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Steel — Hardenability test by end quenching (Jominy test)

Acier — Essai de trempabilité par trempe en bout (essai Jominy)

Reference number
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Foreword

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This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 7, *Methods of testing (other than mechanical tests and chemical analysis)*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459, *ECISS - European Committee for Iron and Steel Standardization,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 642:1999), which has been technically revised.

The main changes are as follows:

— updated the normative references;

— added a new symbol, Id, in Table 1;

— minimum recommended reduction ratio of 5:1, see 6.1;

— revised the test piece dimensions, see 6.1, 6.2 and Figures 1 and 2;

— revised the heat treatment requirements, see 6.3;

— revised configuration of fixing and centring device, see 7.3 and Figure 3;

— revised text concerning water temperature, see 7.4;

— revised requirement for nitric acid solution concentration, see 9.2;

— revised codification of test result, see 10.4 and Figure 6;

— revised A.2 and Figures A.2 and A.3;

— revised Annex C and Bibliography;

— editorial clarifications;

— reduced the number of bibliographical references.

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.

Steel — Hardenability test by end quenching (Jominy test)

1 Scope

This document specifies a method for determining the hardenability of steel by end quenching (Jominy test) by using a test piece 25 mm in diameter and at least 100 mm long.

By agreement and for a defined field of application, the test described in this document can be replaced by the calculation of the Jominy curve according to an accepted mathematical model.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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/

4 Symbols and designations

Symbols and designations used in this document are shown in Table 1.

Table 1 — Symbols and designations

Symbol	Designation	Value
L	Test length of test piece	(97 ± 0,5) mm
D	Diameter of test piece	$\left(25\ ^{+0,5}_{0}\right)$ mm
t	Time during which test piece is maintained at heating temperature	$\left(30\ ^{+5}_{0}\right)$ min
t_m	Maximum time lag between removal of test piece from furnace and start of quenching	5 s
T	Temperature of points on the surface, situated at certain distances from the quenched end	–
T_A	Temperature of austenitizing	–
a	Internal diameter of vertical water supply pipe	(12,5 ± 0,5) mm
h	Height of water jet without test piece in position	(65 ± 10) mm
d_w	Distance from end of water supply pipe to lower end of test piece	(12,5 ± 0,5) mm
e	Depth of flats for measurement of hardness	(0,4 to 0,5) mm
d	Distance, in millimetres, from quenched end to points where hardness is measured	–

Table 1 *(continued)*

Symbol	Designation	Value
J*d*	Measured hardness at distance *d*, in HRC or HV	–
J*xx-d*	Jominy hardenability index at distance *d*, in Rockwell HRC-mm	–
JHV*xx-d*	Jominy hardenability index at distance *d*, in Vickers HV 30-mm	–

5 Principle

The test consists of:

a) heating a cylindrical test piece to a specified temperature in the austenitic range for a specified period of time;

b) quenching it by spraying water on one of its ends under specified conditions;

c) measuring the hardness at certain given points (see 9.4), on flats made along the axis of the test piece, in order to determine the hardenability of the steel by variations of this hardness.

By agreement and for a defined field of application, the test described in this document can be replaced by the calculation of the Jominy curve in accordance with an accepted mathematical model (see Annex C). In case of dispute, the test shall be carried out.

6 Form of test pieces and their preparation

6.1 Sampling

In the absence of specific requirements in the product standard, and unless otherwise agreed on the order and regardless of the thickness (or diameter) of the product, the sampling of test piece from the product can be made:

— either by hot rolling or forging of test piece with 30 mm to 32 mm diameter;

— or by machining of a test piece with diameter $\left(25\ ^{+0,5}_{0}\right)$ mm whose axis shall be at $\left(20\ ^{+5}_{0}\right)$ mm from one of the surfaces of the product (see Figure 1).

In case of products from continuous casting, a minimum reduction ratio 5:1 is recommended before sampling.

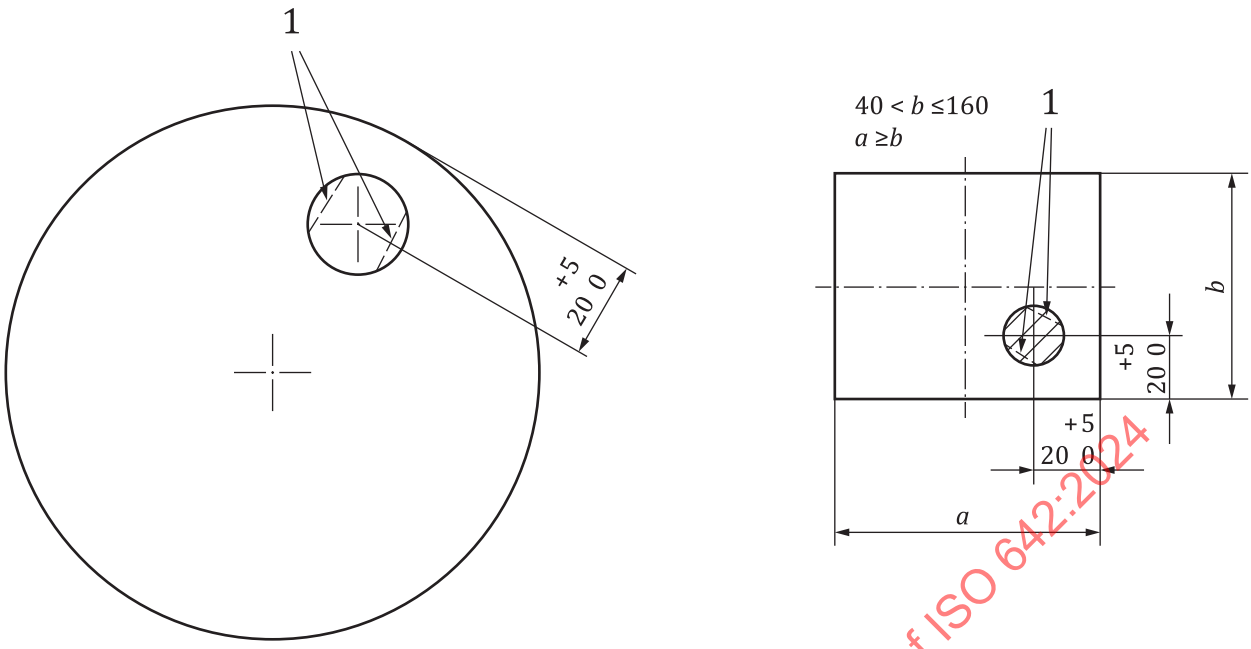
In all the forming processes preceding the machining of the test piece, the deformation of the product from all sides should be as uniform as possible.

In the case of a separately cast reference test piece, the original cross section before deformation shall be at least three times that corresponding to the required diameter of 30 mm to 32 mm.

By special agreement, the test piece can be obtained by a suitable casting process and tested in the as-cast condition.

The flats of the test piece shall have their axes at approximately the same distance from the product surface (see Figure 1). For this purpose, the test piece shall be marked so that its position in the round bar can be clearly recognized.

Dimensions in millimetres



Key

1 test flats for measuring the hardness

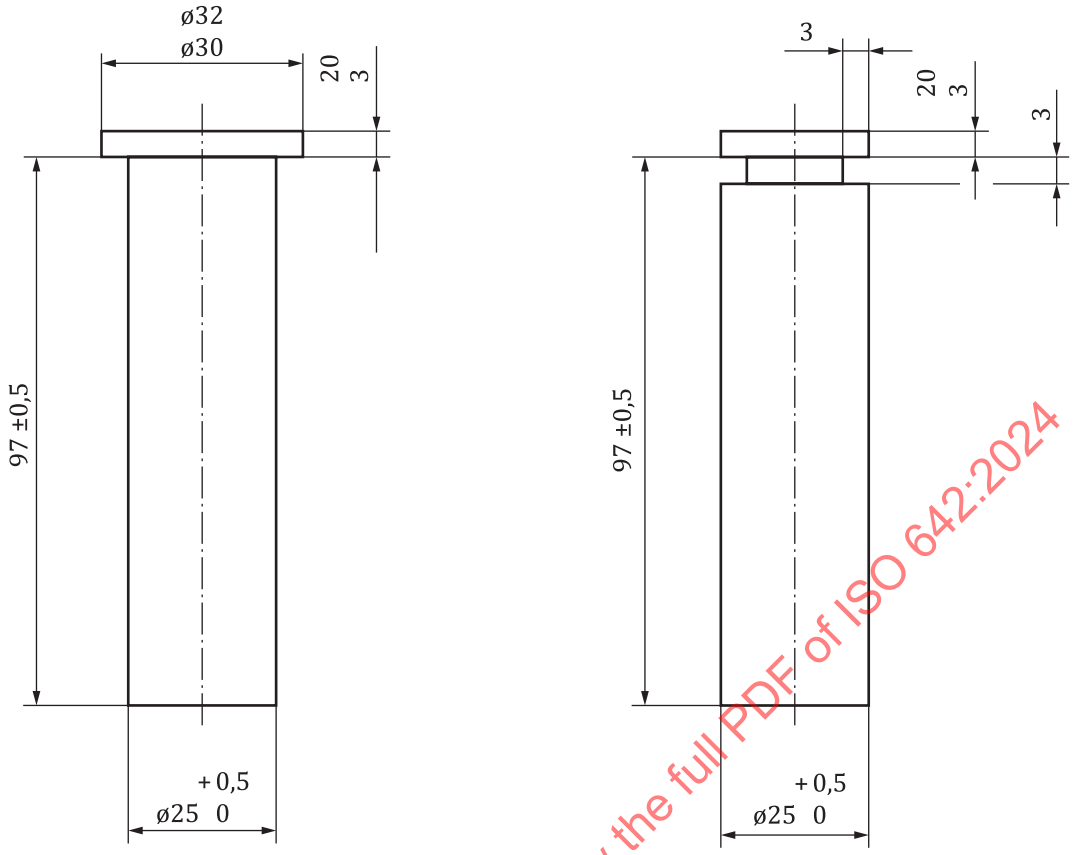
Figure 1 — Sampling of the test piece for machining

6.2 Dimensions

6.2.1 The test piece shall consist of a round bar machined to a diameter of 25 mm and a length of at least 100 mm.

6.2.2 The end of the test piece which will not be quenched shall be 30 mm to 32 mm or 25 mm in diameter, depending upon the form of that end. Two examples, test pieces with a flange or an undercut (to permit rapid centring and fitting in position for the quenching operation by means of an appropriate support) are shown in Figure 2.

Dimensions in millimetres



Flange thickness can be from 3 mm up to and including 20 mm. In case of dispute, reference sample flange thickness shall be 3 mm; sample length shall be 100 mm ± 0,5 mm.

Figure 2 — Dimensions of test piece

6.2.3 The test piece shall, if necessary, be marked (on the end opposite to the end to be quenched) to enable its position to be identified in relation to the original product.

6.3 Heat treatment

If not specified in the material standard or by mutual agreement, the heat treatment of the sample is left to the discretion of the test laboratory. Normalising (typically 30 to 60 minutes) or other heat treatment can be agreed at the time of enquiry and order. The heat treatment shall be carried out in each case in such a way that the finish-machined test piece shows no traces of decarburization.

6.4 Machining

The cylindrical surface of the test piece shall be machined by fine turning; the surface of the test piece end to be quenched shall have a reasonably fine finish, preferably obtained by fine grinding, and should be free from burrs (see Figure 2).

7 Apparatus

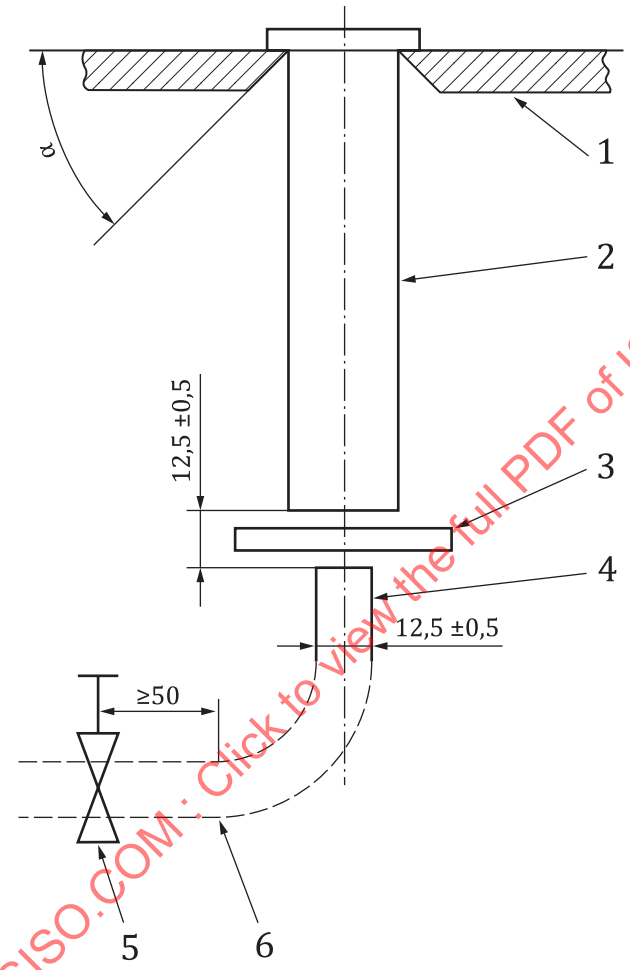
The apparatus consists of a device for quenching the test piece.

7.1 The quenching device consists essentially of a means of suddenly inducing the water jet to impinge on the end of the test piece to be quenched. This can be realized, for example, by a quick action tap and a system

to adjust the flow rate of the water or a disc allowing the water jet to be released and cut off rapidly (see Figure 3). In the case of a quick action tap, the length of the water supply pipe behind the tap shall be at least 50 mm in order to ensure non-turbulent water flow.

7.2 The relative positions of the end of the water supply pipe and the test piece support shall be such that the distance between the end of the water supply pipe and the test piece end to be quenched is (12,5 ± 0,5) mm (see Figure 3).

Dimensions in millimetres



Key

1	device for fixing and centring the test piece	4	end of water supply pipe
2	test piece in position	5	quick-action tap
3	water deflector	6	water supply pipe

Figure 3 — Diagram of quenching device

7.3 The test piece support shall allow precise centring of the test piece above the end of the water supply pipe and the holding of it in position during spraying. It shall be dry while the test piece is being placed in position; the test piece shall be protected from water splashes while it is being placed in position as well as before and during the actual end quenching operation.

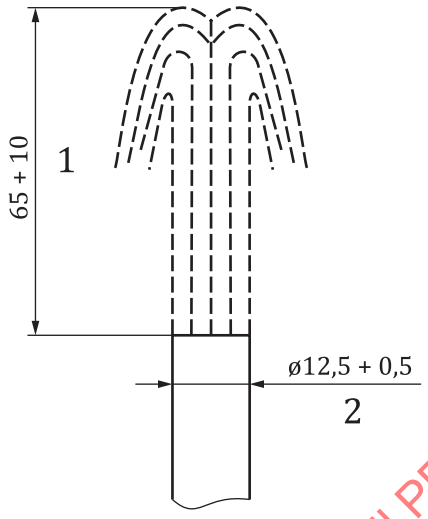
The angle α (see Figure 3) shall be chosen so as to avoid any contact between the support and the lower 97 mm of the test piece.

7.4 The height of the water jet above the end of the water supply pipe without the test piece in position shall be (65 ± 10) mm (see Figure 4).

The water temperature in the pipe shall be between 5 °C and 30 °C. It is recommended to use the water temperature of (20 ± 5) °C.

In the case of comparative tests, tests shall be carried out with the same water temperature.

Dimensions in millimetres



Key

1 height of free water jet

2 diameter of end of water supply pipe

Figure 4 — End of water supply pipe

7.5 The test piece shall be protected from draughts throughout the heating and quenching.

8 Heating and quenching of test piece

8.1 Heating

8.1.1 The test piece shall be heated uniformly to the temperature specified in the relevant product standard or fixed by special agreement for at least 20 min and then maintained for $\left(30\,^{+5}_{0}\right)$ min at the agreed-upon temperature. For particular types of furnace, this period can be determined as a result of previous experience establishing the minimum time necessary for the centre of the test piece to reach the desired temperature (this temperature can be verified by means of, e.g. a thermocouple placed in a hole drilled along the axis of the test piece at the head end).

8.1.2 Precautions shall be taken to minimize decarburization or carburization of the test piece, and to avoid any marked oxidation with formation of scale.

8.2 Quenching

8.2.1 The time between removal of the test piece from the furnace and the commencement of spraying shall not exceed 5 s.

The test piece shall be removed from the furnace and positioned in the holder using tongs. The tongs shall grip the test piece at the end not intended for quenching, either on the circumference of the flange or on the

circumference of the undercut. The device for fixing and centring the test piece shall be dry and at room temperature at the beginning of quenching.

8.2.2 The time of spraying shall be at least 10 min. After this time, the cooling of the test piece can be completed by immersing it in cold water.

9 Measurement of hardness after quenching

9.1 Two flats for measuring the hardness shall be ground on the surface 180° apart and parallel to the axis of the test piece. In the case of test pieces prepared by machining, the two flats shall be at the same distance from the product surface (see Figure 1). They shall be from 0,4 mm to 0,5 mm deep. These flats shall be machined using an abundant supply of coolant with fine grinding wheel to avoid any heating which is likely to modify the microstructure of the test piece.

9.2 It should be ascertained, as follows, that no softening has been caused by grinding: immerse the test piece in a 2 % to 10 % (by volume) nitric acid solution in water until it is completely blackened. The colour obtained shall be uniform.

NOTE An alternate procedure is to wash the sample in hot water, etch it in 5 % nitric acid (concentrated) and 95 % water by volume, wash it in hot water again, immerse it in 50 % hydrochloric acid (concentrated) and 50 % water by volume and dry it in air blast.

If there are any stains, indicating the presence of soft spots, two new flats shall be made at 90° and etched as stated above to make sure that these were acceptable. In this case, the hardness measurement shall be carried out on the second set of flats and this fact shall be recorded in the test report.

9.3 Precautions shall be taken to ensure that the test piece is well supported and is rigidly held during the hardness measurements.

The device for moving the test piece on the hardness testing machine shall allow accurate centring of the flat and spacing of the indentations to within ±0,1 mm. The indentations are made along the axis of the flat, in accordance with ISO 6508-1. The test piece should be firmly held in place.

9.3.1 By special agreement, the Rockwell C hardness measurements may be replaced by measurements of Vickers hardness HV 30 in accordance with ISO 6507-1.

NOTE If necessary, the nitric acid blackening can be removed with a light polish before testing.

9.3.2 It is necessary to ensure that any raised edges of hardness indentations on the first flat do not influence the measurements on the second flat.

9.4 The positions of the measurement points shall be such that one or the other of the following two determinations can be made:

a) drawing of a curve representing variations in hardness (see 9.4.1);

b) determination of hardness at one or more specified points (see 9.4.2).

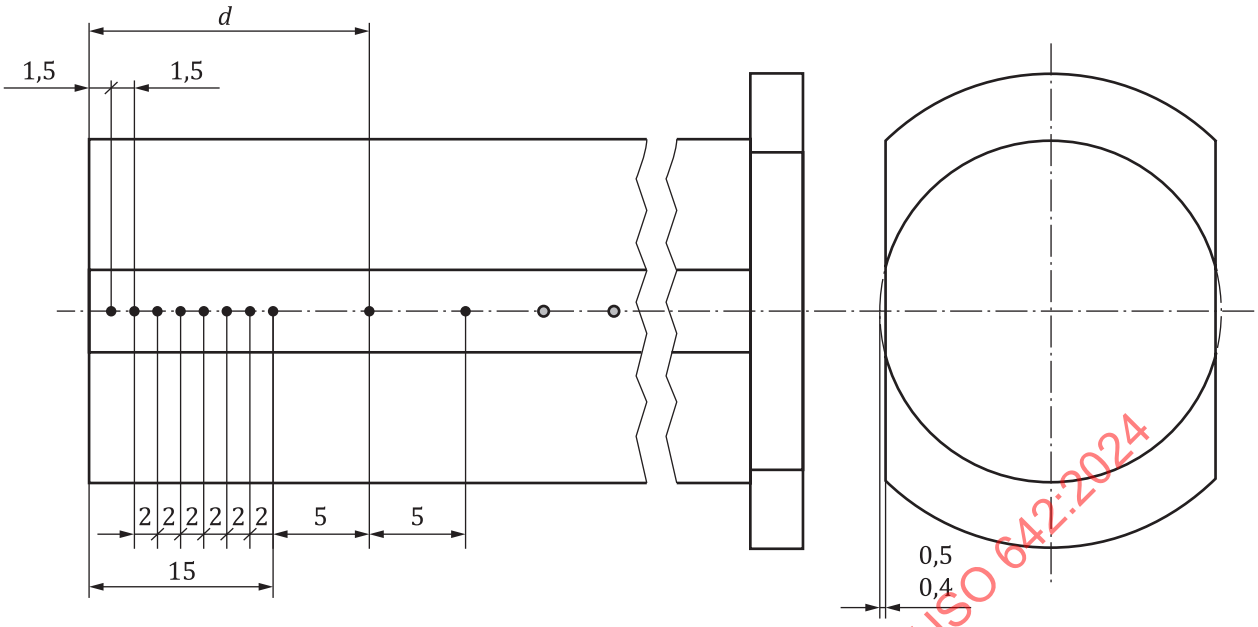
9.4.1 Drawing of a curve representing variations in hardness

9.4.1.1 In the general case, the distances, expressed in millimetres, of the first eight points taken from the quenched end are as follows (see Figure 5):

1,5 - 3 - 5 - 7 - 9 - 11 - 13 - 15

Subsequent points are, in general, at 5 mm intervals.

Dimensions in millimetres



NOTE Dimensions are not to scale.

Figure 5 — Preparation of test piece for measurement of hardness, and position of hardness measurement points

9.4.1.2 In the case of steels of low hardenability, the first measuring point is generally 1,0 mm from the quenched end. The following points are generally spaced at 1 mm intervals to a distance of 11 mm from this end. These are generally followed by five points at 13 mm, 15 mm, 20 mm, 25 mm and 30 mm from the same end.

NOTE The distance between the hardness indentations given in 9.4.1.1 and 9.4.1.2 will not always comply with the minimum distances stated in ISO 6508-1 or ISO 6507-1. For the purposes of this document, however, it is considered that the hardness values obtained will, in general, be sufficiently accurate.

9.4.2 Determination of hardness at specified points

Determination of hardness may be made at one or more points situated at specified distances from the quenched end and including, or not, points specified in 9.4.1.1 and 9.4.1.2.

10 Expression of results

10.1 Hardness at any one point

At each distance *d*, the hardness shall be recorded as the mean of the measurements made at this distance *d* on each of the two flats specified in 9.1 and the value rounded in principle to 0,5 HRC or 10 HV.

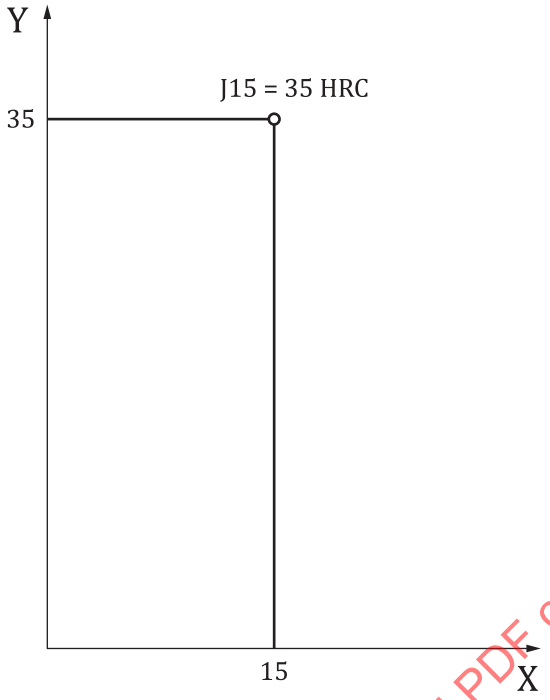
10.2 Drawing of the hardness curves

The distances *d* shall be plotted on the abscissa and the corresponding hardnesses on the ordinate, see Figure 6. It is recommended to use the following scales:

— on the abscissa, either 10 mm corresponding to a distance of 5 mm; or 10 mm corresponding to a distance of 1 mm for steels of low hardenability;

— on the ordinate: 10 mm corresponding to 5 HRC or 50 HV.

NOTE When Jominy curves are produced by computer-aided devices, the computer program scales the axes automatically.



Key

X *d* [mm]

Y HRC

Figure 6 — Hardness at a distance *d* of 15 mm

10.3 Description of the hardenability characteristics of a particular steel

Use one of the following methods:

a) drawing of the hardness curve;

b) statement of the hardness at three points, one point being 1,5 mm (1 mm for low hardenability steels) from the quenched end and the other two points being fixed by special agreement;

c) statement of the hardness at two points situated at distances fixed by special agreement;

d) statement of the hardness at one specified distance from the quenched end;

e) tables of hardness-distance values.

See Annex A for additional information.

10.4 Codification of test result

The test results can be presented with following forms: letter J followed by two numbers:

J*d* = *xx*,

where

d is the distance from the point of measurement to the quenched end, in millimetres;

xx is the hardness, either HRC or HV30.

EXAMPLE

J15 = 35 HRC

J10 = 410 HV30.

NOTE An alternative presentation is J*xx*-*d* (or JHV*xx*-*d*), see A.2.4.

11 Test report

The test report shall contain the following information:

a) a reference to this document, i.e. ISO 642;

b) grade of the steel;

c) cast number;

d) method of sampling;

e) conditions for the normalizing treatment and the heating of the test piece;

f) hardness testing method used;

g) test result.

It is recommended to note the water temperature in order to be able to compare the results.

Annex B gives information on determining cooling rate on the surface of the test piece.

Annex A
(informative)

Specification for the hardenability of a product

A.1 Methods

Use one of the following methods:

a) specify the end quenching (Jominy test) curve(s) of depth of hardness with:

   1) a limiting curve above which the end quenching (Jominy test) curve of depth of hardness of the steel shall lie; or

   2) a limiting curve below which the end quenching (Jominy test) curve of depth of hardness of the steel shall lie; or

   3) the upper and lower end quenching (Jominy test) curves between which the end quenching (Jominy test) curve of the steel shall lie (see Figure A.1);

b) specify particular points on the end quenching (Jominy test) curve (which can be):

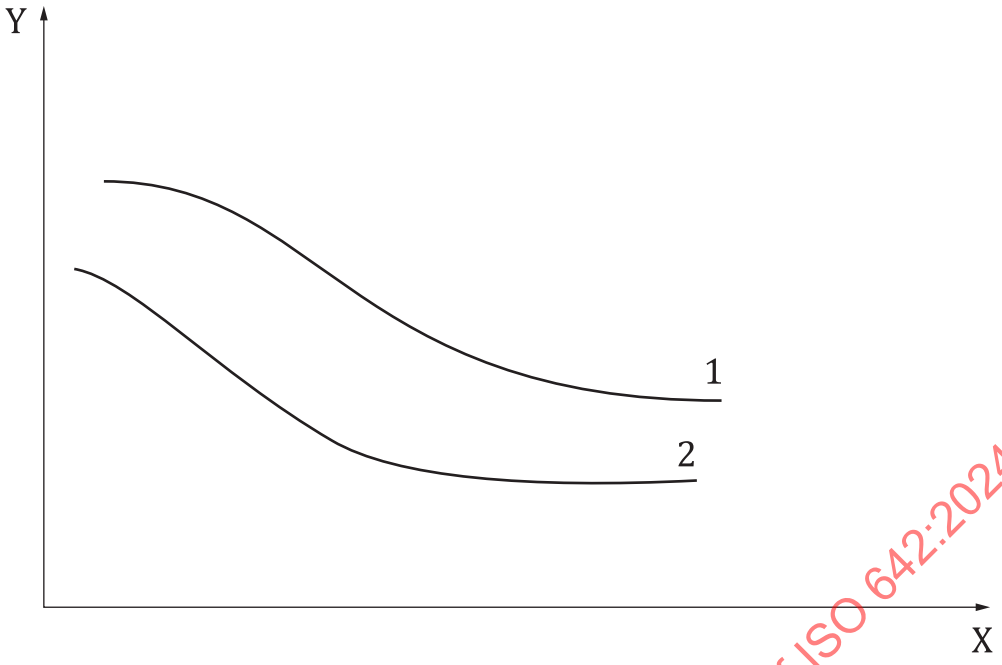
   1) an upper limit; or

   2) a lower limit; or

   3) a range between the two limits:

      i) by indicating the distance from the quenched end for a given hardness; or

      ii) by indicating the hardness at a given distance from the quenched end.



Key

X *d* [mm]
Y HRC
1 upper limit
2 lower limit

Figure A.1 — Specification of hardenability by two limiting curves

A.2 Specifying the hardenability

It is also possible to specify the hardenability as follows:

A.2.1 J6-18 = 45 HRC specifies that the hardness reaches a value of 45 HRC at some point between 6 mm and 18 mm from the quenched end (see Figure A.2).

A.2.2 J15 = 35-48 HRC specifies that, at a distance of 15 mm from the quenched end, the hardness has a value between 35 HRC and 48 HRC (see Figure A.3).

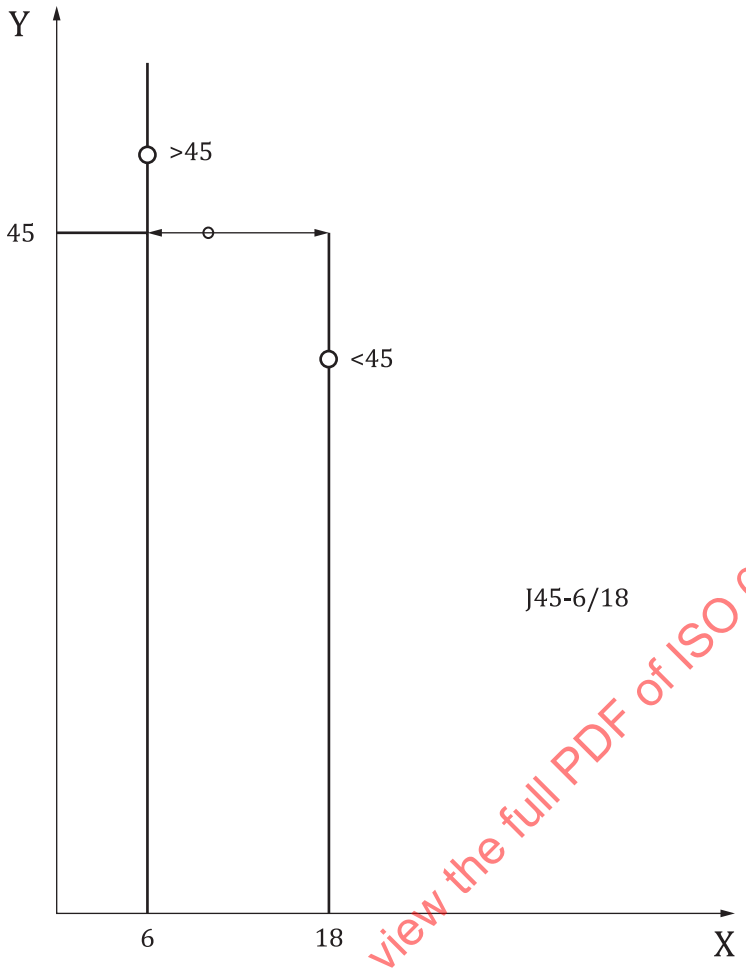
A.2.3 J15 = 340-490 HV specifies that, at a distance of 15 mm from the quenched end, the Vickers hardness is between 340 HV and 490 HV.

A.2.4 In some instances, the following codifications are used.

J35/48-15 specifies that, at a distance of 15 mm from the quenched end, the hardness has a value between 35 HRC and 48 HRC (see Figure A.3).

JHV340/390-15 specifies that, at a distance of 15 mm from the quenched end, the Vickers hardness is between 340 HV and 390 HV.

J45-6/18 specifies that the hardness reaches a value of 45 HRC at some point between 6 mm and 18 mm from the quenched end (see Figure A.2).

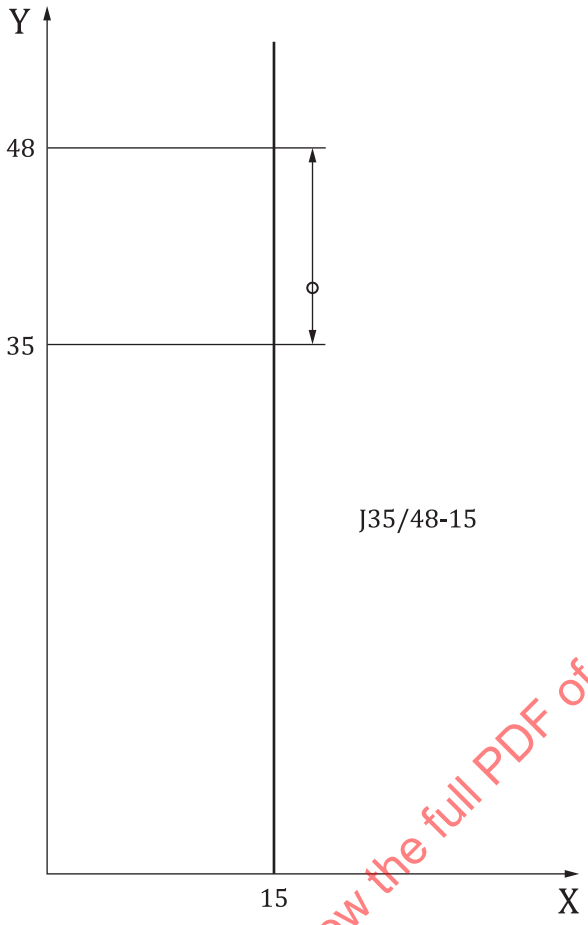


Key

X *d* [mm]

Y HRC

Figure A.2 — Specification of hardenability by a given hardness between two distance limits



Key

X *d* [mm]

Y HRC

Figure A.3 — Specification of hardenability by a range of hardness at a given distance (less recommended)