INTERNATIONAL STANDARD

ISO 4957

Third edition
2018-06

Tool steels

Aciers à outils

Reference number
ISO 4957:2018(E)

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Published in Switzerland

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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).

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).

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

For an explanation on 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 the following URL: 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 third edition cancels and replaces the second edition (ISO 4957:1999), which has been technically revised.

The main changes compared with the previous edition are as follows:

— the delivery condition normalized/normalized rolled has been introduced;

— for surface quality, ISO 9443 for bars and ISO 7788 for plates now apply;

— an additional clause for sorting and reprocessing has been introduced;

— the normative references have been updated.

Tool steels

1 Scope

This document specifies requirements for the following grades of wrought tool steels:

a) non-alloy cold-work tool steels;

b) alloy cold-work tool steels;

c) alloy hot-work tool steels;

d) high-speed tool steels.

If not stated otherwise, this document applies to all types of hot-rolled, forged, cold-drawn or cold-rolled products or products produced by powder metallurgy, which are supplied in one of the surface and heat-treatment conditions given in 6.2 and Table 1.

NOTE Tables 2, 4, 6 and 8 cover only those steels which have gained certain international importance, which does not mean, however, that they are available in all industrial countries. In addition, a number of other steels for tools are specified in regional, national or company standards.

Where the heat resistance of the tools is of particular importance, as for example in the case of tools for hot forming glass, the material selection is based on ISO 4955.

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 1035-1, *Hot-rolled steel bars — Part 1: Dimensions of round bars*

ISO 1035-3, *Hot-rolled steel bars — Part 3: Dimensions of flat bars*

ISO 1035-4:1982, *Hot-rolled steel bars — Part 4: Tolerances*

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

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 7452:2013, *Hot rolled steel plates — Tolerances on dimensions and shape*

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

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

ISO 17577, *Steel — Ultrasonic testing of steel flat products of thickness equal to or greater than 6 mm*

3 Terms and definitions

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

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 http://www.electropedia.org/

3.1
tool steel
special steel suitable for working or processing of materials, for handling and measuring workpieces and, for this purpose, exhibiting high hardness and wear resistance and/or toughness

3.2
cold-work tool steel
non-alloy or alloy *tool steel* (3.1) for applications in which the surface temperature is generally below 200 °C

3.3
hot-work tool steel
alloy *tool steel* (3.1) for applications in which the surface temperature is generally over 200 °C

3.4
high-speed tool steel
steel used mainly for machining and for forming processes and which, because of the chemical composition, has the highest high-temperature hardness and temper resistance up to about 600 °C

4 Classification and designation

4.1 Classification

The classification of the relevant steel grades shall be in accordance with ISO 4948-1.

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.

For information on designation of comparable steels, see Annex C.

5 Information to be supplied by the purchaser

5.1 Mandatory information

The manufacturer shall obtain the following information from the purchaser at the time of enquiry and order:

a) the quantity to be delivered;

b) the product form (e.g. round bar);

c) either the dimensional standard and the dimensions and tolerances selected from it (see 7.4) or any other document covering the dimensions and tolerances required for the product;

d) the reference to this document, i.e. ISO 4957;

e) the designation of the steel type (see Tables 2, 4, 6 and 8);

f) the symbol for the heat-treatment condition on delivery (see Table 1) and, if the products are to be delivered in the quenched and tempered condition, the hardness values required;

g) the type of inspection document in accordance with ISO 10474.

5.2 Options

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 shall be supplied in accordance with the basic specifications of this document (see 5.1):

a) if a surface condition other than "hot worked" or a special surface quality is required, the surface condition (see 6.2.3) and the surface quality (see 7.3);

b) any supplementary requirement that shall be complied with, the symbol and, where necessary, the details of this supplementary requirement (in accordance with Annex B).

5.3 Ordering example

EXAMPLE 2 t hot-rolled round bars in accordance with ISO 1035-1; with a nominal diameter of 30,0 mm; with a nominal length of 4 000 mm; with a tolerance on diameter of ±0,30 mm (class S of ISO 1035-4:1982); with a tolerance on length of ±10 mm (class L2 of ISO 1035-4:1982); all other tolerances as given in ISO 1035-4 for normal cases, surface as hot worked made of steel grade in accordance with this document, type X153CrMoV12 (see Table 4); heat-treatment condition: annealed (soft annealed) (symbol +A, see Table 1); with an inspection certificate 3.1 (see ISO 10474).

2 t rounds ISO 1035-1 and -4 – 30,0 S x 4000 L2

Steel ISO 4957-X153CrMoV12+A

ISO 10474 – 3.1

6 Manufacturing process

6.1 General

The manufacturing process of the steel and the products is left to the discretion of the manufacturer, with the restrictions given in 6.2. Upon request, the purchaser shall be informed what steel making process is being used.

6.2 Heat-treatment condition and surface condition on delivery

6.2.1 General

The heat-treatment and surface conditions of the products shall comply with the agreements made at the time of ordering.

6.2.2 Heat-treatment condition

The heat-treatment conditions are given in Table 1.

Unless otherwise specified in the order, the tool steels [except C45U (Table 2), 35CrMo7, X38CrMo16 and 40CrMnNiMo8-6-4 (Table 4), 55NiCrMoV7 (Table 6)] are delivered in the annealed condition.

6.2.3 Surface condition

Usual surface conditions are

a) the hot-rolled or forged condition (= as hot worked),

b) the machined (ground, polished, turned, peeled or milled) condition, and

c) the cold-reduced condition.

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

7 Requirements

7.1 General requirements

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

7.2 Chemical composition and mechanical properties

Table 1 gives a survey of combinations of usual heat-treatment conditions at delivery and requirements according to Tables 2 to 9 (chemical composition, hardness).

For hardness-tempering temperature curves of the steels, see Annex A.

For hardness penetration depth of non-alloy cold-work tool steels, see Table 2, footnote c.

7.3 Surface quality

7.3.1 All products shall have a smooth surface finish appropriate to the manufacturing processes applied. Minor surface imperfections, which also may occur under normal manufacturing conditions, such as prints originating from rolled-in scale, are not to be regarded as defects.

Bars shall be delivered with surface class A in accordance with ISO 9443 unless otherwise agreed at the time of enquiry and order. Plates shall be delivered in accordance with ISO 7788 unless otherwise agreed at the time of enquiry and order.

7.3.2 Ground, polished or finished-machined products shall be free from surface imperfections and surface decarburization.

7.3.3 Hot-rolled, forged, cold-drawn or rough-machined products shall be ordered with sufficient material to be removed from all surfaces by machining or grinding to allow for

a) surface decarburization, and

b) surface imperfections.

Providing no International Standard for the machining allowances of tool steels is available, the allowances shall be agreed at the time of enquiry and order.

7.4 Shape, dimensions and tolerances

The shape, dimensions and tolerances of the products shall comply with the requirements agreed upon at the time of enquiry and order. The agreements shall, as far as possible, be based on corresponding International Standards or, otherwise, on suitable national standards.

For rolled flat and round bars, the following International Standards that cover dimensions and/or tolerances for products included in this document shall apply: ISO 1035-1, ISO 1035-3 and ISO 1035-4.

For hot rolled plates ISO 7452:2013, Annex A class A shall apply if not otherwise agreed.

NOTE By agreement, the tolerances can be all plus or other disposition than equal plus/minus.

8 Inspection, testing and conformance of products

8.1 Inspection and testing procedures and types of inspection 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. 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 made at the time of enquiry and order, a test report 2.2 is to be provided, this shall cover

a) the statement that the material complies with the requirements of the order, and

b) the results of the cast analysis for all elements specified for the type of steel supplied.

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 8.2 shall be carried out and their results shall be certified in the document.

In addition the document shall cover

a) the results of the cast analysis provided by the manufacturer for all elements specified for the steel type concerned,

b) the results of all inspections and tests ordered by supplementary requirements (in accordance with Annex B), and

c) the symbol letters of numbers connecting the inspection documents, the test pieces and products to each other.

8.2 Specific inspection and testing

8.2.1 Number of sample products

8.2.1.1 Chemical composition

The cast analysis is given by the manufacturer. For product analysis, see B.2.

8.2.1.2 Mechanical properties

8.2.1.2.1 One sample product per test unit shall be tested.

8.2.1.2.2 For material delivered in the annealed or annealed and cold rolled or annealed and cold drawn condition, the test unit shall consist of products from the same cast and the same heat-treatment batch.

In the case of material heat treated in a continuous furnace, a heat-treatment batch is regarded as the quantity of products (of the same cast and dimensions) that, without any interruptions, underwent constant treatment conditions (same furnace temperature, atmosphere and transportation speed) through the furnace.

8.2.1.2.3 For material delivered in the quenched and tempered condition, the test unit shall consist of products from the same cast, heat-treatment and thickness.

However, if the manufacturer verifies that the thickness has no significant effect on the hardness in the quenched and tempered condition, then different thicknesses may be covered in a test unit.

In the case of material heat treated in a continuous furnace, a heat-treatment batch is regarded as the quantity of products (of the same cast and dimensions) that, without any interruptions, underwent constant treatment conditions (same furnace temperature, atmosphere and transportation speed) through the furnace.

8.2.1.3 Inspection of the surface quality

Unless otherwise agreed when ordering (see B.5), the number of products to be inspected for surface quality is left to the discretion of the manufacturer.

8.2.1.4 Dimensional inspection

Unless otherwise agreed when ordering (see B.6), the number of products to be inspected for their shape and dimensions is left to the discretion of the manufacturer.

8.2.2 Sampling

The general conditions for selection and preparation of samples and test pieces shall be in accordance with ISO 377 and ISO 14284.

For the Brinell hardness test, the surface of the sample product or of a test piece taken from the sample product in the delivery condition shall be prepared in accordance with the requirements of ISO 6506-1.

8.2.3 Test methods

The Brinell hardness test shall be made in accordance with ISO 6506-1.

Unless otherwise agreed (see B.5), the surface quality shall be inspected visually.

8.2.4 Retests

For retests, ISO 404 shall apply.

8.2.5 Sorting and reprocessing

For sorting and reprocessing, ISO 404 shall apply.

9 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 B.9).

10 Tables

Table 1 — Combinations of heat-treatment conditions at delivery and requirements in accordance with Tables 2 to 9

	1	2	3											
1	**Heat-treatment condition at delivery**	**Symbol**[a]	**Applicable requirements for**											
			3.1 non-alloy cold-work tool steels			**3.2 alloy cold-work tool steels**			**3.3 hot-work tool steels**			**3.4 high-speed tool steels**		
2	Untreated	+U	Chemical composition acc. to Tables 2 and 3	Hardness acc. to Table 2	—[c]	Chemical composition acc. to Tables 4 and 5	Hardness acc. to Table 4	—[c]	Chemical composition acc. to Tables 6 and 7	Hardness acc. to Table 6	—[c]	Chemical composition acc. to Tables 8 and 9	Hardness acc. to Table 8	—[c]
3	Annealed (soft annealed)[b]	+A[b]			+A[c]			+A[c]			+A[c]			+A[c]
4	Annealed and cold drawn	+A+C			+A and footnote a to Table 2[c]			+A and footnote b to Table 4[c]			+A and footnote b to Table 6[c]			+A and footnote c to Table 8[c]
	Annealed and cold-rolled[d]	+A+CR[d]												
5	Quenched and tempered[e]	+QT[e]	—			[f]			[f]			—		
6	Normalized[g] and tempered	+NT	—			[f]			—			—		

[a] In cases where no heat-treatment condition is specified at the time of ordering, the product will be delivered in the usual heat-treatment condition given in 6.2.2.

[b] Most common heat-treatment condition at delivery.

[c] In addition, the requirements for minimum hardness in the hardening test apply. For verification, see B.3.

[d] Only for steels of Table 8.

[e] Mainly for individually manufactured blocks for moulds and dies.

[f] The hardness requirements are to be agreed at the time of enquiry and order.

[g] Normalizing is performed either by normalizing in furnace or by normalizing forming.

Table 2 — Chemical composition (cast analysis) for non-alloy cold-work tool steels, annealed hardness, austenitizing temperature and hardness in the hardened and tempered condition

Steel name	Mass fraction, %					Hardness (annealed) [a] +A	Hardening test			
	C	Si	Mn	P max.	S max.	HBW max.	Austenitizing temperature °C (±10 °C)	Quenching medium	Tempering temperature °C (±10 °C)	Hardness HRC min.
C45U[b]	0,42 to 0,50	0,15 to 0,40	0,60 to 0,80	0,030	0,030	207[b]	810	W	180	54
C70U[c]	0,65 to 0,75	0,10 to 0,30	0,10 to 0,40	0,030	0,030	183	800	W	180	57
C80U[c]	0,75 to 0,85	0,10 to 0,30	0,10 to 0,40	0,030	0,030	192	790	W	180	58
C90U[c]	0,85 to 0,95	0,10 to 0,30	0,10 to 0,40	0,030	0,030	207	780	W	180	60
C105U[c]	1,00 to 1,10	0,10 to 0,30	0,10 to 0,40	0,030	0,030	212	780	W	180	61
C120U[c]	1,15 to 1,25	0,10 to 0,30	0,10 to 0,40	0,030	0,030	217	770	W	180	62

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 from scrap or other materials used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[a] Hardness in the cold drawn condition (+A+C) may be 20 HBW higher than in the annealed (+A) condition.

[b] This grade is used in the non-heat treated condition.

[c] Steel grades C70U to C120U are due to their chemical composition shallow hardening steels. For diameters of 30 mm, the hardness penetration depth will be approximately 3 mm. Through hardening may only be achieved in diameters up to 10 mm.

Table 3 — Permissible deviations between specified cast analysis and product analysis for non-alloy cold-work tool steels (see Table 2)

Permissible deviations, mass fraction %				
C	**Si**	**Mn**	**P**	**S**
±0,03	±0,03	±0,04	+0,005	+0,005
NOTE The deviations, other than when maxima only are specified, apply either *above* or below the specified limits of the range but not both *above* and below for the same element from different sample products from the same cast. When maxima only are specified, the deviations are positive only. The values are *valid* only if the samples are selected in accordance with ISO 14284, so that they represent the *average* composition of the cross-section of the product.				

Table 4 — Chemical composition (cast analysis) for alloy cold-work tool steels, annealed hardness, austenitizing temperature and hardness in the hardened and tempered condition

Steel name	Mass fraction[a], %								Hardness (annealed)[b] +A HBW	Hardening test			
	C	Si	Mn	Cr	Mo	Ni	V	W	max.	Austenitizing temperature °C (±10 °C)	Quenching medium[c]	Tempering temperature °C (±10 °C)	Hardness HRC min.
105V	1,00 to 1,10	0,10 to 0,30	0,10 to 0,40	—	—	—	0,10 to 0,20	—	212	790	W	180	61
50WCrV8	0,45 to 0,55	0,70 to 1,00	0,15 to 0,45	0,90 to 1,20	—	—	0,10 to 0,20	1,70 to 2,20	229	920	O	180	56
60WCrV8	0,55 to 0,65	0,70 to 1,00	0,15 to 0,45	0,90 to 1,20	—	—	0,10 to 0,20	1,70 to 2,20	229	910	O	180	58
102Cr6	0,95 to 1,10	0,15 to 0,35	0,25 to 0,45	1,35 to 1,65	—	—	—	—	223	840	O	180	60
21MnCr5	0,18 to 0,24	0,15 to 0,35	1,10 to 1,40	1,00 to 1,30	—	—	—	—	217	—[d]	—[d]	—[d]	—[d]
70MnMoCr8	0,65 to 0,75	0,10 to 0,50	1,80 to 2,50	0,90 to 1,20	0,90 to 1,40	—	—	—	248	835	A	180	58
90MnCrV8	0,85 to 0,95	0,10 to 0,40	1,80 to 2,20	0,20 to 0,50	—	—	0,05 to 0,20	—	229	790	O	180	60
95MnWCr5	0,90 to 1,00	0,10 to 0,40	1,05 to 1,35	0,40 to 0,65	—	—	0,05 to 0,20	0,40 to 0,70	229	800	O	180	60
X100CrMoV5	0,95 to 1,05	0,10 to 0,40	0,40 to 0,80	4,8 to 5,5	0,90 to 1,20	—	0,15 to 0,35	—	241	970	A	180	60
X153CrMoV12	1,45 to 1,60	0,10 to 0,60	0,20 to 0,60	11,0 to 13,0	0,70 to 1,00	—	0,70 to 1,00	—	255	1 020	A	180	61
X210Cr12	1,90 to 2,20	0,10 to 0,60	0,20 to 0,60	11,0 to 13,0	—	—	—	—	248	970	O	180	62
X210CrW12	2,00 to 2,30	0,10 to 0,40	0,30 to 0,60	11,0 to 13,0	—	—	—	0,60 to 0,80	255	970	O	180	62
35CrMo7[e]	0,30 to 0,40	0,30 to 0,70	0,60 to 1,00	1,50 to 2,00	0,35 to 0,55	—	—	—	—[e]	—	—	—	—[e]
40CrMnNiMo8-6-4[e,f]	0,35 to 0,45	0,20 to 0,40	1,30 to 1,60	1,80 to 2,10	0,15 to 0,25	0,90 to 1,20[f]	—	—	—[e]	—	—	—	—[e]
45NiCrMo16	0,40 to 0,50	0,10 to 0,40	0,20 to 0,50	1,20 to 1,50	0,15 to 0,35	3,80 to 4,30	—	—	285	850	O	180	52
X40Cr14[g]	0,36 to 0,42	≤ 1,00	≤ 1,00	12,5 to 14,5	—	—	—	—	241	1 010	O	180	52
X38CrMo16[e,f]	0,33 to 0,45	≤ 1,00	≤ 1,50	15,5 to 17,5	0,80 to 1,30	≤ 1,00	—	—	—[e]	—	—	—	—[e]

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 from scrap or other materials used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[a] For all steels: phosphorus ≤ 0,030 % and sulfur ≤ 0,030 % (see, however, footnote f).

[b] Hardness in the cold drawn condition (+A +C) may be 20 HBW higher than in the annealed condition (+A).

[c] Quenching medium: A = air, O = oil, W = water.

[d] This material when carburized, quenched and tempered should achieve a surface hardness of 60 HRC.

[e] This steel is normally supplied in the quenched and tempered condition with a hardness of approximately 300 HBW.

[f] By agreement, sulfur may be increased to between 0,050 % and 0,100 % and Ni may be omitted.

[g] This steel may also be supplied in the pre-heated condition with a hardness of approximately 300 HBW.

Table 5 — Permissible deviations between specified cast analysis and product analysis for alloy cold-work tool steels (see Table 4)

Steel name	Permissible deviations[a], mass fraction %									
	C	Si	Mn	P	S	Cr	Mo	Ni	V	W
105V	±0,03	±0,03	±0,04	+0,005	+0,005	—	—	—	±0,02	—
50WCrV8	±0,03	±0,05	±0,04	+0,005	+0,005	±0,05	—	—	±0,02	±0,07
60WCrV8	±0,03	±0,05	±0,04	+0,005	+0,005	±0,05	—	—	±0,02	±0,07
102Cr6	±0,03	±0,03	±0,04	+0,005	+0,005	±0,07	—	—	—	—
21MnCr5	±0,03	±0,03	±0,08	+0,005	+0,005	±0,05	—	—	—	—
70MnMoCr8	±0,03	±0,03	±0,08	+0,005	+0,005	±0,05	±0,05	—	—	—
90MnCrV8	±0,03	±0,03	±0,08	+0,005	+0,005	±0,05	—	—	±0,02	—
95MnCrW5	±0,03	±0,03	±0,06	+0,005	+0,005	±0,05	—	—	±0,02	±0,04
X100CrMoV5	±0,03	±0,03	±0,04	+0,005	+0,005	±0,10	±0,05	—	±0,03	—
X153CrMoV12	±0,04	±0,03	±0,04	+0,005	+0,005	±0,15	±0,05	—	±0,04	—
X210Cr12	±0,05	±0,03	±0,04	+0,005	+0,005	±0,15	—	—	—	—
X210CrW12	±0,05	±0,03	±0,04	+0,005	+0,005	±0,15	—	—	—	±0,04
35CrMo7	±0,03	±0,03	±0,04	+0,005	+0,005	±0,07	±0,05	—	—	—
40CrMnNiMo8-6-4[b]	±0,03	±0,03	±0,08	+0,005	+0,005	±0,07	±0,03	±0,07	—	—
45NiCrMo16	±0,03	±0,03	±0,04	+0,005	+0,005	±0,07	±0,03	±0,07	—	—
X40Cr14	±0,03	±0,05	±0,04	+0,005	+0,005	±0,15	—	—	—	—
X38CrMo16	±0,03	±0,05	±0,04	+0,005	+0,005	±0,15	±0,05	+0,07	—	—

[a] The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different sample products from the same cast. When maxima only are specified the deviations are positive only. The values are valid only if the samples are selected in accordance with ISO 14284, so that they represent the average composition of the cross-section of the product.

[b] If a range for the sulfur content of this grade is agreed, the permissible deviation shall be ±0,010 %.

Table 6 — Chemical composition (cast analysis) for hot-work tool steels, annealed hardness, austenitizing temperature and hardness in the quenched and tempered condition

Steel name	Mass fraction[a] %								Hardness (annealed)[b] +A HBW max.	Hardening test			
	C	Si	Mn	Cr	Mo	V	W	Others		Austenitizing temperature °C (±10 °C)	Quenching medium[c]	Tempering temperature °C (±10 °C)	Hardness HRC min.
55NiCrMoV7[d,e]	0,50 to 0,60	0,10 to 0,40	0,60 to 0,90	0,80 to 1,20	0,35 to 0,55	0,05 to 0,15	—	Ni: 1,50 to 1,80	248 [e]	850	O	500	42[f]
32CrMoV12-28	0,28 to 0,35	0,10 to 0,40	0,15 to 0,45	2,70 to 3,2	2,50 to 3,00	0,40 to 0,70	—	—	229	1 040	O	550	46
X37CrMoV5-1	0,33 to 0,41	0,80 to 1,20	0,25 to 0,50	4,8 to 5,5	1,10 to 1,50	0,30 to 0,50	—	—	229	1 020	O	550	48
X38CrMoV5-3	0,35 to 0,40	0,30 to 0,50	0,30 to 0,50	4,8 to 5,2	2,70 to 3,2	0,40 to 0,60	—	—	229	1 040	O	550	50
X40CrMoV5-1	0,35 to 0,42	0,80 to 1,20	0,25 to 0,50	4,8 to 5,5	1,20 to 1,50	0,85 to 1,15	—	—	229	1 020	O	550	50
50CrMoV13-15	0,45 to 0,55	0,20 to 0,80	0,50 to 0,90	3,0 to 3,5	1,30 to 1,70	0,15 to 0,35	—	—	248	1 010	O	510	56
X30WCrV9-3	0,25 to 0,35	0,10 to 0,40	0,15 to 0,45	2,5 to 3,2	—	0,30 to 0,50	8,5 to 9,5	—	241	1 150	O	600	48
X35CrWMoV5	0,32 to 0,40	0,80 to 1,20	0,20 to 0,50	4,75 to 5,5	1,25 to 1,60	0,20 to 0,50	1,10 to 1,60	—	229	1 020	O	550	48
38CrCoWV18-17-17	0,35 to 0,45	0,15 to 0,50	0,20 to 0,50	4,0 to 4,7	0,30 to 0,50	1,70 to 2,10	3,8 to 4,5	Co: 4,0 to 4,5	260	1 120	O	600	48

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 from scrap or other materials used in manufacture, of such elements which affect the hardenability, mechanical properties and applicability.

[a] For all steels (unless otherwise specified). phosphorus ≤ 0,030 % and sulfur ≤ 0,020 %.

[b] Hardness in the cold drawn condition (+A+C) may be 20 HBW higher than in the annealed condition (+A).

[c] Quenching medium: O = oil. Usual quenching media for tools are air, gas or salt bath.

[d] The sulfur content for this grade is ≤ 0,030 % .

[e] For greater dimensions, this steel is normally supplied in the quenched and tempered condition with a hardness of approximately 380 HBW.

[f] This value applies for smaller dimensions only.

Table 7 — Permissible deviations between specified cast analysis and product analysis for hot-work tool steels (see Table 6)

Steel name	Permissible deviations, mass fraction %										
	C	Si	Mn	P	S	Cr	Mo	Ni	Co	V	W
55NiCrMoV7	±0,02	±0,03	±0,04	+0,005	+0,005	±0,05	±0,04	±0,07	—	±0,02	—
32CrMoV12-28	±0,02	±0,03	±0,04	+0,005	+0,005	±0,10	±0,10	—	—	±0,04	—
X37CrMoV5-1	±0,02	±0,05	±0,04	+0,005	+0,005	±0,10	±0,05	—	—	±0,04	—
X38CrMoV5-3	±0,02	±0,03	±0,04	+0,005	+0,005	±0,10	±0,10	—	—	±0,04	—
X40CrMoV5-1	±0,02	±0,05	±0,04	+0,005	+0,005	±0,10	±0,05	—	—	±0,05	—
50CrMoV13-15	±0,02	±0,05	±0,04	+0,005	+0,005	±0,10	±0,05	—	—	±0,04	—
X30WCrV9-3	±0,02	±0,03	±0,04	+0,005	+0,005	±0,10	—	—	—	±0,04	±0,10
X35CrWMoV5	±0,02	±0,05	±0,04	+0,005	+0,005	±0,10	±0,05	—	—	±0,04	±0,07
38CrCoWV18-17-17	±0,02	±0,03	±0,04	+0,005	+0,005	±0,10	±0,04	—	±0,10	±0,10	±0,10

NOTE The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different sample products from the same cast. When maxima only are specified the deviations are positive only. The values are valid only if the samples are selected in accordance with ISO 14284, so that they represent the average composition of the cross-section of the product.

Table 8 — Chemical composition (cast analysis) for high-speed tool steels, annealed hardness, austenitizing temperature and hardness in the hardened and tempered condition

Steel name	Mass fraction[a,b], %							Hardness (annealed)[c] +A HBW	Hardening test[e]			
	C	Si max.	Co	Cr	Mo	V	W	max.	Austenitizing Temperature °C (±10 °C)	Quenching medium[d]	Tempering temperature °C (±10 °C) min.	Hardness HRC min.
HSO-4-1	0,77 to 0,85	0,65	—	3,9 to 4,4	4,0 to 4,5	0,90 to 1,10	—	262	1 120	—	560	60
HS1-4-2	0,85 to 0,95	0,65	—	3,6 to 4,3	4,1 to 4,8	1,70 to 2,20	0,80 to 1,40	262	1 180	—	560	63
HS18-0-1	0,73 to 0,83	0,45	—	3,8 to 4,5	—	1,00 to 1,20	17,2 to 18,7	269	1 260	—	560	63
HS2-9-2	0,95 to 1,05	0,70	—	3,5 to 4,5	8,2 to 9,2	1,70 to 2,20	1,50 to 2,10	269	1 200	—	560	64
HS1-8-1	0,77 to 0,87	0,70	—	3,5 to 4,5	8,0 to 9,0	1,00 to 1,40	1,40 to 2,00	262	1 190	—	560	63
HS3-3-2	0,95 to 1,03	0,45	—	3,8 to 4,5	2,50 to 2,90	2,20 to 2,50	2,70 to 3,00	255	1 190	—	560	62
HS6-5-2	0,80 to 0,88	0,45	—	3,8 to 4,5	4,7 to 5,2	1,70 to 2,10	5,9 to 6,7	262	1 220	—	560	64
HS6-5-2C[f]	0,86 to 0,94	0,45	—	3,8 to 4,5	4,7 to 5,2	1,70 to 2,10	5,9 to 6,7	269	1 210	—	560	64
HS6-5-3	1,15 to 1,25	0,45	—	3,8 to 4,5	4,7 to 5,2	2,70 to 3,2	5,9 to 6,7	269	1 200	—	560	64
HS6-5-3C	1,25 to 1,32	0,70	—	3,8 to 4,5	4,7 to 5,2	2,70 to 3,2	5,9 to 6,7	269	1 180	—	560	64
HS6-6-2	1,00 to 1,10	0,45	—	3,8 to 4,5	5,5 to 6,5	2,30 to 2,60	5,9 to 6,7	262	1 200	—	560	64
HS6-5-4	1,25 to 1,40	0,45	—	3,8 to 4,5	4,2 to 5,0	3,7 to 4,2	5,2 to 6,0	269	1 210	—	560	64
HS6-5-2-5[f]	0,87 to 0,95	0,45	4,5 to 5,0	3,8 to 4,5	4,7 to 5,2	1,70 to 2,10	5,9 to 6,7	269	1 210	—	560	64
HS6-5-3-8	1,23 to 1,33	0,70	8,0 to 8,8	3,8 to 4,5	4,7 to 5,3	2,70 to 3,2	5,9 to 6,7	302	1 180	—	560	65
HS10·4-3-10	1,20 to 1,35	0,45	9,5 to 10,5	3,8 to 4,5	3,2 to 3,9	3,00 to 3,5	9,0 to 10,0	302	1 230	—	560	66
HS2-9-1-8	1,05 to 1,15	0,70	7,5 to 8,5	3,5 to 4,5	9,0 to 10,0	0,90 to 1,30	1,20 to 1,90	277	1 190	—	550	66

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 from scrap or other materials used in manufacture, of such elements which affect the hardenability mechanical properties and applicability.

[a] Maximum 0,40 % Mn unless otherwise specified (see footnote f).

[b] Maximum 0,030 % P and S each.

[c] Hardness in the annealed plus cold drawn condition (+A+C) may be 50 HBW and hardness in the annealed plus cold rolled condition (+A+CR) may be 70 HBW higher than in the annealed condition (+A).

[d] For the reference hardening test either oil or salt bath: in cases of dispute, however, only oil. Usual quenching media in practice are air, gas or salt bath.

[e] See B.3.

[f] A sulphur range of 0,060 % to 0,150 % may be agreed at the time of enquiry and order for this grade. In this case a max. of 0,80 % Mn applies.

Table 9 — Permissible deviations between specified cast analysis and product analysis for high-speed tool steels (see Table 8)

Steel name	Mass fraction[a,b], %									
	C	Si	Mn	P	S	Co	Cr	Mo	V	W
HSO-4-1	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,05	—
HS1-4-2	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,07	±0,10
HS18-0-1	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	—	±0,05	±0,20
HS2-9-2	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,07	±0,10
HS1-8-1	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,05	±0,10
HS3-3-2	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,10	±0,10
HS6-5-2	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,07	±0,10
HS6-5-2C	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,07	±0,10
HS6-5-3	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,10	±0,10
HS6-5-3C	±0,04	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,10	±0,10
HS6-6-2	±0,03	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,10	±0,10
HS6-5-4	±0,04	+0,03	+0,04	+0,005	+0,005	—	±0,10	±0,10	±0,10	±0,10
HS6-5-2-5	±0,03	+0,03	+0,04	+0,005	+0,005	±0,10	±0,10	±0,10	±0,07	±0,10
HS6-5-3-8	±0,04	+0,03	+0,04	+0,005	+0,005	±0,10	±0,10	±0,10	±0,10	±0,10
HS10-4-3-10	±0,03	+0,03	+0,04	+0,005	+0,005	±0,15	±0,10	±0,10	±0,10	±0,10
HS2-9-1-8	±0,03	+0,03	+0,04	+0,005	+0,005	±0,10	±0,10	±0,10	±0,05	±0,10

[a] The deviations, other than when maxima only are specified, apply either above or below the specified limits of the range but not both above and below for the same element from different sample products from the same cast. When maxima only are specified the deviations are positive only. The values are valid only if the samples are selected in accordance with ISO 14284, so that they represent the average composition of the cross-section of the product.

[b] If a range for the sulfur content is agreed, the permissible deviation shall be ±0,010 %.

11 Location of test pieces in the hardening test

11.1 Product diameter or thickness ≥ 15 mm

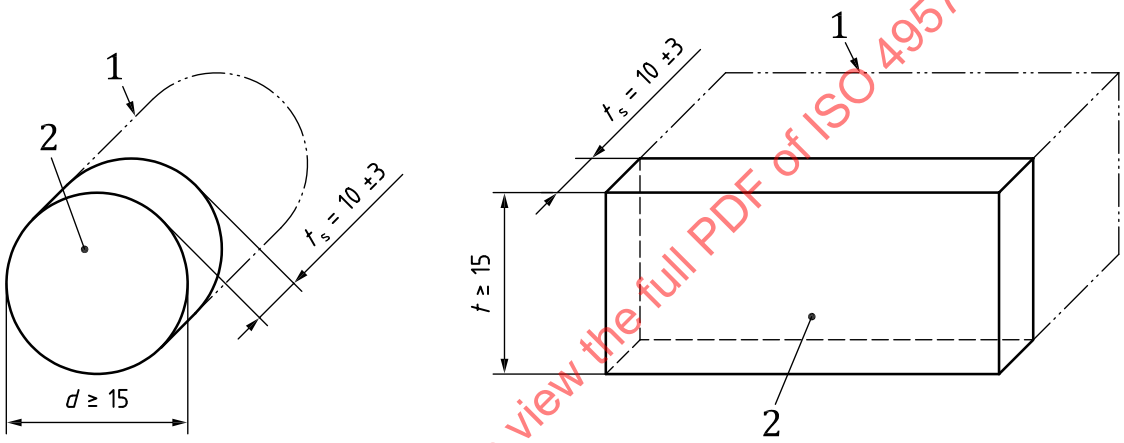
The test piece shall, according to the choice of the manufacturer,

a) be identical with the test sample, as demonstrated in Figure 1 a),

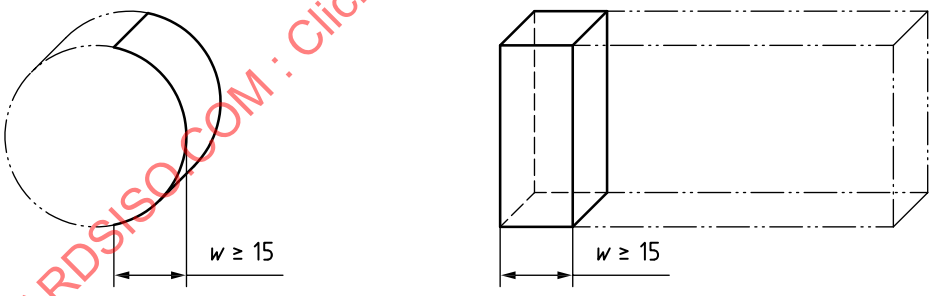
b) be taken from the sample by one cut as demonstrated in Figure 1 b), or

c) be taken from the sample by two cuts as demonstrated in Figure 1 c).

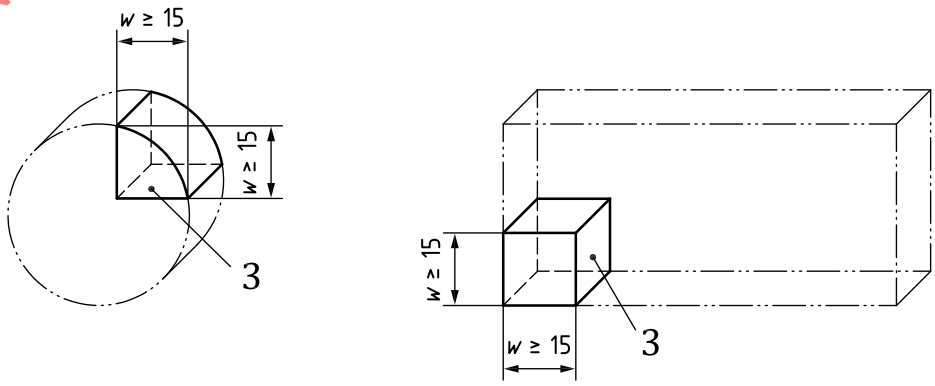
Dimensions in millimetres



(a) Test piece identical with the test sample



(b) Test piece taken from the sample by one cut



(c) Test piece taken from the sample by two cuts

Key

1 product
2 sample
3 test piece

Figure 1 — Location of test pieces in the hardening test — Product diameter or thickness ≥ 15 mm

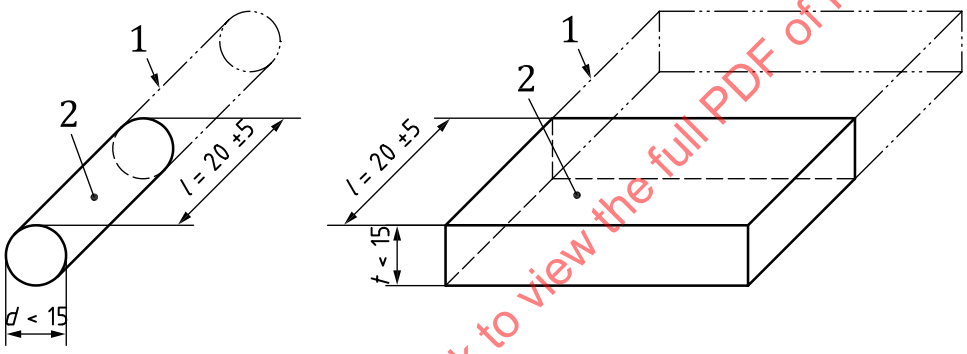
11.2 Product diameter or thickness < 15 mm

The test piece shall, according to the choice of the manufacturer,

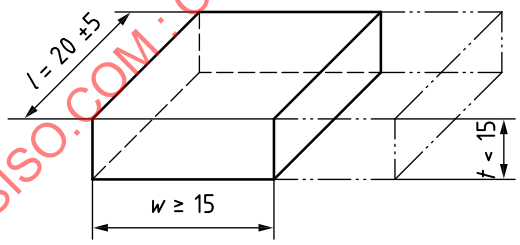
a) be identical with the test sample, as shown in Figure 2 a), or

b) be taken from rectangular samples by one cut as demonstrated in Figure 2 b).

Dimensions in millimetres



(a) Test piece identical with the test sample



(b) Test piece taken from rectangular samples by one cut

Key

1 product
2 sample

d diameter
l length
t thickness
t_s sample thickness
w width

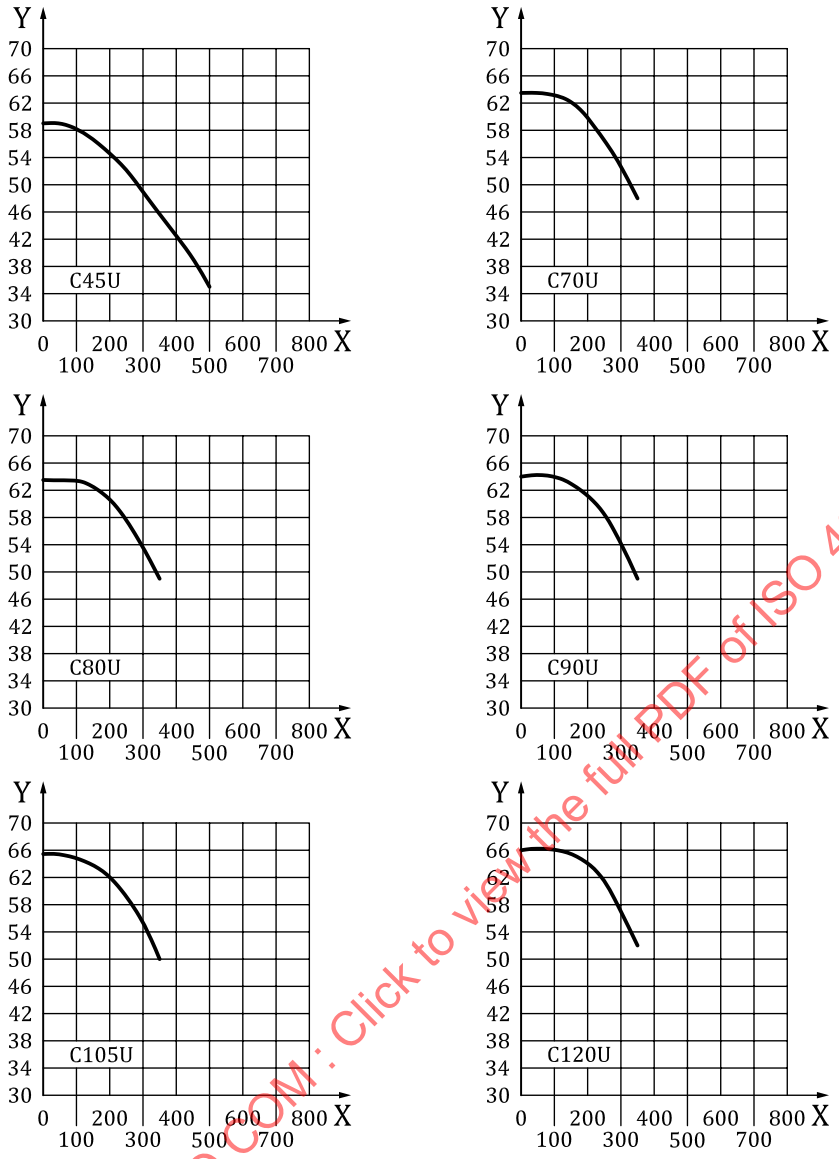
Figure 2 — Location of test pieces in the hardening test — Product diameter or thickness < 15 mm

Annex A
(informative)

Hardness-tempering temperature curves

The hardness-tempering temperature curves of the steels are given for guidance in Figures A.1 to A.4. In these figures, the austenitizing temperature and the quenching medium (W = water, O = oil, A = air) are mentioned.

NOTE The hardness-tempering temperature-curve for a certain steel type can vary to a considerable extent depending on the chemical composition of the cast, the hardening conditions and the tempering conditions. Consequently, the curves in Figures A.1 to A.4, which originate from data from different sources, can, for the time being, give only a rough guide to the tempering behaviour of the steels. They are assumed to apply with the above reservations for test pieces that have been tempered at the relevant tempering temperature but that, in all other respects, have been prepared according to the conditions for the hardening test (see B.3). When applying the curves for an estimation of the hardness that can be expected in quenched and tempered tools, it is taken into account that the optimum heat-treatment conditions for the tools are not necessarily identical with those specified for the test pieces and also that the times for heating given in B.3 are not valid for thicker tools.



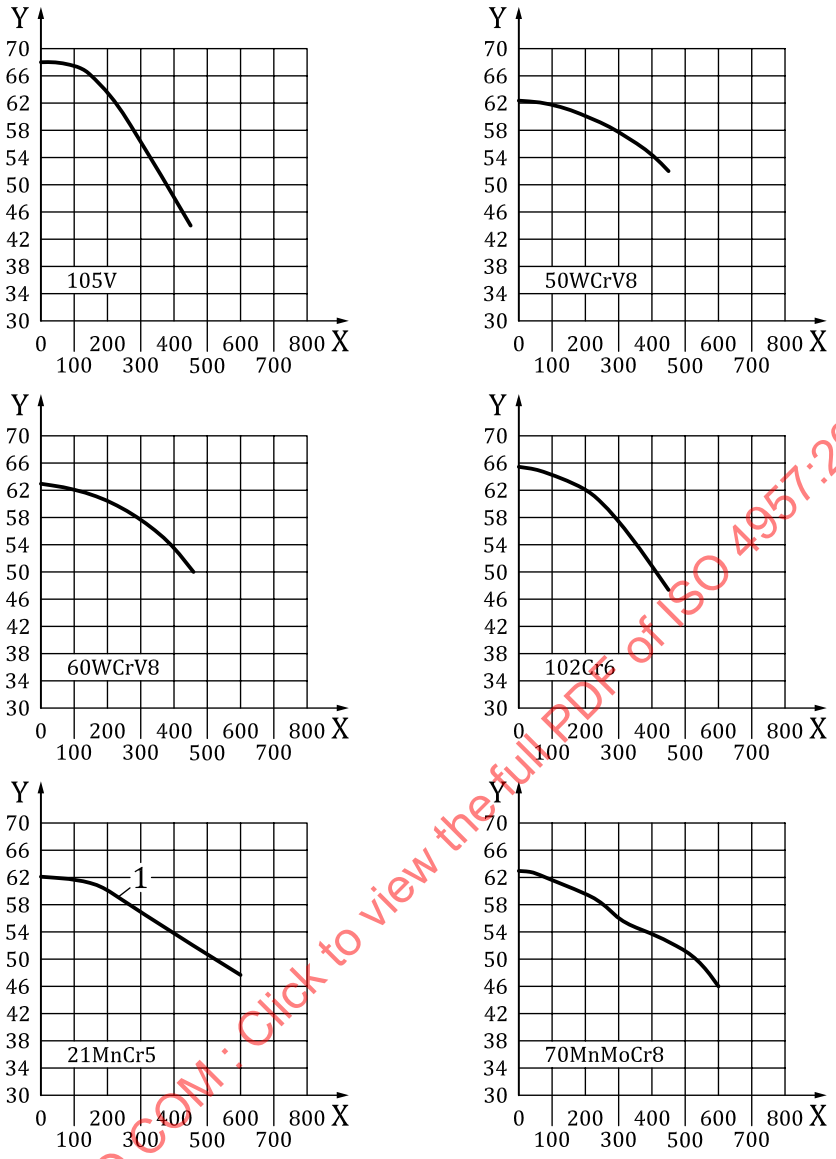
Key

X tempering temperature, °C

Y hardness HRC

Heat treatment C45U: 810 °C/W, C70U: 800°C/W, C80U: 790°C/W, C90U: 780 °C/W, C105U: 780 °C/W, C120U: 770 °C/W.

Figure A.1 — Hardness-tempering temperature curves for unalloyed cold-work tool steels (see Table 2)



Key

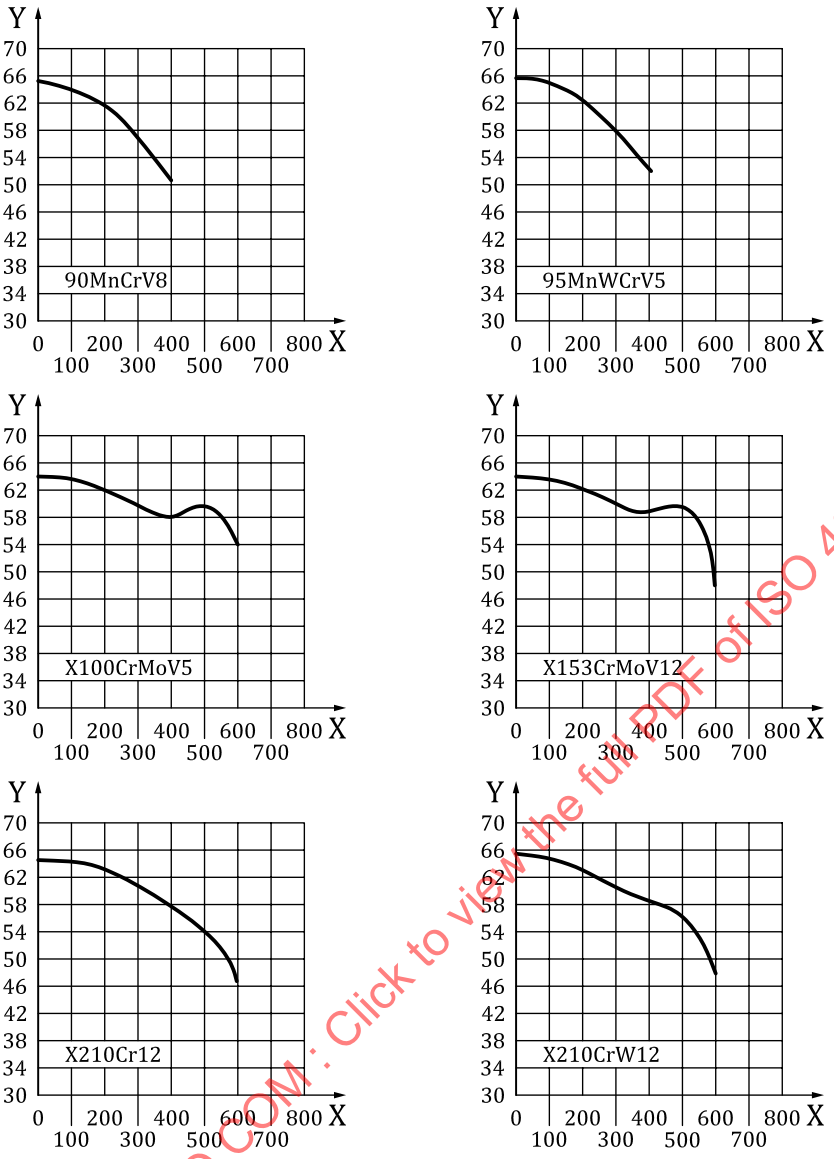
X tempering temperature, °C

Y hardness HRC

1 hardness of the case hardened surface

Heat treatment 105V: 790 °C/W, 50WCrV8: 920 °C/O, 60WCrV8: 910 °C/O, 102Cr6: 84 °C/O, 21MnCr5: 820 °C/O, 70MnMoCr8: 835 °C/O.

Figure A.2 — Hardness-tempering temperature curves for alloyed cold-work tool steels (see Table 4)



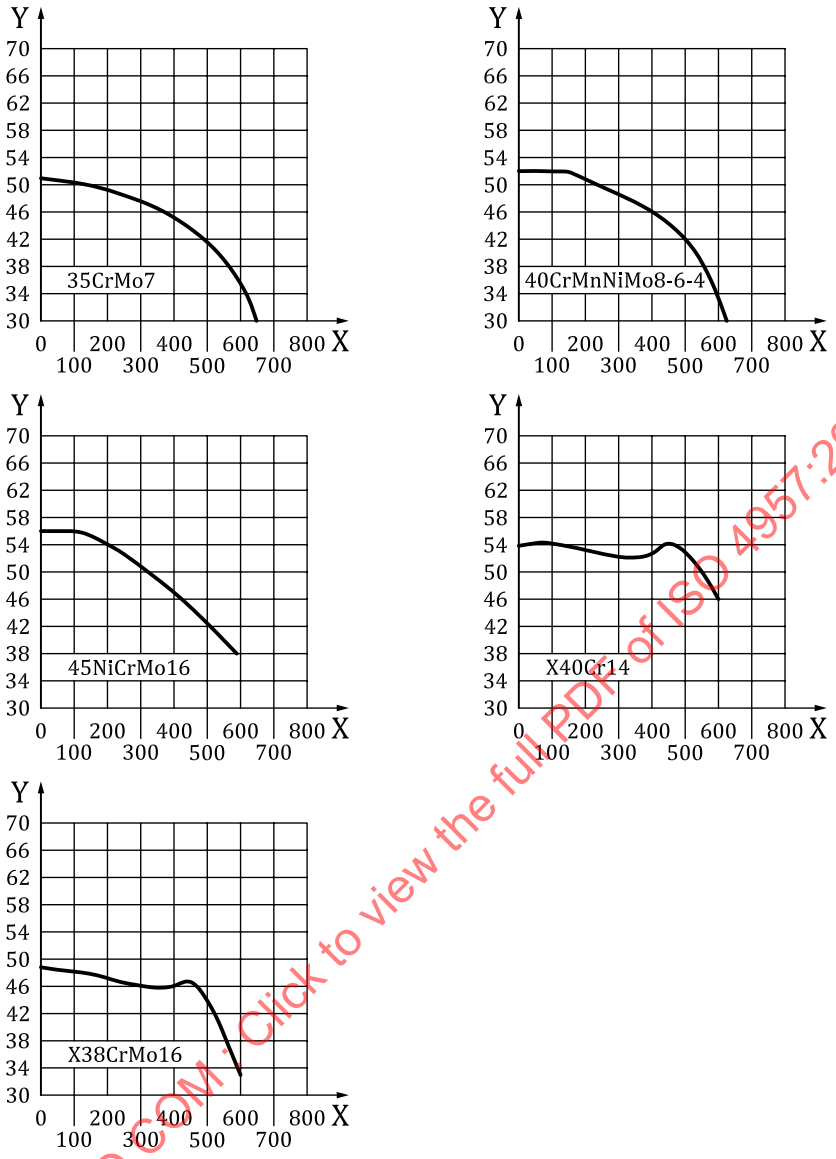
Key

X tempering temperature, °C

Y hardness HRC

Heat treatment 90MnCrV8: 790 °C/O, 95MnWCrV5: 800 °C/O, X100CrMoV5: 970 °C/AW, X153CrMoV12: 1 020 °C/A, X210Cr12: 970 °C/O, X210CrW12: 970 °C/O

Figure A.2 — *(continued)*



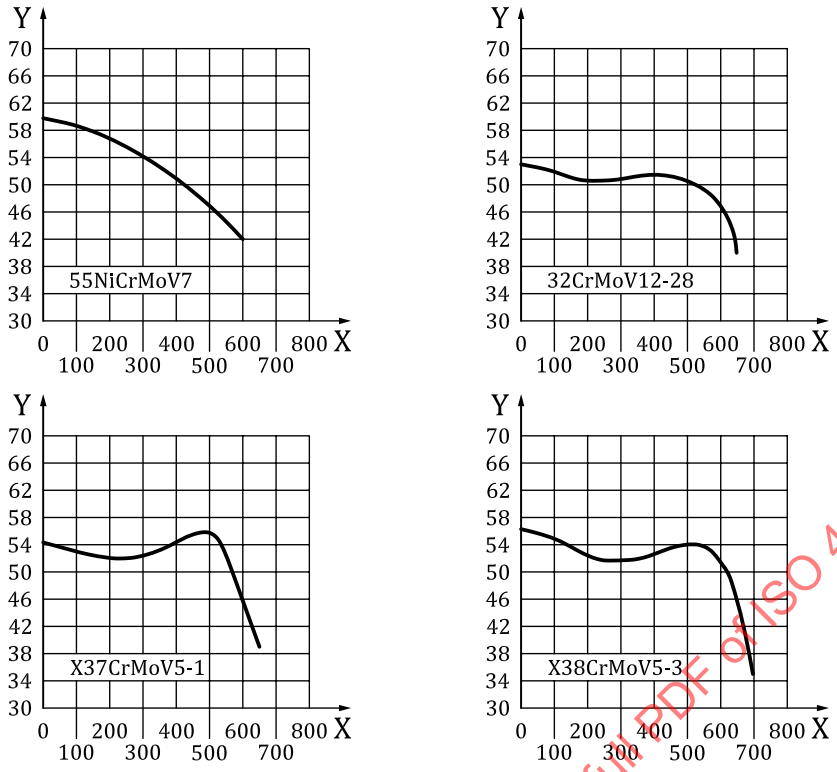
Key

X tempering temperature, °C

Y hardness HRC

Heat treatment 35CrMo7: see Table 4 footnote e, 40CrMnNiMo8-6-4: see Table 4 footnote e, 45NiCrMo16: 850 °C/W, X40Cr14: 1 010 °C/W, X38CrMo16: see Table 4 footnote e.

Figure A.2 — *(continued)*



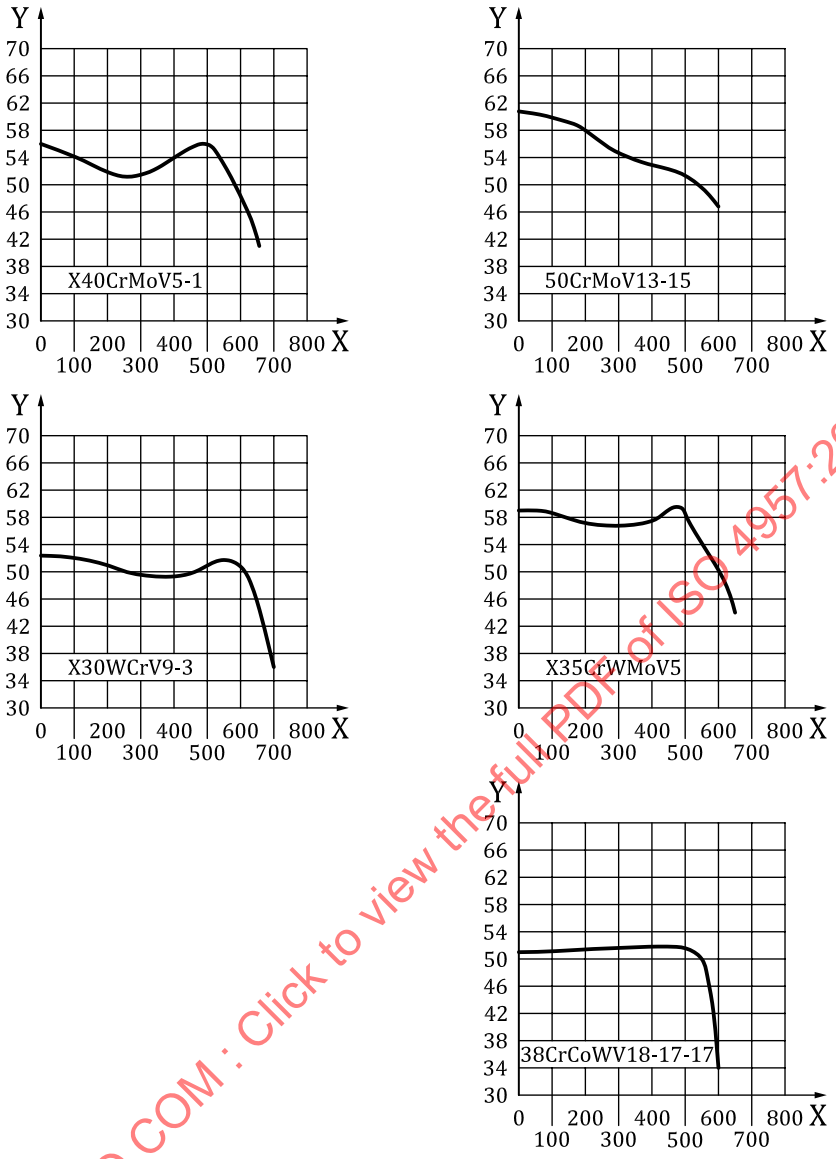
Key

X tempering temperature, °C

Y hardness HRC

Heat treatment 55NiCrMoV7: 850 °C/O, 32CrMoV12-28: 1 040 °C/O, X37CrMoV5-1: 1 020 °C/O, X38CrMoV5-3: 1 040 °C/O.

Figure A.3 — Hardness-tempering temperature curves for hot-work tool steels (see Table 6)



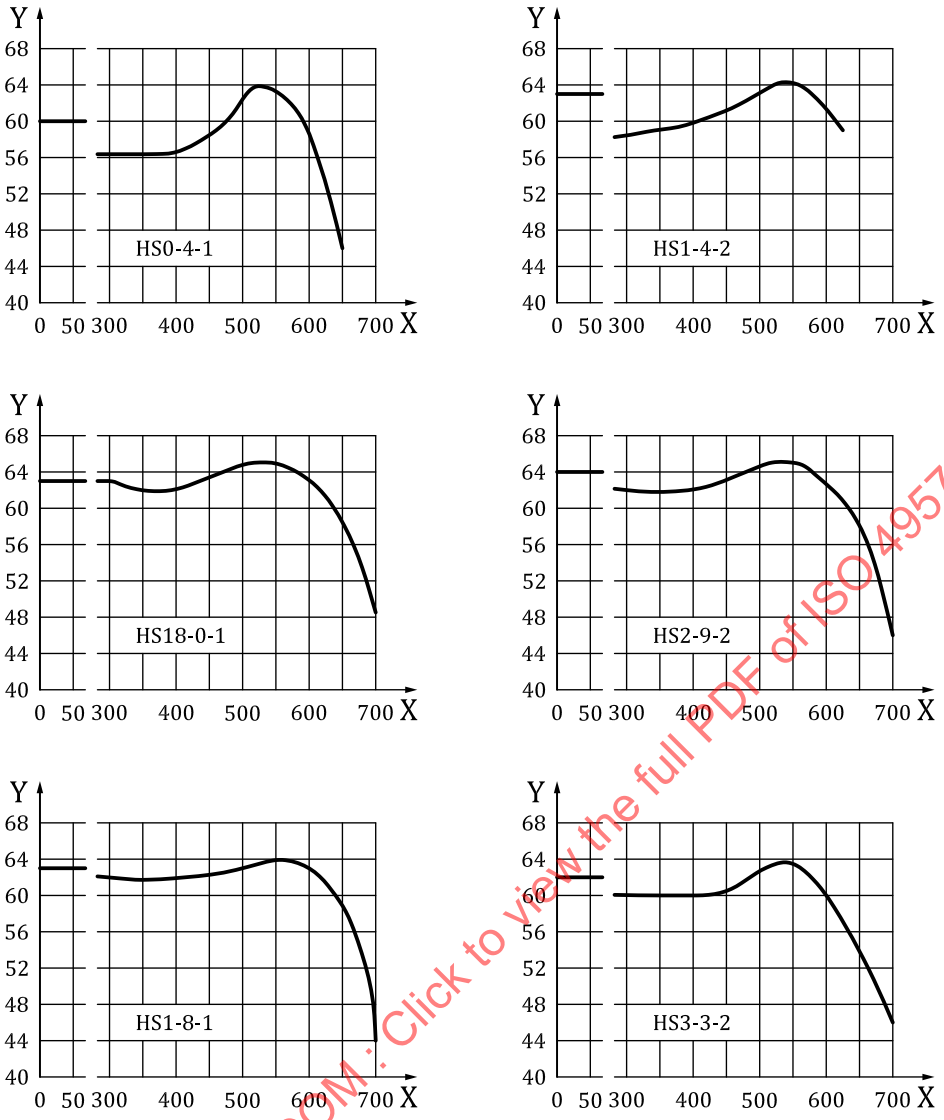
Key

X tempering temperature, °C

Y hardness HRC

Heat treatment X40CrMoV5-1: 1 020 °C/O, 50CrMoV13-15: 1 010 °C/O, X30WCrV9-3: 1 150 °C/O, X35CrWMoV5: 1 020 °C/O, 38CrCoWV18-17-17: 1 120 °C/O.

Figure A.3 — *(continued)*



Key

X tempering temperature, °C

Y hardness HRC

Heat treatment HS0-4-1: 1 120 °C/O, HS1-4-2: 1 180 °C/O, HS18-0-1: 1 260 °C/O, HS2-9-2: 1 200 °C/O, HS1-8-1: 1 190 °C/O, HS3-3-2: 1 190 °C/O.

Figure A.4 — Hardness-tempering temperature curves for high-speed tool steels (see Table 8)