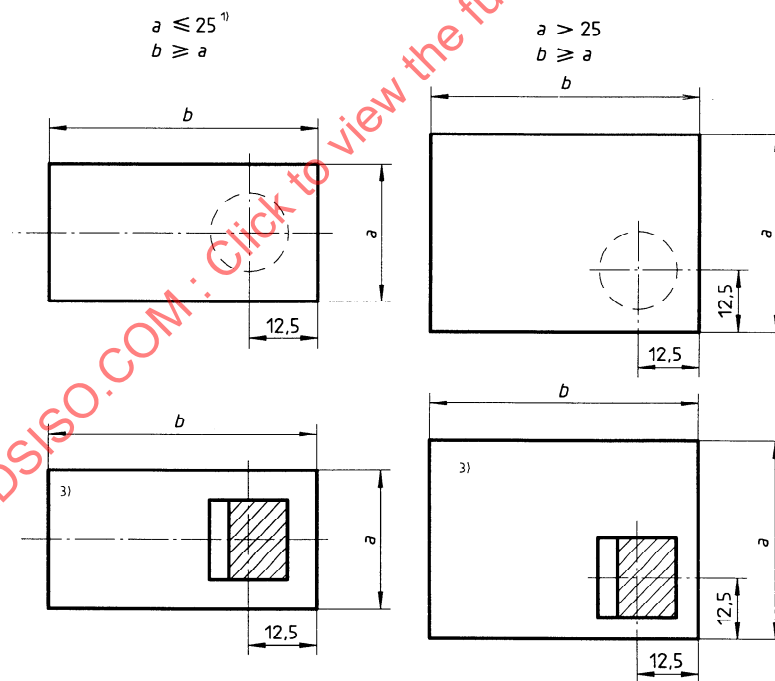
6.3.5 Internal soundness

For the selection and preparation of the test pieces for the verification of the content of non-metallic inclu-

Dimensions in millimetres



Circular and similar shaped sections



Tensile test piece

Notch

Impact test piece

- 1) For small products (d or $a \leq 25$ mm), the test piece shall, if possible, consist of an unmachined part of the bar.
- 2) For round bars, the direction of the notch axis shall be approximately parallel to the direction of the diameter running through the cross-section of the test piece.
- 3) For rectangular bars, the notch axis shall be perpendicular to the widest rolling surface.

Figure 1 — Location of the test pieces in bars and wire rods

sions, the indications in ISO 4967 or other agreed standards apply.

6.3.6 Outer soundness

For the verification of surface quality, see ISO 9443.

6.3.7 Decarburization

Etched transverse microsections with sharp edges shall be prepared for a microscopic examination of decarburization. However, in cases of dispute, with the exception of products in the cold-drawn condition, the microsection shall be hardened, taking precautions to prevent decarburization or carburization. After hardening, the microsections shall be prepared for microhardness measurements by grinding and polishing. In all cases, the requirements of ISO 3887 shall be observed.

6.4 Methods of test

6.4.1 Chemical analysis

In the case of dispute about the analytical method, the chemical composition shall be determined in accordance with a reference method specified in ISO standards listed in ISO/TR 9769.

6.4.2 Hardenability test

The end-quench hardenability test shall be carried out in accordance with ISO 642. The temperature for quenching shall be in accordance with tables 7, 8, 15, 16 or 17.

6.4.3 Tensile test and impact test

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

6.4.3.2 The impact test shall be carried in accordance with ISO 83 or ISO 148.

6.4.4 Structure

The austenitic grain size shall be tested in accordance with ISO 643 on test pieces prepared in accordance with 6.3.4.

6.4.5 Internal soundness

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

6.4.6 Outer soundness

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.

6.4.7 Decarburization

When testing the products with regard to their decarburization (see ISO 3887), the depth of the ferritic completely decarburized zone and that of the ferritic-pearlitic partially decarburized zone are usually measured by microscope at a magnification of $\times 100$, at the four ends of the diameters of the two etched planes perpendicular to each other. 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 shall be calculated.

In cases of dispute, with the exception of products in the cold-drawn condition, the decarburization shall be checked by microhardness 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 2) shall be calculated. The single values e_1 to e_4 represent, according to figure 2, 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 decarburization, is measured in the outer zone of the microsection.

6.5 Retests

For retests, ISO 404 shall apply.

7 Specific requirements for bright products of case-hardening steels

7.1 Scope

This clause covers the specific requirements for the bright products of case-hardening steels. It applies for thicknesses up to 160 mm in the case of unalloyed steels and up to 80 mm in the case of alloyed steels.

7.2 Requirements

7.2.1 Survey of combinations of usual treatment conditions on delivery and requirements

Table 2 gives a survey of combinations of usual treat-

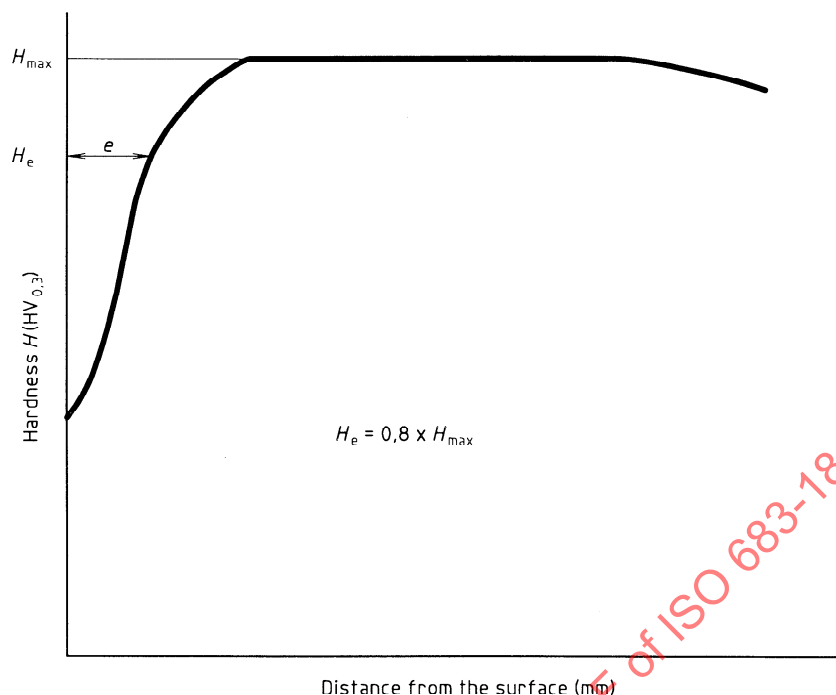


Figure 2 — Determination of the depth of the decarburized zone

ment conditions, on delivery and requirements concerning chemical composition, mechanical properties and hardenability.

7.2.2 Chemical composition

7.2.2.1 The chemical composition of the steel, determined by the cast analysis, shall be in accordance with the specifications in table 3.

7.2.2.2 Table 4 gives the permissible deviations between the values given in table 3 and those from the product analysis.

7.2.3 Hardenability and mechanical properties

7.2.3.1 Where the steel is not ordered according to hardenability requirements, i.e. where the steel type designations of tables 3, 5 and 6 are applied, and not the designations given in table 7 or 8 (besides the requirements for chemical composition), the requirements for mechanical properties given in table 2, column 4.2, apply for the particular heat-treatment condition. In this case, the values of hardenability given in table 7 are for guidance only.

7.2.3.2 Where the steel is, by using the designations given in table 7 or 8, ordered to normal (see table 7) or to narrowed (see table 8) hardenability requirements, the values of hardenability given in table 7 or 8, respectively, apply in addition to the requirements given in table 2, columns 4.1 and 4.2 [see footnote 1) to table 3].

7.2.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 2.

7.2.5 Machinability

All steels are machinable in the conditions "annealed to maximum hardness requirements" and "treated to improve machinability".

Where improved machinability is required, the grades with a specified sulfur range should be ordered.

7.2.6 Shearability

Under suitable shearing conditions (avoiding local stress peaks, preheating, application of blades with a profile adapted to that of the product, etc.) all steels are shearable in the condition "annealed to maximum hardness requirements".

Table 2 — Combinations of usual treatment conditions on delivery and requirements for case-hardening steels

1	2		3	4		5		
1	Treatment condition on delivery ¹⁾		Symbol	Applicable requirements if the steel is ordered with the designation given in table 3, 5 or 6		table 7 or 8		
				4.1	4.2	5.1	5.2	5.3
2	Cold drawn ²⁾		TC	Chemical composition according to tables 3 and 4	In the case of unalloyed steels, mechanical properties according to table 5, column 3; in the case of alloyed steels, maximum tensile strength according to table 6, column 3	As in column 4 [see footnote 1) to table 3]		Hardenability values according to table 7 or 8
3	Peeled ³⁾		P		—			
4	Ground		G					
5	Cold drawn ²⁾	and stress relieved	TC + TSR		The values shall, if necessary, be agreed upon			
6	Peeled ³⁾		P + TSR					
7	Ground		G + TSR					
8	Cold drawn ²⁾	and annealed to maximum hardness requirements	TC + TA		Maximum hardness according to table 5, column 4, or table 6, column 4			
9	Peeled ³⁾		P + TA					
10	Ground		G + TA					
11	Cold drawn ²⁾	and treated to improve machinability	TC + M		Hardness range according to table 6, column 5			
12	Peeled ³⁾		P + M					
13	Ground		G + M					
14	Treated to improve machinability and cold drawn		M + TC		Hardness range according to table 6, column 6			

1) Other treatment conditions, for example “treated to ferrite-pearlite structure”, may be agreed upon at the time of enquiry and order. The condition “annealed to achieve a spheroidization of the carbides”, as required for cold heading and cold extrusion, is covered in ISO 4954.

2) For rounds with diameters over 50 mm, it is more usual to apply peeling instead of drawing.

3) Peeling is in general possible for diameters of 16 mm and over.

Table 3 — Types of case-hardening steel and chemical composition (applicable to cast analysis)

Elements which are not mentioned 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 material used during manufacture, of elements which could affect the hardenability, mechanical properties and applicability.

Type of steel ^(2) 3) 4)	Chemical composition [% (m/m)] ¹⁾							
	C	Si ⁵⁾	Mn	P max.	S	Cr	Mo	Ni
C 10	0,07 to 0,13	0,15 to 0,40	0,30 to 0,60	0,035	0,035 max.	—	—	—
C 15 E4	0,12 to 0,18	0,15 to 0,40	0,30 to 0,60	0,035	0,035 max.	—	—	—
C 15 M2					0,020 to 0,040			
20 Cr 4	0,17 to 0,23	0,15 to 0,40	0,60 to 0,90	0,035	0,035 max.	0,90 to 1,20	—	—
20 CrS 4					0,020 to 0,040			
16 MnCr 5	0,13 to 0,19	0,15 to 0,40	1,00 to 1,30	0,035	0,035 max.	0,80 to 1,10	—	—
16 MnCrS 5					0,020 to 0,040			
20 MnCr 5	0,17 to 0,23	0,15 to 0,40	1,10 to 1,40	0,035	0,035 max.	1,00 to 1,30	—	—
20 MnCrS 5					0,020 to 0,040			
20 NiCrMo 2	0,17 to 0,23	0,15 to 0,40	0,65 to 0,95	0,035	0,035 max.	0,30 to 0,65	0,15 to 0,25	0,40 to 0,70
20 NiCrMoS 2					0,020 to 0,040			
18 CrNiMo 7	0,15 to 0,21	0,15 to 0,40	0,35 to 0,65	0,035	0,035 max.	1,50 to 1,80	0,25 to 0,35	1,40 to 1,70

1) In the case of grades with specified hardenability requirements (see tables 7 and 8), except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. These deviations shall, however, not exceed $\pm 0,01$ % (m/m) in the case of carbon and the values given in table 4 in all other cases.

2) Steels with machinability which has been improved either by the addition of lead or by controlled sulfide morphology may be available on request.

3) Additional case-hardening steels are covered by ISO 683-11:1987.

4) These designations are in accordance with the system proposed in ISO/TR 4949.

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

Table 4 — Permissible deviations between specified analysis and product analysis for case-hardening steels

Element	Permissible maximum content according to cast analysis	Permissible deviation ¹⁾
	[% (m/m)]	[% (m/m)]
C	≤ 0,23	± 0,02
Si	≤ 0,40	± 0,03
Mn	≤ 1,00	± 0,04
	> 1,00 ≤ 1,40	± 0,06
P	≤ 0,035	+ 0,005
S	≤ 0,040	+ 0,005 ²⁾
Cr	≤ 1,80	± 0,05
Mo	≤ 0,30	± 0,03
	> 0,30 ≤ 0,35	± 0,04
Ni	≤ 1,00	± 0,03
	> 1,00 ≤ 1,70	± 0,05

1) ± means that in one cast the deviation may occur over the upper value or under the lower value of the specified range in table 3, but not both at the same time.

2) For steels with a specified range of sulfur contents [0,020 % (m/m) to 0,040 % (m/m) according to cast analysis], the permissible deviation is ± 0,005 % (m/m).

Table 5 — Mechanical properties of bright unalloyed case-hardening steels

1	2		3			4
Type of steel	Thickness ¹⁾ mm		Treatment condition on delivery ²⁾			TC + TA or P + TA or G + TA Hardness HB
			TC ³⁾ 4)			
			Yield stress N/mm ²	Tensile strength N/mm ²	Elongation (<i>L</i> ₀ = 5 <i>d</i> ₀) %	
	over	up to and including	min.			max.
C 10		5	400	500	7	131
	5	10	360	470	8	
	10	16	310	420	9	
	16	25	285	400	10	
	25	40	270	390	11	
	40	100	170	340	12	
	100	160	To be agreed			
C 15 E4 C 15 M2		5	430	540	6	143
	5	10	390	500	7	
	10	16	340	450	8	
	16	25	315	440	9	
	25	40	300	420	10	
	40	100	190	370	12	
	100	160	To be agreed			

1) See 3.4.

2) See table 2.

3) For flats and steels that have been drawn several times, the specifications are given as reference data; however, deviations from the limiting values of ± 10 % are to be taken into account. No values can be given for special sections.

4) The mechanical properties in the cold-drawn conditions can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.

Table 6 — Mechanical properties of bright alloyed case-hardening steels

1	2		3	4	5	6
Type of steel	Thickness ¹⁾		Treatment condition on delivery ²⁾			
			TC ³⁾ 4)	TC + TA or P + TA or G + TA	TC + M or P + M or G + M	M + TC ⁵⁾
	mm		Tensile strength N/mm ²	Hardness HB	Hardness HB	Hardness HB
	over	up to and including	max.	max.		
20 Cr 4	16	16	820	197	149 to 197	149 to 297
20 CrS 4	40	40	750			
16 MnCr 5	16	16	820	207	156 to 207	156 to 307
16 MnCrS 5	40	40	720			
20 MnCr 5	16	16	850	217	170 to 217	170 to 317
20 MnCrS 5	40	40	780			
20 NiCrMo 2	16	16	820	197	161 to 212	161 to 312
20 NiCrMoS 2	40	40	750			
18 CrNiMo 7	16	16	900	229	179 to 229	179 to 329
	40	40	870			
		80	820			

1) See 3.4.

2) See table 2.

3) Initial treatment to be chosen by the manufacturer.

4) The mechanical properties in the cold-drawn condition can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.

5) Unless otherwise agreed, these values are applicable for diameters up to 60 mm.

NOTE — It should be noted that, for a reduction in cross-section of more than 10 %, it is difficult to observe these limits.

Table 5 — Mechanical properties of bright unalloyed case-hardening steels

1	2		3			4
Type of steel	Thickness ¹⁾ mm		Treatment condition on delivery ²⁾			TC + TA or P + TA or G + TA Hardness HB
			TC ³⁾ 4)			
			Yield stress N/mm ²	Tensile strength N/mm ²	Elongation (<i>L</i> ₀ = 5 <i>d</i> ₀) %	
	over	up to and including	min.			max.
C 10		5	400	500	7	131
	5	10	360	470	8	
	10	16	310	420	9	
	16	25	285	400	10	
	25	40	270	390	11	
	40	100	170	340	12	
	100	160	To be agreed			
C 15 E4 C 15 M2		5	430	540	6	143
	5	10	390	500	7	
	10	16	340	450	8	
	16	25	315	440	9	
	25	40	300	420	10	
	40	100	190	370	12	
	100	160	To be agreed			

1) See 3.4.

2) See table 2.

3) For flats and steels that have been drawn several times, the specifications are given as reference data; however, deviations from the limiting values of ± 10 % are to be taken into account. No values can be given for special sections.

4) The mechanical properties in the cold-drawn conditions can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.

Table 6 — Mechanical properties of bright alloyed case-hardening steels

1	2		3	4	5	6
Type of steel	Thickness ¹⁾		Treatment condition on delivery ²⁾			
			TC ³⁾ 4)	TC + TA or P + TA or G + TA	TC + M or P + M or G + M	M + TC ⁵⁾
	mm		Tensile strength N/mm ²	Hardness HB	Hardness HB	Hardness HB
	over	up to and including	max.	max.		
20 Cr 4	16	16	820	197	149 to 197	149 to 297
20 CrS 4	40	40	750			
16 MnCr 5	16	16	820	207	156 to 207	156 to 307
16 MnCrS 5	40	40	720			
20 MnCr 5	16	16	850	217	170 to 217	170 to 317
20 MnCrS 5	40	40	780			
20 NiCrMo 2	16	16	820	197	161 to 212	161 to 312
20 NiCrMoS 2	40	40	750			
18 CrNiMo 7	16	16	900	229	179 to 229	179 to 329
	40	40	870 820			

1) See 3.4.
2) See table 2.
3) Initial treatment to be chosen by the manufacturer.
4) The mechanical properties in the cold-drawn condition can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.
5) Unless otherwise agreed, these values are applicable for diameters up to 60 mm.

NOTE — It should be noted that, for a reduction in cross-section of more than 10 %, it is difficult to observe these limits.

Table 7 — Hardness limits for steel types with specified (normal) hardenability (H-grades, see 7.2.3)

Type of steel	Quenching temperature ¹⁾ °C	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
20 Cr 4 H 20 CrS 4 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 H 16 MnCrS 5 H	900 ± 5	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
		min.	39	36	31	28	24	21	—	—	—	—	—	—	—
20 MnCr 5 H 20 MnCrS 5 H	900 ± 5	max.	49	49	48	46	43	42	41	39	37	35	34	33	32
		min.	41	39	36	33	30	28	26	25	23	21	—	—	—
20 NiCrMo 2 H 20 NiCrMoS 2 H	900 ± 5	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—
18 CrNiMo 7 H	860 ± 5	max.	48	48	48	48	47	47	46	46	44	43	42	41	41
		min.	40	40	39	38	37	36	35	34	32	31	30	29	29
1) Time for austenitizing (for guidance): 0,5 h minimum. For further quenching conditions, see ISO 642.															

Table 8 — Hardness limits for steel types with narrowed hardenability scatterbands (HH and HL-grades)

Type of steel	Quenching temperature ¹⁾ °C	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
20 Cr 4 HH 20 CrS 4 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 HL 20 CrS 4 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 HH 16 MnCrS 5 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 HL 16 MnCrS 5 HL	900 ± 5	max.	44	43	40	37	34	32	30	28	26	25	24	23	22
		min.	39	36	31	28	24	21	—	—	—	—	—	—	—
20 MnCr 5 HH 20 MnCrS 5 HH	900 ± 5	max.	49	49	48	46	43	42	41	39	37	35	34	33	32
		min.	44	42	40	37	34	33	31	30	28	26	25	24	23
20 MnCr 5 HL 20 MnCrS 5 HL	900 ± 5	max.	46	46	44	42	39	37	36	34	32	30	29	28	27
		min.	41	39	36	33	30	28	26	25	23	21	—	—	—
20 NiCrMo 2 HH 20 NiCrMoS 2 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 HL 20 NiCrMoS 2 HL	900 ± 5	max.	46	44	40	36	31	29	27	26	23	21	20	20	—
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—
18 CrNiMo 7 HH	860 ± 5	max.	48	48	48	48	47	47	46	46	44	43	42	41	41
		min.	43	43	42	41	40	40	39	38	36	35	34	33	33
18 CrNiMo 7 HL	860 ± 5	max.	45	45	45	45	44	43	42	42	40	39	38	37	37
		min.	40	40	39	38	37	36	35	34	32	31	30	29	29

1) Time for austenitizing (for guidance) 0,5 h minimum. For further quenching conditions, see ISO 642.

Table 9 — Test conditions for the verification of the requirements given in column 2

1	2		3	4	5	6	7
No.	Requirements		Amount of testing			Sampling ¹⁾	Test method
		See tables	Test unit ²⁾	Number of			
				sample products per test unit	tests per sample product		
1	Chemical composition	3 + 4	C	(The cast analysis is provided by the manufacturer; for the product analysis, see 6.2.1.)			
2	Tensile properties	5 or 6	C + D + T	1	1	The test pieces for the tensile test shall be taken in accordance with figure 1.	In cases of dispute, the tensile test shall be carried out in accordance with ISO 6892 on proportional test pieces with a gauge length of $L_0 = 5,65 \sqrt{S_0}$, where S_0 is the area of the cross-section of the test piece.
3	Hardness in the condition TA or M	5 or 6	C + D + T	1	1	In cases of dispute, the hardness shall be measured, if possible, at the circumference of the product at a distance of $1 \times$ thickness from one end and, in cases of products with square or rectangular cross-section, at a distance of $0,25 \times b$ (where b is the width of the product) from one longitudinal edge.	According to ISO 6506.
4	Hardenability	7 or 8	C	1	1	In cases of dispute, if possible the sampling method given in ISO 642:1979, 5.1, a) or b1), shall be applied. In all other cases, the sampling method (including the method which starts from separately cast and subsequently hot-worked test ingots or from cast and not hot-worked samples) is left to the discretion of the manufacturer, unless otherwise agreed at the time of enquiry and order.	The test shall be carried out in accordance with ISO 642. The temperature for quenching shall be in accordance with table 7 or 8.

NOTE — Verification of the requirements is only necessary if an inspection certificate or an inspection report is ordered and if the requirement is applicable according to table 2, column 4 or 5.

1) The general conditions for selection and preparation of test samples and test pieces should be in accordance with ISO 377-1 in the case of mechanical tests, and in accordance with ISO 14284 for the determination of chemical composition.

2) The test shall be carried out separately for each cast as indicated by "C", each dimension as indicated by "D", and each heat-treatment batch as indicated by "T". Products with different thicknesses may be regrouped, if the thicknesses lie in the same dimensional range for mechanical properties and if the differences in thickness do not affect the properties. In cases of doubt, the thinnest and thickest product shall be tested.

8 Specific requirements for bright products of steels for quenching and tempering

8.1 Scope

This clause covers the specific requirements for the bright products of steels for quenching and tempering. It applies for thicknesses up to 250 mm in the case of unalloyed steels and up to 80 mm in the case of steels with 1,30 % (m/m) to 1,65 % (m/m) of manganese and alloyed steels.

8.2 Requirements

8.2.1 Survey of combinations of usual treatment conditions on delivery and requirements

Table 10 gives a survey of combinations of usual treatment conditions on delivery and requirements concerning chemical composition, mechanical properties and hardenability.

8.2.2 Chemical composition

8.2.2.1 The chemical composition of the steel, determined according to the cast analysis, shall be in accordance with the specifications in table 11.

8.2.2.2 Table 12 gives the permissible deviations between the values given in table 11 and those from the product analysis.

8.2.3 Hardenability and mechanical properties

8.2.3.1 Where the steel is not ordered according to hardenability requirements, i.e. where the steel type designations of tables 11, 13 and 14 are applied, and not the designations given in tables 15 to 17 (besides the requirements for chemical composition), the requirements for mechanical properties given in table 10, column 4.2, apply for the particular treatment condition. In this case, the values of hardenability in the end-quench test given in table 15 are for guidance only.

8.2.3.2 Where the steel is, by using the designations given in tables 15 to 17, ordered to normal (see table 15) or to narrowed (see tables 16 and 17) end-quench hardenability requirements, the values of hardenability given in table 15, 16 or 17, respectively, apply in addition to the requirements given in table 10, columns 4.1 and 4.2 [see footnote 3) to table 11].

8.2.4 Treatment condition at the time of delivery

The steels are usually delivered in one of the treatment conditions listed in table 10.

8.2.5 Machinability

All steels are machinable in the condition "annealed to maximum hardness requirements".

Where improved machinability is required, the grades with a specified sulfur range should be ordered.

8.2.6 Shearability

8.2.6.1 Under suitable shearing conditions (avoiding local stress peaks, preheating, application of blades with a profile adapted to that of the product, etc.) all steels are shearable in the annealed condition.

8.2.6.2 The steels C 18, C 20, C 25, C 30 and C 35 and the corresponding E4 and M2-grades are, under suitable conditions, shearable when delivered in the cold-drawn or peeled condition.

Table 10 — Combinations of usual treatment conditions on delivery and requirements for direct-hardening steels

1	2		3	4		5		
1	Treatment condition on delivery ¹⁾		Symbol	Applicable requirements if the steel is ordered with the designation given in table				
				11, 12, or 14		15, 16 or 17		
				4.1	4.2	5.1	5.2	5.3
2	Cold drawn ²⁾		TC	Chemical composition according to tables 11 and 12	Mechanical properties according to table 13, column 3 ³⁾ , or table 14, column 3 ³⁾	As in column 4 [see footnote 3) to table 11]		Hardenability values according to table 15, 16 or 17
3	Peeled ⁴⁾		P		3)			
4	Ground		G					
5	Cold drawn ²⁾	and stress relieved	TC + TSR		The values shall, if necessary, be agreed upon			
6	Peeled ⁴⁾		P + TSR					
7	Ground		G + TSR					
8	Cold drawn ²⁾	and annealed to maximum hardness requirements	TC + TA		Maximum hardness according to table 5, column 4 ³⁾ , or table 6, column 4 ³⁾			
9	Peeled ⁴⁾		P + TA					
10	Ground		G + TA					
11	Cold drawn ²⁾	and normalized	TC + TN		Mechanical properties according to table 13, column 5			
12	Peeled ⁴⁾		P + TN					
13	Ground		G + TN					
14	Cold drawn ²⁾	and quenched + tempered	TC + TQ + TT		Mechanical properties according to table 13, column 6, or table 14, column 5			
15	Peeled ⁴⁾		P + TQ + TT					
16	Ground		G + TQ + TT					
17	Quenched and tempered	and cold drawn	TQ + TT + TC		Mechanical properties according to table 13, column 6 or table 14, column 5, subject to footnote 5)			
18		and peeled	TQ + TT + P					
19		and ground	TQ + TT + G					

1) Other treatment conditions, for example "certain annealing conditions to achieve a determined structure" may be agreed upon at the time of enquiry and order. The condition "annealed to achieve a spheroidization of the carbides", as required for cold heading and cold extrusion, is covered in ISO 4954.

2) For rounds with diameters over 50 mm, it is more usual to apply peeling instead of drawing.

3) For deliveries in treatment conditions TC, P, G, TC + TSR, P + TSR, G + TSR, TC + TA, P + TA and G + TA, the mechanical properties given in table 13, columns 5 and 6, and in table 14, column 5, shall be achievable after appropriate heat treatment, if so agreed at the time of enquiry and order.

4) Peeling is in general possible for diameters of 16 mm and over.

Table 11 — Types of direct-hardening steel and specified chemical composition (applicable to cast analysis)

Elements which are not mentioned 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 material used during manufacture, of elements which could affect the hardenability, mechanical properties and applicability.

Type of steel ^{1) 2)}	Chemical composition ³⁾								
	% (m/m)								
	C	Si	Mn	P max.	S	Cr	Mo	Ni	V
C 18	0,15 to 0,20	0,10 to 0,40	0,60 to 0,90	0,045	≤ 0,045				
C 20	0,17 to 0,23	0,10 to 0,40	0,30 to 0,60	0,045	≤ 0,045				
C 20 E4				0,035	≤ 0,035				
C 20 M2					0,020 to 0,040				
C 25	0,22 to 0,29	0,10 to 0,40	0,40 to 0,70	0,045	≤ 0,045				
C 25 E4				0,035	≤ 0,035				
C 25 M2					0,020 to 0,040				
(C 30)	0,27 to 0,34	0,10 to 0,40	0,50 to 0,80	0,045	≤ 0,045				
(C 30 E4)				0,035	≤ 0,035				
(C 30 M2)					0,020 to 0,040				
C 35	0,32 to 0,39	0,10 to 0,40	0,50 to 0,80	0,045	≤ 0,045				
C 35 E4				0,035	≤ 0,035				
C 35 M2					0,020 to 0,040				
(C 40)	0,37 to 0,44	0,10 to 0,40	0,50 to 0,80	0,045	≤ 0,045				
(C 40 E4)				0,035	≤ 0,035				
(C 40 M2)					0,020 to 0,040				
C 45	0,42 to 0,50	0,10 to 0,40	0,50 to 0,80	0,045	≤ 0,045				
C 45 E4				0,035	≤ 0,035				
C 45 M2					0,020 to 0,040				
(C 50)	0,47 to 0,55	0,10 to 0,40	0,60 to 0,90	0,045	≤ 0,045				
(C 50 E4)				0,035	≤ 0,035				
(C 50 M2)					0,020 to 0,040				
C 55	0,52 to 0,60	0,10 to 0,40	0,60 to 0,90	0,045	≤ 0,045				
C 55 E4				0,035	≤ 0,035				
C 55 M2					0,020 to 0,040				
C 60	0,57 to 0,65	0,10 to 0,40	0,60 to 0,90	0,045	≤ 0,045				
C 60 E4				0,035	≤ 0,035				
C 60 M2					0,020 to 0,040				
28 Mn 6	0,25 to 0,32	0,10 to 0,40	1,30 to 1,65	0,035	≤ 0,035				
36 Mn 6	0,33 to 0,40	0,10 to 0,40 ⁴⁾	1,30 to 1,65	0,035	≤ 0,035				
42 Mn 6	0,39 to 0,46	0,10 to 0,40 ⁴⁾	1,30 to 1,65	0,035	≤ 0,035				
34 Cr 4	0,30 to 0,37	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20			
34 CrS 4					0,020 to 0,040				
37 Cr 4	0,34 to 0,41	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20			
37 CrS 4					0,020 to 0,040				
41 Cr 4	0,38 to 0,45	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20			
41 CrS 4					0,020 to 0,040				

Type of steel ^{1) 2)}	Chemical composition ³⁾								
	% (m/m)								
	C	Si	Mn	P max.	S	Cr	Mo	Ni	V
25 CrMo 4	0,22 to 0,29	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20	0,15 to 0,30		
25 CrMoS 4					0,020 to 0,040				
34 CrMo 4	0,30 to 0,37	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20	0,15 to 0,30		
34 CrMoS 4					0,020 to 0,040				
42 CrMo 4	0,38 to 0,45	0,10 to 0,40 ⁴⁾	0,60 to 0,90	0,035	≤ 0,035	0,90 to 1,20	0,15 to 0,30		
42 CrMoS 4					0,020 to 0,040				
50 CrMo 4	0,46 to 0,54	0,10 to 0,40 ⁴⁾	0,50 to 0,80	0,035	≤ 0,035	0,90 to 1,20	0,15 to 0,30		
36 CrNiMo 4	0,32 to 0,40	0,10 to 0,40 ⁴⁾	0,50 to 0,80	0,035	≤ 0,035	0,90 to 1,20	0,15 to 0,30	0,90 to 1,20	
36 CrNiMo 6	0,32 to 0,39	0,10 to 0,40 ⁴⁾	0,50 to 0,80	0,035	≤ 0,035	1,30 to 1,70	0,15 to 0,30	1,30 to 1,70	
31 CrNiMo 8	0,27 to 0,34	0,10 to 0,40 ⁴⁾	0,30 to 0,60	0,035	≤ 0,035	1,80 to 2,20	0,30 to 0,50	1,80 to 2,20	
51 CrV 6	0,47 to 0,55	0,10 to 0,40 ⁴⁾	0,60 to 1,00	0,035	≤ 0,035	0,80 to 1,10			0,10 to 0,25

1) Steels with machinability which has been improved either by the addition of lead or by higher sulfur levels up to about 0,100 % (m/m) S (including controlled sulfide morphology) may be available on request.

2) The designations are in accordance with the system proposed in ISO/TR 4949.

3) In the case of the grades with specified hardenability requirements (see tables 15 to 17), except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. These deviations shall, however, not exceed ± 0,01 % (m/m) in the case of carbon and the values given in table 12 in all other cases.

4) Steels may be supplied with a lower silicon content, in which case alternative means of deoxidation must be used.

Table 12 — Permissible deviations between specified analysis and product analysis for direct-hardening steels

Element	Permissible maximum content according to cast analysis	Permissible deviation ¹⁾
	% (m/m)	% (m/m)
C	$\leq 0,30$	$\pm 0,02$
	$> 0,30 \leq 0,55$	$\pm 0,03$
	$> 0,55 \leq 0,65$	$\pm 0,04$
Si	$\leq 0,40$	$\pm 0,03$
Mn	$\leq 1,00$	$\pm 0,04$
	$> 1,00 \leq 1,65$	$\pm 0,06$
P	$\leq 0,045$	$+ 0,005$
S	$\leq 0,045$	$+ 0,005$ ²⁾
Cr	$\leq 2,00$	$\pm 0,05$
	$> 2,00 \leq 2,20$	$\pm 0,10$
Mo	$\leq 0,30$	$\pm 0,03$
	$> 0,30 \leq 0,50$	$\pm 0,04$
Ni	$\leq 2,00$	$\pm 0,05$
	$> 2,00 \leq 2,20$	$\pm 0,07$
V	$\leq 0,25$	$\pm 0,02$
1) $\pm$ means that in one cast 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. 2) For steels with a specified range of sulfur contents [0,020 % (m/m) to 0,040 % (m/m) according to cast analysis], the permissible deviation is $\pm 0,005$ % (m/m).		

Table 13 — Mechanical properties of bright unalloyed direct-hardening steels

1	2		3			4	5			6				
Type of steel	Thickness 1)		Treatment condition on delivery 2)											
			TC3) 4)			TC + TA or P + TA or G + TA	TC + TN or P + TN or G + TN			TC + TQ + TT5) or P + TQ + TT or G + TQ + TT				
	over	up to and including	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Hardness	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Impact energy for E4 and M2-grades	
			N/mm ²	N/mm ²	%	HB	N/mm ²	N/mm ²	%	N/mm ²	N/mm ²	%	KU6) J	KV6) J
min.	min.	min.	min.	min.	min.	min.	min.		min.	min.				
C 18		5	430	500	7	156	415	485	18	To be agreed				—
	5	10												
	10	16												
	16	25												
	25	40												
	40	100												
	100	250	To be agreed											
C 20		5	460	580	5	156	210	400	27	To be agreed				
C 20 E4	5	10	415	540	5									
	10	16	370	490	7									
C 20 M2	16	25	340	470	8									
	25	40	320	450	9									
	40	100	210	400	11									
	100	250	To be agreed											
C 25		5	490	610	5	156	260	470	22	370	550 to 700	19	35	45
C 25 E4	5	10	445	580	6									
	10	16	400	530	7									
	C 25 M2	16	25	370	510		8							
25		40	350	490	9									
40		100	230	440	10									
	100	250	To be agreed				To be agreed							
C 30		5	520	650	5	170	260	510	20	400	600 to 750	18	30	40
C 30 E4	5	10	475	610	6									
	10	16	430	570	7									
	C 30 M2	16	25	395	550		8							
25		40	370	520	9									
40		100	250	480	9									
	100	250	To be agreed				230	460	21	To be agreed				

1	2		3			4	5			6				
Type of steel	Thickness 1)		Treatment condition on delivery 2)											
			TC3)4)			TC + TA or P + TA or G + TA	TC + TN or P + TN or G + TN			TC + TQ + TT5) or P + TQ + TT or G + TQ + TT				
	over	up to and in- cluding	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Hard- ness	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Impact energy for E4 and M2-grades KU6) KV6) J	
			N/mm ²	N/mm ²	%		HB	N/mm ²	N/mm ²	%	N/mm ²	N/mm ²		%
min.	min.	min.	min.	min.	min.	min.	min.		min.	min.				
C 35 C 35 E4 C 35 M2		5	550	680	5	183	300	550	18	430	630 to 780	17	25	35
	5	10	500	650	6									
	10	16	460	610	7		270	520	19	380	600 to 750	19	25	25
	16	25	425	590	8									
	25	40	400	560	9					320	550 to 700	20	25	35
	40	100	270	520	9									
	100	250	To be agreed											
C 40 C 40 E4 C 40 M2		5	580	720	4	197	320	580	16	460	650 to 800	16	20	30
	5	10	530	690	5									
	10	16	490	650	6		290	550	17	400	630 to 780	18	20	30
	16	25	455	630	7									
	25	40	430	600	8					350	600 to 750	19	20	30
	40	100	290	550	9									
	100	250	To be agreed											
C 45 C 45 E4 C 45 M2		5	610	750	4	207	340	620	14	490	700 to 850	14	15	25
	5	10	560	730	5									
	10	16	520	690	5		305	580	16	430	650 to 800	16	15	25
	16	25	475	660	6									
	25	40	450	640	7					370	630 to 780	17	15	25
	40	100	305	580	8									
	100	250	To be agreed											
C 50 C 50 E4 C 50 M2		5	640	790	4	217	355	650	12	520	750 to 900	13	—	—
	5	10	590	760	5									
	10	16	550	730	5		320	610	14	460	700 to 850	15	—	—
	16	25	505	700	6									
	25	40	480	680	7					400	650 to 800	16	—	—
	40	100	320	610	8									
	100	250	To be agreed											

1	2		3			4	5			6					
Type of steel	Thickness 1)		Treatment condition on delivery 2)												
	mm		TC3)4)			TC + TA or P + TA or G + TA	TC + TN or P + TN or G + TN			TC + TQ + TT ⁵⁾ or P + TQ + TT or G + TQ + TT					
	over	up to and in- cluding	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Hard- ness	Yield stress	Tensile strength	Elongation ($L_0 = 5d_0$)	Yield stress	Tensile stress	Elongation ($L_0 = 5d_0$)	Impact energy for E4 and M2 grades		
			N/mm ²	N/mm ²	%	HB	N/mm ²	N/mm ²	%	N/mm ²	N/mm ²	%	KU6) J	KV6)	
min.	min.	min.	min.	min.	min.	min.	min.		min.	min.					
C 55 C 55 E4 C 55 M2		5	670	820	4	229	370	680	11	550	800 to 950	12	—	—	
	5	10	620	800	5										
	10	16	590	780	5		330	640	12	490	750 to 900	14	—	—	
	16	25	535	740	6										
	25	40	510	720	6										
	40	100	330	640	7										
	100	250	To be agreed					300	620	12	To be agreed				
C 60 C 60 E4 C 60 M2		5	700	860	4	241	380	710	10	580	850 to 1 000	11	—	—	
	5	10	630	840	5										
	10	16	570	800	5		340	670	11	520	800 to 950	13	—	—	
	16	25	520	740	5										
	25	40	480	720	6					450	750 to 900	13	—	—	
	40	100	340	670	7										
	100	250	To be agreed					310	650	11	To be agreed				

1) See 3.4.

2) See table 10.

3) Initial treatment to be chosen by the manufacturer.

4) The mechanical properties in the cold-drawn condition can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.

5) For treatment condition TQ + TT + TC, the minimum values given in this table for elongation and impact energy are reduced to 75 %. The values for yield stress and tensile strength are in this case higher than the figures shown in this table.

6) Unless otherwise agreed, the choice between the ISO U-test piece and ISO V-test piece is left to the manufacturer. In the next edition of this part of ISO 683, only KV-values will be retained.

7) Up to 63 mm in diameter.

Table 14 — Mechanical properties of bright alloyed direct-hardening steels and steels 28 Mn 6, 36 Mn 6 and 42 Mn 6

1	2		3	4	5				
Type of steel	Thickness ¹⁾ mm		Treatment condition on delivery ²⁾						
			TC ^{3) 4)}	TC + TA or P + TA or G + TA	TC + TQ + TT ⁵⁾ or P + TQ + TT or G + TQ + TT				
	over	up to and in- cluding			Tensile strength	Hardness	Yield stress	Tensile strength	Elongation (<i>L</i> ₀ = 5 <i>d</i> ₀)
			N/mm ²	HB	N/mm ²	N/mm ²	%	KU ⁶⁾	KV ⁶⁾
			max.	max.	min.		min.	min.	
28 Mn 6		16	920	223	590	800 to 950	13	25	35
	16	40	900		490	700 to 850	15	30	40
	40	80	880		440	650 to 800	16	30	40
36 Mn 6		16	930	229	640	850 to 1 000	12	20	35
	16	40	910		540	750 to 900	14	25	40
	40	80	890		460	700 to 850	15	25	40
42 Mn 6		16	940	229	690	900 to 1 050	12	25	35
	16	40	920		590	800 to 950	14	30	40
	40	80	900		480	750 to 900	15	30	40
34 Cr 4 34 CrS 4		16	940	223	700	900 to 1 100	12	25	35
	16	40	920		590	800 to 950	14	30	40
	40	80	900		460	700 to 850	15	30	40
37 Cr 4 37 CrS 4		16	960	235	750	950 to 1 150	11	20	30
	16	40	940		630	850 to 1 000	13	25	35
	40	80	920		510	750 to 900	14	25	35
41 Cr 4 41 CrS 4		16	980	241	800	1 000 to 1 200	11	20	30
	16	40	960		660	900 to 1 100	12	25	35
	40	80	940		560	800 to 950	14	25	35
25 CrMo 4 25 CrMoS 4		16	880	212	700	900 to 1 100	12	30	45
	16	40	860		600	800 to 950	14	35	50
	40	80	840		450	700 to 850	15	35	50
34 CrMo 4 34 CrMoS 4		16	940	223	800	1 000 to 1 200	11	25	35
	16	40	920		650	900 to 1 100	12	30	40
	40	80	900		550	800 to 950	14	30	45
42 CrMo 4 42 CrMoS 4		16	980	241	900	1 100 to 1 300	10	20	30
	16	40	960		750	1 000 to 1 200	11	25	35
	40	80	940		650	900 to 1 100	12	25	35
50 CrMo 4		16	1 050	248	900	1 100 to 1 300	9	15 ⁷⁾	30 ⁷⁾
	16	40	990		780	1 000 to 1 200	10	20 ⁷⁾	30 ⁷⁾
	40	80	970		700	900 to 1 100	12	20 ⁷⁾	30 ⁷⁾

1	2		3	4	5				
Type of steel	Thickness ¹⁾ mm		Treatment condition on delivery ²⁾						
			TC ³⁾⁴⁾	TC + TA or P + TA or G + TA	TC + TQ + TT ⁵⁾ or P + TQ + TT or G + TQ + TT				
	over	up to and in- cluding			Tensile strength N/mm ²	Hardness HB	Yield stress N/mm ²	Tensile strength N/mm ²	Elongation (L ₀ = 5d ₀) %
			max.	max.	min.		min.	min.	
	36 CrNiMo 4		16	1 000	248	900	1 100 to 1 300	10	25
16		40	980	800		1 000 to 1 200	11	30	40
40		80	960	700		900 to 1 100	12	30	45
36 CrNiMo 6		16	1 000	248	1 000	1 200 to 1 400	9	20	35
	16	40	980		900	1 100 to 1 300	10	25	45
	40	80	960		800	1 000 to 1 200	11	30	45
31 CrNiMo 8		16	1 000	248	850	1 030 to 1 230	12	35	30
	16	40	980		850	1 030 to 1 230	12	35	30
	40	80	960		800	980 to 1 180	12	35	35
51 CrV		16	1 050	248	900	1 100 to 1 300	9	15 ⁷⁾	30 ⁷⁾
	16	40	990		800	1 000 to 1 200	10	20 ⁷⁾	30 ⁷⁾
	40	80	970		700	900 to 1 100	12	20 ⁷⁾	30 ⁷⁾

1) See 3.4.

2) See table 10.

3) Initial treatment to be chosen by the manufacturer.

4) The mechanical properties in the cold-drawn condition can vary as a function of the initial properties of the bars and on the amount of cold drawing. Therefore, these values shall be considered to be applicable, unless otherwise agreed.

5) For treatment condition TQ + TT + TC, the minimum values given in this table for elongation, and impact energy are reduced to 75 %. The values for yield stress and tensile strength are in this case higher than the figures shown in this table.

6) Unless otherwise agreed, the choice between the ISO U-test piece and ISO V-test piece is left to the manufacturer. In the next edition of this part of ISO 683, only KV-values will be retained.

7) Tentative values.

Table 15 — Hardness limits for steel types with specified (normal) hardenability (H-grades, see 8.2.3)

Type of steel	Quenching temperature °C	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of test piece of															
			1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30
C 35 E4 H ¹⁾	870 ± 5	max.	58	57	55	53	49	41	34	31	28	27	26	25	24	23	20	—
C 35 M2 H ¹⁾		min.	48	40	33	24	22	20	—	—	—	—	—	—	—	—	—	—
C 40 E4 H ¹⁾	870 ± 5	max.	60	60	59	57	53	47	39	34	31	30	29	28	27	26	25	24
C 40 M2 H ¹⁾		min.	51	46	35	27	25	24	23	22	21	20	—	—	—	—	—	—
C 45 E4 H ¹⁾	850 ± 5	max.	62	61	61	60	57	51	44	37	34	33	32	31	30	29	28	27
C 45 M2 H ¹⁾		min.	55	51	37	30	28	27	26	25	24	23	22	21	20	—	—	—
C 50 E4 H ¹⁾	850 ± 5	max.	63	62	61	60	58	55	50	43	36	35	34	33	32	31	29	28
C 50 M2 H ¹⁾		min.	56	53	44	34	31	30	30	29	28	27	26	25	24	23	20	—
C 55 E4 H ¹⁾	830 ± 5	max.	65	64	63	62	60	57	52	45	37	36	35	34	33	32	30	29
C 55 M2 H ¹⁾		min.	58	55	47	37	33	32	31	30	29	28	27	26	25	24	22	20
C 60 E4 H ¹⁾	830 ± 5	max.	67	66	65	63	62	59	54	47	39	37	36	35	34	33	31	30
C 60 M2 H ¹⁾		min.	60	57	50	39	35	33	32	31	30	29	28	27	26	25	23	21

1) The hardenability values for these 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.

Type of steel	Quenching temperature °C	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of test piece of														
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
28 Mn 6 H	850 ± 5	max.	54	53	50	48	44	41	38	35	31	29	27	26	25	25	24
		min.	45	42	36	27	21	—	—	—	—	—	—	—	—	—	—
36 Mn 6 H	840 ± 5	max.	59	58	57	54	49	45	41	38	35	33	31	30	30	30	30
		min.	51	48	42	35	27	23	20	—	—	—	—	—	—	—	—
42 Mn 6 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	—	—	—	—
34 Cr 4 H 34 CrS 4 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 H 37 CrS 4 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 H 41 CrS 4 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	—	—	—
25 CrMo 4 H 25 CrMoS 4 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 H 34 CrMoS 4 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 H 42 CrMoS 4 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
50 CrMo 4 H	850 ± 5	max.	65	65	64	64	63	63	63	62	61	60	58	57	55	54	54
		min.	58	58	57	55	54	53	51	48	45	41	39	38	37	36	36
36 CrNiMo 4 H	850 ± 5	max.	59	59	58	58	57	57	57	56	55	54	53	52	51	50	49
		min.	51	50	49	49	48	47	46	45	43	41	39	38	36	34	33
36 CrNiMo 6 H	845 ± 5	max.	58	58	58	58	57	57	57	57	57	57	57	57	57	57	57
		min.	50	50	50	50	49	48	48	48	48	47	47	47	46	45	44
31 CrNiMo 8 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
51 CrV 4 H	850 ± 5	max.	65	65	64	64	63	62	62	61	60	58	57	55	54	53	53
		min.	57	56	55	54	53	52	50	48	44	41	37	35	34	33	32

Table 16 — Tentative hardness limits for unalloyed steel types with narrowed hardenability scatterbands (HH and HL-grades)

Type of steel	Quenching temperature °C	Tentative values of hardness HRC at a distance, in millimetres, from quenched end of test piece of		
		1	4	5
C 35 E4 HH4, C 35 M2 HH4 C 35 E4 HH14, C 35 M2 HH14	870 ± 5	— 51 to 58	34 to 53 34 to 53	— —
C 35 E4 HL4, C 35 M2 HL4 C 35 E4 HL14, C 35 M2 HL14	870 ± 5	— 48 to 55	24 to 43 24 to 43	— —
C 40 E4 HH4, C 40 M2 HH4 C 40 E4 HH14, C 40 M2 HH14	870 ± 5	— 54 to 60	38 to 57 38 to 57	— —
C 40 E4 HL4, C 40 M2 HL4 C 40 E4 HL14, C 40 M2 HL14	870 ± 5	— 51 to 57	27 to 46 27 to 46	— —
C 45 E4 HH4, C 45 M2 HH4 C 45 E4 HH14, C 45 M2 HH14	850 ± 5	— 57 to 62	41 to 60 41 to 60	— —
C 45 E4 HL4, C 45 M2 HL4 C 45 E4 HL14, C 45 M2 HL14	850 ± 5	— 55 to 60	30 to 49 30 to 49	— —
C 50 E4 HH5, C 50 M2 HH5 C 50 E4 HH15, C 50 M2 HH15	850 ± 5	— 58 to 63	— —	40 to 58 40 to 58
C 50 E4 HL5, C 50 M2 HL5 C 50 E4 HL15, C 50 M2 HL15	850 ± 5	— 56 to 61	— —	31 to 49 31 to 49
C 55 E4 HH5, C 55 M2 HH5 C 55 E4 HH15, C 55 M2 HH15	830 ± 5	— 60 to 65	— —	42 to 60 42 to 60
C 55 E4 HL5, C 55 M2 HL5 C 55 E4 HL15, C 55 M2 HL15	830 ± 5	— 58 to 63	— —	33 to 51 33 to 51
C 60 E4 HH5, C 60 M2 HH5 C 60 E4 HH15, C 60 M2 HH15	830 ± 5	— 62 to 67	— —	44 to 62 44 to 62
C 60 E4 HL5, C 60 M2 HL5 C 60 E4 HL15, C 60 M2 HL15	830 ± 5	— 60 to 65	— —	35 to 53 35 to 53

Table 17 — Hardness limits for steels with a manganese range of 1,30 % (m/m) to 1,65 % (m/m) and for alloyed steels with narrowed hardenability scatterbands (HH and HL-grades)

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

Type of steel	Quenching temperature °C	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of test piece of														
			1,5	3	5	7	9	11	13	15	20	25	30	35	40	45	50
34 CrMo 4 HH 34 CrMoS 4 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
34 CrMo 4 HL 34 CrMoS 4 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 HH 42 CrMoS 4 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 HL 42 CrMoS 4 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
50 CrMo 4 HH	850 ± 5	max.	65	65	64	64	63	63	63	62	61	60	58	57	55	54	54
		min.	60	60	59	58	57	56	55	53	50	47	45	44	43	42	42
50 CrMo 4 HL	850 ± 5	max.	63	63	62	61	60	60	59	57	56	54	52	51	49	48	48
		min.	58	58	57	55	54	53	51	48	45	41	39	38	37	36	36
36 CrNiMo 4 HH	850 ± 5	max.	59	59	58	58	57	57	57	56	55	54	53	52	51	50	49
		min.	54	53	52	52	51	50	50	49	47	45	44	43	41	39	38
36 CrNiMo 4 HL	850 ± 5	max.	56	56	55	55	54	54	53	52	51	50	48	47	46	45	44
		min.	51	50	49	49	48	47	46	45	43	41	39	38	36	34	33
36 CrNiMo 6 HH	845 ± 5	max.	58	58	58	58	57	57	57	57	57	57	57	57	57	57	57
		min.	53	53	53	53	52	51	51	51	51	50	50	50	50	49	48
36 CrNiMo 6 HL	845 ± 5	max.	55	55	55	55	54	54	54	54	54	54	54	54	53	53	53
		min.	50	50	50	50	49	48	48	48	48	47	47	47	46	45	44
31 CrNiMo 8 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 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
51 CrV 4 HH	850 ± 5	max.	65	65	64	64	63	62	62	61	60	58	57	55	54	53	53
		min.	60	59	58	57	56	55	54	52	49	47	44	42	41	40	39
51 CrV 4 HL	850 ± 5	max.	62	62	61	61	60	59	58	57	55	52	50	48	47	46	46
		min.	57	56	55	54	53	52	50	48	44	41	37	35	34	33	32