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

Part 6:
**Hot-rolled steels for quenched and
tempered springs**

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

Partie 6: Aciers laminés à chaud pour ressorts trempés et revenus

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Contents

	Page
Foreword.....	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Classification and designation	2
4.1 Classification.....	2
4.2 Designation.....	2
5 Information to be supplied by the purchaser	3
5.1 Mandatory information.....	3
5.2 Supplementary or special requirements.....	3
5.3 Ordering example.....	3
6 Manufacturing process	4
6.1 General.....	4
6.2 Deoxidation.....	4
6.3 Heat-treatment condition at delivery.....	4
6.3.1 Normal delivery condition.....	4
6.3.2 Particular heat treatment condition.....	4
6.3.3 Particular surface condition.....	4
6.4 Traceability of the cast.....	4
7 Requirements	4
7.1 General.....	4
7.2 Chemical composition.....	4
7.3 Mechanical properties.....	5
7.4 Shearability.....	5
7.5 Surface quality.....	5
7.6 Grain size.....	5
7.7 Non-metallic inclusions.....	5
7.7.1 Microscopic inclusions.....	5
7.7.2 Macroscopic inclusions.....	6
7.8 Internal soundness.....	6
7.9 Surface decarburization.....	6
7.10 Spheroidization of carbides.....	6
7.11 Dimensions, tolerances and shape.....	6
8 Inspection	6
8.1 Testing procedures and type of documents.....	6
8.2 Specific inspection.....	7
8.2.1 Verification of the hardenability and hardness.....	7
8.2.2 Summary of inspection and frequency of testing.....	7
8.3 Sampling.....	8
8.3.1 Selection and preparation of samples for the product analysis.....	8
8.3.2 Sampling for the hardenability and hardness test.....	8
9 Test methods	9
9.1 Chemical analysis.....	9
9.2 Hardness test and hardenability test.....	9
9.2.1 Hardness in treatment conditions +A, +S or +AC.....	9
9.2.2 Verification of hardenability.....	9
9.3 Retest.....	9
10 Marking	9
Annex A (normative) Supplementary or special requirements	23

Annex B (informative) Maximum dimensions for flats and rounds based on the 100 % hardenability scatterband	25
Annex C (informative) Guidance values for the mechanical properties of quenched and tempered test pieces	26
Annex D (informative) Designation of steels given in this document and of comparable grades covered in various designation systems	27
Bibliography	28

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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 document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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

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

This fourth edition cancels and replaces the third edition (ISO 683-14:2004), which has been technically revised.

The main changes are as follows:

- partial structure revision;
- editorial revision.

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.

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

Part 6: Hot-rolled steels for quenched and tempered springs

1 Scope

This document specifies the technical delivery requirements for round and flat bars and wire rods manufactured from the alloyed steels listed in [Table 4](#), intended for hot-formed and subsequently heat-treated springs or cold-formed and subsequently heat-treated springs. The products are supplied in one of the heat-treatment conditions given for the different types of products in [Table 2](#) and in one of the surface conditions given in [Table 3](#).

NOTE 1 [Table 4](#) only considers steels that have gained certain international importance. This does, however, not mean that these are available in all industrial countries. In addition, a great number of other steels are specified in regional and national standards.

NOTE 2 Non-alloy steels also for the production of springs are covered by the wire rod specification in ISO 16120-4.

NOTE 3 International Standards relating to steels conforming with the chemical composition requirements in [Table 4](#), but supplied in other product forms or other treatment conditions or intended for special applications, are given in 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, *Steel — Hardenability test by end quenching (Jominy test)*

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

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

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

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

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

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

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

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

ISO 23825, *Method for evaluating the nodularity of spheroidal carbides — Steels for cold heading and cold extruding*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 377, ISO 643, ISO 3887, ISO 9443, ISO 4885, ISO 4948-1, ISO 4948-2, ISO 6929 and the following apply.

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

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

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

3.1

hot-rolled steels for quenched and tempered springs

steels which are, because of their resilience in the quenched and tempered condition, particularly suitable for the manufacture of spring-like components of all kinds

Note 1 to entry: The resilience of the steel depends on their elastic deformability, which enables them to sustain loading within a given range without exhibiting any permanent deformation when the load is removed. The properties required of the steels for springs are obtained by increasing carbon contents and alloying constituents such as silicon, manganese, chromium, molybdenum and vanadium, and also by heat-treatment, i.e. hardening in oil with subsequent tempering.

3.2

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. All steel grades covered by this document are alloy special steels.

4.2 Designation

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

NOTE Designation of steels covered by this document and of comparable grades covered in various other designation systems are given in [Annex D](#).

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 (round bar, flat bar, wire rod, etc.);
- c) either the designation of the dimensional standard and the dimensions and tolerances selected from it (see [7.11](#)) or 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 683-6:2023;
- e) the designation of the steel type given in [Table 4](#) and, where appropriate, the symbols for the core hardness grade (see [7.3](#) and [Table 7](#)) or the restricted hardenability grade (see [7.3](#) and [Table 9](#));
- 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 Supplementary or special requirements

A number of options are specified in this document and listed below.

- a) if a heat-treatment condition other than the untreated condition is required, see the symbol for this other condition (see [Table 2](#), column 2);
- b) if a surface condition other than “hot-worked” or a special surface quality is required, see the surface condition (see [Table 3](#)) and the surface quality (see [7.5](#));
- c) product analysis (see [7.2](#), [8.2.2](#) and [9.1](#));
- d) any requirement concerning the verification of fine grain steel, see [7.6](#) and [A.2](#);
- e) any requirement for the verification of the non-metallic inclusions, see [7.7.1](#);
- f) any requirements for non-destructive testing, see [7.8](#) and [A.3](#);
- g) any requirements for testing the depth of decarburization, see [7.9](#) and [A.4](#);
- h) any requirement for the verification of the carbide spheroidization, see [7.10](#) and [A.5](#);
- i) any requirements concerning special or additional marking, see [Clause 10](#) and [A.6](#).

5.3 Ordering example

EXAMPLE 50 t hot-rolled round bars according to ISO 1035-1 with a nominal diameter of 20,0 mm and a nominal length of 8 000 mm with a diameter tolerance of $\pm 0,25$ mm (= class S of ISO 1035-4) and a length tolerance of 0 mm to 100 mm (= class L2 of ISO 1035-4) and all other tolerances as given in ISO 1035-4 for normal cases, made of steel grade ISO 683-6, 51CrV4 in the heat-treatment condition soft annealed (symbol +A), surface blast cleaned (symbol +BC); with an inspection certificate 3.1 (see ISO 10474).

50 t round bars ISO 1035 – 20,0S × 8 000L2

ISO 683-6 – 51CrV4+A+BC

ISO 10474 – 3.1

6 Manufacturing process

6.1 General

The manufacturing process for the steel and for the products is, with the restrictions given by the requirements in [6.2](#) to [6.4](#), left to the discretion of the manufacturer.

6.2 Deoxidation

All steels shall be fully killed.

6.3 Heat-treatment condition at delivery

6.3.1 Normal delivery condition

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

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 2](#), lines 3 to 6.

6.3.3 Particular surface condition

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 3](#), lines 3 to 6.

6.4 Traceability of the cast

The steels shall be delivered separated by casts.

7 Requirements

7.1 General

[Table 2](#) gives a survey of combinations of usual heat-treatment conditions at delivery, product forms and requirements in accordance with [Tables 4](#) to [9](#) (chemical composition, maximum dimensions for a minimum core hardness, maximum hardness, hardenability).

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

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

7.2 Chemical composition

The chemical composition determined by cast analysis shall conform with the values in [Table 4](#).

Permissible deviations between the limiting values for cast analysis and the values for product analysis are given in [Table 5](#).

If specified at the time of the enquiry and order, the product analysis shall be carried out.

7.3 Mechanical properties

Where the steel is not ordered according to core hardness or restricted hardenability requirements, i. e. where the steel type designations of [Table 6](#) or [Table 8](#) and not the designations given in [Table 7](#) or [Table 9](#) apply, the requirements for chemical composition, hardenability and maximum hardness cited in [Table 2](#), (column 5) shall apply as appropriate, for the particular heat-treatment condition (see footnote b to [Table 4](#)).

Where the steel is, by using the designations given in [Table 9](#), ordered in accordance with restricted hardenability requirements, the values of restricted hardenability given in [Table 9](#) shall apply, in addition to the requirements cited in [Table 2](#), columns 5 (1) and 5 (2).

NOTE 1 The values in [Table 8](#) and [Table 9](#) for normal and restricted hardenability requirements are visualized in [Figure 1](#).

Where the steel is, by using the designations given in [Table 7](#), ordered in accordance with core hardness requirements, the values of core hardenability given in [Table 7](#) shall apply, in addition to the requirements cited in [Table 2](#), columns 5 (1) and 5 (2). In this case, the values of end-quench hardenability given in [Table 8](#) are for guidance purposes only.

NOTE 2 The maximum dimensions given in [Table 7](#) correspond to the restricted hardenability scatterband in accordance with [Table 9](#). For smaller sizes (see [Table B.1](#)) the normal hardenability scatterband in accordance with [Table 8](#) might be sufficient.

NOTE 3 For the grades 38Si7+CH and 46Si7+CH, maximum dimensions for the minimum core hardness after quenching cannot be delivered.

7.4 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 normally shearable not only in the condition +S but also in condition +A (see [Table 2](#)).

7.5 Surface quality

All products shall have a workmanlike finish.

Bars and wire rod shall be delivered with surface class A in accordance with ISO 9443, unless otherwise agreed at the time of enquiry and order. For flat bars, the details of verification shall be agreed upon at the time of enquiry and order.

Removal of surface discontinuities by welding is not permitted.

If surface discontinuities are removed by other methods, the kind and permissible depth for removal of surface discontinuities should, where appropriate, be agreed upon at the time of enquiry and order.

7.6 Grain size

The steel shall show an austenitic grain size of 6 or finer. For the verification of the fine grain size, see [A.2](#).

7.7 Non-metallic inclusions

7.7.1 Microscopic inclusions

The 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.

7.7.2 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.

7.8 Internal soundness

The steel shall be free from internal defects likely to have an adverse effect. If verification is agreed, the method and acceptance limits shall be agreed at the time of enquiry and order, see [A.3](#).

7.9 Surface decarburization

Bars and wire rod with as-rolled surface of steel in the untreated condition (+U), in the treated to improve shearability condition (+S), in the soft annealed condition (+A) and in the annealed to achieve spheroidization of the carbides condition (+AC) shall be free from complete decarburization.

The values for the admissible partial surface decarburization given in [Table 10](#) apply for the untreated condition (+U), for the treated to improve shearability condition (+S), for the soft annealed condition (+A) and for the annealed to achieve spheroidization of the carbides condition (+AC). If verification is agreed at the time of enquiry and order, see [A.4](#).

7.10 Spheroidization of carbides

If the steel is ordered in the heat-treatment condition 'annealed to achieve spheroidization of carbides' (+AC) the degree of spheroidization shall be at least 70 % unless otherwise agreed at the time of enquiry and order, for verification see [A.5](#).

NOTE As the carbon content decreases, it becomes more difficult to obtain spheroidized cementite.

7.11 Dimensions, tolerances and shape

The shape, dimensions and tolerances of the products shall conform with the requirements agreed upon at the time of enquiry and order. The agreements should be based on References [9] to [13], otherwise national and regional standards may be used.

8 Inspection

8.1 Testing procedures and type of documents

8.1.1 Products conforming with this document shall be ordered and delivered with one of the inspection documents either with non-specific or specific inspection specified in ISO 10474 or another equivalent standard, e.g. EN 10204 or JIS G 0415. The type of document shall be agreed upon at the time of enquiry and order. If the order does not contain any specification of this type, a test report 2,2 shall be issued.

8.1.2 If, in accordance with the agreements at the time of enquiry and order, non-specific inspection with a test report 2,2 must be provided, this shall cover:

- a) a confirmation that the material complies with the requirements of the order;
- b) the results of the cast analysis for all elements specified for the steel type supplied.

8.1.3 If, in accordance with the agreements in the order, specific inspection with an inspection certificate 3.1 or 3.2 must be provided, the specific inspections and tests described in [6.2](#) shall be carried out and their results shall be certified in the document.

In addition, the inspection certificate shall cover:

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

8.2 Specific inspection

8.2.1 Verification of the hardenability and hardness

For steels ordered with the designation given in [Tables 4, 8 or 9](#), unless otherwise agreed, only the end-quench hardenability requirements in accordance with [Tables 8 or 9](#) shall be verified.

For steels ordered without end-quench hardenability requirements but with core hardness requirements, i.e. with the symbol +CH in the designation, the hardness requirements given for the relevant heat-treatment condition in [Table 2](#), column 5 (2) and the core hardenability in accordance with [Table 7](#) shall be verified.

8.2.2 Summary of inspection and 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 the specifications in [Table 1](#).

NOTE Verification of the requirements is only necessary if an inspection certificate 3.1 or 3.2 is ordered and if the requirement is applicable in accordance with [Table 2](#), columns 5, 6 or 7.

Table 1 — Summary of inspection and frequency of testing

Requirements		See Table	Amount of testing			Sampling	Test method
			Test unit ^a	Number of sample products per test unit	tests per sample product		
Mandatory tests							
Chemical composition (cast analysis)		4 + 5	Once per cast			–	–
Mechanical properties							
	Hardness in the condition +S, +A or +AC	7	C + D + T	1	1	See 8.3.2.1	See 9.2.2
	Hardenability	8 or 9	C	1	1	See 8.3.2.2	See 9.2.1
	Hardenability (maximum dimension for a specified core hardness)	6	C	1	1	See 8.3.2.3	See 9.2.1
Visual and dimensional inspection		–	in accordance with the manufacturer's procedure			–	–
Options/supplementary requirements							
Chemical composition (for product analysis)		4 + 5	C	1	1	See 8.3.1	See 9.1
Supplementary requirements in accordance with Annex A		–	in Annex A			–	–
^a 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".							

8.3 Sampling

8.3.1 Selection and preparation of samples for the 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.

8.3.2 Sampling for the hardenability and hardness test

8.3.2.1 General

The general conditions for selection and preparation of test samples and test pieces shall be in accordance with ISO 377.

8.3.2.2 Sampling for the hardness test

In cases of dispute, the hardness shall be measured as such: in cases of round products at the circumference of the product at a distance of 1 x thickness from one end and, in cases of products with square or rectangular cross section, at a distance of 0,25 x *b* (*b* is the width of the product) from one longitudinal edge. If the above prescriptions prove unrealistic, a more appropriate position of the hardness indentations shall be agreed upon at the time of enquiry and order.

8.3.2.3 Sampling for the hardenability test

In cases of dispute, the sampling method given in ISO 642 shall be applied.

8.3.2.4 Sampling for the hardenability test (maximum dimension for a specified core hardness)

The test piece for evaluation of the core hardenability shall have, depending on the specified core hardness of 54 HRC or 56 HRC, the cross-sectional dimensions given in [Table 7](#). The length of the test piece shall be at least twice its diameter or thickness. The test piece shall be hardened in accordance with the specifications of [Table 7](#) and then be cut transverse to its longitudinal axis.

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 cases of dispute, the method for 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 test and hardenability test

9.2.1 Hardness in treatment conditions +A, +S or +AC

For products in treatment conditions +A (soft annealed), +S (treated to improve shearability) or +AC (annealed to achieve a spheroidization of the carbides), the hardness shall be measured in accordance with ISO 6506-1.

9.2.2 Verification of hardenability

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

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

9.3 Retest

ISO 404 shall apply for retests.

10 Marking

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

Table 2 — Combinations of usual heat-treatment conditions on delivery, product forms and requirements in accordance with Tables 4 to 9

1	2		3	4	5			6			7		
	Heat treatment condition on delivery	Symbol	Applicable for bars (rounds and flats) and ribbed and grooved bars	wire rod	Unless otherwise agreed		If the steel is ordered with the designation given in Table 9		If the steel is ordered with the designation given in Table 7				
					1	2	3	1	2	3	1	2	3
2	Untreated (as hot-rolled)	+AR	x	x	Chemical composition according to Tables 4 and 5 (see footnote b in Table 4)	-	Hardenability values in accordance with Table 8	As in columns 5 (1) and 5 (2)	As in columns 5 (1) and 5 (2)	Restricted hardenability values in accordance with Table 9	As in columns 5 (1) and 5 (2)	As in columns 5 (1) and 5 (2)	Maximum diameter or thickness for core hardness in accordance with Table 7
3	Treated to improve shearability	+S	x	-	Maximum Brinell hardness in accordance with Table 6	Column +S							
4	Soft annealed	+A	x	x		Column +A							
5	Annealed to achieve spheroidization of the carbides	+AC	x	x		Column +AC							
6	Others												

Other treatment conditions may be agreed upon at the time of enquiry and order.

Table 3 — Surface condition at delivery

	1	2	3	4	5
1	Surface condition at delivery		Symbol	In general, applicable for bar	
				wire rod	
2	Unless otherwise agreed	As hot-worked	None or HW	x	x
3	Particular conditions supplied by agreement	HW + pickled	PI	x	x
4		HW + blast cleaned	BC	x	x
5		HW + surface removal ^a	-	x	x
6		Others			
^a	The type of surface removal may be agreed upon, for example, by reference to the relevant dimensional standard.				

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Table 4 — Steel grades and chemical composition (applicable to cast analysis)

Steel name	Chemical composition ^{a, b} mass fraction %								
	C	Si	Mn	P ^c	S ^c	Cr	Mo	V	Cu + Sn
46Si7	0,42 to 0,50	1,50 to 2,00	0,50 to 0,80	0,025	0,025	–	–	–	Cu+10Sn ≤ 0,60
56SiCr7	0,52 to 0,60	1,60 to 2,00	0,70 to 1,00	0,025	0,025	0,20 to 0,40	–	–	
61SiCr7	0,57 to 0,65	1,60 to 2,00	0,70 to 1,00	0,025	0,025	0,20 to 0,40	–	–	
55SiCr6-3	0,51 to 0,59	1,20 to 1,60	0,50 to 0,80	0,025	0,025	0,50 to 0,80	–	–	
55SiCrV6-3	0,51 to 0,59	1,20 to 1,60	0,50 to 0,80	0,025	0,025	0,50 to 0,80	–	0,10 to 0,20	
55Cr3	0,52 to 0,59	0,40	0,70 to 1,00	0,025	0,025	0,70 to 1,00	–	–	
60Cr3	0,55 to 0,65	0,40	0,70 to 1,10	0,025	0,025	0,70 to 1,00	–	–	
51CrV4	0,47 to 0,55	0,40	0,60 to 1,00	0,025	0,025	0,80 to 1,10	–	0,10 to 0,25	
60CrMo3-3	0,56 to 0,64	0,40	0,70 to 1,00	0,025	0,025	0,70 to 1,00	0,25 to 0,35	–	
52CrMoV4	0,48 to 0,56	0,40	0,70 to 1,00	0,025	0,025	0,90 to 1,20	0,15 to 0,25	0,10 to 0,20	

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.

^a Maximum values unless otherwise indicated.

^b In the case of the grades with specified hardenability requirements (+H see [Table 8](#) and +HH see [Table 9](#)), except for phosphorus and sulfur, deviations from the limits for cast analysis are permissible according to [Table 5](#) and in the case of carbon shall not exceed ±0,01 % (mass fraction).

^c Lower maximum values may be agreed at the time of enquiry and order.

Table 5 — Permissible deviations between the product analysis and the limiting values given in Table 4 for the cast analysis

Element	Permissible maximum content according to cast analysis Mass fraction %	Permissible deviation ^a Mass fraction %
C	$x \leq 0,55$	$\pm 0,03$
	$0,55 < x \leq 0,65$	$\pm 0,04$
Si	$x \leq 0,40$	$\pm 0,03$
	$0,40 < x \leq 2,20$	$\pm 0,05$
Mn	$x \leq 1,00$	$\pm 0,04$
	$1,00 < x \leq 1,10$	$\pm 0,05$
P	$x \leq 0,030$	$+0,005$
S	$x \leq 0,030$	$+0,005$
Cr	$x \leq 1,20$	$\pm 0,05$
Mo	$x \leq 0,30$	$\pm 0,03$
	$0,30 < x \leq 0,35$	$\pm 0,04$
V	$x \leq 0,25$	$\pm 0,02$

^a "±" means that in one cast the deviation may occur over the upper or under the lower value of the specified range in Table 4, but not both at the same time.

Table 6 — Maximum hardness in different heat-treatment conditions

Steel name	Maximum Brinell hardness in the heat-treatment condition		
	treated to improve shearability +S	soft annealed +A	annealed to achieve spheroidization of the carbides +AC
46Si7	280	248	230
56SiCr7	280	248	230
61SiCr7	280	248	230
55SiCr6-3	280	248	230
55SiCrV6-3	280	248	230
55Cr3	280	248	230
60Cr3	280	248	230
51CrV4	280	248	230
60CrMo3-3	280	248	230
52CrMoV4	280	248	230

Table 7 — Maximum dimensions for flats and rounds for specified core hardness (provisional values)

Steel name	Specified core hardness after quenching ^a (minimum) HRC	Maximum dimensions ^b for		Specified core hardness after quenching ^c (minimum) HRC	Maximum dimensions ^b for		Heat-treatment for verifying the maximum dimensions	
		flats (thickness)	rounds (diameter)		flats (thickness)	rounds (diameter)	Quenching temperature °C	Quenching agent
		mm			mm			
56SiCr7+CH	54	13	20	56	11	18	830 to 860	Oil
61SiCr7+CH	54	16	25	56	14	22	830 to 860	Oil
55SiCr6-3+CH	54	20	33	56	18	30	830 to 860	Oil
55SiCrV6-3+CH	54	22	35	56	18	30	830 to 860	Oil
55Cr3+CH	54	14	21	56	10	16	830 to 860	Oil
60Cr3+CH	54	d	d	56	d	d	830 to 860	Oil
51CrV4+CH	54	25	40	56	20	30	830 to 860	Oil
60CrMo3-3+CH	54	55	85	56	51	80	830 to 860	Oil
52CrMoV4+CH	54	35	55	56	29	45	830 to 860	Oil

^a Larger proportions of bainite are to be expected.

^b The values are derived from the lower hardenability curve for 2/3-hardenability range (see [Table 8](#)).

^c Small proportions of bainite are to be expected.

^d Maximum dimensions may be agreed at the time of enquiry and order.

Table 8 — Hardness limits (tentative values) for steel types with specified hardenability (100 % range) (+H-grades, see 7.3)

Steel name	Quenching temperature for end-quench test °C	Limits 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
46Si7+H	880 ± 5	max.	63	60	53	46	42	39	36	34	31	29	28	27	27	26	25
		min.	56	50	40	33	29	26	23	21	-	-	-	-	-	-	-
56SiCr7+H	850 ± 5	max.	65	65	64	63	62	60	57	54	47	42	39	37	36	36	35
		min.	60	58	55	50	44	40	37	35	32	30	28	26	25	24	24
61SiCr7+H	850 ± 5	max.	68	68	67	65	63	61	60	58	51	46	43	41	39	39	38
		min.	60	59	57	54	48	45	42	39	35	32	31	30	29	28	28
55SiCr6-3+H	850 ± 5	max.	66	66	66	65	65	64	64	63	59	55	49	44	40	37	35
		min.	57	56	56	55	53	52	50	46	36	32	29	28	27	26	25
55SiCrV6-3+H	860 ± 5	max.	67	66	65	63	62	60	57	55	47	43	40	38	37	36	35
		min.	57	56	55	50	44	40	37	35	32	30	28	26	25	24	24
55Cr3+H	850 ± 5	max.	65	65	64	63	63	62	61	60	57	52	48	45	42	40	39
		min.	57	56	55	54	52	48	43	39	33	30	28	27	26	25	24
60Cr3+H	850 ± 5	max.	66	66	65	65	64	63	62	62	60	57	52	48	45	44	43
		min.	59	59	57	56	53	50	45	41	35	32	30	29	28	27	26
51CrV4+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
60CrMo3-3+H	850 ± 5	max.	65	65	65	65	65	65	65	65	64	64	63	63	63	63	63
		min.	60	60	60	60	60	60	60	59	58	56	54	50	46	43	41
52CrMoV4+H	850 ± 5	max.	65	65	64	64	63	63	63	62	62	62	62	61	61	61	60
		min.	57	56	56	56	54	52	51	50	48	47	46	46	45	44	44

NOTE See also [Figure 1](#).

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Table 9 — Hardness limits (tentative values) for steel types with specified hardenability (restricted range) (+HH-Grades, see 7.3)

Steel name	Quenching temperature for end-quench test °C	Limits 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
46Si7+HH	880 ± 5	max.	63	60	53	46	42	39	36	34	31	29	28	27	27	26	25
		min.	58	53	44	37	33	30	27	25	-	-	-	-	-	-	-
56SiCr7+HH	850 ± 5	max.	65	65	64	63	62	60	57	54	47	42	39	37	36	36	35
		min.	61	60	58	54	50	47	44	40	37	34	32	30	29	28	28
61SiCr7+HH	850 ± 5	max.	68	68	67	65	63	61	60	58	51	46	43	41	39	39	38
		min.	63	62	60	58	53	50	48	45	40	37	35	34	32	32	31
55SiCr6-3+HH	850 ± 5	max.	66	66	66	65	65	64	64	63	59	55	49	44	40	37	35
		min.	60	59	59	58	57	56	55	52	44	40	36	33	31	30	28
55SiCrV6-3+HH	860 ± 5	max.	67	66	65	63	62	60	57	55	47	43	40	38	37	36	35
		min.	60	59	58	54	50	47	44	42	37	34	32	30	29	28	28
55Cr3+HH	850 ± 5	max.	65	65	64	63	63	62	61	60	57	52	48	45	42	40	39
		min.	60	59	58	57	56	53	49	46	41	37	35	33	31	30	29
60Cr3+HH	850 ± 5	max.	66	66	65	65	64	63	62	62	60	57	52	48	45	44	43
		min.	61	61	60	59	57	54	51	48	44	41	38	36	34	33	32
51CrV4+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
60CrMo3-3+HH	850 ± 5	max.	65	65	65	65	65	65	65	65	64	64	63	63	63	63	63
		min.	62	62	62	62	62	62	62	61	60	59	57	54	52	50	48
52CrMoV4+HH	850 ± 5	max.	65	65	64	64	63	63	63	62	62	62	62	61	61	61	60
		min.	60	59	59	59	57	56	55	54	53	52	51	51	50	50	49

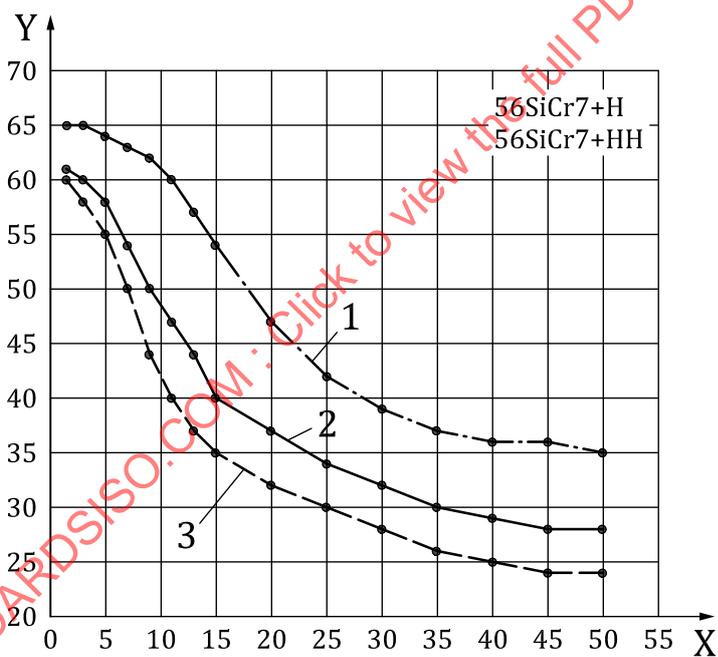
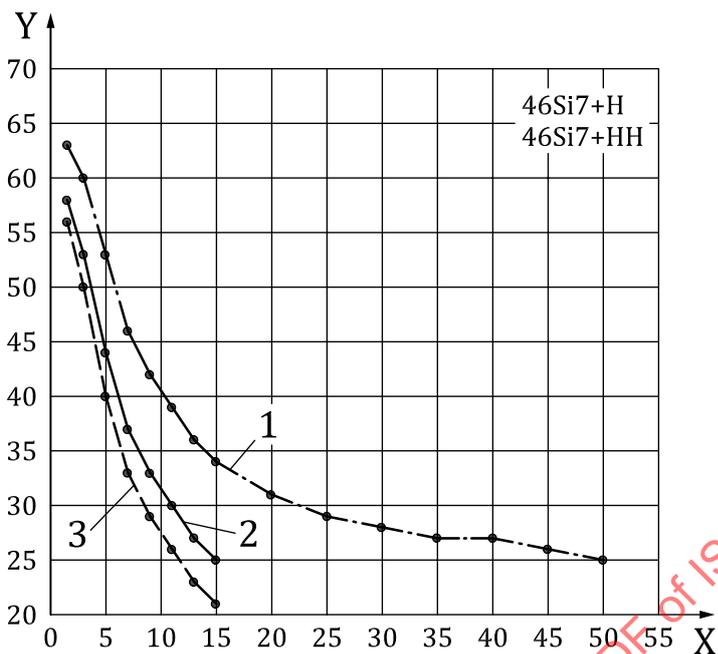
NOTE See also [Figure 1](#).

Table 10 — Admissible partial surface decarburization

Dimensions in millimetres

Steel name	Flat bars		Round bars		Wire rod	
	Thickness, δ	Depth of decarburization max.	Diameter, D	Depth of decarburization max.	Diameter, D	Depth of decarburi- zation max.
46Si7	$5 \leq \delta \leq 25$	$0,01 \delta + 0,25^a$	$D \leq 10$	0,15	by agreement	
56SiCr7 61SiCr7 55SiCr6-3 55SiCrV6-3	$25 < \delta$	To be agreed upon	$D > 10$	$0,015 D$		
55Cr3	$5 \leq \delta \leq 40$	$0,01 \delta + 0,15^a$	$D \leq 10$	0,10	by agreement	
60Cr3 51CrV4 60CrMo3-3 52CrMoV4	$40 < \delta$	To be agreed upon	$D > 10$	$0,010 D$		

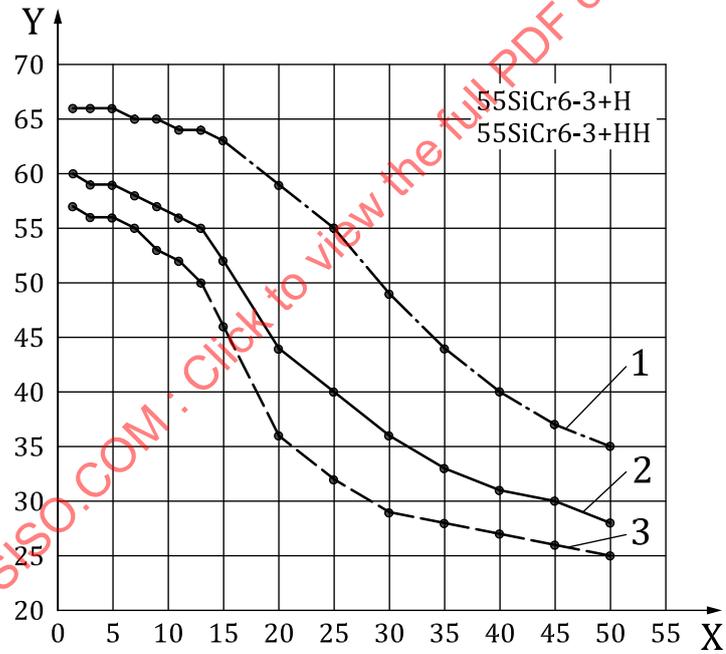
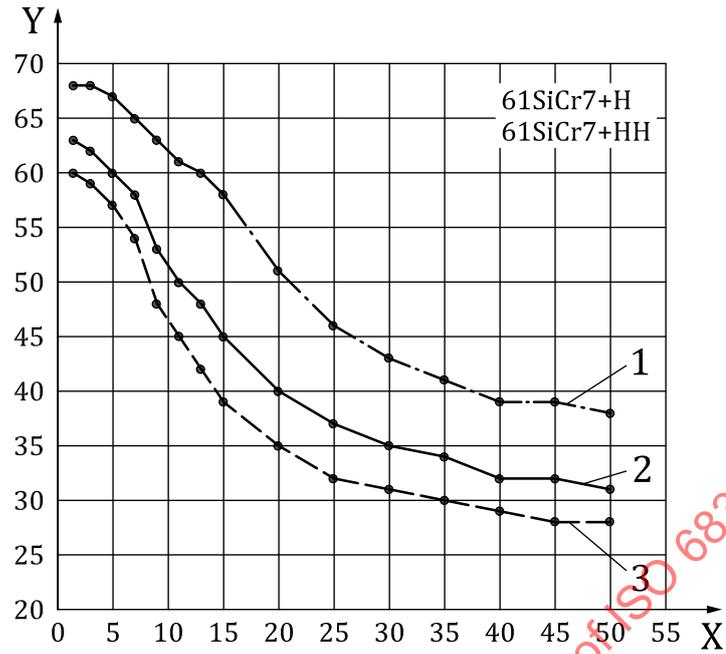
^a These values apply for a width/thickness ratio of ≥ 2 . In cases of smaller ratios, the values shall be agreed upon.



Key

- | | | | |
|---|--|---|------------------------|
| X | distance from quenched end of test piece, mm | 2 | lower limit, +HH-grade |
| Y | hardness, HRC | 3 | lower limit, +H-grade |
| 1 | upper limit | | |

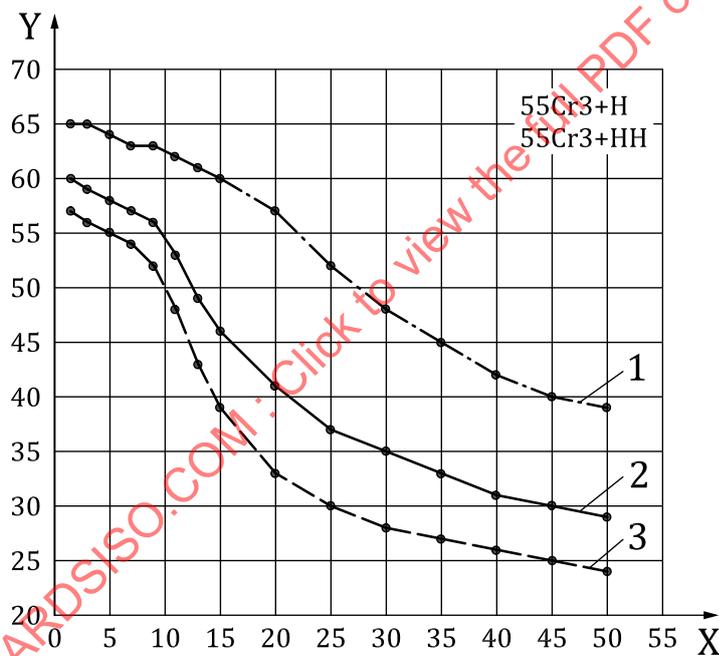
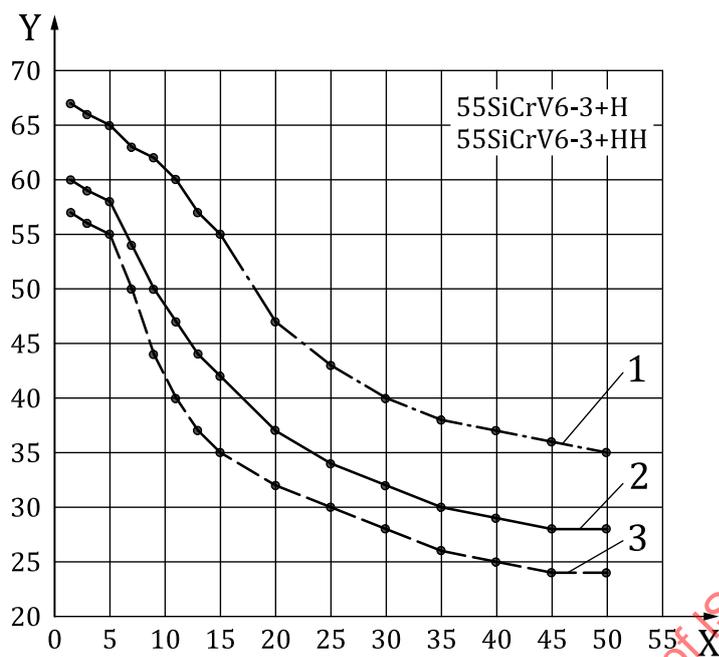
Figure 1 — Scatterbands for end-quench hardenability



Key

- | | | | |
|---|--|---|------------------------|
| X | distance from quenched end of test piece, mm | 2 | lower limit, +HH-grade |
| Y | hardness, HRC | 3 | lower limit, +H-grade |
| 1 | upper limit | | |

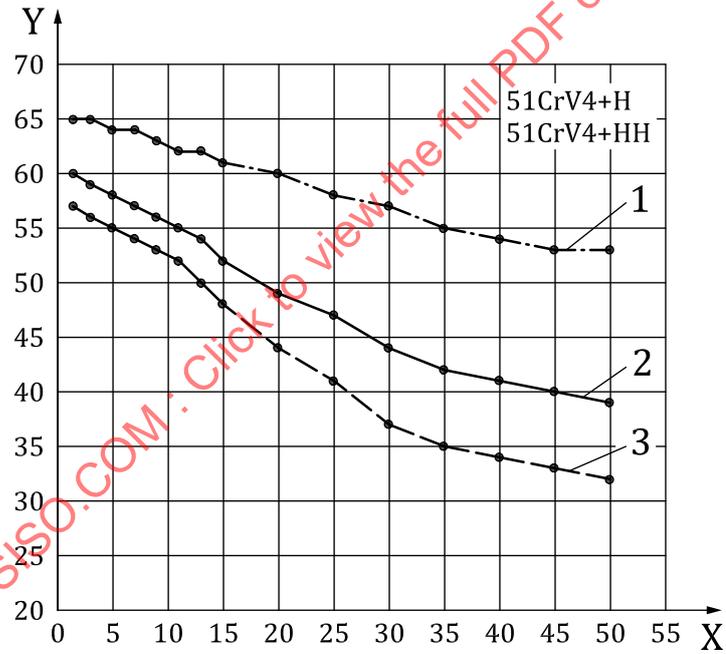
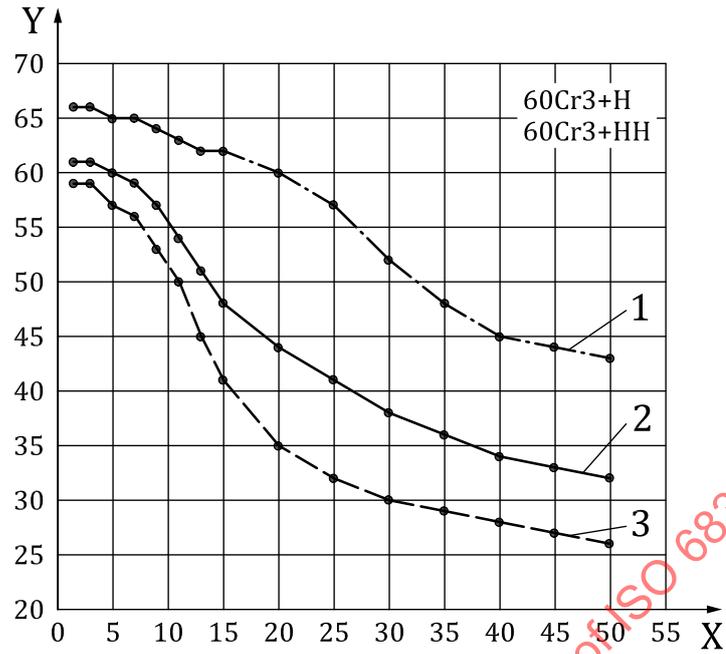
Figure 1 — Scatterbands for end-quench hardenability (continued)



Key

- | | | | |
|---|--|---|------------------------|
| X | distance from quenched end of test piece, mm | 2 | lower limit, +HH-grade |
| Y | hardness, HRC | 3 | lower limit, +H-grade |
| 1 | upper limit | | |

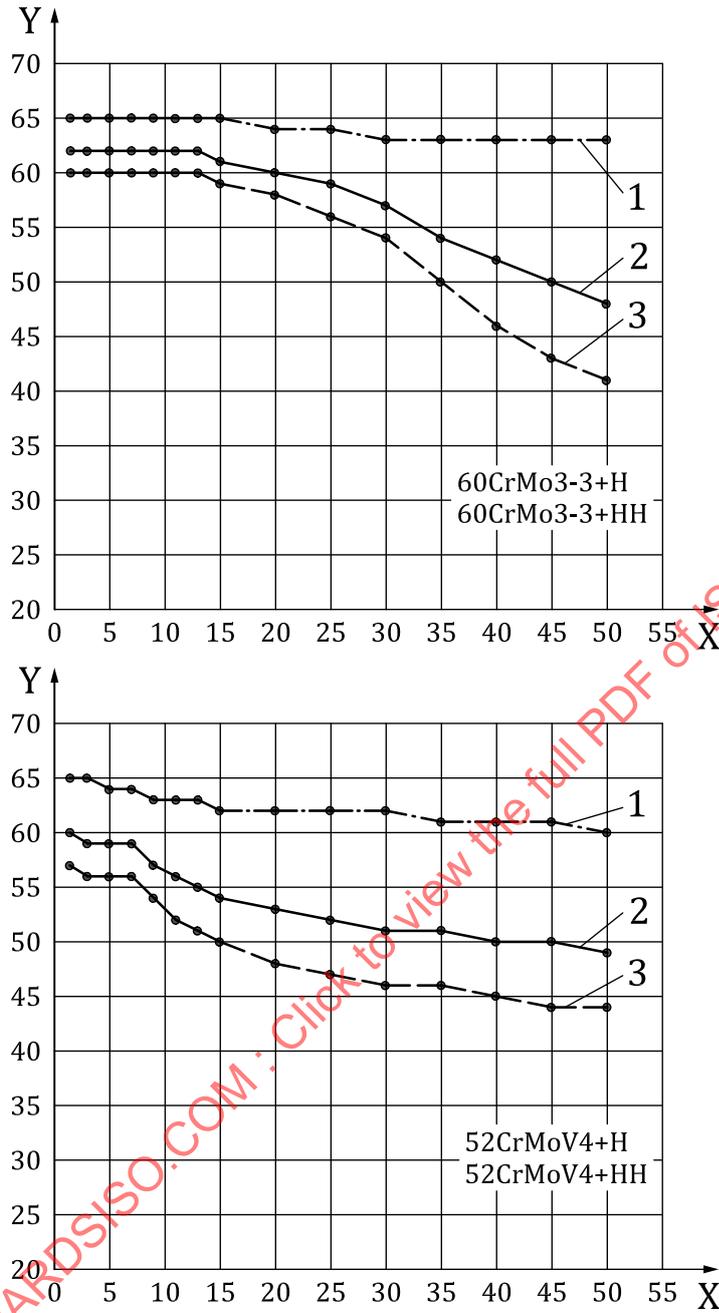
Figure 1 — Scatterbands for end-quench hardenability (continued)



Key

- | | | | |
|---|--|---|------------------------|
| X | distance from quenched end of test piece, mm | 2 | lower limit, +HH-grade |
| Y | hardness, HRC | 3 | lower limit, +H-grade |
| 1 | upper limit | | |

Figure 1 — Scatterbands for end-quench hardenability (continued)



Key

X	distance from quenched end of test piece, mm	2	lower limit, +HH-grade
Y	hardness, HRC	3	lower limit, +H-grade
1	upper limit		

Figure 1 — Scatterbands for end-quench hardenability (concluded)