

इस्पात — अंत शमन द्वारा कठोरणीयता
परीक्षण (जॉमिनी परीक्षण)
(दूसरा पुनरीक्षण)

Steel — Hardenability Test by
End Quenching (Jominy Test)

(Second Revision)

ICS 77.040.99

© BIS 2024

© ISO 1999



भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

April 2024

Price Group 9

NATIONAL FOREWORD

This Indian Standard (Second Revision) is identical to ISO 642 : 1999 'Steel — Hardenability test by end quenching (Jominy test)' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Metallography and Heat-Treatment Sectional Committee and approval of the Metallurgical Engineering Division Council.

This standard was first published in 1966 and subsequently revised in 1981. This revision has been undertaken to align it with ISO 642 : 1999 under dual numbering system to harmonize it with the latest developments that have taken place at international level.

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical with those used in Indian Standard. Attention is especially drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, it should be read as 'Indian Standard'; and
- b) Comma (,) has been used as a decimal marker while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exists. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the edition indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
ISO 6507-1 Metallic materials — Vickers hardness test — Part 1: Test method	IS 1501 (Part 1) : 2020/ISO 6507-1 : 2018 Metallic materials — Vickers hardness test: Part 1 Test method (<i>fifth revision</i>)	Identical
ISO 6508-1 Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)	IS 1586 (Part 1) : 2018/ISO 6508-1 : 2016 Metallic materials — Rockwell hardness test: Part 1 Test Method (<i>fifth revision</i>)	Identical
ISO 6508-2 Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T)	IS 1586 (Part 2) : 2018/ISO 6508-2 : 2015 Metallic materials — Rockwell hardness test: Part 2 Verification and calibration of testing machines and indenters (<i>fifth revision</i>)	Identical
ISO 6508-3 Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T)	IS 1586 (Part 3) : 2018/ISO 6508-3 : 2015 Metallic materials — Rockwell hardness test: Part 3 Calibration of reference blocks (<i>fifth revision</i>)	Identical

In reporting the result of a test or analysis made in accordance with this standard, is to be rounded off, it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical-values (*second revision*)'.

Contents	Page
1 Scope	1
2 Normative references	1
3 Principle	1
4 Symbols and designations	2
5 Form of test pieces and their preparation	2
6 Apparatus	3
7 Heating and quenching of test piece	6
8 Preparation for, and measurement of, hardness after quenching	6
9 Expression of results	7
10 Test report	8
Annex A (informative) Specification for the hardenability of a product	10
Annex B (informative) Additional information to clause 10	13
Annex C (informative) Calculation of the hardenability	15
Bibliography	16

Indian Standard

STEEL — HARDENABILITY TEST BY END QUENCHING

(JOMINY TEST)

(*Second Revision*)

1 Scope

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

NOTE By agreement and for a defined field of application, the test described in this International Standard may 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.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method.*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T).*

ISO 6508-2, *Metallic materials — Rockwell hardness test) — Part 2: Verification and calibration of testing machines (scales A, B, C, D, E, F, G, H, K, N, T).*

ISO 6508-3, *Metallic materials — Rockwell hardness test — Part 3: Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T).*

3 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, on longitudinal flats made on the test piece, in order to determine the hardenability of the steel by variations of this hardness.

4 Symbols and designations

Symbol	Designation	Value
L	Total length of test piece	$(100 \pm 0,5)$ mm
D	Diameter of test piece	$(25^{+0,5}_0)$ mm
t	Time during which test piece is maintained at heating temperature	(30^{+5}_0) min
t_m	Maximum time lag between removal of test piece from furnace and start of quenching	5 s
T	Temperature of cooling water	(20 ± 5) °C
a	Internal diameter of vertical water supply pipe	$(12,5 \pm 0,5)$ mm
h	Height of water jet without test piece in position	(65 ± 10) mm
l	Distance from end of water supply pipe to lower end of test piece	$(12,5 \pm 0,5)$ mm
e	Depth of flats for measurement of hardness	$(0,4 \text{ to } 0,5)$ mm
d	Distance, in millimetres, from quenched end to points where hardness is measured	
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 Form of test pieces and their preparation

5.1 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 test piece with diameter $(25^{+0,5}_0)$ mm whose axis shall be at least at (20^{+5}_0) mm from the surface product (see Figure 1).

In case of products from continuous casting, a minimum reduction ratio 8:1 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 must 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.

5.2 Dimensions

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

5.2.2 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.

5.2.3 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.

5.3 Heat treatment

Unless otherwise agreed, the test piece shall be normalized before machining and quenching. The normalizing process shall be carried out at the average temperature within the range specified in the material standard. If the material standard does not specify a temperature for normalizing, the normalizing temperature shall be subject to special agreement or duly selected by the testing department. The holding time at normalizing temperature shall be (30^{+5}_0) min.

The heat treatment shall be carried out in each case in such a way that the finish-machined test piece shows absolutely no traces of decarburization.

5.4 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).

6 Apparatus

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

6.1 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 e.g., 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.

6.2 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 $(12,5 \pm 0,5)$ mm (see Figure 3).

6.3 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.

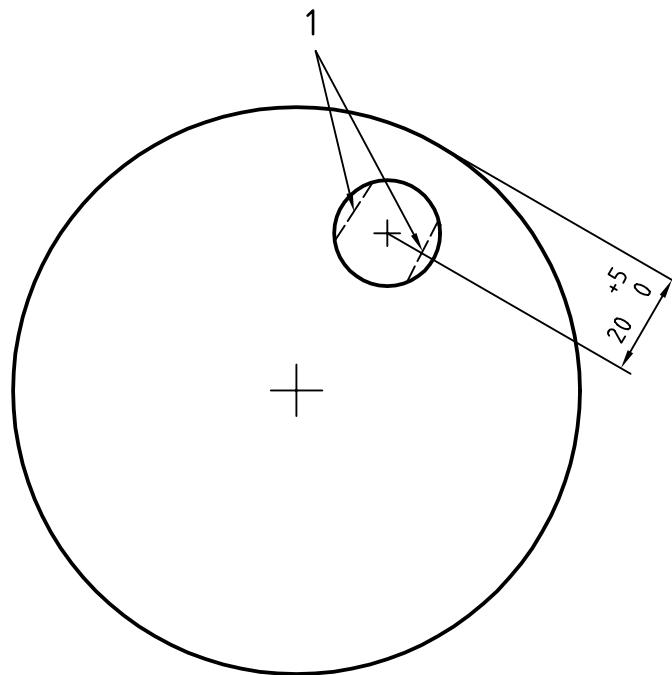
6.4 The height of the water jet above the end of the water supply pipe without the test piece in position shall be (65 ± 10) mm (see Figure 4).

The water temperature in the pipe shall be (20 ± 5) °C.

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

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

Dimensions in millimetres



Key

1 Test flats.

Figure 1 — Sampling by machining of the test piece

Dimensions in millimetres

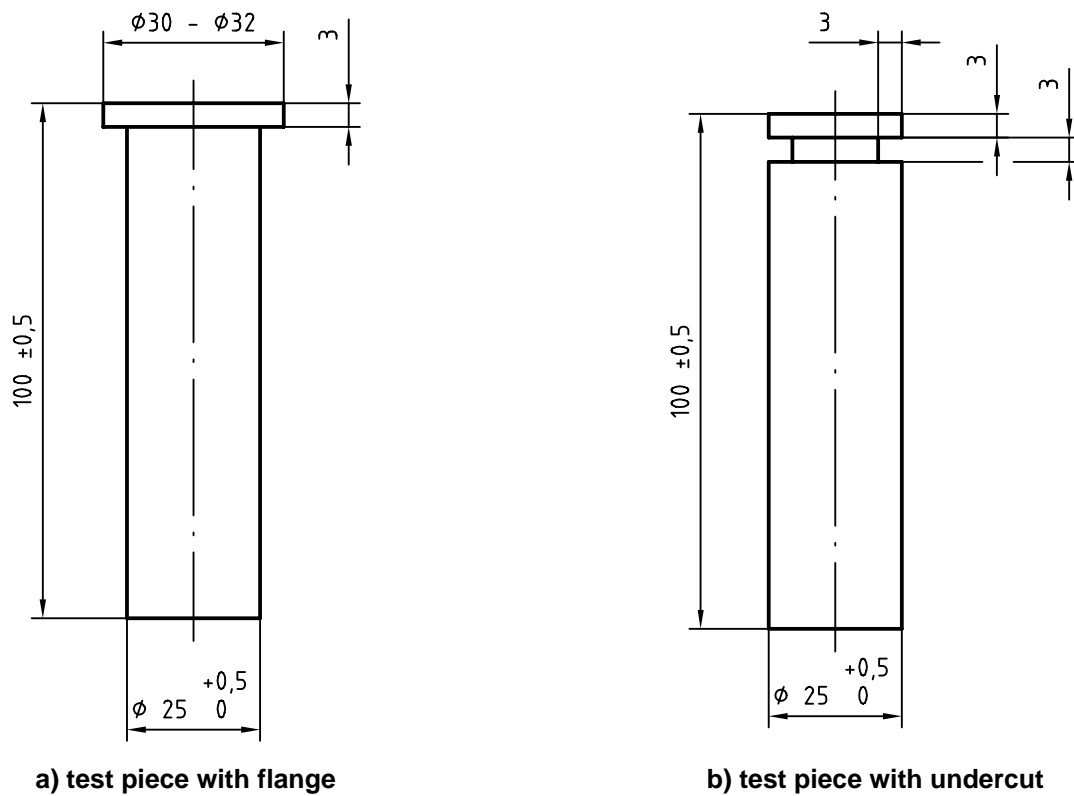
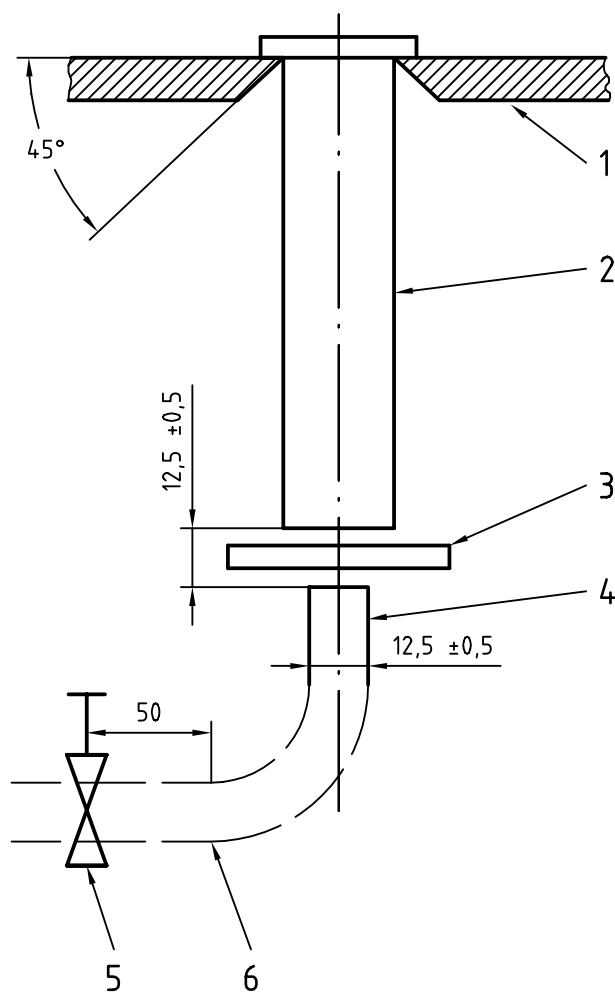


Figure 2 — Dimensions of test piece

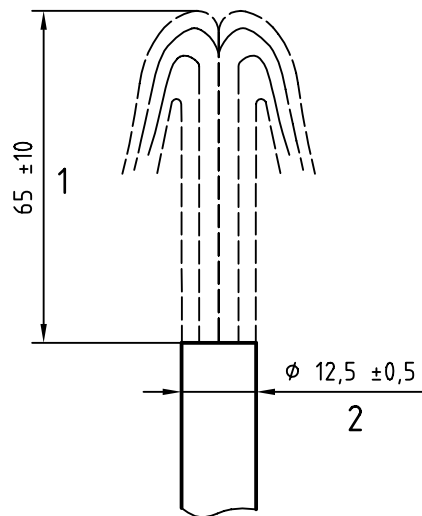
Dimensions in millimetres



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 Disc. | 6 Water supply pipe. |

Figure 3 — Diagram of quenching device



Key

- 1 Height of free water jet.
- 2 Diameter of end of water supply pipe.

Figure 4 — End of water supply pipe

7 Heating and quenching of test piece

7.1 Heating

7.1.1 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 $(30 \begin{smallmatrix} +5 \\ 0 \end{smallmatrix})$ 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).

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

7.2 Quenching

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

During its removal from the furnace and positioning in the holder, the test piece shall only be held with the tongs at the end which is not to be quenched either on the flange side or the undercut side.

7.2.2 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.

8 Preparation for, and measurement of, hardness after quenching

8.1 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.

8.2 It should be ascertained, as follows, that no softening has been caused by grinding: immerse the test piece in a 5 % (V/V) nitric acid solution in water until it is completely blackened. The colour obtained shall be uniform.

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.

8.3 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 $\pm 0,1$ mm. The latter are made along the axis of the flat, in accordance with ISO 6508-1, ISO 6508-2 and ISO 6508-3.

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

8.3.2 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.

8.4 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 8.4.1);
- b) determination of hardness at one or more specified points (see 8.4.2).

8.4.1 Drawing of a curve representing variations in hardness

8.4.1.1 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.

8.4.1.2 In the case of steels of low hardenability, the first measuring point shall be 1,0 mm from the quenched end; the following points shall be spaced at 1 mm intervals to a distance of 11 mm from this end. The last five points shall be, respectively, 13 mm, 15 mm, 20 mm, 25 mm and 30 mm from the same end.

NOTE It is realized that the distance between the hardness indentations given in 8.4.1.1 and 8.4.1.2 will not always comply with the minimum distances stated in ISO 6508. For the purposes of this International Standard, however, it is considered that the hardness values obtained will, in general, be sufficiently accurate.

8.4.2 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, the first point specified in 8.4.1.1 and 8.4.1.2.

9 Expression of results

9.1 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 8.1 and the value rounded in principle to 0,5 HRC or 10 HV.

9.2 Drawing of the hardness curves

The distances d shall be plotted on the abscissa and the corresponding hardnesses on the ordinate. 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 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 will scale the axes automatically.

9.3 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.

9.4 Codification of test result

The test result can be expressed in the following form: the letter J followed by two numbers as follows:

J_{xx-d}

where

xx is the hardness, either HRC or HV 30;

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

EXAMPLES

J35-15 shows that at a distance of 15 mm from the quenched end the hardness is 35 HRC (see Figure 6),

JHV 450-10 shows that at a distance of 10 mm from the quenched end the hardness is 450 HV 30.

NOTE It is also possible to use the code $Jd = xx$, see A.2.4.

10 Test report

The test report shall contain the following information:

- a) reference to this International Standard, i.e., ISO 642;
- b) grade of the steel;
- c) cast number;
- d) chemical composition;
- e) method of sampling;
- f) conditions for the normalizing treatment and the heating of the test piece;

- g) hardness testing method used;
- h) test result.

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

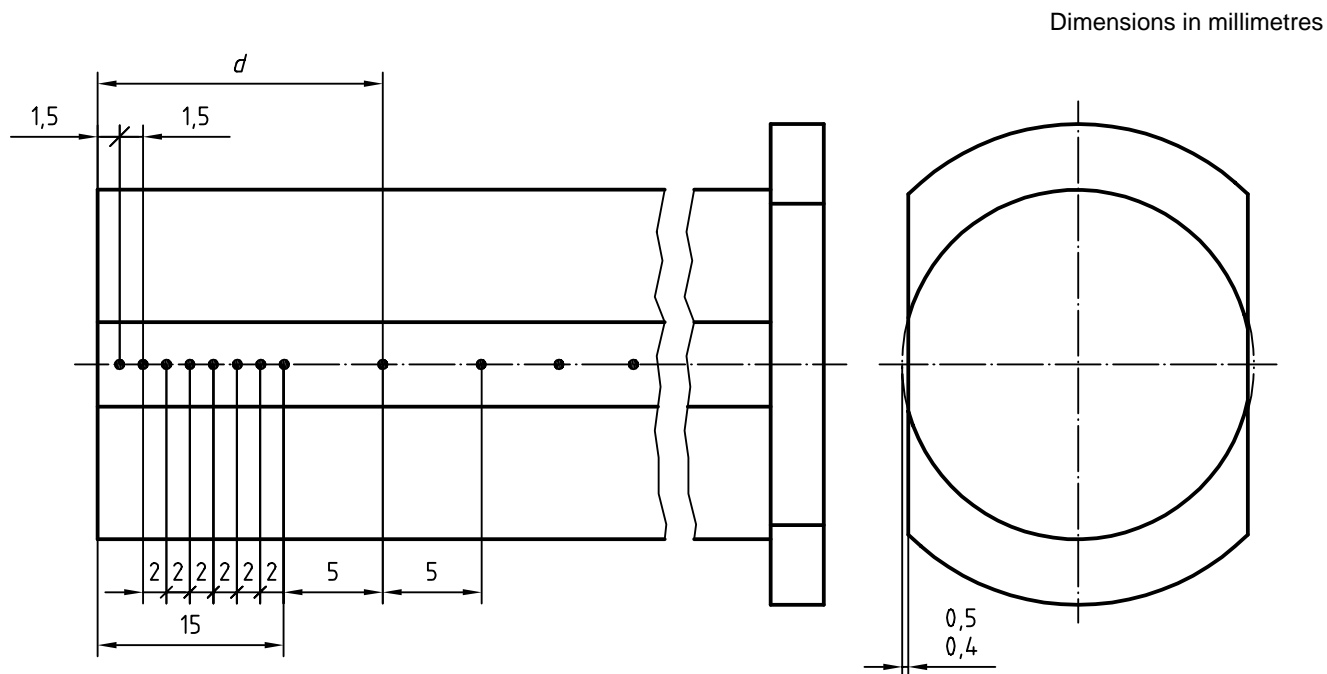


Figure 5 — Preparation of test piece for measurement of hardness, and position of hardness measurement points

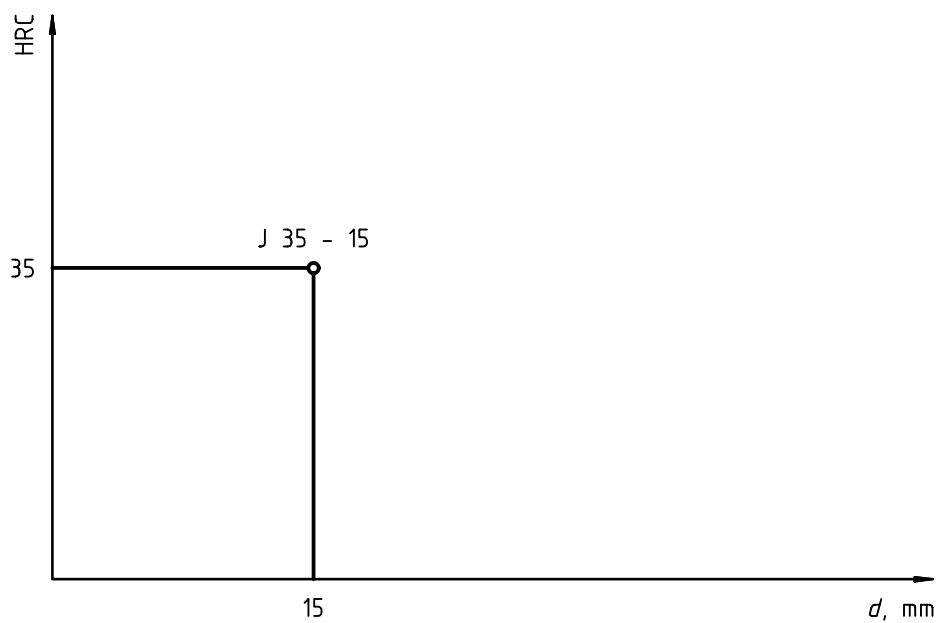


Figure 6 — Hardness at a distance d of 15 mm

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):
 - an upper limit; or
 - a lower limit; or
 - 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.

A.2 Specifying the hardenability

It is also possible to specify the hardenability as follows.

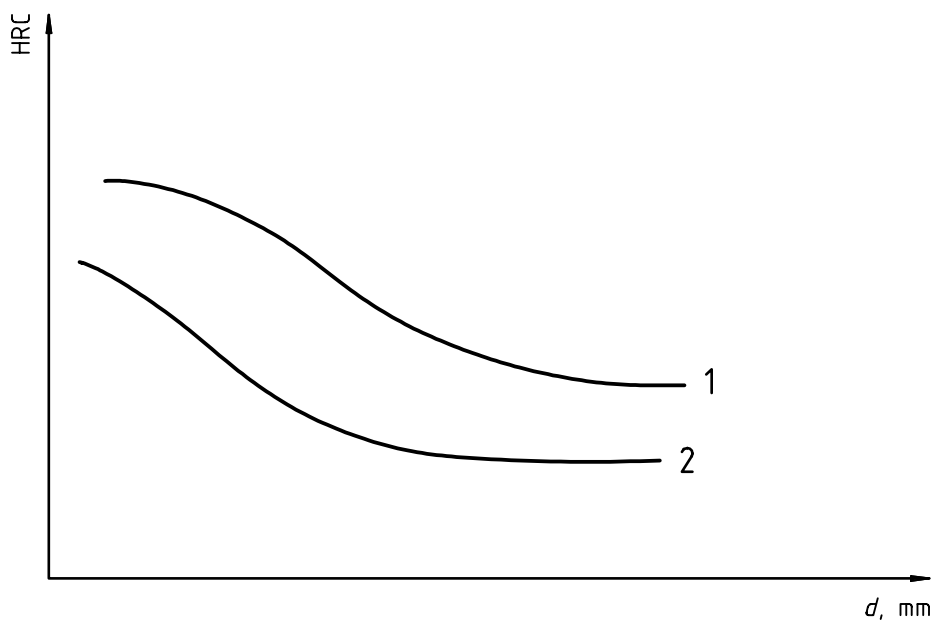
A.2.1 J 45-6/18 shows that the hardness reaches a value of 45 HRC at some point between 6 mm and 18 mm from the quenched end (see Figure A.2).

A.2.2 J 35/48-15 shows 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 JHV 340/490-15 shows that, at a distance of 15 mm from the quenched end, the Vickers hardness is between HV 340 and HV 490.

A.2.4 In some countries, the following codification is used.

J 15 = 35/45 shows that, at a distance of 15 mm from the quenched end, the HRC value is between 35 and 45.



Key
1 Upper limit
2 Lower limit

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

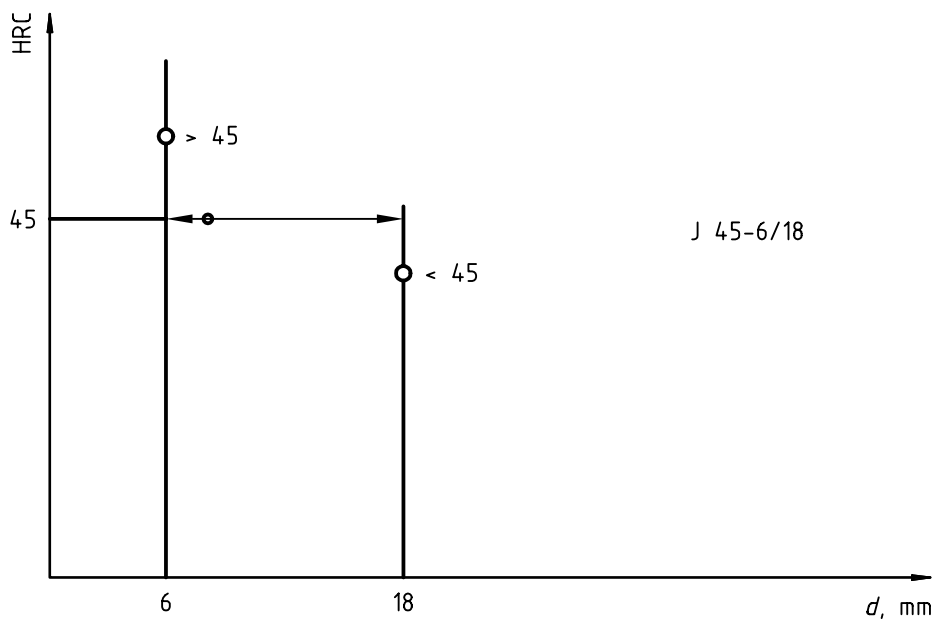


Figure A.2 — Specification of hardenability by a given hardness between two distance limits

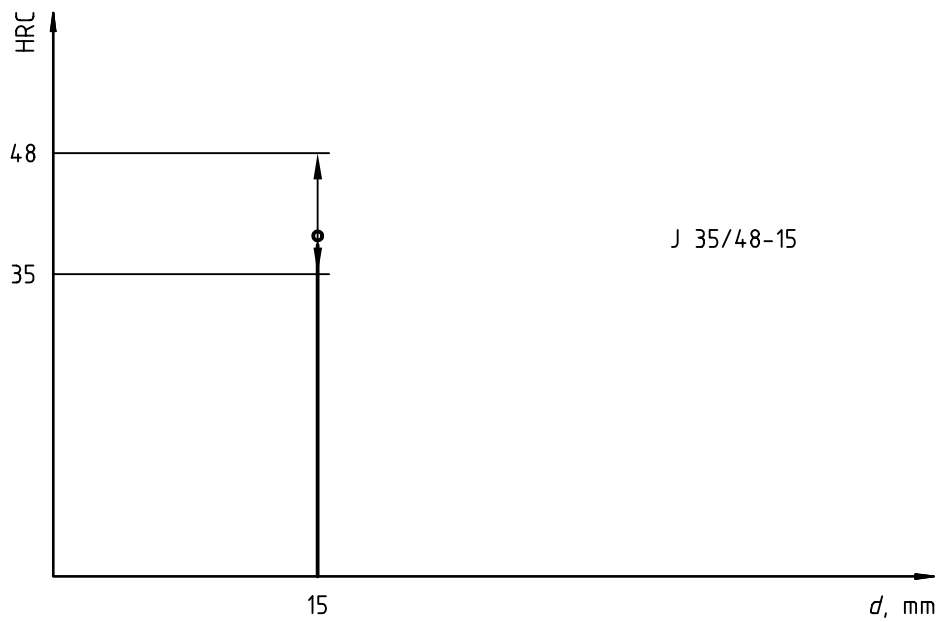


Figure A.3 — Specification of hardenability by a range of hardness at a given distance

Annex B (informative)

Additional information to clause 10

In many cases, it could be useful to know the cooling rate on the surface of the test piece.

The conditions of the quenching process defined in clause 6 and in 7.2 permit the cooling rate of the end of the test piece to be considered as constant.

Subject to the fact that one can, at a first approximation, neglect on the one hand the amount of heat produced by structural changes in the steel during cooling and, on the other hand, the differences in thermal conductivity for different grades of steel in relation to a standard test piece, the variations of temperature along the length of the test piece can be expressed in different ways. The following are given as examples for information.

- a) Figure B.1: network of curves giving the ratio θ/θ_A as a function of time

where

θ_A is the temperature of austenitizing;

θ is the temperature of points on the surface, situated at certain distances from the quenched end.

- b) Figure B.2: variation of the cooling rates, in degrees Celsius per second, of points on the surface of the Jominy test piece at approximately 700 °C, as a function of their distance from the quenched end.

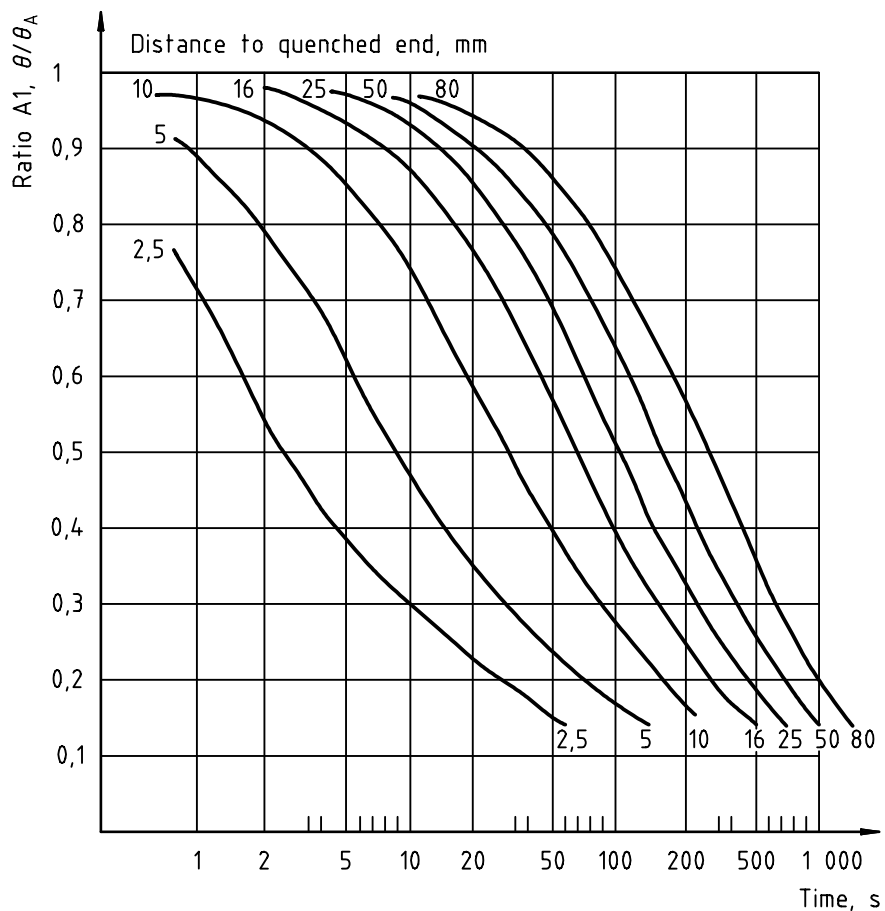


Figure B.1 — Network of curves giving the ratio θ/θ_A as a function of time

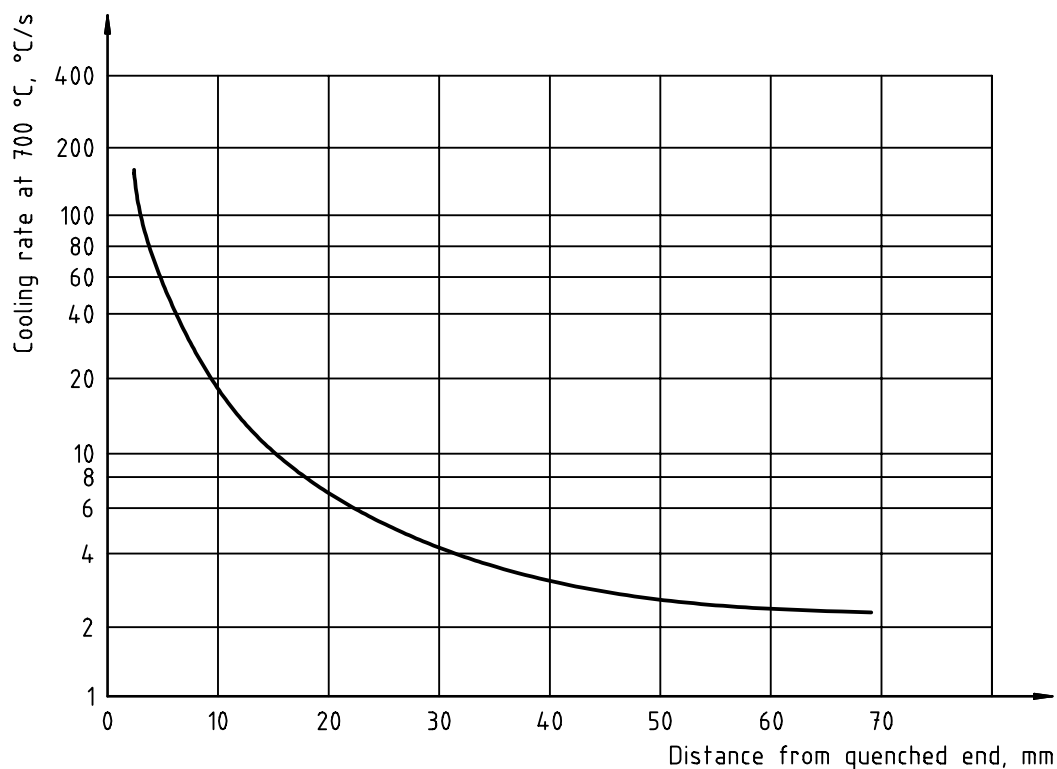


Figure B.2 — Variation of the cooling rates, in degrees Celsius per second, of points on the surface of the Jominy test piece at approximately 700 °C as a function of their distance from the quenched end

Annex C (informative)

Calculation of the hardenability

With the aid of computer facilities, calculation models by treatment of numerical data have been developed to determine the Jominy curve from the chemical composition (cast analysis).

These models, duly verified, are based on a great number of test results. The equations used for calculation of the hardenability are different in function of the nature of steel and of their origin and of the used model.

Bibliography

- [1] JOMINY, W.E., *Standardization of Hardenability Tests*, Metal Progress, Vol. 40, December 1941, pp. 911-914.
- [2] GROSSMAN, M.A., *Hardenability Calculated from Chemical Composition*, Trans. AIME, Vol. 150, 1942, pp. 227-259.
- [3] FIELD, J., *Calculation of Jominy End-Quench Curve from Analysis*, Metal Progress, Vol. 43, March 1943, pp. 402-405.
- [4] LAMONT, J.L. and CRAFTS, W., *The Effect of Silicon on Hardenability*, Trans. AIME, Vol. 154, 1943, pp. 386-394.
- [5] HILL, M. *The End-Quench Test: Reproducibility*, Trans. ASM, Vol. 31, December 1943, pp. 923-942.
- [6] KRAMER, I.R., HAFNER, R.H. and TOLEMAN, S.L., *Effect of Sixteen Alloying Elements on Hardenability of Steel*, Trans. AIME, Vol. 158, 1944, pp. 138-156.
- [7] CRAFTS, W. and LAMONT, J.L., *Effect of Some Elements on Hardenability*, Trans. AIME, Vol. 158, 1944, pp. 157-167.
- [8] BOYD, L.H. and FIELD, J., *Calculation of the Standard End Quench Hardenability Curve from Chemical Composition and Grain Size*, Contributions to the Metallurgy of Steel, No. 12, AISI, New York, February 1946.
- [9] WILSON, W. Jr., *Limitations of Hardenability Indices*, Frontier, Vol. 9, March 1946, pp. 3-5,16.
- [10] HODGE, J.M. and OREHOSKI, M.A., *Hardenability Effects in Relation to the Percentage of Martensite*, Trans. AIME, Vol. 167, 1946, pp. 502-512.
- [11] HODGE, J.M. and OREHOSKI, M.A., *Relationship Between Hardenability and Percentage of Martensite in Some Low-Alloy Steels*, Trans. AIME, Vol. 167, 1946, pp. 627-642.
- [12] BROPHY, G.R. and MILLER, A.J., *An Appraisal of the Factor Method for Calculating the Hardenability of Steel from Composition*, Trans. AIME, Vol. 167, 1946, pp. 654-669.
- [13] KRAMER, I.R., SIEGEL, S. and BROOKS, J.G., *Factors for the Calculation of Hardenability*, Trans. AIME, Vol. 167, 1946, pp. 670-697.
- [14] CRAFTS, W. and LAMONT, J. L., *Addition Method for Calculating Rockwell C Hardness of the Jominy Hardenability Test*, Trans. AIME, Vol. 167, 1946, pp. 698-718.
- [15] TROIANO, A.R. and KLINGLER, L.J., *Limitations of the End-Quench Hardenability Test*, Trans. ASM, Vol. 44, 1952, pp. 775-802.
- [16] BIRTALAN, J., HENLEY, R.G. Jr. and CHRISTENSON, A.L., *Thermal Reproducibility of the End-Quench Test*, Trans. ASM, Vol. 46, 1954, pp. 928-947.
- [17] KAPADIA, B.M., BROWN R.M. and MURPHY, W.J., *The Influence of Nitrogen, Titanium, and Zirconium on the Boron Hardenability Effect in Constructional Alloy Steels*, Trans. AIME, Vol. 242, August 1968, pp. 1689-1694.
- [18] MOSER, A. and LEGAT, A., *A Calculation of Hardenability from the Chemical Composition*, Hart.-Techn. Mitt., Vol. 24, July 1969, pp. 100-105.
- [19] JUST, E., *New Formulas for Calculating Hardenability Curves*, Metal Progress, Vol. 96, November 1969, pp. 87-88.

- [20] MAYNIER, P., DOLLET, J. and BASTIEN, P., *The influence of Alloying Elements on the Quench Characteristics of Low-Alloy Steels*, Rev. Mét., Vol. 67, April 1970, pp. 343-351.
- [21] BROWN, G.T. and JAMES, B.A., *The Accurate Measurement, Calculation, and Control of Steel Hardenability*, Metallurgical Transactions, Vol. 4, October 1973, pp. 2245-2256.
- [22] JATCZAK, C.F., *Hardenability in High Carbon Steels*, Metallurgical Transactions, Vol. 4, October 1973, pp. 2267-2277.
- [23] BLONDEAU, R., MAYNIER, P. and DOLLET, J., *Prediction of the Hardness and Strength of Plain and Low-Alloy Steels from their Structure and Composition*, Mém. Sci. Rev. Mét., Vol. 70, December 1973, pp. 883-892 (BISI Translation No. 12248).
- [24] BLONDEAU, R., MAYNIER, P. and DOLLET, J., *Prediction of the Hardness and Strength of Carbon and Low-Alloy Steels from their Structure and Composition*, Aciers spéciaux., Vol. 27, 1974, pp. 9-16 ; and Traitement Thermique, Vol. 82, 1974, pp. 33-40.
- [25] JATCZAK, C.F., *Measurement of Hardenability and its Calculation from Composition*, Trait. Therm., Vol. 95, May 1975, pp. 53-62.
- [26] DOANE, D.V., *A Critical Review of Hardenability Predictors*, Hardenability Concepts with Applications to Steel, The Metallurgical Society of AIME, Warrendale, PA, 1978, pp. 351-396.
- [27] BROWN, G.T., *Re-Appraisal of the Jominy Test and its Applications*, Hardenability Concepts with Applications to Steel, The Metallurgical Society of AIME, Warrendale, PA, 1978, pp. 273-289.
- [28] KUNZE, C.T. and RUSSELL, J.E., *The Generation of Accurate Jominy Data: Its Use to Improve the Grossman Hardenability Factors*, Hardenability Concepts with Applications to Steel, The Metallurgical Society of AIME, Warrendale, PA, 1978, pp. 290-308.
- [29] KASAI, Y., OHTA, H. and NARUSE, T., *On the New Jominy-Curve Predictor, J-COMP*, Denki Seiko, Vol. 52, No. 1, January 1981, pp. 58-65.
- [30] HERGAT, V., *Precautions to Take for the Good Execution of a Jominy Test*, Métaux-Corrosi.-Ind., Vol. 56, No. 666, February 1981, pp. 75-80.
- [31] KANAZAWA, S., *Estimation of Hardenability of Steels*, Tetsu-to-Hagane, Vol. 67, February 1981, pp. 295-302.
- [32] MAYNIER, P., PEUTEUIL, L. and DOLLET, J., *Use of Data Processing for the Prediction of Mechanical Properties of Carbon and Low-Alloy Steels*, Rev. Met., Cah. Inf. Tech., Vol. 78, August-September 1981, pp. 715-721.
- [33] FACCENDA, V. and PARETO, G., *Prediction of Jominy Hardenability from Chemical Analysis of Steel*, Metall. Ital., Vol. 75, March 1983, pp. 171-179.
- [34] DIETRICH, H., SCHMIDT, W. and SCHÜLER, V., *Shortcomings of the Jominy End-Quench Test*, Thyssen Edelstahl Tech. Ber., Vol. 10, No. 2, December 1984, pp. 133-144.
- [35] DIETRICH, H., SCHMIDT, W. and SCHAFFRATH, W., *The Accuracy of Methods Reported in Literature to Calculate the End-Quench Hardening Curve by Chemical Analysis*, Thyssen Edelstahl Tech. Ber., Vol. 10, No. 2, December 1984, pp. 145-157 (BISI No. 26779).
- [36] DE ANDRES, M.P., CARSI, M. and MARTINEZ, A., *Program for Calculating the Hardenability of Automotive Steels*, Rev. Metal., Vol. 22, July-August 1986, pp. 243-252.
- [37] FREIBURG, A., *Methods for Determining Hardenability in End-Quench Test from Chemical Composition*, Stahl und Eisen, Vol. 106, No. 23, 17 November 1986, pp. 63-68 (BISI No. 25834).
- [38] FRODL, D., KRIEGER, K., LEPPER, D., LÜBBEN, A., ROHLOFF, H., SCHÜLER, F. and SCHÜLER, V., *Calculation of Hardenability in the End-Quench Test*, Stahl und Eisen, Vol. 106, No. 24, 1986, pp. 69-75 (BISI No. 25504).
- [39] DRESSEL, P.G. et al., *Variation of Hardenability in the Jominy End Quench Test Due to the Test Laboratories and Pretreatment States*, Stahl und Eisen, Vol. 106, 1 December 1986, pp. 1354-1362.

- [40] TARTAGLIA, J.M., ELDIS, G.T. and GEISLER, J.J., *Hyperbolic Secant Method for Predicting Jominy Hardenability: An example Using 0.2C-Ni-Cr-Mo Steels*, J. Heat Treating, Vol. 4, No. 4, December 1986, pp 352-364.
- [41] TOTH, M., MAROSNE, B.M. and KOCSISNE, B.M., *Reproducibility of the Jominy Test and its Consequences in the Steel Industry*, 5th International Congress on Heat Treatment of Materials, Vol. 1, Intl. Fed. for the Heat Treatment of Materials, Budapest, 1986, pp. 211-217.
- [42] DE ANDRES, M.P. and CARSI, M., *Hardenability: an Alternative to the Use of Grain Size as Calculation Parameter*, J. Materials Science, Vol. 22, 1987, pp. 2707-2716.
- [43] DE ANDRES, M.P., CARSI, M., ANACABE, N. and PENALBA, F., *Use of a Computer to Estimate, According to Hardenability Bands, the Composition of a Given Steel During its Manufacturing Process*, Rev. Metal., Vol. 24, May-June 1988, pp. 180-187.
- [44] UENO, M. and ITOH, K., *New Empirical Formula For Estimation of Hardenability from Chemical Compositions*, Tetsu-to-Hagane, Vol. 74, June 1988, pp. 1073-1080.
- [45] KIRKALDY, J.S. and FELDMAN, S.E., *Optimization of Steel Hardenability Control*, J. Heat Treating, Vol. 7, No. 1, 1989, pp. 57-64.
- [46] GULDEN, H., KRIEGER, K. and LEPPER, D., *Calculation of Hardenability in the End Quench Test of Heat Treatable Alloy Steels with 1 % Chromium*, Stahl und Eisen, Vol. 109, 10 November 1989, pp. 113-117.
- [47] LUND, T., *Measurement and Prediction of Jominy Hardenability*, Scandinavian J. Metallurgy, Vol. 19, 1990, pp. 227-235.
- [48] GULDEN, H. et al., *Calculation of Hardenability in the End Quench Test for Case-Hardening and Quenched and Tempered Steels*, Stahl und Eisen, Vol. 111, 15 July 1991, pp. 103-110.
- [49] MOSTERT, R.J. and VAN ROOYEN, G.T., *Novel Model for Accurate Calculation of Hardenability and Continuous Cooling Transformation*, Materials Science and Technology, Vol. 7, September 1991, pp. 803-811.
- [50] SCHÜLER, P., *Calculation of Hardenability in the Jominy End Quench Test on the Basis of the Chemical Composition of Steels*, La Revue de Métallurgie - CIT, Vol. 89, January 1992, pp. 93-103.
- [51] CASPARI, R. et al., *Calculation of Hardenability in the End Quench Test for Case-Hardening and Quenched and Tempered Steels*, Harterei-Tech. Mitt., Vol. 47, May-June 1992, pp. 183-188.

NOTE The above titles contain articles about Jominy test reproducibility.

- [52] *Hardenability of Alloy Steels*, American Society for Metals, Cleveland, 1939.
- [53] CRAFTS, W. and LAMONT, J.L., *Hardenability and Steel Selection*, Pitman Publishing Corp., New York, 1949.
- [54] GROSSMAN, M.A., *Elements of Hardenability*, American Society for Metals, Cleveland, 1952.
- [55] SIEBERT, C.A., DOANE, D.V. and BREEN, D.H., *The Hardenability of Steels — Concepts, Metallurgical Influences, and Industrial Applications*, American Society for Metals, Metals Park, OH, 1977.
- [56] DOANE, D.V. and KIRKALDY, J.S., *Hardenability Concepts with Applications to Steel*, The Metallurgical Society of AIME, Warrendale, PA, 1978.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 2016* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Head (Publication & Sales), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: MTD 22 (22104).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones: 2323 0131, 2323 3375, 2323 9402

Website: www.bis.gov.in

Regional Offices:

Central : 601/A, Konnectus Tower -1, 6th Floor,
DMRC Building, Bhavbhuti Marg, New
Delhi 110002

Telephones

{ 2323 7617

Eastern : 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V,
Salt Lake, Kolkata, West Bengal 700091

{ 2367 0012
2320 9474

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg,
Chandigarh 160019

{ 265 9930

Southern : C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113

{ 2254 1442
2254 1216

Western : Manakalya, 4th Floor, NTH Complex (W Sector), F-10, MIDC, Andheri
(East), Mumbai 400093

{ 283 25838

Branches : AHMEDABAD, BENGALURU, BHOPAL, BHUBANESHWAR, CHANDIGARH, CHENNAI, COIMBATORE, DEHRADUN, DELHI, FARIDABAD, GHAZIABAD, GUWAHATI, HARYNA, HUBLI, HYDERABAD, JAIPUR, JAMMU & KASHMIR, JAMSHEDPUR, KOCHI, KOLKATA, LUCKNOW, MADURAI, MUMBAI, NAGPUR, NOIDA, PARWANOO, PATNA, PUNE, RAIPUR, RAJKOT, SURAT, VIJAYAWADA.