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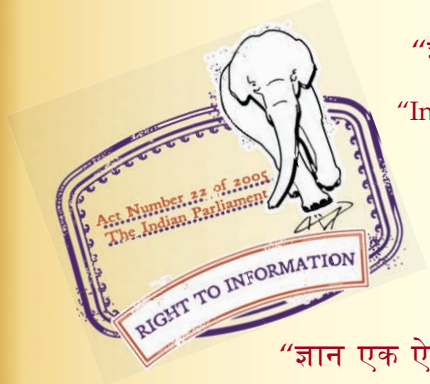

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Indian Standard

METHOD FOR END QUENCH TEST FOR HARDENABILITY OF STEEL

(First Revision)

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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December 1981

Indian Standard

METHOD FOR END QUENCH TEST FOR HARDENABILITY OF STEEL

(First Revision)

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METHOD FOR END QUENCH TEST FOR HARDENABILITY OF STEEL

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 31 July 1981, after the draft finalized by the Methods of Physical Tests Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 For heat treatable steels, it is very often necessary to know their relative ability to harden under heat treatment. This standard prescribes the method of end quench or Jominy test which is largely conducted to assess the hardenability of steel.

0.3 This standard was first published in 1966. In this revision, additional requirements for the hardening apparatus have been included and the provision for carrying out the test on sub-size test-pieces has been deleted. This standard is based on ISO/R 642-1979 — Hardenability test of steel by end quenching (Jominy test).

0.4 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

---

1. SCOPE

1.1 This standard prescribes the method for determining the hardenability of steel by end quench or Jominy test.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definition given in IS : 1956 (Part I)-1976† shall apply.

---

*Rules for rounding off numerical values (*revised*).

†Glossary of terms relating to iron and steel: Part I General metallurgy, heat treatment and testing.

3. PRINCIPLE OF THE TEST

3.1 The test consists in heating a test piece to a given temperature for a specified period of time followed by water quenching at one end and measuring the hardness at various points, from the quenched end along the length of the test piece in order to determine the hardenability of the steel by variation of this hardness.

4. REFERENCE NUMBERS

4.1 The reference numbers used in this standard are given in Table 1.

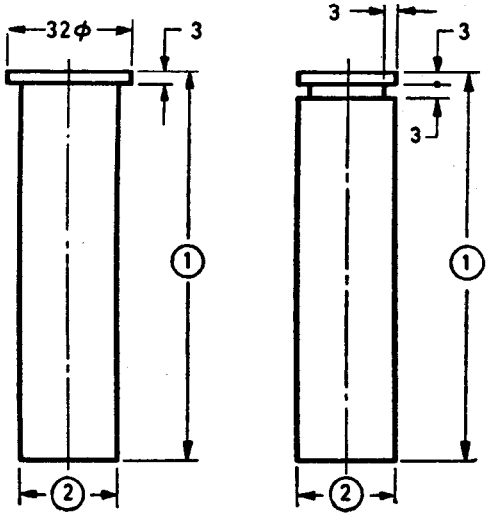
TABLE 1 REFERENCE NUMBERS

REFERENCE NO. (SEE-ALSO FIG. 1, 2 AND 3)	DESCRIPTION	VALUE
1	Total length of test piece	100 ± 0·5 mm
2	Diameter	$25 \begin{matrix} + 0{\cdot}5 \\ - 0 \end{matrix}$
3	Time during which the test piece is maintained at the heating temperature	30 ± 5 min
4	Maximum time lag between removal of the test piece from the furnace and the start of quenching	5 sec
5	Temperature of water	5 to 30°C
6	Inside diameter of vertical water supply pipe	12·5 ± 0·5 mm
7	Height of free water jet (that is, without test piece in position)	65 ± 10 mm
8	Distance from tip of nozzle to the bottom of test piece	12·5 ± 0·5 mm
9	Depth of flats for the measurement of hardness	0·4 to 0·5 mm

5. TEST PIECE

5.1 The test piece shall consist of a round bar machined to 25 mm dia and 100 mm long.

5.2 The unmachined end of the test piece may have either a flange or an undercut so as to permit rapid centralizing of the test piece and fitting it into place, at the time of quenching, by means of an appropriate support (*see* Fig. 1A & 1B).



1A Test Piece Having Flange at the end

1B Test Piece Having an Undercut

All dimensions in millimetres.

FIG. 1. TEST PIECES

5.3 In general, the forged or rolled test bars shall be normalized before final machining. For special requirements, heat treatment other than normalizing may also be carried out subject to mutual agreement between the contracting parties.

5.3.1 Even if after the treatment as specified **4.3** the test bar is still too hard for machining, it may be ground or, by mutual agreement, it may be softened under conditions which should be so chosen as to modify the austenitic grain size as little as possible. All the treatments carried out shall be stated in the test report.

5.3.2 Unless otherwise specified, the normalizing treatment shall be carried out under conditions specified in the relevant material standard. The holding time at normalizing temperature shall be between 30 and 60 min.

5.3.3 The test bar so treated shall not show any sign of decarburization.

5.4 Mechining shall be done either by grinding or by polishing with a smooth file or emery paper; the surface of the end of the test piece to be hardened shall have a reasonably fine finish.

5.5 Where the size of the product does not permit preparation of the standard test piece, the test bar sample shall be taken from the nearest semi from which the product is processed, so that the standard test piece is obtained.

5.6 **Cast Specimens** — As an alternative, the specimen may be cast during the pouring of steel. A graphite or metal mould may be used to form an overlength specimen of approximately 25 mm diameter, which shall be cut to the standard specimen size, or the mould may be used to form a 32 mm diameter specimen, which shall be machined to the final specimen size. Cast test pieces need not be normalized.

6. TEST PROCEDURE

6.1 Heating of the Test Piece

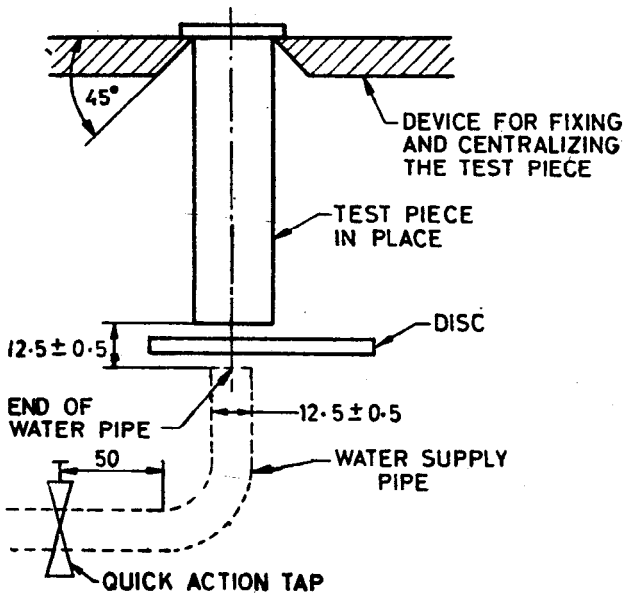
6.1.1 The test piece shall be heated uniformly and then maintained for not less than 30 min at the specified temperature. For particular types of furnaces, this duration may be laid down as a result of previous experience, establishing the minimum time necessary for the centre of the piece to reach the desired temperature (this temperature may be verified, for example, by means of a thermocouple placed in a hole drilled along the axis of the test piece at the head end).

6.1.2 Precautions shall be taken to avoid any decarburization of the test piece as well as its carburization or a marked oxidation. A furnace with a controlled atmosphere may be used or the test piece may be placed in a mild steel vessel as shown in Fig. 4. The bottom of this vessel shall be covered either with a graphite plate or with a cast iron shot on which the test piece shall rest.

6.2 Hardening of the Test Piece

6.2.1 The hardening apparatus (*see* Fig. 2) consists essentially of a means of fixing and centralizing the test piece placed vertically above the water jet. The water pipe shall contain a quick action tap, as well as a system to vary the flow rate of water. The length of the water supply pipe behind the tap shall be at least 50 mm in order to ensure non-turbulent water flow. The device may also contain a disc allowing rapid opening and closing at the water jet.

6.2.2 The relative positions of the water supply pipe (12·5 ± 0·5 mm diameter) and of the test piece support shall be such that the distance between the end of the water supply pipe and the face of the test piece to be hardened shall be 12·5 ± 0·5 mm (*see* Fig. 2).



All dimensions in millimetres.

FIG. 2. DIAGRAM OF HARDENING APPARATUS

6.2.3 The test piece support shall enable automatic centralizing of the test piece above the water supply pipe and holding it during spraying. It shall be dry while the test piece is in position; splashing of water onto the test piece shall be avoided while it is being placed in position and before the actual hardening starts.

6.2.4 The height of the water jet above the end of the water pipe without the test piece in position shall be 65 ± 10 mm (*see* Fig. 3). The water temperature in the pipe shall be between 5°C and 30°C.

NOTE — To determine the force of the water jet, the dimension of the circle covered by water diverted by the test piece and falling on a horizontal plane 60 mm below the end of the pipe can be measured. The diameter of the moistened circle should be 210 mm.

6.2.5 The hardening device shall be protected from draughts.

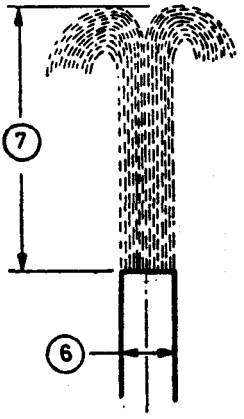


FIG. 3. WATER JET

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

6.2.7 The water supply tap shall be opened as soon as the test piece is fixed in position and the time of spraying shall be at least 10 min. After this time, the cooling of the test piece shall be completed by immersing it in cold water.

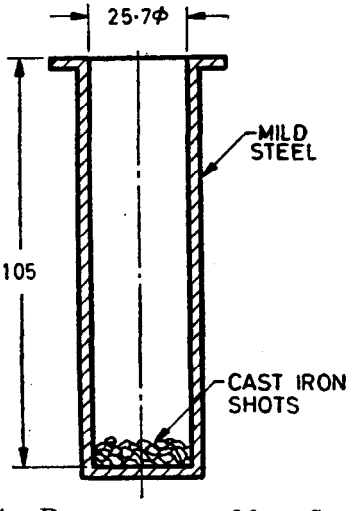


FIG. 4. DESCRIPTION OF MILD STEEL VESSEL

7. MEASUREMENT OF HARDNESS AFTER HARDENING

7.1 Two flats for measuring the hardness shall be ground on the surface 180° apart and parallel to the axis of the test piece, along its entire length. The two flats shall be at the same distance away from the product surface. They shall be 0·4 to 0·5 mm deep and shall be ground with an abundant supply of coolant so as to prevent any heating likely to modify the microstructure of the quenched test piece.

7.2 It shall be ascertained that no softening by grinding has taken place by immersing the test piece in a 5 percent solution of nitric acid in water until it is completely blackened. After washing in hot water, the test piece shall be immersed for 2 or 3 s in a 50 percent solution of hydrochloric acid in water; it shall then be re-washed in hot water and dried in an air blast. The colour obtained shall be uniform.

7.2.1 If there are any stains indicating the presence of soft spots, two new flats shall be prepared and tested as stated above.

7.3 The test piece shall then be secured in a suitable holder and measurements of Rockwell hardness, on *C* scale shall be carried out on the axis of the flats (*see* IS : 1586-1968*).

7.3.1 The hardness measurements may also be made on the Vickers scale with a 30 kgf load (*see* IS : 1501-1968†).

7.4 It is recommended that while measuring the hardness on the second flat, the burrs formed in measuring the hardness on the first flat should be removed by grinding.

7.5 The location of the points for hardness measurements shall be such as to enable either of the two determinations as given in **6.5.1** and **6.5.2** to be made.

7.5.1 *Drawing up of a Curve Representing Variations in Hardness* — In this case, the distances of the first eight points taken from the quenched end (distance expressed in mm) shall be as follows:

1·5, 3, 5, 7, 9, 11, 13 and 15

subsequent points being in general at 5 mm intervals. However, the interval between the measurement points after the first point is not binding; it need not be so close if the curve does not show any uncertainty, but on the other hand it shall be closer in the regions where the line needs to be precise.

*Method for Rockwell hardness test (B & C scales) for steel, (*first revision*).
†Method for Vickers hardness test for steel (*first revision*).

7.5.1.1 In the case of steel having a low depth of hardness, the first measuring point shall be 1·5 mm from the hardened end, the subsequent point being spaced at 0·75 mm intervals to a distance of 12 mm from this end. The last four points shall be 15, 19, 22 and 25 mm away from the same end.

NOTE — It shall be realized that the interval between hardness indentations, specified in **6.5.1** and **6.5.1.1** may not always comply with the requirements of IS : 1586-1960 Method for Rockwell hardness test (B + C scales) however, it is considered that the hardness values obtained in general will be sufficiently accurate.

7.5.1.2 The device for moving the test piece on the hardness machine shall allow accurate centralizing of the ground flat and accurate centralizing of the indentations. The indentations are generally made along the axis of the flat; but if this is not possible, the indentations may be made symmetrically along two lines parallel to and at a distance of less than 0·5 mm from the axis.

7.5.2 Determination of hardness may be made at one or more points situated at specified distances from the hardened end.

7.6 At each distance *d*, the hardness to be recorded shall be the mean of the measurements made at this distance *d* on each of the two flats stated in **7.1**.

7.6.1 If the values determined at the same distance on the two opposite faces, vary widely from each other, two more surfaces 90° apart from the original surface shall be ground and hardness survey carried out on the new surfaces. The average of the three values, after discarding the one showing wide variation shall be taken as the mean value of the hardness at that distance.

8. PRESENTATION OF RESULTS

8.1 Test results shall include the following.

8.1.1 *Drawing of the Hardness Curves* — Hardness curves shall be obtained by plotting distance *d* on the abscissa and the corresponding hardnesses on the ordinate.

8.1.2 *Description of the Hardenability Characteristics of a Particular Steel.*

8.1.2.1 It shall be done by one of the following methods:

a) By drawing its hardness curve; or

b) By the hardness at three points, one point being 1·5 mm from the hardened end and the other two points fixed by agreement; or

c) By the hardness at two points situated at distances fixed by agreement; and

d) By the hardness at one specified distance from the quenched end.

8.1.3 *Specification for the Hardenability of the Product* — It shall be furnished by one of the following methods:

a) By the curve(s) of depth of hardness which is either a curve above which the Jominy curve of depth of hardness of the steel shall be found, or a curve below which the Jominy curve of depth of hardness of the steel shall be found; or the two limits of scatter defining the area in which the curve of the steel shall be found (*see* Fig. 5A).

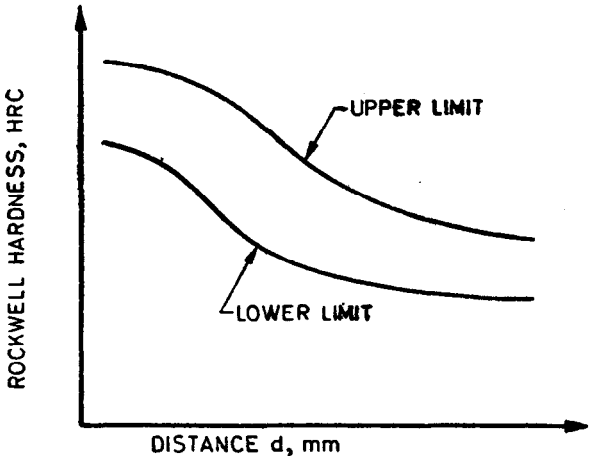


FIG. 5A SPECIFICATION OF TWO LIMITING CURVES

b) By particular points of the curve giving the depth of hardness and which may be the upper limit or the lower limit or a range between the two limits, either by the distance from the quenched face for a given hardness or by the hardness at a given distance from the quenched end.

8.1.3.1 In all these cases, the description may be expressed in the form of an index of hardenability consisting of the letter *J* followed by two numbers. The first number denotes the hardness HRC, and the second denotes the distance in mm from the point of measurement to the quenched end.

Examples:

J 35/15 shows that at a distance of 15 mm from the quenched end the hardness is 35 HRC (*see* Fig. 5B).

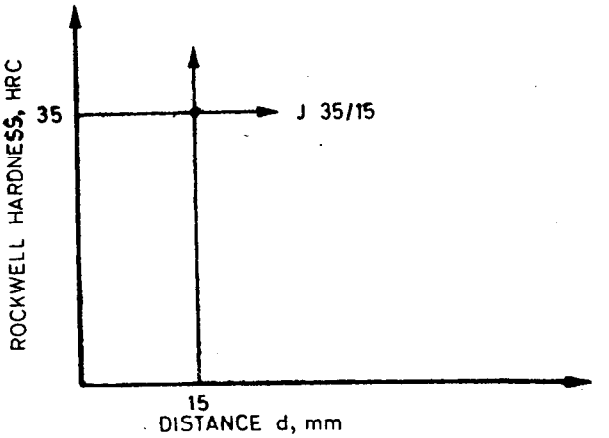


FIG 5B SPECIFICATION BY HARDNESS AT DISTANCE 'd'

J 45/6-18 shows that the hardness reaches a values of 45 HRC at some point between 6 and 18 mm from the quenched end (*see* Fig. 5C).

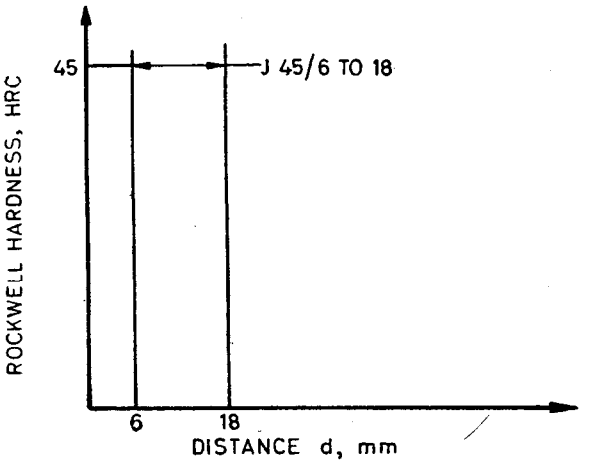


FIG. 5C SPECIFICATION BY HARDNESS BETWEEN TWO DISTANCES

J 35-48/15 shows that at a distance of 15 mm from the quenched end the hardness HRC is between 35 and 48 (*see* Fig. 5D).

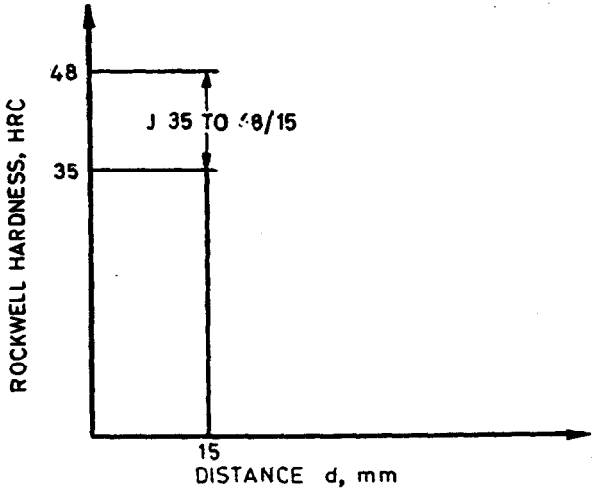


FIG. 5D SPECIFICATIONS BY A RANGE OF HARDNESS AT A GIVEN DISTANCE

8.1.3.2 If the Jominy index is expressed as Vickers hardness HV 30, it shall include the symbol HV to avoid confusion (for example, JHV 340-490/15).

8.2 In many cases, it may be useful to know the cooling rate on the surface of the test piece. This may be expressed by plotting the cooling rates in °C/s at points on the surface of the Jominy test piece at 700°C as a function of their distance from the hardened end (*see* Fig. 6).

9. TEST REPORT

9.1 The test report shall include the following information:

a) the grade of the steel,

b) the cast number,

c) the chemical composition,

d) the method of sampling,

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

f) the method used for determining hardness, and

g) the test method.

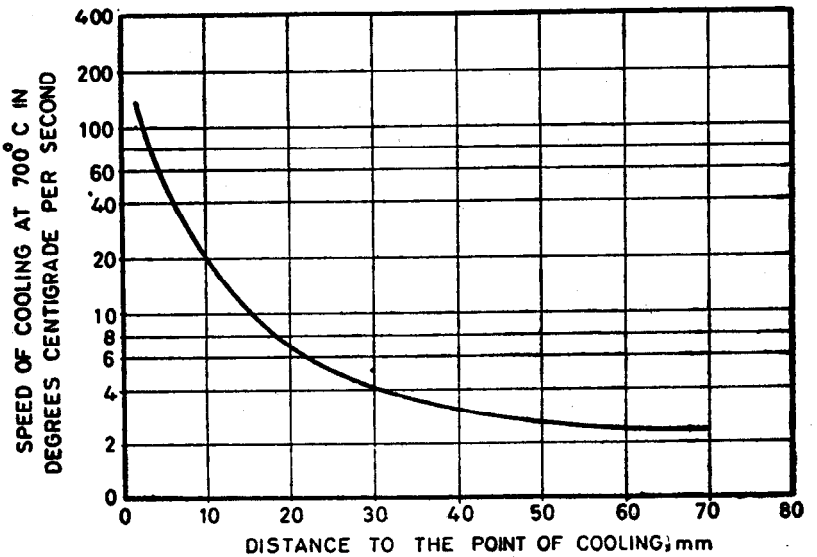


FIG. 6 COOLING CURVE

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