International Standard 642

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Steel — Hardenability test by end quenching (Jominy test)

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FOREWORD

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 642 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in June 1978.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	Norway
Austria	Hungary	Poland
Belgium	India	Romania
Brazil	Iran	South Africa, Rep. of
Bulgaria	Ireland	Spain
Canada	Italy	Sweden
Chile	Japan	Switzerland
Czechoslovakia	Korea, Dem.P.Rep. of	Turkey
Denmark	Korea, Rep. of	United Kingdom
Egypt, Arab Rep. of	Mexico	USA
Finland	Netherlands	USSR
France	New Zealand	Yugoslavia

No member body expressed disapproval of the document.

This International Standard cancels and replaces ISO Recommendation R 642-1967, of which it constitutes a technical revision.

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CONTENTS

Steel — Hardenability test by end quenching (Jominy test)

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the method for determining the hardenability of steel by the end quench, or Jominy, test.

2 REFERENCES

ISO/R 80, *Rockwell hardness test (B and C scales) for steel.*

ISO/R 81, *Vickers hardness test for steel (load 5 to 100 kgf).*

3 PRINCIPLE

The test consists in :

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;

c) measuring the hardness either between two selected points or 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 ± 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 min
t_m	Maximum time lag between removal of test piece from furnace and start of quenching	5 s
T	Temperature of cooling water	5 to 30 °C
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
l	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	
J..-d	Jominy hardenability index at distance d, in Rockwell HRC-mm	
J HV..-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 relevant product standard, the method of sampling and the position of the test sample shall be the subject of a special agreement.

The sampling method may vary according to the dimensions of the test bar; for example :

a) for diameter ⩽ 40 mm, the test piece is obtained by machining;

b) for diameters > 40 mm, either of the two sampling methods given below may be applied :

1) — for diameters ⩽ 150 mm, the rough bar is forged to a diameter of 40 mm;

— for diameters > 150 mm, the test piece is taken so that its axis is 20 mm below the surface of the product; in this case, the flats specified in 8.1 can then be made so that the material under investigation is situated at approximately the same distance below the surface of the product as the axis of the test piece (see figure 1);

2) — the test piece is taken so that its axis is 20 mm below the surface of the product, with the same position of the flats as previously (see figure 1).

By special agreement, the test sample may be obtained by casting.

NOTE — If possible, it is preferable to prepare the test sample by forging.

When the size of the product does not permit preparation of the standard Jominy test piece, the Jominy test piece shall be made from the nearest semi-finished product from which the product will be processed.

5.2 Dimensions of test piece

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 32 or 25 mm in diameter, depending upon whether the test piece has a flange or an undercut (to permit rapid centring and fitting in position, for the quenching operation, by means of an appropriate support). (See figure 2).

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

5.3 Heat treatment

Forged or rolled test samples shall be given a normalizing treatment before final machining. For special requirements, other heat treatments may be used.

5.3.1 In cases where it is of special interest to know the hardenability of the steel in the softened condition (for example, in the spheroidized condition), the test piece may be treated accordingly.

5.3.2 Except by special agreement, the normalizing treatment shall be carried out under conditions laid down in the product specification for the steel. The period for which the normalizing temperature is maintained shall be between 30 and 60 min.

5.3.3 The rough bar shall be treated so that the machined test piece is completely free from even 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 be a reasonably fine finish, preferably obtained by fine grinding, and should be free from burrs.

6 APPARATUS

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

6.1 The quenching device, shown in figure 4, consists essentially of a means of fixing and centring the test piece vertically above the end of a water supply pipe which contains both a quick-action tap and a system to adjust the flow rate of the 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 incorporate a disk allowing the water jet to be released and cut off rapidly.

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 ± 0,5 mm (see figure 4).

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 and before the actual quenching operation starts.

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 5).

NOTE — To check 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 wetted circle should be 210 mm.

The water temperature in the pipe shall be between 5 and 30 °C.

6.5 The test device shall be protected from draughts throughout the quenching procedure.

7 HEATING AND QUENCHING OF TEST PIECE

7.1 Heating

7.1.1 The test piece shall be heated uniformly and then maintained for 30 ± 5 min at the temperature specified in the relevant product standard or fixed by special agreement. For particular types of furnaces, 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, for example, 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 avoid decarburization of the test piece, or its carburization or a marked oxidation with formation of scale. Austenitizing in a salt bath is prohibited. For example, a furnace with a controlled atmosphere can be used or the test piece can be placed in a mild steel vessel, as shown in figure 3. The bottom of this vessel shall be covered either with graphite granules or with cast iron shot on which the test piece will rest.

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.

7.2.2 The water supply tap shall open rapidly.

7.2.3 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 MEASUREMENTS 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 to 0,5 mm deep. These flats shall be machined using an abundant supply of coolant to avoid any heating 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. After washing in hot water, immerse the test piece for 2 or 3 s in a 50 % (*V/V*) hydrochloric acid solution in water; then wash again in hot water and dry in an air blast. The colour obtained shall be uniform. In usual practice, the use of the nitric acid etch only is sufficient. If there are any stains, indicating the presence of soft spots, two new flats shall be made and tested as stated above.

8.3 Precautions shall be taken to ensure that the test piece is well supported and is rigidly held during the hardness measurements. (It is convenient for the holder to be fitted on a carriage with a guide screw to enable the points of measurement to be spaced at accurate distances.)

With the test piece secured in a suitable holder, measurements of Rockwell C hardness shall be carried out on the axis of the flats under a load of 1 470 N (150 kgf) (conical diamond indenter, see ISO/R 80).

8.3.1 The Rockwell C hardness measurements may be replaced by measurements of Vickers hardness under a 294 N (30 kgf) load (see ISO/R 81).

8.3.2 It is recommended that, before making hardness tests on the second flat, any raised edges of hardness indentations on the first flat be removed by grinding.

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

In this case, the distances, expressed in millimetres, of the first eight points taken from the quenched end are as follows (see figure 6) :

1,5 – 3 – 5 – 7 – 9 – 11 – 13 – 15

Subsequent points are in general at 5 mm intervals. However, the interval between the measurement points after the first point is not binding; it need not be as close if the curve does not show any uncertainty, but on the other hand it shall be closer in the regions where the curve needs to be precise (see note in 8.4.1.1).

8.4.1.1 In the case of steels of low hardenability, the first measuring point shall be 1,5 mm from the quenched end; the following points shall be spaced at 0,75 mm intervals to a distance of 12 mm from this end. The last four points shall be respectively 15 – 19 – 22 and 25 mm from the same end.

NOTE – It is realized that the distance between the hardness indentations given in 8.4.1 and 8.4.1.1 will not always comply with the minimum distances stated in ISO/R 80. For the purposes of this International Standard, however, it is considered that the hardness values obtained will in general be sufficiently accurate; however, see 8.4.1.2, which recommends the staggering of indentations.

8.4.1.2 The device for moving the test piece on the hardness testing machine shall allow accurate centring of the flat, and accurate spacing of the indentations. The latter

are made generally along the axis of the flat; when 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.

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 (1,5 mm from the quenched end).

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.

9.2 Drawing of the hardness curves

The distances *d* shall be plotted on the abscissae and the corresponding hardnesses on the ordinates, using the following scales :

- on the ordinates : 10 mm corresponding to 5 HRC or 50 HV;
- on the abscissae, either

  10 mm corresponding to a distance of 5 mm; or

  15 mm corresponding to a distance of 5 mm.

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 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.

9.4 Specification for the hardenability of the product

Use one of the following methods :

a) specify the Jominy curve(s) of depth of hardness which is (are)

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

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

3) the upper and lower Jominy curves between which the Jominy curve of the steel shall lie.

b) specify particular points on the Jominy curve (which can be

- an upper limit,
- or a lower limit,
- or a range between the two limits),

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

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

In all these cases, the characteristics can be expressed in the form of an "index of hardenability". This index consists of the letter J followed by two numbers, as follows :

J *xx*–*d*

Where

xx is the Rockwell C hardness;

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

Examples :

a) Measurement result

J 35–15 shows that at a distance of 15 mm from the quenched end the hardness is 35 HRC.

b) Specifications

J 45–6/18 shows that the hardness reaches a value of 45 HRC at some point between 6 and 18 mm from the quenched end;

J 35/48–15 shows that at a distance of 15 mm from the quenched end the hardness has a value between 35 and 48 HRC.

9.5 Indication of method

9.5.1 The method of determining the hardnesses shall always be recorded in the report.

9.5.2 If the Jominy index is expressed as a Vickers hardness HV 30, it shall include the symbol HV to avoid any confusion.

Example :

J HV 340/490–15 shows that, at a distance of 15 mm from the quenched end, the Vickers hardness is between 340 and 490.

10 TEST REPORT

The test report shall contain the following information :

a) grade of the steel;

b) cast number;

c) chemical composition

d) method of sampling;

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

f) the hardness testing method used;

g) the test result.

NOTES

1 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.

2 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 8 : 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 9 : 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.