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

Part 3:  
**Case-hardening steels**

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

*Partie 3: Aciers pour cémentation*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

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

This fourth edition cancels and replaces the third edition (ISO 683-3:2019), which has been technically revised. The main changes are as follows:

- steel grades 23MnCrMo5-5-4 and 17NiCrMoS6-4 have been added;
- the lower silicon content in [Table 3](#) has been deleted and replaced by a new option in [Clause A.4](#).

A list of all parts in the ISO 683 series can be found on the ISO website.

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

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

## Part 3: Case-hardening steels

### 1 Scope

This document specifies the technical delivery requirements for

- semi-finished products, hot formed (e.g. blooms, billets, slabs) (see NOTE 1),
- bars (see NOTE 1),
- wire rod,
- finished flat products, and
- hammer or drop forgings (see NOTE 1)

manufactured from the case-hardening non-alloy or alloy steels listed in Table 3 and supplied in one of the heat-treatment conditions given for the different types of products in Table 1 and in one of the surface conditions given in Table 2.

The steels are, in general, intended for the manufacture of case-hardened machine parts.

NOTE 1 Hammer-forged semi-finished products (blooms, billets, slabs, etc.), seamless rolled rings and hammerforged bars are covered under semi-finished products or bars and not under the term “hammer and drop forgings”.

NOTE 2 For International Standards relating to steels conforming with the requirements for the chemical composition in Table 3, however, supplied in other product forms or treatment conditions than given above or intended for special applications, and for other related International Standards, see the Bibliography.

### 2 Normative references

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

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

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

ISO 642:1999, *Steel — Hardenability test by end quenching (Jominy test)*

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

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

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

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

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

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

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

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

ISO 6929, *Steel products — Vocabulary*

ISO 7788, *Steel — Surface finish of hot-rolled plates and wide flats — Delivery requirements*

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

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

ISO 10474, *Steel and steel products — Inspection documents*

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

### 3 Terms and definitions

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

NOTE For deviations from these terms and definitions, see NOTE 1 of the Scope and footnote b of [Table 2](#).

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **case-hardening steel**

steel with a relatively low carbon content, which are carburized or carbonitrided on their surface and subsequently hardened

Note 1 to entry: These steels, after hardening, have a high degree of hardness in the surface zone and good resistance to wear, while the core material is characterized principally by extreme toughness.

Note 2 to entry: Further possibilities for heat treatment of case-hardening steels are, for example, nitrocarburizing and nitriding.

#### 3.2

##### **non-alloy steel**

as defined in ISO 4948-1

#### 3.3

##### **alloy steel**

as defined in ISO 4948-1

## 4 Classification and designation

### 4.1 Classification

The classification of the relevant steel grades is in accordance with ISO 4948-1 and ISO 4948-2. Steel grades C10E, C10R, C15E, C15R, C16E, C16R and 22Mn6 are non-alloy special steels. All other steel grades covered by this document are alloy special steels.



## 4.2 Designation

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

A comparison between the designation of steels given in this document with various designation systems is given in [Annex B](#).

## 5 Information to be supplied by the purchaser

### 5.1 Mandatory information

The following information shall be supplied by the purchaser at the time of enquiry and order:

- a) quantity to be delivered;
- b) designation of the product form (slab, bloom, billet, round bar, square or hexagonal bar, wire rod, wide flats, sheet, plate, strip, forging, etc.);
- c) either the designation of the dimensional standard(s) and the dimensions and tolerances selected from this or these (see [7.8](#)) or, for example, in the case of drop forgings, the designation of the drawing or any other document covering the dimensions and tolerances required for the product;
- d) a reference to this document, i.e. ISO 683-3;
- e) the designation of the steel type given in [Table 3](#);
- f) standard designation for a test report 2.2 or, if required, any other type of inspection document in accordance with ISO 10474 or another equivalent standard, e.g. EN 10204 or JIS G 0415.

### 5.2 Options and/or supplementary or special requirements

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

- a) if a heat-treatment condition other than the untreated condition is required, the symbol for this other condition (see [Table 1](#), column 2);
- b) if a surface condition other than “hot worked” or a special surface quality is required, the surface condition (see [Table 2](#)) and the surface quality (see [7.7.3](#));
- c) any requirement for restricted hardenability scatter bands for alloy steels (+HH, +HL; see [7.1.1](#), [Table 6](#) and [Figure 1](#));
- d) if any supplementary requirement shall be complied with, the symbol and, where necessary, the details of this supplementary requirement in accordance with [Annex A](#);
- e) any requirement for the verification of non-metallic inclusion content (see [7.5](#));
- f) verification of hardenability and, if agreed, the information about calculation of the hardenability (see [9.2.2](#));
- g) any requirement concerning suitability of bars and rod for bright drawing (see [7.7.4](#));
- h) any requirement relating to removal of surface defects (see [7.7.5](#)).

### 5.3 Ordering example

EXAMPLE 50 hot-rolled round bars in accordance with ISO 1035-1 with a nominal diameter of 40 mm and a nominal length of 8 000 mm with diameter tolerance according to class S and with length tolerance according to class L2 of ISO 1035-4 made of steel grade ISO 683-3, 20MnCr5 (see Table 3) in the heat-treatment condition annealed (+A), surface blast cleaned (+BC) (see Table 2), product analysis/option A.3 with an inspection certificate 3.1 in accordance with ISO 10474.

50 Round bars ISO 1035 – 40,0S × 8 000L2  
ISO 683-3 – 20MnCr5+A+BC, Option A.3  
ISO 10474 – 3.1

## 6 Manufacturing process

### 6.1 General

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

For minimum reduction ratio or minimum thickness deformation ratio of rolled and forged products, see Clause A.5.

### 6.2 Deoxidation

All steels shall be fully deoxidized.

### 6.3 Heat-treatment condition and surface condition at delivery

#### 6.3.1 Normal condition at delivery

Unless otherwise agreed at the time of enquiry and order, the products shall be delivered in the untreated condition, i.e. hot-worked condition.

#### 6.3.2 Particular heat-treatment condition

If so agreed at the time of enquiry and order, the products shall be delivered in one of the heat-treatment conditions given in Table 1, row numbers 3 to 8.

#### 6.3.3 Particular surface conditions

If so agreed at the time of enquiry and order, the products shall be delivered in one of the particular surface conditions given in Table 2, row numbers 3 to 6.

### 6.4 Traceability of the cast

The products shall be traceable to the cast, see Clause 10.

## 7 Requirements

### 7.1 Chemical composition, hardness and hardenability

#### 7.1.1 General

Table 1 gives a survey on combinations of usual heat-treatment conditions at delivery, product forms and requirements as specified in Tables 3 to 7 (chemical composition, hardenability, maximum hardness and hardness range).

In special cases, variations in these technical delivery requirements or additions to them can form the subject of an agreement at the time of enquiry and order (see 5.2 and Annex A).

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

### 7.1.2 Hardenability

Unless otherwise agreed for alloy steels, the hardenability requirements given in Table 5 apply. If agreed at the time of enquiry and order, alloy steels with restricted hardenability scatter bands given in Table 6 or shown in Figure 1 shall be supplied.

A classification of steel grades according to minimum tensile strength as a function of diameter after hardening and tempering is given in Annex C.

### 7.1.3 Chemical composition

The chemical composition determined by cast analysis shall conform with the values in Table 3.

Permissible deviations between the limiting values for cast analysis and the values for product analysis are given in Table 4.

The product analysis shall be carried out when specified, at the time of the enquiry and order (see Clause A.3).

## 7.2 Machinability

All steels are machinable in the conditions “soft-annealed”, “treated to hardness range”, “treated to ferrite/pearlite structure” and “normalized”.

Lowering the silicon content can have a negative influence on the machinability. For details on a minimum silicon content, see Clause A.4.

Where improved machinability is required, the grades with a specified sulfur range should be ordered and/or with a specific treatment to improve machinability (see also Table 3, footnote b).

## 7.3 Cold shearability

**7.3.1** 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 cold shearable in the condition “soft-annealed”.

**7.3.2** Under suitable conditions, steel grades 28Cr4, 28CrS4, 20MnCr5, 20MnCrS5, 24CrMo4, 24CrMoS4, 22CrMoS3-5, 20MoCr4, 20MoCrS4, 16NiCr4, 16NiCrS4, 18NiCr5-4, 17CrNi6-6, 15NiCr13, 17NiCrMo6-4, 23MnCrMo5-5-4 and 18CrNiMo7-6, are also cold shearable when delivered in the condition “treated to improve shearability” with the hardness requirements given in Table 7.

**7.3.3** Under suitable conditions, the non-alloy steels and steels 17Cr3, 17CrS3, 20Cr4, 20CrS4, 16MnCr5, 16MnCrS5, 16MnCrB5, 18CrMo4, 18CrMoS4, 20NiCrMo2-2 and 20NiCrMoS2-2 are cold shearable when delivered in the untreated condition.

## 7.4 Grain size

Unless otherwise agreed at the time of enquiry and order, the steel shall show a fine grain structure with an austenitic grain size of 5 and finer, when tested in accordance with ISO 643. For verification, see Clause A.1.

## 7.5 Non-metallic inclusions

### 7.5.1 Microscopic inclusions

The special steels shall have a certain degree of cleanness. However, verification of the non-metallic inclusion content requires a special agreement. If there is such an agreement at the time of enquiry and order, the microscopic non-metallic inclusion content shall be determined to an agreed procedure and within agreed limits in accordance with ISO 4967 or another equivalent standard.

For grades with specified minimum sulfur content, the agreement should not include sulfides.

### 7.5.2 Macroscopic inclusions

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

## 7.6 Internal soundness

Where appropriate, requirements relating to the internal soundness of the products shall be agreed at the time of enquiry and order (see [Clause A.2](#)).

## 7.7 Surface condition

**7.7.1** All products shall have a smooth surface finish appropriate to the manufacturing processes applied.

**7.7.2** Minor surface imperfections which can occur under normal manufacturing conditions, such as prints originating from rolled-in scale, shall not be regarded as defects.

**7.7.3** Bars and wire rod are delivered with surface class A in accordance with ISO 9443 and hot-rolled plates and wide flats shall be delivered with a surface in accordance with ISO 7788, unless otherwise agreed at the time of enquiry and order.

Where no International Standard on the surface quality of steel products exists, and where appropriate, detailed requirements referring to this characteristic shall be agreed at the time of enquiry and order.

It is more difficult to detect and eliminate surface discontinuities from coiled products than from cut lengths. This should be taken into account when agreements on surface quality are made.

NOTE Bars and wire rod for cold heading and cold extrusion are covered fully by ISO 4954.

**7.7.4** If suitability of bars and rod for bright drawing is required, this shall be agreed at the time of enquiry and order.

**7.7.5** Removal of surface discontinuities by welding shall only be permitted with the approval of the customer or his or her representative. If surface discontinuities are repaired, the method and maximum depth of removal shall be agreed at the time of enquiry and order.

## 7.8 Shape, dimensions and tolerances

The nominal dimensions, tolerances on dimensions and shape of the product shall be agreed at the time of enquiry and order, if possible, with reference to the dimensional standards listed in the Bibliography.

## 8 Inspection

### 8.1 Testing procedures and types of documents

**8.1.1** Products complying with this document shall be ordered and delivered with one of the inspection documents as specified in ISO 10474 or another equivalent standard (e.g. EN 10204 or JIS G 0415). The type of document shall be agreed at the time of enquiry and order. If the order does not contain any specification of this type, a test report shall be issued.

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

- a) confirmation that the material complies with the requirements of the order;
- b) results of the cast analysis for all elements specified in [Table 3](#) for the steel grade concerned.

**8.1.3** If, in accordance with the agreements in the order, an inspection certificate 3.1 or 3.2 is to be provided, the specific inspections and tests described in [8.3](#) and [Clause 9](#) shall be carried out and the results shall be confirmed in the inspection certificate.

In addition, the inspection certificate shall cover the following:

- a) confirmation that the material complies with the requirements of the order;
- b) results of the cast analysis for all elements specified in [Table 3](#) for the steel grade concerned;
- c) results of all inspections and tests ordered by supplementary requirements (see [Annex A](#));
- d) the symbol, letters or numbers relating the test certificates, the test pieces and products to each other.

### 8.2 Frequency of testing

The amount of testing, the sampling conditions and the test methods to be applied for the verification of the requirements shall be in accordance with [Table 9](#).

### 8.3 Tests to be carried out for specific inspection

#### 8.3.1 General

For non-alloy steels and for alloy steels without requirements concerning the verification of hardenability, the hardness requirements according to [Table 1](#), columns 8.2 and 9.2 and [Table 7](#) shall be verified.

For alloy steels being ordered with the verification of hardenability, only the hardenability requirements according to [Tables 5](#) and [6](#) shall be verified, unless otherwise agreed.

#### 8.3.2 Visual and dimensional inspection

The extent of the products to be inspected to ensure compliance with this document is at the manufacturer's discretion.

## 9 Test methods

### 9.1 Chemical analysis

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

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

### 9.2 Hardness and hardenability tests

#### 9.2.1 Verification of hardness

For products in the heat-treatment conditions +S (treated to improve shearability), +A (soft-annealed), +TH (treated to hardness range), +FP (treated to ferritic-pearlitic structure) and +N (normalized), the hardness shall be measured in accordance with ISO 6506-1 (see [Tables 7 and 9](#)).

#### 9.2.2 Verification of hardenability

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

If a calculation formula is not available or in case of dispute, an end quench hardenability test shall be carried out in accordance with ISO 642 and [Table 9](#). The temperature for quenching shall conform with [Table 8](#). The hardness values shall be determined in accordance with ISO 6508-1 scale C.

### 9.3 Retests

Retests of case hardening steels and criteria shall be as specified in ISO 404.

## 10 Marking

The manufacturer shall mark the products or the bundles or boxes containing the products in a suitable way so that it is possible to identify the cast, steel type and origin of the delivery (see [Clause A.6](#)).

**Table 1 — Combinations of usual heat-treatment conditions at delivery, product forms and requirements according to [Tables 3 to 7](#)**

No.	1	2	3	4	5	6	7	8		9			
1	Heat-treatment condition at delivery	Symbol	Applicable to					Applicable requirements					
			semi-finished products	bars	wire rod	flat products	hammer and drop forgings	Non-alloy steel grades		Alloy steel grades			
								8.1	8.2	9.1	9.2	9.3	
2	Untreated	None or +U	x	x	x	x	x	Chemical composition according to <a href="#">Tables 3 and 4</a>	—	As in column 8 (see footnote <sup>b</sup> to <a href="#">Table 3</a> )	Hardenability values according to <a href="#">Table 5</a> or <a href="#">6</a>	If option <a href="#">5.2 f</a> ) is ordered, the verification of hardenability and, if agreed, the information about calculation of the hardenability (see <a href="#">9.2.2</a> )	
3	Treated to improve shearability	+S	x	x	—	—	—						Column +S
4	Soft-annealed	+A	x	x	x	x	x						Column +A
5	Treated to hardness range	+TH	—	x	x	x	x						Column +TH
6	Treated to ferrite-pearlite structure <sup>a</sup>	+FP	—	x	—	—	x						Column +FP
7	Normalized or normalizing forming	+N	—	x	—	x	—						Column +N
8	Others	Other treatment conditions, for example certain annealing conditions to achieve a certain structure, may be agreed at the time of enquiry and order. The condition “annealed to achieve a spheroidization of the carbides (+AC)”, as required for cold heading and cold extrusion, is covered in ISO 4954.											
<sup>a</sup> For products of certain grades, a 100 % ferrite-pearlitic structure cannot be achieved, despite an adapted heat-treatment, e.g. isothermal tempering in bars of 18CrNiMo7-6 gives F+P+B structure at any time.													

Table 2 — Surface condition at delivery

No.	1	2	3	4	5	6	7	8	9
1	Surface condition at delivery		Symbol	In general, applicable to				Notes	
				semi-finished products (as blooms, billets)	bars	wire rod	flat products		hammer and drop forgings <sup>a</sup>
2	Unless otherwise agreed	Hot worked	None or +HW	x <sup>b</sup>	x	x	x	x	—
3	Particular conditions supplied by agreement	Hot worked and pickled	+PI	x	x	x	x	x	— <sup>d</sup>
4		Hot worked and blast cleaned	+BC	x	x	x	x	x	
5		Hot worked and rough machined	+RM <sup>c</sup>	—	x	x	—	x	
6		Others	—	—	x	x	x	x	

<sup>a</sup> See NOTE 1 to Clause 1.

<sup>b</sup> The term “hot worked” also includes the continuously cast (+CC) condition in the case of semi-finished products.

<sup>c</sup> Since machine allowances for the term “rough machined” are not yet fixed, the details are to be agreed at the time of enquiry and order.

<sup>d</sup> In addition, certain surface treatments, such as oiled, limed or phosphated, may be agreed on.



Table 3 — Steel grades and chemical composition (applicable to cast analysis)<sup>a,b,c</sup>

Steel name	Mass fraction <sup>d</sup> %								
	C	Si	Mn	P	S	Cr	Mo	Mn, Cu and B	
Non-alloy steels									
C10E	0,07 to 0,13	0,40	0,30 to 0,60	0,025	0,035	0,40	0,10	0,40	Cu: 0,30
C10R					0,020 to 0,040				
C15E	0,12 to 0,18	0,40	0,30 to 0,60	0,025	0,035	0,40	0,10	0,40	Cu: 0,30
C15R					0,020 to 0,040				
C16E	0,12 to 0,18	0,40	0,60 to 0,90	0,025	0,035	0,40	0,10	0,40	Cu: 0,30
C16R					0,020 to 0,040				
22Mn6	0,18 to 0,25	0,40	1,30 to 1,65	0,025	0,035	0,40	0,10	0,40	Cu: 0,30
Alloy steels									
17Cr3	0,12 to 0,20	0,40	0,60 to 0,90	0,025	0,035	0,70 to 1,25	—	—	Cu: 0,40
17CrS3					0,020 to 0,040				
20Cr4	0,17 to 0,23	0,40	0,60 to 0,90	0,025	0,035	0,90 to 1,20	—	—	Cu: 0,40
20CrS4					0,020 to 0,040				
28Cr4	0,24 to 0,31	0,40	0,60 to 0,90	0,025	0,035	0,90 to 1,20	—	—	Cu: 0,40
28CrS4					0,020 to 0,040				
16MnCr5	0,14 to 0,19	0,40	1,00 to 1,30	0,025	0,035	0,80 to 1,10	—	—	Cu: 0,40
16MnCrS5					0,020 to 0,040				
16MnCrB5	0,14 to 0,19	0,40	1,00 to 1,30	0,025	0,035	0,80 to 1,10	—	—	Cu: 0,40 B: 0,0008 to 0,0050 <sup>e</sup>
20MnCr5	0,17 to 0,22	0,40	1,10 to 1,40	0,025	0,035	1,00 to 1,30	—	—	Cu: 0,40
20MnCrS5					0,020 to 0,040				
18CrMo4	0,15 to 0,21	0,40	0,60 to 0,90	0,025	0,035	0,90 to 1,20	0,15 to 0,25	—	Cu: 0,40
18CrMoS4					0,020 to 0,040				
24CrMo4	0,20 to 0,27	0,40	0,60 to 0,90	0,025	0,035	0,90 to 1,20	0,15 to 0,30	—	Cu: 0,40
24CrMoS4					0,020 to 0,040				

<sup>a</sup> For steels with hardenability requirements (see Tables 5 and 6), except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. However, these deviations shall not exceed in the case of carbon  $\pm 0,01$  % and, in all other cases, the values according to Table 4.

<sup>b</sup> Steels with improved machinability either by higher sulfur levels up to about 0,10 % S (including controlled sulfide morphology) or lead additions may be supplied on request. In the first case, the upper limit of the manganese content may be increased by 0,15 %.

<sup>c</sup> Additional case-hardening steels, predominantly used for bearings, are covered by ISO 683-17.

<sup>d</sup> Maximum values unless otherwise stated.

<sup>e</sup> In this case, boron is added not for increase of hardenability, but to improve the toughness of the case-hardened zone.

Table 3 (continued)

Steel name	Mass fraction <sup>d</sup> %								
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu and B
22CrMoS3-5	0,19 to 0,24	0,40	0,70 to 1,00	0,025	0,020 to 0,040	0,70 to 1,00	0,40 to 0,50	—	Cu: 0,40
20MoCr4	0,17 to 0,23	0,40	0,70 to 1,00	0,025	0,035	0,30 to 0,60	0,40 to 0,50	—	Cu: 0,40
20MoCrS4					0,020 to 0,040				
16NiCr4	0,13 to 0,19	0,40	0,70 to 1,00	0,025	0,035	0,60 to 1,00	—	0,80 to 1,10	Cu: 0,40
16NiCrS4					0,020 to 0,040				
18NiCr5-4	0,16 to 0,21	0,40	0,60 to 0,90	0,025	0,035	0,90 to 1,20	—	1,20 to 1,50	Cu: 0,40
17CrNi6-6	0,14 to 0,20	0,40	0,50 to 0,90	0,025	0,035	1,40 to 1,70	—	1,40 to 1,70	Cu: 0,40
15NiCr13	0,12 to 0,18	0,40	0,35 to 0,65	0,025	0,035	0,60 to 0,90	—	3,00 to 3,50	Cu: 0,40
20NiCrMo2-2	0,17 to 0,23	0,40	0,65 to 0,95	0,025	0,035	0,35 to 0,70	0,15 to 0,25	0,40 to 0,70	Cu: 0,40
20NiCrMoS2-2					0,020 to 0,040				
17NiCrMo6-4	0,14 to 0,20	0,40	0,60 to 0,90	0,025	0,035	0,80 to 1,10	0,15 to 0,25	1,20 to 1,60	Cu: 0,40
17NiCrMoS6-4					0,020 to 0,040				
23MnCrMo5-5-4	0,20 to 0,25	0,40	1,10 to 1,40	0,025	0,035	1,10 to 1,40	0,20 to 0,50	0,60	Cu: 0,40
18CrNiMo7-6	0,15 to 0,21	0,40	0,50 to 0,90	0,025	0,035	1,50 to 1,80	0,25 to 0,35	1,40 to 1,70	Cu: 0,40
<p>Elements not quoted in this table shall 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 shall be taken to prevent the addition of such elements from scrap or other materials used in manufacture, which affect the hardenability, mechanical properties and applicability.</p> <p><sup>a</sup> For steels with hardenability requirements (see <a href="#">Tables 5 and 6</a>), except for phosphorus and sulfur, insignificant deviations from the limits for cast analysis are permissible. However, these deviations shall not exceed in the case of carbon <math>\pm 0,01</math> % and, in all other cases, the values according to <a href="#">Table 4</a>.</p> <p><sup>b</sup> Steels with improved machinability either by higher sulfur levels up to about 0,10 % S (including controlled sulfide morphology) or lead additions may be supplied on request. In the first case, the upper limit of the manganese content may be increased by 0,15 %.</p> <p><sup>c</sup> Additional case-hardening steels, predominantly used for bearings, are covered by ISO 683-17.</p> <p><sup>d</sup> Maximum values unless otherwise stated.</p> <p><sup>e</sup> In this case, boron is added not for increase of hardenability, but to improve the toughness of the case-hardened zone.</p>									

**Table 4 — Permissible deviations between the product analysis and the limiting values given in Table 3 for the cast analysis**

Element	Permissible maximum content or range according to cast analysis	Permissible deviation <sup>a</sup>
	mass fraction %	mass fraction <sup>a</sup> %
C	$0,07 < C \leq 0,31$	$\pm 0,02$
Si	$\leq 0,40$	$\pm 0,03$
Mn	$\leq 1,00$	$\pm 0,04$
	$1,00 < Mn \leq 1,65$	$\pm 0,06$
P	$\leq 0,05$	$+0,005$
S	$\leq 0,040$	$\pm 0,005$
Cr	$\leq 1,80$	$\pm 0,05$
Mo	$\leq 0,30$	$\pm 0,03$
	$0,30 < Mo \leq 0,50$	$\pm 0,04$
Ni	$\leq 1,00$	$\pm 0,03$
	$1,00 < Ni \leq 2,00$	$\pm 0,05$
	$2,00 < Ni \leq 3,50$	$\pm 0,07$
Cu	$\leq 0,40$	$+0,05$
B	$\leq 0,005 0$	$\pm 0,000 3$

<sup>a</sup>  $\pm$  means that, in one cast, the deviation can occur over the upper value or under the lower value of the specified range in Table 3, but not both at the same time.

**Table 5 — Hardness limits for steel grades with specified (normal) hardenability (+H-grades; see 7.1.1)**

Steel name	Symbol	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of a test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
17Cr3 17CrS3	+H	max.	47	44	40	33	29	27	25	24	23	21	—	—	
		min.	39	35	25	20	—	—	—	—	—	—	—	—	
20Cr4 20CrS4	+H	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
		min.	41	38	31	26	23	—	—	—	—	—	—	—	—
28Cr4 28CrS4	+H	max.	53	52	51	49	45	42	39	36	33	30	29	28	27
		min.	45	43	39	34	25	22	20	—	—	—	—	—	—
16MnCr5 16MnCrS5 16MnCrB5	+H	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
		min.	35	33	31	28	24	21	—	—	—	—	—	—	—
20MnCr5 20MnCrS5	+H	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	-	-	-
18CrMo4 18CrMoS4	+H	max.	47	46	45	42	39	37	35	34	31	29	28	27	26
		min.	39	37	34	30	27	24	22	21	—	—	—	—	—
24CrMo4 24CrMoS4	+H	max.	52	52	51	50	48	46	43	41	37	35	33	32	31
		min.	44	43	40	37	34	32	29	27	23	21	20	—	—
22CrMoS3-5	+H	max.	50	49	48	47	45	43	41	40	37	35	34	33	32
		min.	42	41	37	33	31	28	26	25	23	22	21	20	—
20MoCr4 20MoCrS4	+H	max.	49	47	44	41	38	35	33	31	28	26	25	24	24
		min.	41	37	31	27	24	22	—	—	—	—	—	—	—
16NiCr4 16NiCrS4	+H	max.	47	46	44	42	40	38	36	34	32	30	29	28	28
		min.	39	36	33	29	27	25	23	22	20	—	—	—	—
18NiCr5-4	+H	max.	49	48	46	44	42	39	37	36	34	32	31	31	30
		min.	41	39	35	32	29	27	25	24	21	20	—	—	—
17CrNi6-6	+H	max.	47	47	46	45	43	42	41	39	37	35	34	34	33
		min.	39	38	36	35	32	30	28	26	24	22	21	20	20
15NiCr13	+H	max.	46	46	46	46	45	44	43	41	38	35	34	34	33
		min.	38	37	36	34	31	29	27	26	24	22	22	21	21
20NiCrMo2-2 20NiCrMoS2-2	+H	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—
17NiCrMo6-4 17NiCrMoS6-4	+H	max.	48	48	47	46	45	44	42	41	38	36	35	34	33
		min.	40	39	37	34	30	28	27	26	24	23	22	21	—
23MnCr- Mo5-5-4	+H	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
18CrNiMo7-6	+H	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

**Table 6 — Hardness limits for steels with narrowed hardenability scatterbands  
(+HH and +HL grades)**

Steel name	Symbol	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of a test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	40
17Cr3 17CrS3	+HH	max.	47	44	40	33	29	27	25	24	21	—	—	—	
		min.	42	38	30	24	20	—	—	—	—	—	—	—	
	+HL	max.	44	41	35	29	25	21	20	—	—	—	—	—	
		min.	39	35	25	20	—	—	—	—	—	—	—	—	
20Cr4 20CrS4	+HH	max.	49	48	46	42	38	36	34	32	29	27	26	24	23
		min.	44	41	36	31	28	26	24	22	—	—	—	—	—
	+HL	max.	46	45	41	37	33	31	29	27	24	22	21	—	—
		min.	41	38	31	26	23	21	—	—	—	—	—	—	—
28Cr4 28CrS4	+HH	max.	53	52	51	49	45	42	39	38	33	30	29	28	27
		min.	48	46	43	36	32	29	26	23	20	—	—	—	—
	+HL	max.	50	49	47	42	38	35	33	30	27	24	23	22	21
		min.	45	43	39	29	25	22	20	—	—	—	—	—	—
16MnCr5 16MnCrS5 16MnCrB5	+HH	max.	47	46	44	41	39	37	35	33	31	30	29	28	27
		min.	42	39	35	32	29	26	24	22	20	—	—	—	—
	+HL	max.	44	43	40	37	34	32	30	28	26	25	24	23	22
		min.	39	36	31	28	24	21	—	—	—	—	—	—	—
20MnCr5 20MnCrS5	+HH	max.	49	49	48	46	43	42	41	39	37	35	34	33	32
		min.	44	42	40	37	34	33	31	30	28	26	25	24	23
	+HL	max.	46	46	44	42	39	37	36	34	32	30	29	28	27
		min.	41	39	36	33	30	28	26	25	23	21	—	—	—
18CrMo4 18CrMoS4	+HH	max.	47	46	45	42	39	37	35	34	31	29	28	27	26
		min.	42	40	38	34	31	28	26	25	22	20	—	—	—
	+HL	max.	44	43	41	38	35	33	31	30	27	25	24	23	22
		min.	39	37	34	30	27	24	22	21	—	—	—	—	—
24CrMo4 24CrMoS4	+HH	max.	52	52	51	50	48	46	43	41	37	35	33	32	31
		min.	47	46	44	41	39	37	34	32	28	26	24	23	22
	+HL	max.	49	49	47	46	43	41	38	36	32	30	29	28	27
		min.	44	43	40	37	34	32	29	27	23	21	20	—	—
22CrMoS3-5	+HH	max.	50	49	48	47	45	43	41	40	37	35	34	33	32
		min.	45	44	41	38	36	33	31	30	28	26	25	24	23
	+HL	max.	47	46	44	42	40	38	36	35	32	31	30	29	28
		min.	42	41	37	33	31	28	26	25	23	22	21	20	—
20MoCr4 20MoCrS4	+HH	max.	49	47	44	41	38	35	33	31	28	26	25	24	24
		min.	44	40	35	32	29	26	24	22	—	—	—	—	—
	+HL	max.	46	44	40	36	33	31	29	27	24	22	21	20	20
		min.	41	37	31	27	24	22	—	—	—	—	—	—	—
16NiCr4 16NiCrS4	+HH	max.	47	46	44	42	40	38	36	34	32	30	29	28	28
		min.	42	39	37	33	31	29	27	26	24	22	21	20	20
	+HL	max.	44	43	40	38	36	34	32	30	28	26	25	24	24
		min.	39	36	33	29	27	25	23	22	20	—	—	—	—

Table 6 (continued)

Steel name	Symbol	Limit of range	Hardness HRC at a distance, in millimetres, from quenched end of a test piece of												
			1,5	3	5	7	9	11	13	15	20	25	30	35	30
18NiCr5-4	+HH	max.	49	48	46	44	42	39	37	36	34	32	31	31	30
		min.	44	42	39	36	33	31	29	28	25	24	23	23	22
	+HL	max.	46	45	42	40	38	35	33	32	28	28	27	27	26
		min.	41	39	35	32	29	27	25	24	21	20	—	—	—
17CrNi6-6	+HH	max.	47	47	46	45	43	41	39	37	35	34	34	33	
		min.	42	41	39	38	36	34	32	30	28	26	25	25	24
	+HL	max.	44	44	43	42	39	38	37	35	33	31	30	29	29
		min.	39	38	36	35	32	30	28	26	24	22	21	20	20
15NiCr13	+HH	max.	46	46	46	46	45	44	43	41	38	35	34	34	33
		min.	41	40	39	38	36	34	32	31	29	26	26	25	25
	+HL	max.	43	43	43	42	40	39	38	36	33	31	30	30	29
		min.	38	37	36	34	31	29	27	26	24	22	22	21	21
20NiCrMo2-2 20NiCrMoS2-2	+HH	max.	49	48	45	42	36	33	31	30	27	25	24	24	23
		min.	44	41	36	31	27	24	22	21	—	—	—	—	—
	+HL	max.	46	44	40	36	31	29	27	26	23	21	20	20	—
		min.	41	37	31	25	22	20	—	—	—	—	—	—	—
17NiCrMo6-4 17NiCrMoS6-4	+HH	max.	48	48	47	46	45	44	42	41	38	36	35	34	33
		min.	43	42	40	38	35	33	32	31	29	27	26	25	24
	+HL	max.	45	45	44	42	40	39	37	36	33	32	31	30	29
		min.	40	39	37	34	30	28	27	26	24	23	22	21	—
23MnCr- Mo5-5-4	+HH	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
	+HL	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
18CrNiMo7-6	+HH	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
	+HL	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

**Table 7 — Hardness requirements for products delivered in the conditions “treated to improve shearability (+S)”, “soft-annealed (+A)”, “treated to hardness range (+TH)”, “treated to ferrite-pearlite structure (+FP)” or “normalized (+N)”**

Steel name	Brinell hardness in condition							
	+S max.	+A max.	+TH min.    max.		+FP min.    max.		+N min.    max.	
Non-alloy steels								
C10E C10R	—	131	—	—	—	—	85	140
C15E C15R	—	143	—	—	—	—	95	—
C16E C16R	—	156	—	—	—	—	100	155
22Mn6	—	197	149	197	—	—	—	—
Alloy steels								
17Cr3 17CrS3	—	174	—	—	—	—	—	—
20Cr4 20CrS4	—	197	149	197	—	—	—	—
28Cr4 28CrS4	255	217	166	217	156	207	—	—
16MnCr5 16MnCrS5 16MnCrB5	—	207	156	207	140	—	138	—
20MnCr5 20MnCrS5	255	217	170	217	152	201	140	201
18CrMo4 18CrMoS4	—	207	156	207	140	—	—	—
24CrMo4 24CrMoS4	255	212	—	—	—	—	—	—
22CrMoS3-5	255	217	170	217	152	201	—	—
20MoCr4 20MoCrS4	255	207	156	207	140	—	—	—
16NiCr4 16NiCrS4	255	217	166	217	156	207	—	—
18NiCr5-4	255	223	170	223	156	207	—	—
17CrNi6-6	255	229	175	229	156	207	—	—
15NiCr13	255	229	179	229	166	217	—	—
20NiCrMo2-2 20NiCrMoS2-2	—	212	161	212	149	194	—	—
17NiCrMo6-4 17NiCrMoS6-4	255	229	179	229	149	201	—	—
23MnCrMo5-5-4	255	229	179	229	159	207	—	—
18CrNiMo7-6	255	229	179	229	159	207	—	—

Table 8 — Conditions for heat treating test bars and treatment of the steels

Steel name	End quench test austenitizing temperature <sup>a</sup>	Carburizing temperature <sup>b</sup>	Direct and simple hardening temperature <sup>c,d</sup>	Double hardening <sup>c</sup>		Tempering temperature <sup>e</sup>
	°C			°C	Core-hardening temperature <sup>d</sup>	
Non-alloy steels						
C10E C10R	—	880 to 980	830 to 870	880 to 920	780 to 820	150 to 200
C15E C15R	—	880 to 980	830 to 870	880 to 920	780 to 820	150 to 200
C16E C16R	—	880 to 980	830 to 870	880 to 920	780 to 820	150 to 200
22Mn6	—	880 to 980	830 to 870	880 to 920	780 to 820	150 to 200
Alloy steels						
17Cr3 17CrS3	880 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
20Cr4 20CrS4	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
28Cr4 28CrS4	850 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
16MnCr5 16MnCrS5 16MnCrB5	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
20MnCr5 20MnCrS5	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
18CrMo4 18CrMoS4	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
24CrMo4 24CrMoS4	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
22CrMoS3-5	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
20MoCr4 20MoCrS4	910 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200
16NiCr4 16NiCrS4	880 ± 5	880 to 980	820 to 860	850 to 890	780 to 820	150 to 200
18NiCr5-4	880 ± 5	880 to 980	820 to 860	840 to 880	780 to 820	150 to 200
17CrNi6-6	870 ± 5	880 to 980	820 to 860	830 to 870	780 to 820	150 to 200
15NiCr13	850 ± 5	880 to 980	810 to 850	840 to 880	780 to 820	150 to 200
20NiCrMo2-2 20NiCr- MoS2-2	900 ± 5	880 to 980	820 to 860	860 to 900	780 to 820	150 to 200

<sup>a</sup> Time for austenitizing as a guide: 30 min minimum.

<sup>b</sup> The carburizing temperature depends on the chemical composition of the steel, the mass of the product and the carburizing medium. If the steels are direct hardened, in general a temperature of 950 °C is not exceeded. For special procedures, e.g. under vacuum, higher temperatures (for example 1 020 °C to 1 050 °C) are not unusual.

<sup>c</sup> The kind of quenching agent depends, for example, on the shape of the products, the cooling conditions and the amount of furnace filling.

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

<sup>e</sup> Time for tempering as a guide: 1 h minimum.



Table 8 (continued)

Steel name	End quench test austenitizing temperature <sup>a</sup>	Carburizing temperature <sup>b</sup>	Direct and simple hardening temperature <sup>c,d</sup>	Double hardening <sup>c</sup>		Tempering temperature <sup>e</sup>
				Core-hardening temperature <sup>d</sup>	Case-hardening temperature <sup>d</sup>	
	°C	°C	°C	°C	°C	°C
17NiCrMo6-4 17NiCr-MoS6-4	900 ± 5	880 to 980	810 to 850	830 to 870	780 to 820	150 to 200
23MnCr-MoS5-5-4	860 ± 5	880 to 1050	860 to 900	890 to 920	780 to 820	150 to 200
18CrNiMo7-6	860 ± 5	880 to 980	810 to 850	830 to 870	780 to 820	150 to 200
The temperatures given for carburizing, direct and simple hardening, core-hardening, case-hardening and tempering are for guidance. The actual temperatures chosen should be those that give the required properties.						
<p><sup>a</sup> Time for austenitizing as a guide: 30 min minimum.</p> <p><sup>b</sup> The carburizing temperature depends on the chemical composition of the steel, the mass of the product and the carburizing medium. If the steels are direct hardened, in general a temperature of 950 °C is not exceeded. For special procedures, e.g. under vacuum, higher temperatures (for example 1 020 °C to 1 050 °C) are not unusual.</p> <p><sup>c</sup> The kind of quenching agent depends, for example, on the shape of the products, the cooling conditions and the amount of furnace filling.</p> <p><sup>d</sup> If the steels are direct hardened and if there is a danger of distortion, they should be quenched from a temperature between the core-hardening and case-hardening temperatures.</p> <p><sup>e</sup> Time for tempering as a guide: 1 h minimum.</p>						

**Table 9 — Test conditions for the verification of the requirements given in column 1**

No.	1	2	Amount of testing		Sampling <sup>b</sup>	Test method	
	Requirements		Test unit <sup>a</sup>	Number of			
		See Table					sample products per test unit
1	Chemical composition	<a href="#">Table 3</a> <a href="#">Table 4</a>	C	(The cast analysis is given by the manufacturer; for product analysis, see <a href="#">Clause A.3</a> )			
2	Hardenability	<a href="#">Table 5</a> <a href="#">Table 6</a>	C	1	In cases of dispute, if possible, the sampling method given in ISO 642:1999, 5.1, a) or b 1) 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 conformity with ISO 642. The quenching temperature shall be as specified in <a href="#">Table 8</a> . The hardness values shall be determined in accordance with scale C of ISO 6508-1.	
3	Hardness				Hardness tests		
3a	Hardness in the condition +S or +A, +TH or FP	<a href="#">Table 7</a>	C and D and T	1	1	In case of dispute, the hardness shall be measured, if possible, at following point of the surface: <ul style="list-style-type: none"> <li>— in case of round bars at a distance equal to the diameter from one end of the bar,</li> <li>— in case of bars with square and rectangular cross section and in case of flat products at a distance equal to the thickness from one end and 0,25 w (w = width of the product) from one longitudinal edge.</li> </ul>	In accordance with ISO 6506-1.

<sup>a</sup> The tests 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 thickness may be grouped 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 the thickest product shall be tested.

<sup>b</sup> The general conditions for the selection and preparation of samples and test pieces should be in accordance with ISO 377 and ISO 14284.

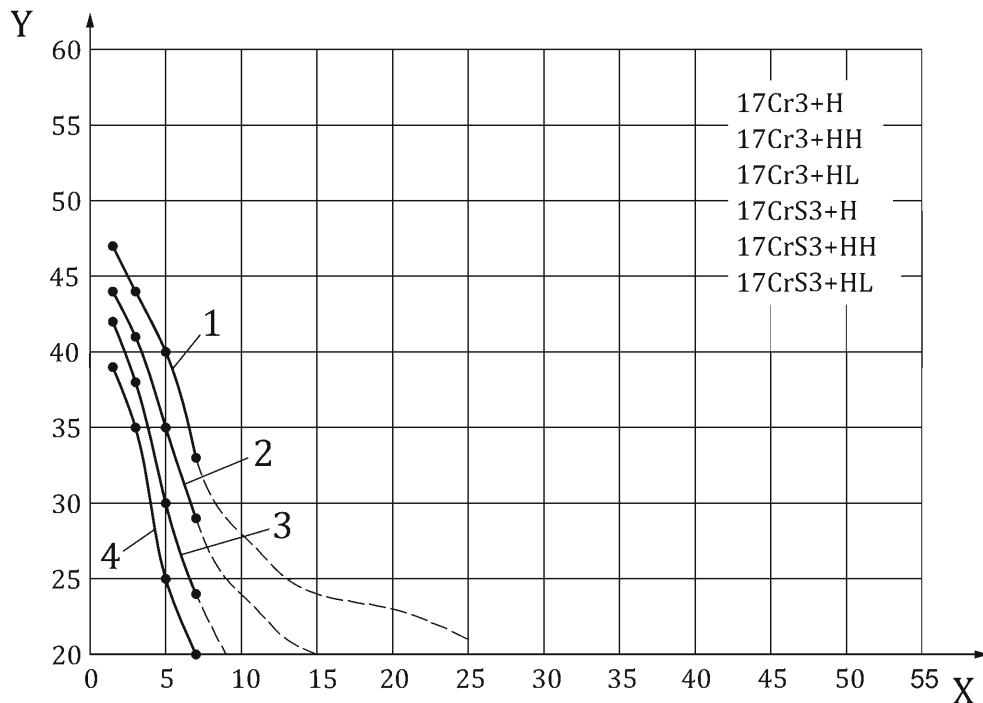
Table 9 (continued)

No.	1	2	Amount of testing		5 Sampling <sup>b</sup>	6 Test method	
	Requirements		Test unit <sup>a</sup>	Number of sample products per test unit			tests per sample product
		See Table					
3b	Hardness in the condition +N	<a href="#">Table 7</a>	C	1	1	In accordance with ISO 6506-1.	

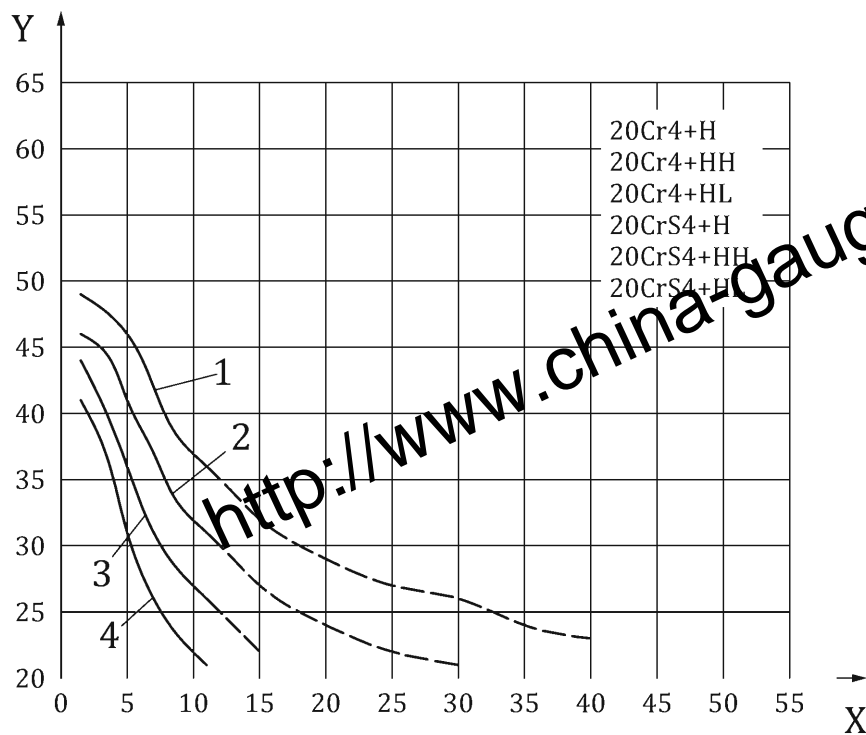
Verification of the requirements is only necessary if an inspection certificate is ordered and if the requirement is applicable to [Table 1](#), column 8 or 9.

<sup>a</sup> The tests 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 thickness may be grouped 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 the thickest product shall be tested.

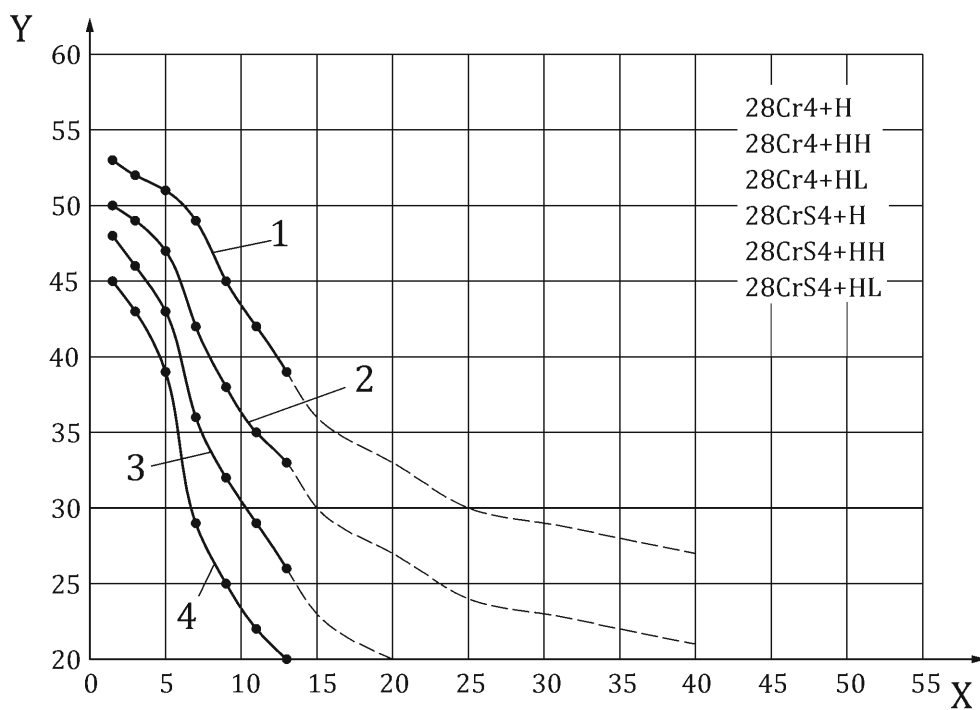
<sup>b</sup> The general conditions for the selection and preparation of samples and test pieces should be in accordance with ISO 377 and ISO 14284.



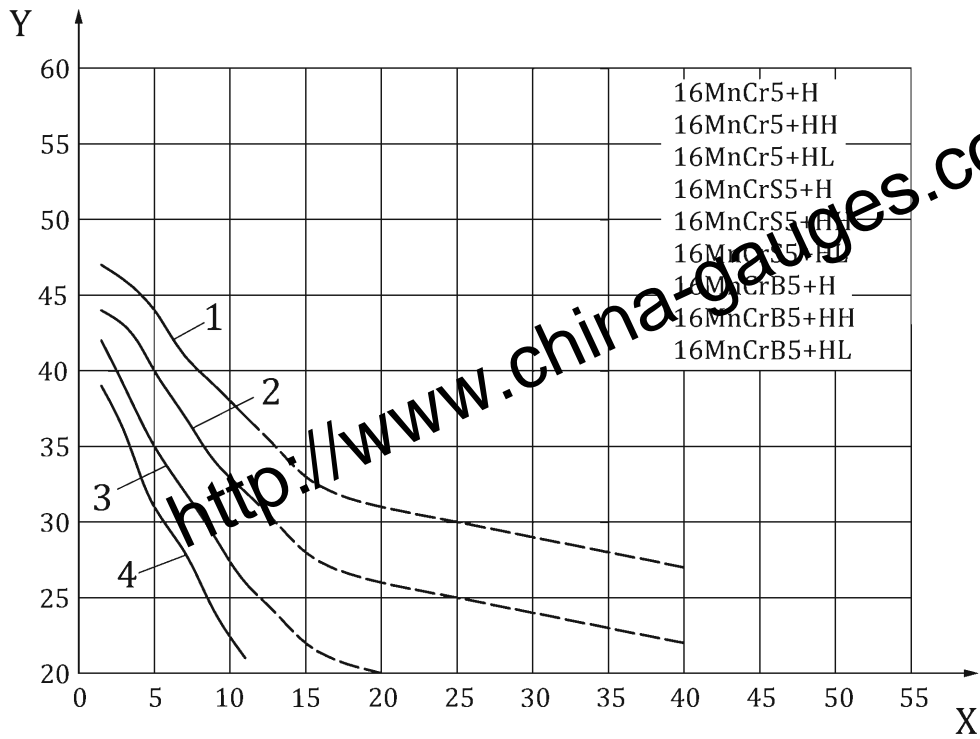
a)



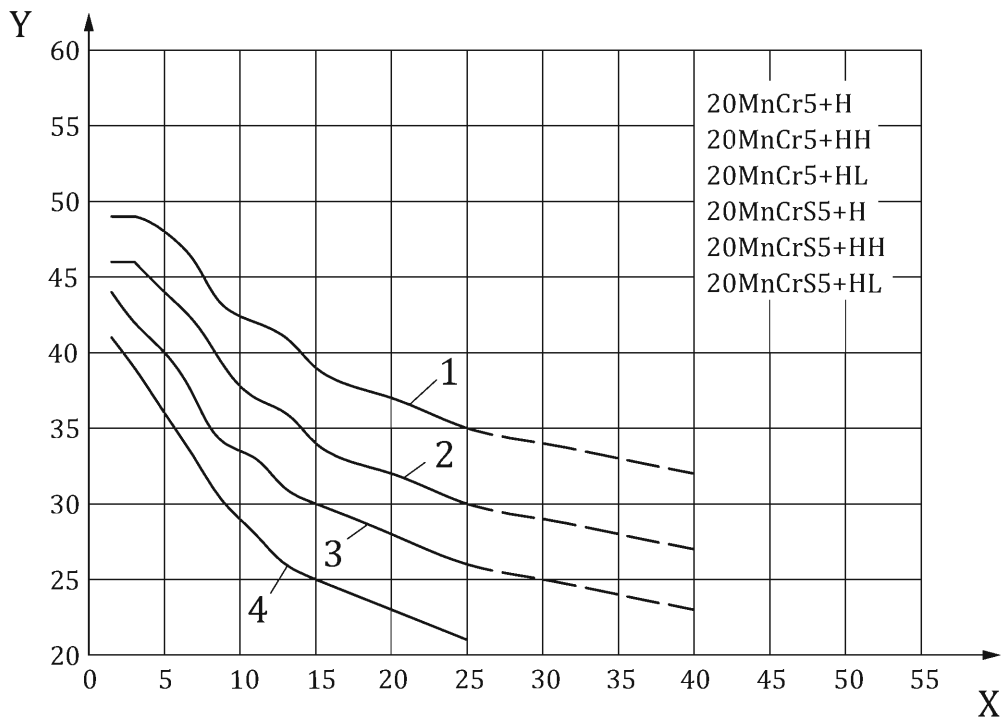
b)



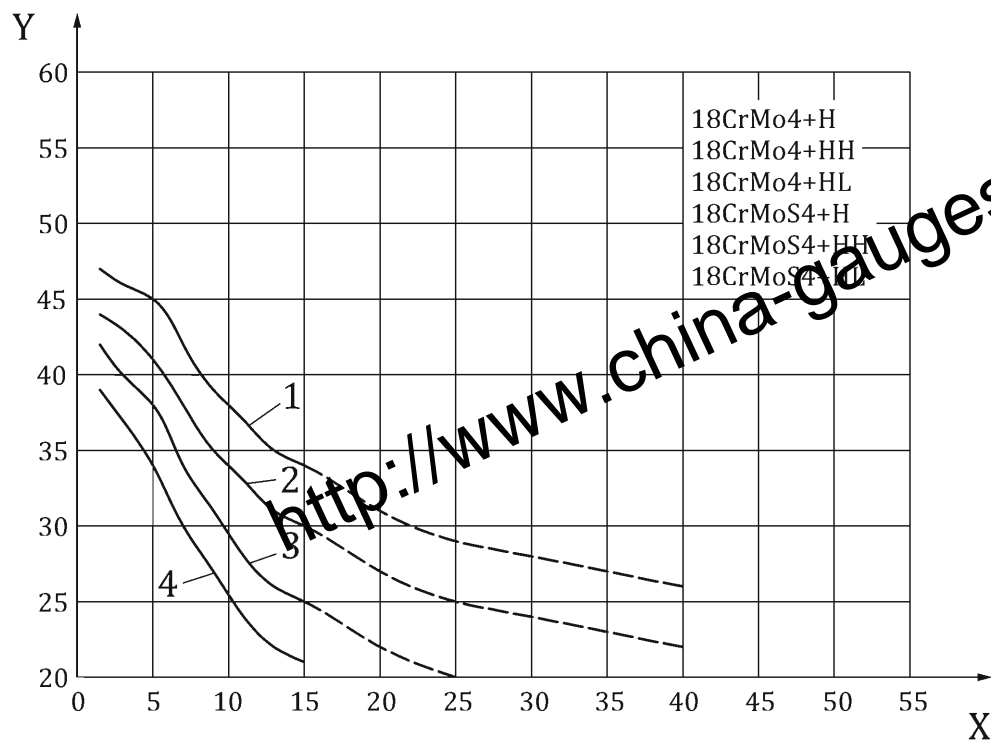
c)



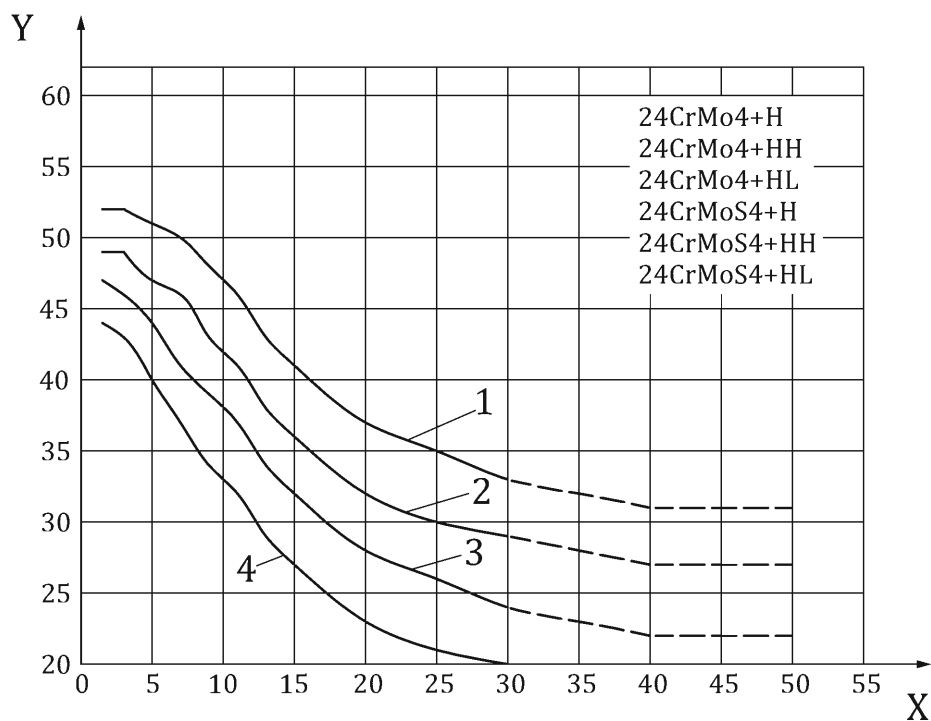
d)



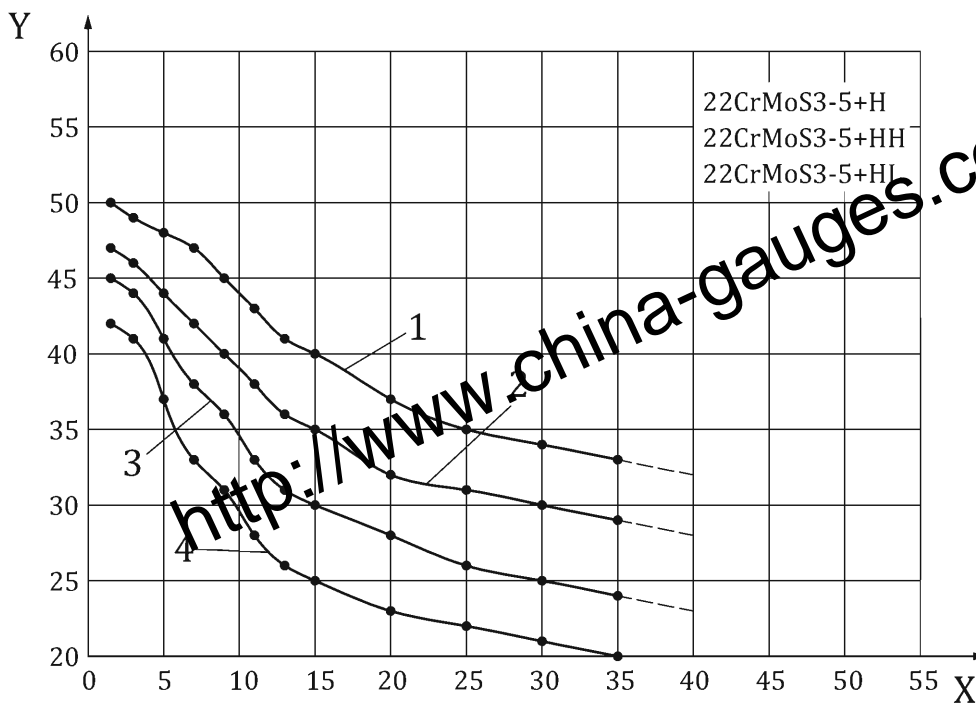
e)



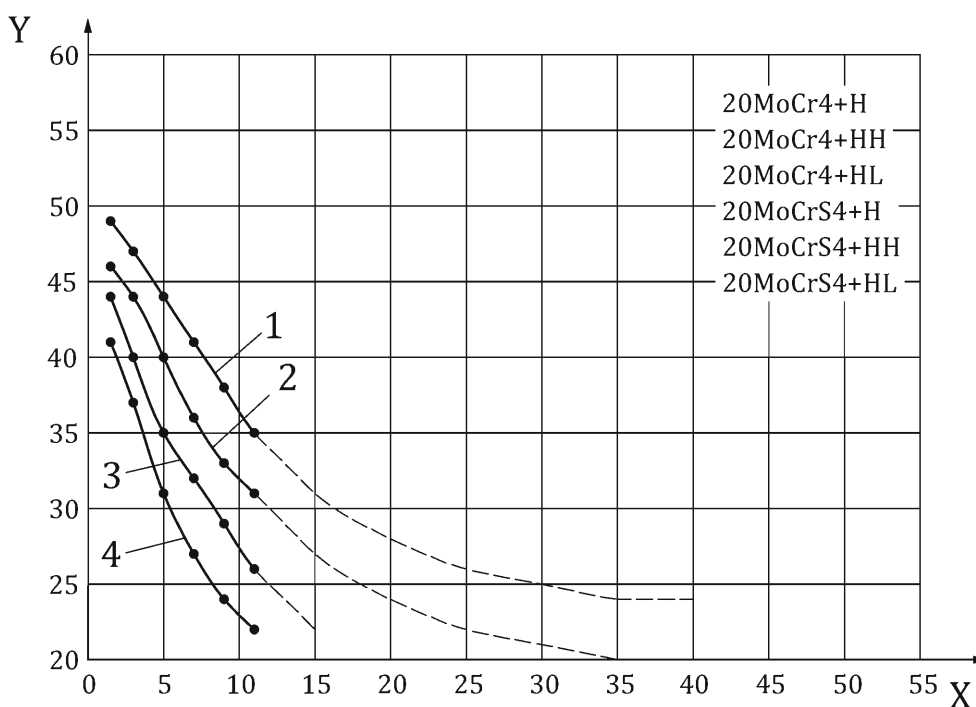
f)



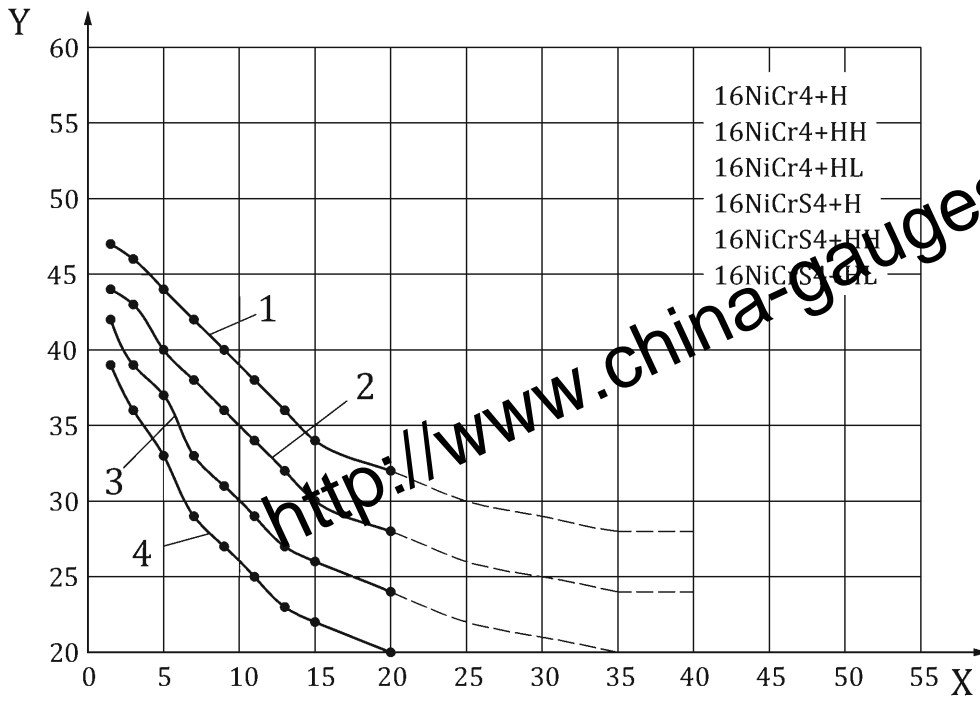
g)



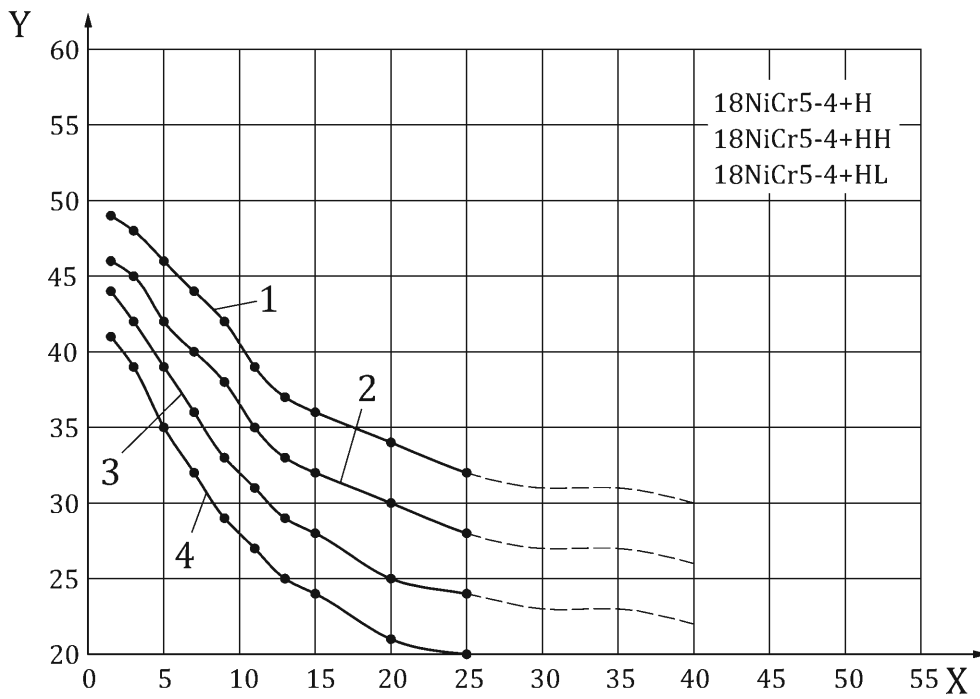
h)



i)

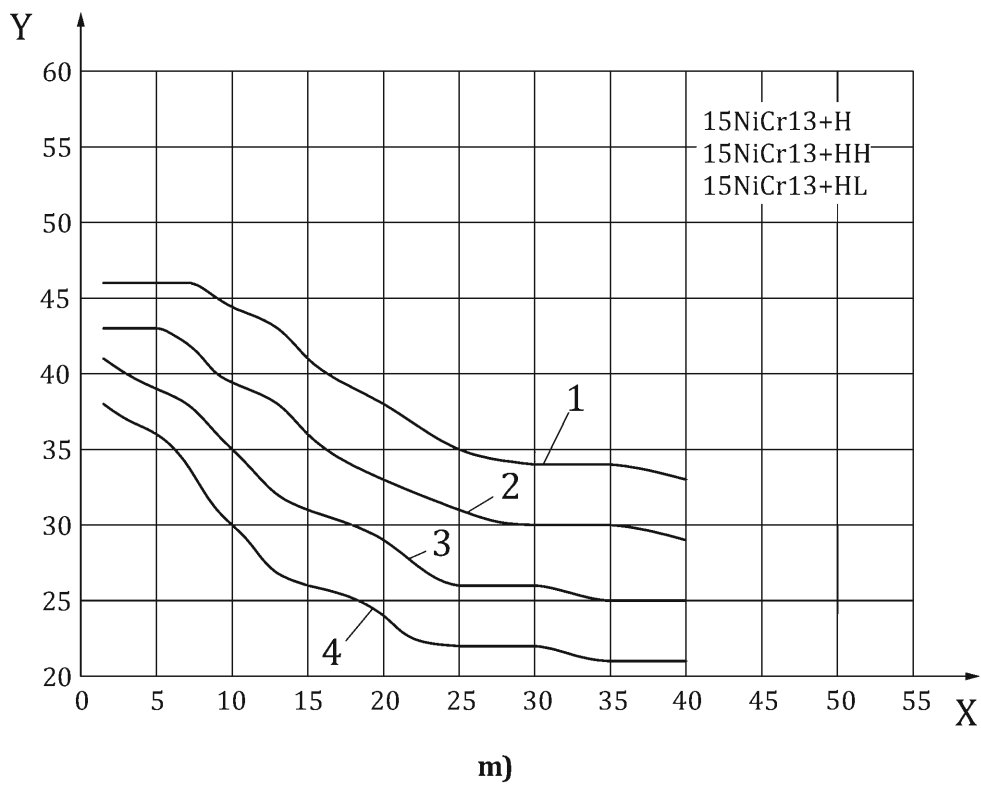
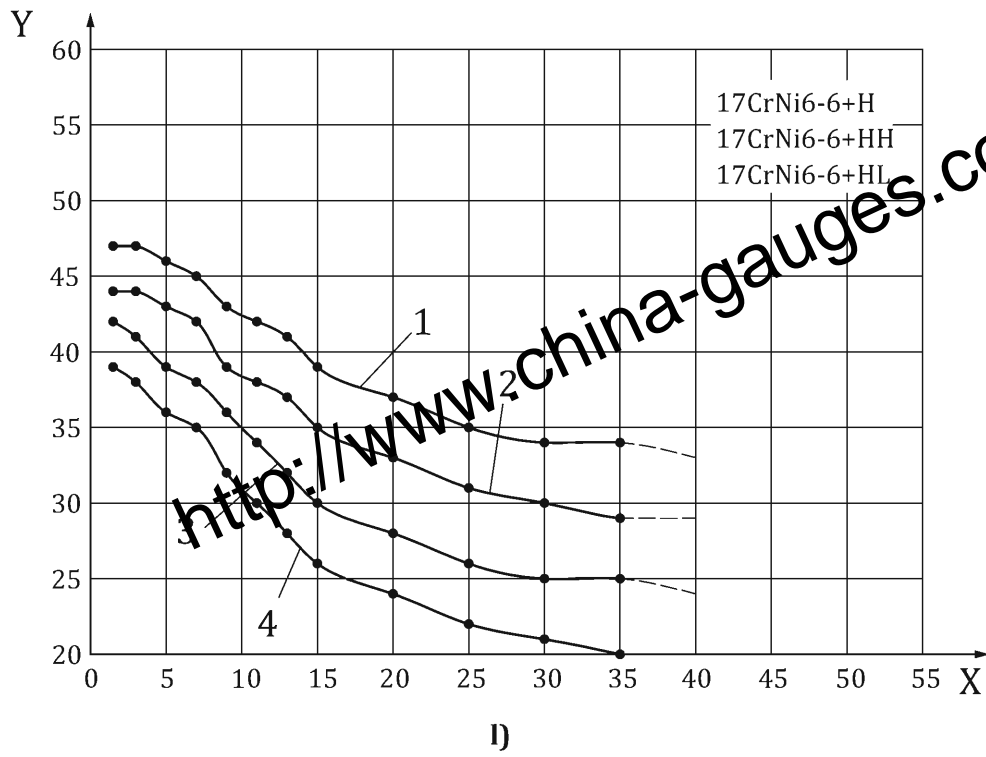


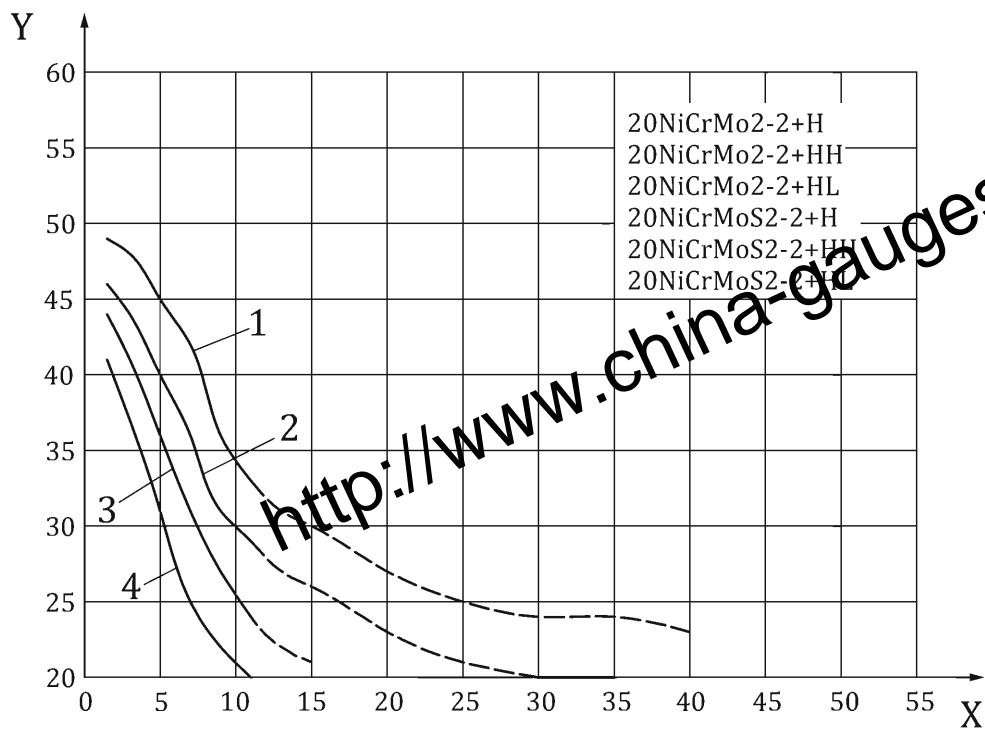
j)



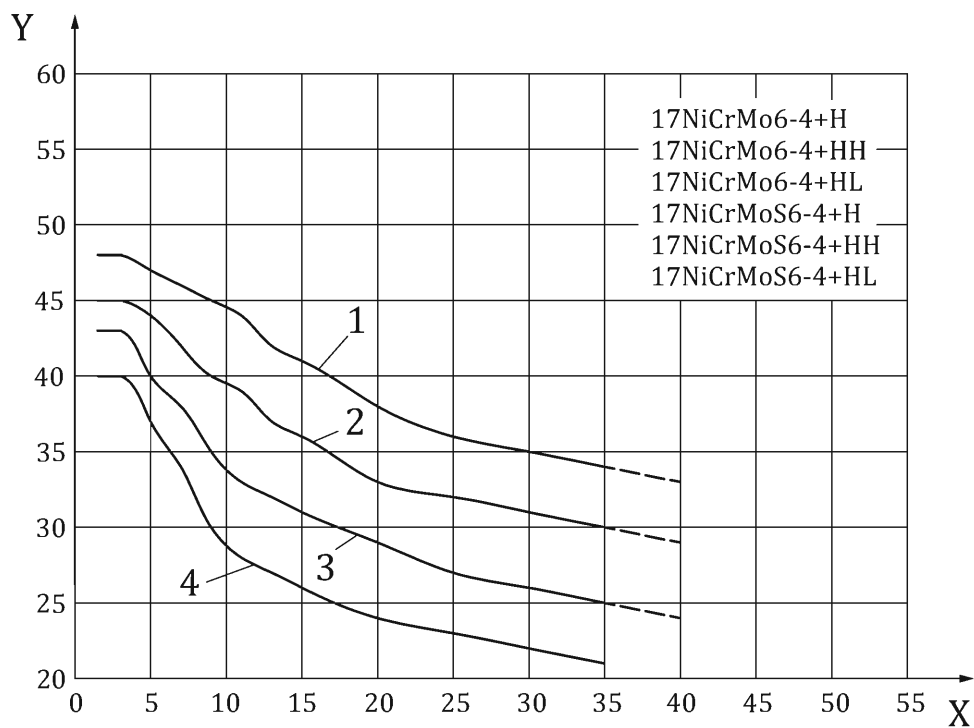
k)



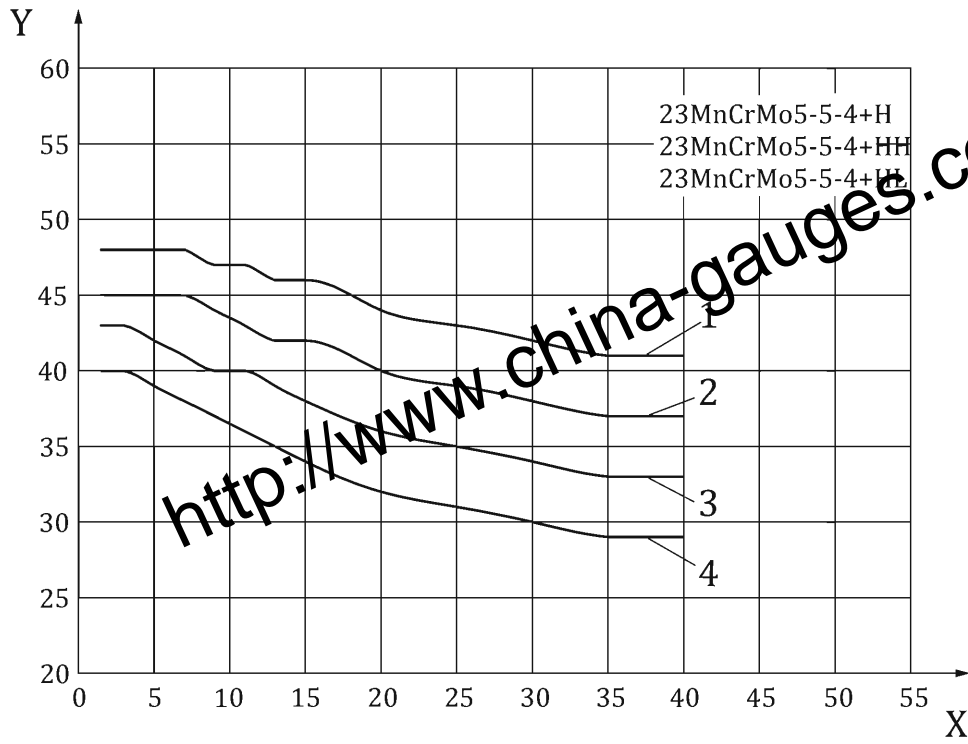




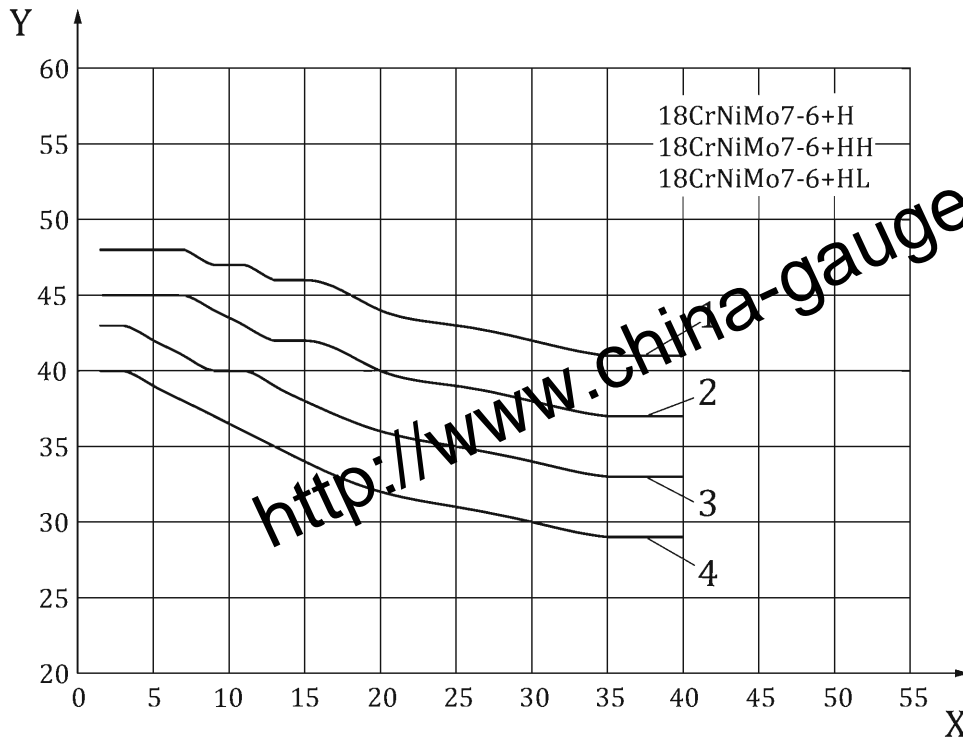
n)



o)



p)



q)

**Key**

X	distance from quenched end of test piece, mm	2	upper limit, +HL grades
Y	hardness, HRC	3	lower limit, +HH grades
1	upper limit	4	lower limit

**Figure 1 — Scatter bands for Rockwell C hardness in end quench hardenability test**

## Annex A (normative)

### Supplementary or special requirements

NOTE It is intended that one or more of the following supplementary or special requirements be applied, but only where specified in the enquiry and order. It is intended that, where necessary, details of these requirements be agreed by the manufacturer and purchaser at the time of enquiry and order.

#### A.1 Fine grain steel

Fine grain steel shall have a ferrite grain size of 5 or finer. If specific testing is ordered, the grain size requirement is to be verified by determining the aluminium content or micrographically. The fine grain structure is normally achieved, when the total aluminium content is a minimum of 0,018 %. In such a case, the micrographic investigation is not necessary. The aluminium content shall be given in the inspection document.

Otherwise, one test piece per cast shall be inspected for the determination of the apparent austenitic grain size. Sampling and sample preparation shall be as specified in ISO 643. The steel shall be tested in accordance with the Mc-Quaid-Ehn method described in ISO 643 and the grain structure shall be considered satisfactory if 70 % of the area is within the specified size limits.

Unless otherwise agreed at the time of enquiry and order, the grain size shall be determined from a carburized specimen. Carburization shall be achieved by maintaining the specimen in carburizing powder at  $950\text{ °C} \pm 10\text{ °C}$  for 6 h. This is generally done by keeping the carburizing chamber at  $950\text{ °C} \pm 10\text{ °C}$  for 8 h, including a preheating period. In most cases, a carburized layer of approximately 1 mm is obtained. After carburizing, cooling of the specimen at a rate slow enough ensures the cementite precipitating on the grain boundaries of the hypoeutectoid zone of the carburized layer.

#### A.2 Non-destructive tests

The products shall be non-destructively tested, under conditions and to a standard agreed at the time of enquiry and order.

#### A.3 Product analysis

One product analysis shall be carried out per cast for the determination of all elements for which values are specified for the cast analysis of the steel type concerned.

The conditions for sampling shall be in accordance with ISO 14284. In case of dispute, the analysis shall be carried out, if possible, in accordance with a reference method taken from one of the International Standards listed in ISO/TR 9769.

#### A.4 Minimum silicon content

Steels can be supplied with:

- a minimum silicon content of 0,15 % for grades C10E, C10R, C15E, C15R, C16E, C16R, 17Cr3, 17CrS3, 20Cr4, 20CrS4, 16MnCr5, 15MnCrS5, 16MnCrB5, 20MnCr5, 20MnCrS5, 18CrMo4, 18CrMoS4, 16NiCr4, 16NiCrS4, 18NiCr5-4, 17CrNi6-6, 15NiCr13, 20NiCrMo2-2, 20NiCrMoS2-2, 17NiCrMo6-4, 17NiCrMoS6-4 and 18CrMo7-6; or

- with a minimum silicon content of 0,10 % for grades 22Mn6, 24CrMo4, 24CrMoS4, 22CrMoS3-5, 20MoCr4 and 20MoCrS4.

NOTE A low silicon content decreases the risk of internal oxidation during carburizing. Because silicon is a deoxidising element, it is usually replaced with aluminium in such cases. This can deteriorate the machinability.

### A.5 Reduction ratio and deformation ratio

If the central soundness of the hot-rolled or forged products is important, the purchaser shall be aware that a minimum reduction ratio (referred to the cross-section) for long products or a minimum thickness deformation ratio (referred to the thickness) for flat products is necessary. In this case, a minimum reduction ratio or a minimum thickness deformation ratio (e.g. 4:1), for example, may be agreed at the time of enquiry and order.

### A.6 Special agreements for marking

The products shall be marked in the way specially agreed at the time of enquiry and order.

## Annex B (informative)

### Designation of steels given in this document and of comparable grades covered in various designation systems

**Table B.1 — Designation of steels given in this document and of comparable grades covered in various designation systems**

Steel designations in accordance with									
ISO name (ISO 683-3)	ISO number (ISO 683-3)	ASTM/UNS <sup>a</sup>	EN ISO 683-3 and EN 10084:2008 <sup>b</sup>	JIS G 4052 <sup>c</sup>		GB/T 5216 <sup>d</sup>			
Non-alloy steel grades									
C10E	—	—	C10E	1.1121	S10C	n	—	—	—
C10R	—	—	C10R	1.1207	—	—	—	—	—
C15E	—	—	C15E	1.1141	S15C	n	—	—	—
C15R	—	—	C15R	1.1140	—	—	—	—	—
C16E	—	—	C16E	1.1148	—	—	—	—	—
C16R	—	—	C16R	1.1208	—	—	—	—	—
22Mn6	—	—	22Mn6	1.1160	SMn420	n	—	—	—
Alloy steel grades									
17Cr3	—	—	17Cr3	1.7016	—	—	15CrH	n	—
17CrS3	—	—	17CrS3	1.7014	—	—	—	—	—
20Cr4	—	—	20Cr4	1.7027	SCr420/ SCr420H	n	20CrH	i	—
20CrS4	—	—	20CrS4	1.7028	—	—	—	—	—
28Cr4	—	—	28Cr4	1.7030	—	—	28CrH	i	—
28CrS4	—	—	28CrS4	1.7036	—	—	—	—	—
16MnCr5	—	—	16MnCr5	1.7131	—	—	16CrMnH	i	—
16MnCrS5	—	—	16MnCrS5	1.7139	—	—	—	—	—
16MnCrB5	—	—	16MnCrB5	1.7160	—	—	15CrMnBH	n	—
20MnCr5	—	—	20MnCr5	1.7147	—	—	20CrMnH	i	—
20MnCrS5	—	—	20MnCrS5	1.7149	—	—	—	—	—
18CrMo4	—	—	18CrMo4	1.7243	SCM418 SCM418H	n	20CrMoH	n	—
18CrMoS4	—	—	18CrMoS4	1.7244	—	—	—	—	—
<b>Key</b>									
i identical steel to ISO steel grade									
n steel grade with closer match of composition, but not identical									
<sup>a</sup> US steel listed in ASTM and in UNS. If the steel number is given in brackets, then the steel only has a UNS number.									
<sup>b</sup> European steel listed in EN ISO 683-3 and in withdrawn EN 10084:2008.									
<sup>c</sup> JIS G 4052 is a Japanese Industrial Standard.									
<sup>d</sup> GB/T 5216 is a Chinese National Standard.									

Table B.1 (continued)

Steel designations in accordance with

ISO name (ISO 683-3)	ISO number (ISO 683-3)	ASTM/UNS <sup>a</sup>		EN ISO 683-3 and EN 10084:2008 <sup>b</sup>		JIS G 4052 <sup>c</sup>		GB/T 5216 <sup>d</sup>	
24CrMo4	—	—	—	24CrMo4	1.7208	SCM425/ SCM425H	n	—	—
24CrMoS4	—	—	—	24CrMoS4	1.7209	—	—	—	—
Alloy steel grades									
22CrMoS3-5	—	—	—	22CrMoS3-5	1.7338	—	—	22CrMoH	n
20MoCr4	—	—	—	20MoCr4	1.7321	—	—	—	—
20MoCrS4	—	—	—	20MoCrS4	1.7323	—	—	—	—
16NiCr4	—	—	—	16NiCr4	1.5714	—	—	—	—
16NiCrS4	—	—	—	16NiCrS4	1.5715	—	—	—	—
18NiCr5-4	—	—	—	18NiCr5-4	1.5810	—	—	—	—
17CrNi6-6	—	—	—	17CrNi6-6	1.5918	—	—	17Cr2Ni2H	i
15NiCr13	—	—	—	15NiCr13	1.5752	SNC815 SNC815H	n	—	—
20NiCrMo2-2	—	—	—	20NiCr- Mo2-2	1.6523	SNM220 SNM220H	n	20CrNiMoH	i
20NiCr- MoS2-2	—	—	—	20NiCr- MoS2-2	1.6526	—	—	—	—
17NiCr- Mo6-4	—	—	—	17NiCr- Mo6-4	1.6566	—	—	—	—
17NiCr- MoS6-4	—	—	—	17NiCr- MoS6-4	1.6569	—	—	—	—
23MnCr- Mo5-5-4	—	—	—	23MnCr- Mo5-5-4	1.7920	—	—	—	—
18CrNiMo7-6	—	—	—	18CrNi- Mo7-6	1.6587	—	—	18Cr2Ni2 MoH	i
<b>Key</b>									
i identical steel to ISO steel grade									
n steel grade with closer match of composition, but not identical									
<sup>a</sup> US steel listed in ASTM and in UNS. If the steel number is given in brackets, then the steel only has a UNS number.									
<sup>b</sup> European steel listed in EN ISO 683-3 and in withdrawn EN 10084:2008.									
<sup>c</sup> JIS G 4052 is a Japanese Industrial Standard.									
<sup>d</sup> GB/T 5216 is a Chinese National Standard.									



## Annex C (informative)

### Classification of steel grades according to minimum tensile strength as a function of diameter after hardening and tempering at 200 °C

**Table C.1 — Classification of steel grades according to minimum tensile strength as a function of diameter after hardening and tempering at 200 °C**

$R_m$ MPa min.	$d \leq 16$ mm	$16 \text{ mm} < d \leq 40$ mm	$40 \text{ mm} < d \leq 100$ mm
1 200	20MnCr5, 20MnCrS5, 17NiCrMo6-4, 17NiCrMoS6-4, 18NiCr5-4, 17CrNi6-6, 23MnCr- Mo5-5-4, 18CrNiMo7-6		
1 100	22CrMoS3-5, 18CrMo4, 18CrMoS4, 20NiCrMo2-2, 20NiCrMoS2-2	18NiCr5-4, 17CrNi6-6, 23MnCr- Mo5-5-4, 18CrNiMo7-6	
1 000	15NiCr13, 16MnCr5, 16MnCrS5, 16MnCrB5, 16NiCr4, 16NiCrS4	17NiCrMo6-4, 17NiCrMoS6-4	
900	20MoCr4, 20MoCrS4, 28Cr4, 28CrS4	20MnCr5, 20MnCrS5, 22CrMoS3-5	
800	C16E, C16R, 17Cr3, 17CrS3, C15E, C15R	18CrMo4, 18CrMoS4, 15NiCr13, 16MnCr5, 16MnCrS5, 16MnCrB5, 16NiCr4, 16NiCrS4  20NiCrMo2-2, 20NiCrMoS2-2, 20MoCr4, 20MoCrS4	18NiCr5-4, 17CrNi6-6, 18CrNiMo7-6, 22CrMoS3-5, 23MnCrMo5-5-4, 17NiCrMo6-4, 17NiCrMoS6-4
700		28Cr4, 28CrS4	15NiCr13, 20MnCr5, 20MnCrS5
600		17Cr3, 17CrS3, C16E, C16R, C15E, C15R	18CrMo4, 18CrMoS4, 20NiCrMo2-2, 20NiCrMoS2-2, 28Cr4, 28CrS4, 16MnCr5, 16MnCrS5, 16MnCrB5
500	C10E, C10R		
400		C10E, C10R	

## Bibliography

### Related standards

- [1] ISO 683-1, *Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Non-alloy steels for quenching and tempering*
- [2] ISO 683-2, *Heat-treatable steels, alloy steels and free-cutting steels — Part 2: Alloy steels for quenching and tempering*
- [3] ISO 683-4, *Heat-treatable steels, alloy steels and free-cutting steels — Part 4: Free-cutting steels*
- [4] ISO 683-5, *Heat treatable steels, alloy steels and free-cutting steels — Part 5: Nitriding steels*
- [5] ISO 683-14, *Heat-treatable steels, alloy steels and free-cutting steels — Part 14: Hot-rolled steels for quenched and tempered springs*
- [6] ISO 683-17, *Heat-treated steels, alloy steels and free-cutting steels — Part 17: Ball and roller bearing steels*
- [7] ISO 683-18, *Heat-treatable steels, alloy steels and free-cutting steels — Part 18: Bright steel products*
- [8] ISO 4954, *Steels for cold heading and cold extruding*
- [9] ISO 4960, *Steel strip, cold-reduced with a mass fraction of carbon over 0,25 %*

### Dimensional standards

- [10] ISO 1035-1, *Hot-rolled steel bars — Part 1: Dimensions of round bars*
- [11] ISO 1035-2, *Hot-rolled steel bars — Part 2: Dimensions of square bars*
- [12] ISO 1035-3, *Hot-rolled steel bars — Part 3: Dimensions of flat bars*
- [13] ISO 1035-4, *Hot-rolled steel bars — Part 4: Tolerances*
- [14] ISO 7452, *Hot-rolled steel plates — Tolerances on dimensions and shape*
- [15] ISO 16124, *Steel wire rod — Dimensions and tolerances*
- [16] ISO 16160, *Hot-rolled steel sheet products — Dimensional and shape tolerances*

### Other standards

- [17] EN 10204, *Metallic products — Types of inspection documents*
- [18] EN 10247, *Micrographic examination of the non-metallic inclusion content of steels using standard pictures*
- [19] GB/T 5216, *Structural steels subject to end-quench hardenability requirements*
- [20] JIS G 0415, *Steel and steel products — Inspection documents*
- [21] JIS G 0555, *Microscopic testing method for the non-metallic inclusions in steel*
- [22] JIS G 4052, *Structural steels with specified hardenability bands*
- [23] SAE J406c, *Methods of Determining Hardenability of Steels*

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