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HARDENABILITY TEST BY END QUENCHING STEEL (JOMINY TEST)

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BRIEF HISTORY

The ISO Recommendation R 642, *Hardenability test by end quenching steel (Jominy test)*, was drawn up by Technical Committee ISO/TC 17, *Steel*, the Secretariat of which is held by the British Standards Institution (BSI).

Work on this question by the Technical Committee began in 1958 and led, in 1965, to the adoption of a Draft ISO Recommendation.

In January 1966, this Draft ISO Recommendation (No. 919) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies:

Argentina	France	Romania
Australia	Germany	Spain
Austria	Hungary	Sweden
Belgium	India	Switzerland
Brazil	Israel	Turkey
Canada	Italy	U.A.R.
Chile	Japan	United Kingdom
Czechoslovakia	Korea, Rep. of	U.S.A.
Denmark	Netherlands	Yugoslavia
Finland	Norway	

No Member Body opposed the approval of the Draft.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in December 1967, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 642 December 1967

HARDENABILITY TEST BY END QUENCHING STEEL (JOMINY TEST)

1. PRINCIPLE OF TEST

The test consists in

1.1 heating a test piece to a given temperature for a specified period of time;

1.2 cooling it by spraying water on its end;

1.3 either assessing the hardness between two selected points, or measuring it at certain given points along its length, in order to determine the hardenability of the steel by variations of this hardness.

2. SYMBOLS AND DESIGNATIONS

Reference number	Symbol	Designation	Value
1		Total length of test piece	100 ± 0.5 mm
2		Diameter	25 ± 0.5 mm
3		Time during which the test piece is maintained at the heating temperature	30 ± 5 minutes
4		Maximum time lag between removal of the test piece from the furnace and the start of quenching	5 seconds
5		Temperature of the cooling water	5 to 30 °C
6		Internal diameter of vertical water supply pipe	12.5 ± 0.5 mm
7		Height of water jet 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 mm*
10	*d*	Distance in millimetres from points where hardness is measured to quenched end	mm
11	J xx-*d*	Jominy hardenability index at distance *d*	in Rockwell HRC-mm
11 a	J HVxx-*d*	*ditto*	in Vickers HV 30-mm

* In certain cases, the product specification may require a greater depth.

3. TYPE OF TEST PIECES AND THEIR PREPARATION

3.1 Dimensions of the test piece

3.1.1 The test piece consists of a round bar machined to 25 mm diameter and 100 mm long.

3.1.2 The unmachined end of this test piece* is 32 or 25 mm in diameter depending upon whether the test piece has a flange or an undercut (so as to permit rapid centralizing and fitting into place, at the time of quenching, by means of an appropriate support (see Fig. 1)).

3.1.3 The test piece should, if necessary, be marked (on the opposite end to the end to be used for hardening) to enable the position to be identified in relation to the original bar.

3.1.4 Such marking is necessary, in particular, when the steel under consideration has only a low depth of hardness and the hardenability of the material between the centre and the surface of bars greater than 50 mm in side or in diameter has to be determined.

In this case, the test piece is generally taken from the bar in such a manner that its axis, parallel to the axis of the bar, is situated midway between the centre and the surface. The flats specified in clause 6.1 can then be made so that the material situated approximately at the same distance in the bar as the axis of the test piece is under investigation.

3.2 The forged or rolled test pieces are given a normalizing treatment before final machining. For special requirements other heat treatments can be used.

3.2.1 In cases where it is of special interest to know the hardenability of the steel in the softened condition, the test piece may be treated accordingly.

3.2.2 Except by special agreement, the normalizing treatment should be carried out under conditions specified in the product specification for the steel.

3.2.3 The rough bar should be treated so that the machined test piece is completely free from decarburization, even from traces thereof.

3.3 The cylindrical surface of the test piece is machined by fine turning; the surface of the test piece end to be hardened should have a reasonably fine finish, preferably obtained by further polishing.

* Depending upon the dimensions of the sample bar from which the test piece is taken, the rough bar can be reduced to the above dimensions by rolling or forging. It can also be obtained directly by casting; in this case, it is cast at the same time as the cast sample is taken, and this is taken at the end of the steelmaking process.

4. APPARATUS

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

4.1 The hardening device, shown in Figure 3, page 10, consists essentially of a means of fixing and centralizing the test piece placed vertically above the water supply pipe. The water supply pipe contains a quick action tap.

4.2 The relative positions of the end of the water supply pipe (12.5 ± 0.5 mm internal diameter) and of the test piece support should be such that the distance between the end of the water supply pipe and the test piece face to be hardened should be 12.5 ± 0.5 mm (see Fig. 3).

4.3 The test piece support should enable precise centralizing of the test piece above the end of the water supply pipe and the holding of it during spraying. It should be dry while the test piece is being placed in position; splashing of water should be kept away from the test piece while it is being placed in position and before the actual quenching operation starts.

4.4 The height of the water jet above the end of the water supply pipe without the test piece in position should be 65 ± 10 mm* (see Fig. 4). The water temperature in the pipe should be between 5 and 30 °C.

4.5 The hardening device should be protected from draughts.

5. TEST REQUIREMENTS

5.1 Heating of the test piece

5.1.1 The test piece is heated uniformly and then maintained for 30 ± 5 minutes at the specified temperature (see product standard or special agreement). For particular types of furnaces, this duration can 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 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).

5.1.2 Precautions should be taken to avoid any decarburization of the test piece, or its carburization or a marked oxidation with formation of scale. 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 2, page 9. The bottom of this vessel should be covered either with graphite granules or with cast iron shot on which the test piece will rest.

5.2 Hardening of the test piece

5.2.1 The time between removal of the test piece from the furnace and the commencement of spraying should not exceed 5 seconds.

5.2.2 The water supply tap should open rapidly.

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

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* 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. PREPARATION FOR AND MEASUREMENTS OF HARDNESS AFTER HARDENING

6.1 Two flats for measuring the hardness are ground on the surface 180° apart along the entire length of the hardened test piece. They should be 0.4 mm deep. These flats are made with an abundant supply of coolant so as to avoid overheating likely to modify the micrographic structure of the test piece.

6.2 It should be ascertained that no softening by grinding has taken place as follows: immerse the test piece in a 5 per cent v/v nitric acid solution in water until it is completely blackened. After washing in hot water, the test piece should be immersed for 2 or 3 seconds in a 50 per cent v/v hydrochloric acid solution in water; it should then be rewashed in hot water and dried in an air blast. The colour obtained should be uniform.

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

6.3 The test piece should be secured in a suitable holder*, and measurements of Rockwell C hardness should be carried out on the axis of the flats under a load of 150 kgf (conical diamond indenter, see ISO Recommendation R 80 *Rockwell Hardness Test (B and C Scales) for Steel*).

6.3.1 The Rockwell C hardness measurements can be replaced by measurements of Vickers hardness under a 30 kgf load (see ISO Recommendation R 81, *Vickers Hardness Test for Steel*).

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

6.4 The positions of the measurement points should 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 clause 6.4.1).
(*b*) Determination of hardness at one or more specified points (see clause 6.4.2).

6.4.1 *Drawing of a curve representing variations in hardness*; in this case the successive intervals of the first eight points taken from the hardened end (distance expressed in millimetres) are:

1.5 — 1.5 — 2 — 2 — 2 — 2 — 2 — 2 (total 15 mm),

subsequent points being in general at 5 mm intervals. However, the interval between the measurement points after the first point is not binding; it needs not be so close if the curve does not show any uncertainty, but on the other hand it should be closer in the regions where the line needs to be precise (see note to clause 6.4.1.1).

6.4.1.1 In the case of steel having a low depth of hardness, the first measuring point is 1.5 mm from the hardened end; the following should be spaced at 0.75 mm intervals to a distance of 12 mm from this end. The last four points should be respectively 15 — 19 — 22 and 25 mm from the same end.

NOTE. — It is realized that the distance apart of the hardness indentations given in clauses 6.4.1 and 6.4.1.1 will not always comply with the minimum distances stated in ISO/R 80, *Rockwell hardness test (B and C scales) for steel*. For the purposes of this ISO Recommendation, however, it is considered that the hardness values obtained will in general be sufficiently accurate, but attention is drawn to clause 6.4.1.2 which recommends the staggering of indentations.

* Precautions should be taken to ensure that the test piece is well supported and is rigidly held during the 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 intervals of distance.

6.4.1.2 The device for moving the test piece on the hardness machine should allow accurate spacing of the indentations. To avoid any interference between adjacent indentations, it is desirable to allow measurements to be along two parallel lines of the same flat, but with displacement of the steps (one series between 1.5 and 12 mm, the other between 2.25 and 11.25 mm).

If this is not possible, two pairs of flats should be made at 180° one to the other on the test piece. The measurements of hardness carried out on each group of the two adjacent flats will be displaced as above.

6.4.2 *Determination of hardness can be made at one or more points* situated at specified distances from the end and including or not the first point specified in clause 6.4.1 (1.5 mm from the hardened end).

7. EXPRESSION OF RESULTS

7.1 **Hardness at any one point.** At each distance *d*, the hardness to be recorded is the mean of the measurements made at this distance *d* on each of the two flats stated in clause 6.1.

7.2 **Drawing of the hardness curves.** The distances *d* are on the abscissae and the corresponding hardnesses on the ordinates, using such a scale that the diagram obtained can be easily read.

7.3 **Description of the hardenability characteristics of a particular steel**

Use one of the three following methods:

(*a*) drawing its hardness curve;

(*b*) hardness in three points, one point being 1.5 mm from the hardened end and the other two points fixed by agreement;

(*c*) hardness at two points situated at distances fixed by agreement;

(*d*) hardness at one specified distance from the hardened end.

7.4 **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 should be found,

or

(2) a limiting curve below which the Jominy curve of depth of hardness of the steel should be found,

or

(3) the upper and lower Jominy curves between which the Jominy curve of the steel should be found.

(*b*) Specify *particular points on the Jominy curve* and which can be

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

(1) by the distance to the hardened face for a given hardness,

or

(2) the hardness at a given distance to the hardened face.

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

J HRC—*d*

where

HRC is the Rockwell hardness C

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

Examples

J 35 — 15 shows that at a distance of 15 mm from the hardened end the hardness is 35 HRC;

J 45 — 6.18 shows that the hardness reaches a value of 45 HRC at some point between 6 and 18 mm from the hardened end;

J 35.48 — 15 shows that at a distance of 15 mm the hardness HRC is between 35 and 48.

7.5 Indication of method. The method of determining the hardnesses should always *be recorded in the report.*

7.5.1 If the Jominy index is expressed as a Vickers hardness HV 30, it should include the symbol HV to avoid all confusion.

Example

J HV 340.490 — 15 shows that, at a distance of 15 mm from the hardened end, the Vickers hardness is between 340 and 490.

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 hardening process defined in section 4 and clause 5.2 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 which the changes in steel structure bring about during cooling and, on the other hand, the differences in thermal conductivity for different types of steel in relation to a test piece type, 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*) *Graph 1*

Network of curves giving the ratio $\frac{\theta}{\theta_A}$ as a function of time,

where

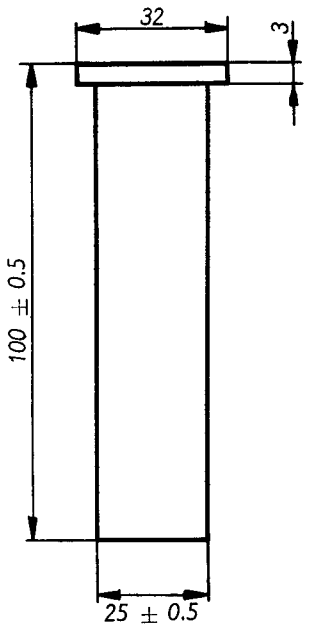
θ_A is the temperature of austenitization and

θ is the temperature of points on the surface, situated at certain distances from the point of cooling.

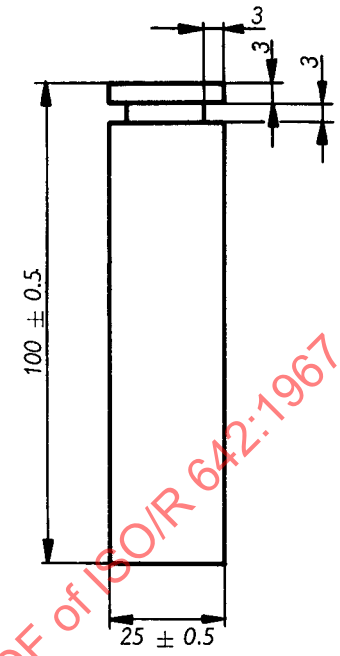
(*b*) *Graph 2*

Variation of the cooling speeds, in degrees Celsius per second, of the temperature of points on the surface of the Jominy test piece at approximately 700 °C as a function of their distance from the point of cooling.

Dimensions in millimetres



(a) — With a flange



(b) — With an undercut

FIG. 1. — **Dimensions of test piece**

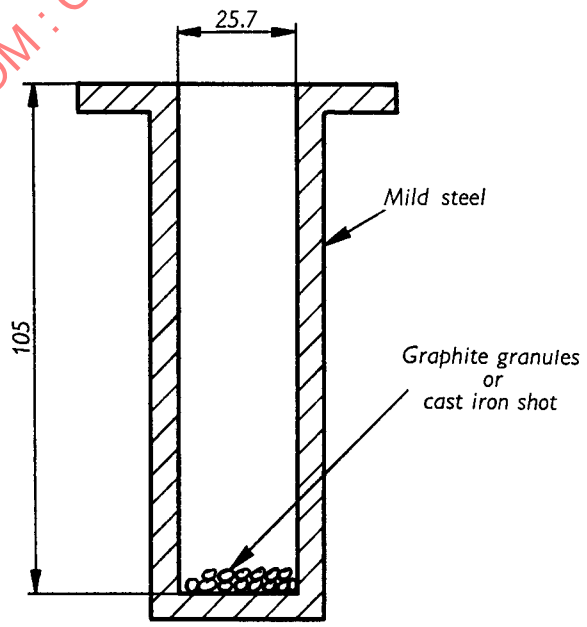


FIG. 2. — **Mild steel vessel for heating the test piece**

Dimensions in millimetres

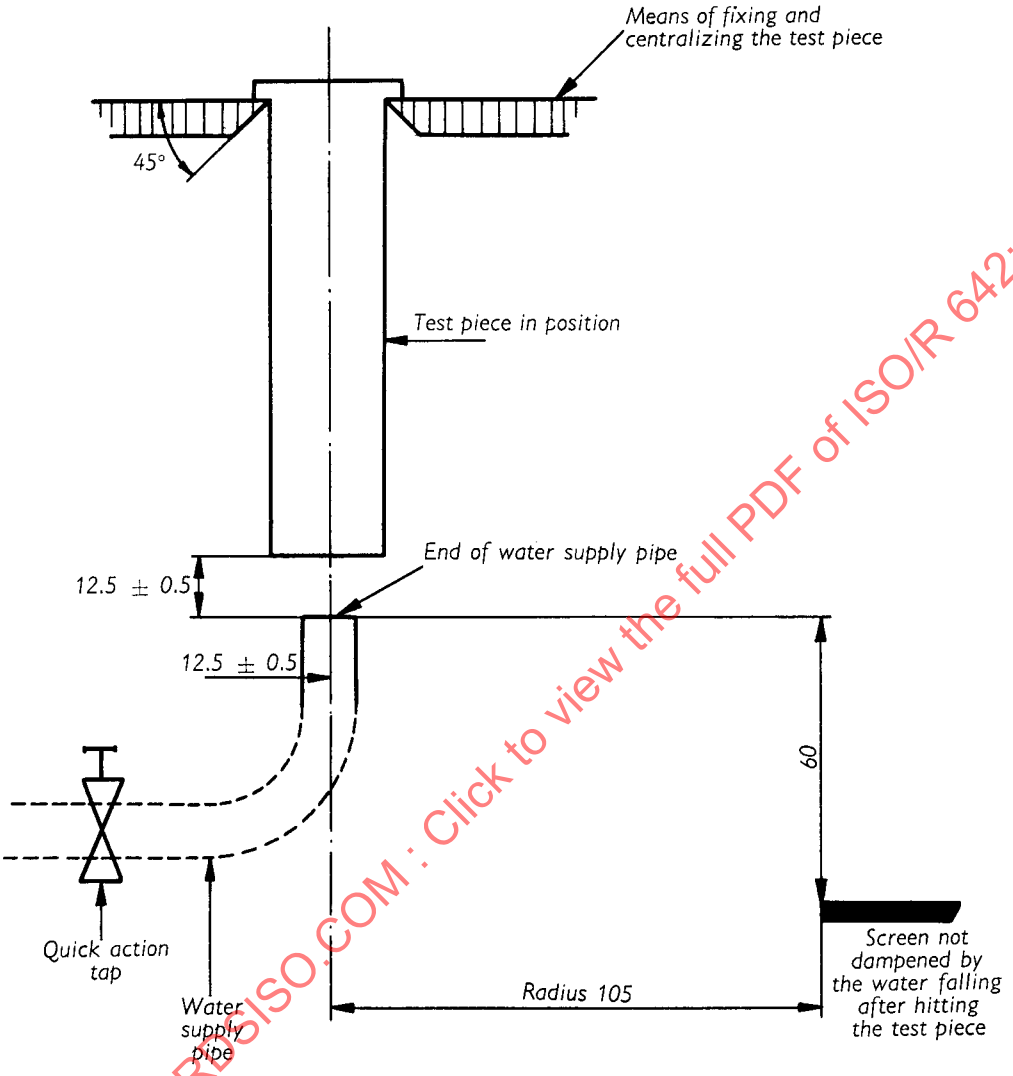


FIG. 3. — **Diagram of hardening apparatus**

Dimensions in millimetres

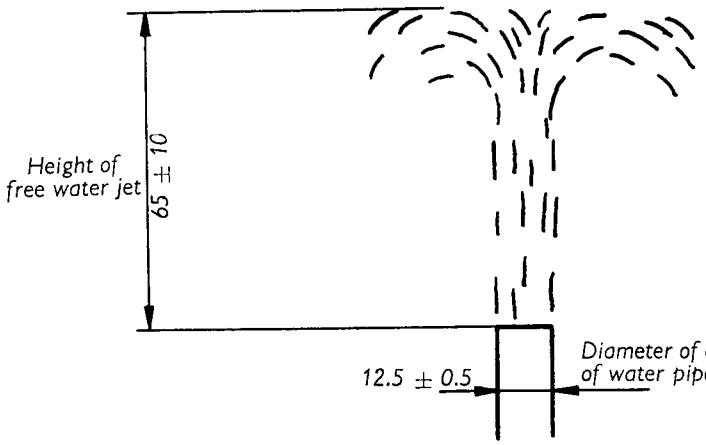


FIG. 4. — **Water pipe end**

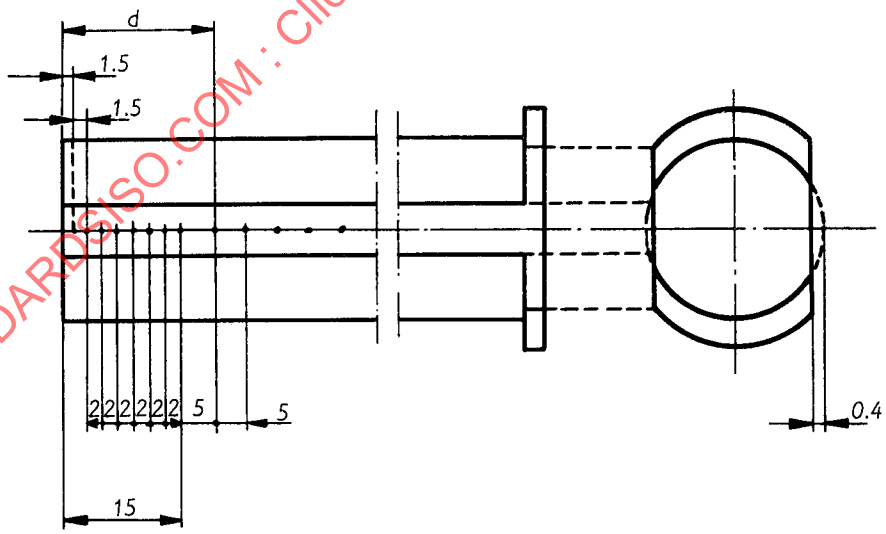


FIG. 5. — **Preparation of the test piece for measurement of hardness and position of hardness measurement points**

Dimensions in millimetres

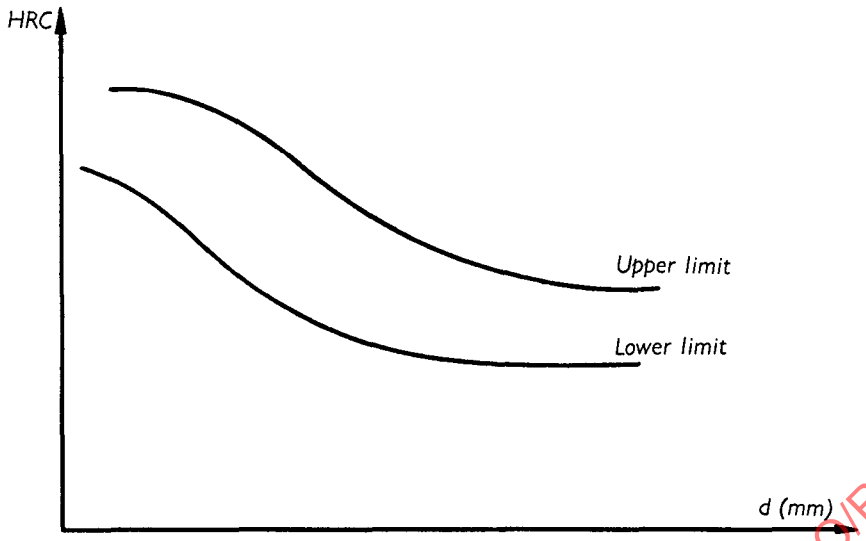


FIG. 6 (*a*) — **Specification by two limiting curves**

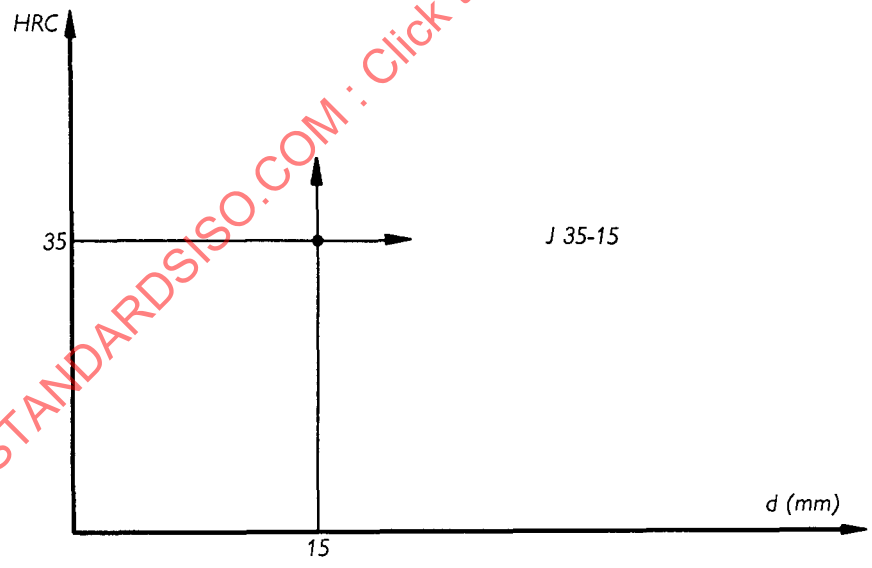


FIG. 6 (*b*) — **Specification by hardness at distance *d***