International Standard ISO 2039/2

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Plastics — Determination of hardness by the ball indentation method — Part 2 : Rockwell hardness

Plastiques — Détermination de la dureté — Méthode par pénétration à la bille — Partie 2 : Dureté Rockwell

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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 2039/2 was developed by Technical Committee ISO/TC 61, *Plastics*, and was circulated to the member bodies in June 1978.

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

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Plastics — Determination of hardness by the ball indentation method — Part 2 : Rockwell hardness

1 Scope and field of application

1.1 This part of ISO 2039 specifies a method for determining the indentation hardness of plastics by means of the Rockwell hardness tester using the Rockwell M, L and R hardness scales.

1.2 A Rockwell hardness number is directly related to the indentation hardness of a plastic material; the higher the Rockwell hardness number, the harder the material. Due to a short overlap of Rockwell hardness scales by this procedure, two different Rockwell hardness numbers of different scales may be obtained on the same material, both of which may be technically correct.

1.3 For materials having high creep and recovery, the time-factors involved in application of the major and minor loads have a considerable effect on the results of the measurements.

1.4 An alternative method of using the apparatus to give hardness on the Rockwell-α hardness scale is specified in the annex which shows how this scale may be related to the hardness measurement of ISO 2039/1.

2 References

ISO 48, *Vulcanized rubbers — Determination of hardness (Hardness between 30 and 85 IRHD).*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 868, *Plastics — Determination of indentation hardness by means of a durometer (Shore hardness).*

ISO 2039/1, *Plastics and ebonite — Determination of hardness by the ball indentation method — Part 1.* 1)

3 Principle

3.1 This is a method for determining hardness in which a constant minor load is applied to a steel ball resting on the material to be tested, followed by application of a major load, and then followed by a return to the same minor load, all at specified limits for times of loading. The actual measurement is based on the total depth of penetration, minus the elastic recovery after a fixed time following removal of the major load, minus the penetration resulting from the minor load. The Rockwell hardness number is derived from the net increase in depth of impression as the load on an indentor is increased from a fixed minor load to a major load and then returned to the same minor load.

3.2 Each Rockwell hardness scale division represents 0,002 mm vertical movement of the indentor. In practice, the Rockwell hardness number is derived from the following relationship :

$$HR = 130 - e$$

where

HR is the Rockwell hardness number;

e is the depth of impression after removal of the major load, in units of 0,002 mm.

NOTE — This relationship only holds for the E, M, L and R scales.

4 Apparatus

4.1 The apparatus is a standard Rockwell hardness tester which comprises essentially

— a **rigid frame** supporting an adjustable platform fitted with a plate at least 50 mm in diameter to support the test specimen;

— an **indentor** with its associated fittings;

— a **device** for applying the appropriate loads to the indentor without impact.

4.2 The indentor comprises a polished steel ball of Vickers hardness at least 7 MN/m^2 which rolls freely in its housing. The ball shall not deform during the test or show damage after a test. The diameter of the indentor depends upon the Rockwell scale in use (see 4.5).

1) At present at the stage of draft. (Revision of ISO 2039-1973.)

4.3 The indentor is equipped with a dial gauge or other suitable device to measure the depth of penetration of the indentor to within 0,001 mm. It is desirable but not essential for the dial gauge to be calibrated in Rockwell hardness numbers (one Rockwell scale division = 0,002 mm). When the machine is so directly calibrated, it is usual for the dial gauge to have a black and a red scale, the latter allowing automatically for the constant of 130 in the derivation of Rockwell hardness number on the M, L and R scales (see 3.2). Alternative means of measurement of penetration and display of data may be used, provided that the accuracy is at least equal to the dial gauge.

4.4 The appropriate loads for the M, L and R scales are as given in 4.5. In each case the minor load is 98,07 N. Provision is usually made in the Rockwell machine to apply the minor load to the specimen by means of a screw capstan which raises the platform supporting the test specimen until the latter contacts the indentor. In these circumstances the dial gauge has an indicated point to show when the minor load has been fully applied; reference should be made to the manufacturer's handbook before operating the machine. The adjustment of speed of load-application is of great importance. Adjust the dash-pot on the Rockwell tester so that the operating handle completes its travel in 4 to 5 s with no specimen on the machine or no load applied by the indentor to the anvil. The major load shall be 980,7 N for this calibration.

4.5 The major and minor loads and indentor diameters for the Rockwell scales are as follows :

Rockwell Hardness scale	Minor load	Major load	Indentor diameter
	N	N	mm
R	98,07	588,4	12,7 ± 0,015
L	98,07	588,4	6,35 ± 0,015
M	98,07	980,7	6,35 ± 0,015
E	98,07	980,7	3,175 ± 0,015

Both the major and minor loads shall be accurate to within 2 %.

NOTE — The E scale is used for calibration only for the purpose of this International Standard.

4.6 The machine should be mounted on a level, rigid base free from vibration. If the machine mounting is unavoidably subjected to vibration (for example, in the vicinity of other test machines), the Rockwell tester may be mounted on a metal plate with sponge rubber at least 25 mm thick, or upon any other mountings which effectively damp the vibration.

4.7 The testing apparatus is calibrated periodically using a test block of metal (cast iron, aluminium and magnesium alloys, bearing metals) of known Rockwell hardness, using the Rockwell E scale. In this way any faults due to malfunctioning of the load application device or frame deformation will be observed; these faults shall be corrected before use. Ancillary checks may be made at frequent intervals using blocks calibrated for use when the machine is set up in the R, L or M test modes.

5 Test specimen

5.1 The standard test specimen shall be a flat sheet at least 6 mm thick. It shall be of a suitable area to meet the requirements of 7.4. The test specimen does not necessarily have to be square. It shall not show any evidence of imprint by the indentor on the supported surface after a test.

5.2 Where specimens of the minimum thickness specified in 5.1 are not available, the test specimen shall be made up of a pile of thinner test specimens of the same thickness and the same material, provided that the surfaces of the individual pieces are in total contact and not held apart by any form of surface imperfections (as, for example, sink marks or burrs from saw cuts).

5.3 All indentations shall be made on one surface only of the test specimen.

5.4 One test specimen is sufficient for the determination of Rockwell hardness and at least five measurements shall be made on each test specimen of isotropic materials.

5.5 If the material under test is anisotropic, the direction of indentation shall be specified in relation to the axes of anisotropy. If results in more than one direction are required, test specimens shall be prepared so that at least five Rockwell hardness measurements may be determined in each direction.

6 Conditioning

The test specimens shall be conditioned before testing in the atmosphere specified in the appropriate International Standard relating to the material under test or in one of those specified in ISO 291.

7 Procedure

7.1 Unless otherwise specified, testing shall be performed in the same standard atmosphere as used for conditioning the test specimen.

7.2 Check that the major and minor loads and the indentor diameter are correct for the Rockwell hardness scale in use (see 4.5). Discard the first reading after changing a ball adjustment, as the indentor does not properly seat by hand-adjustment in the housing chuck. The full pressure of the major loads is required to seat the indentor shoulder into the chuck.

7.3 Place the test specimen on the platform. Check that the surface of the test specimen and that of the indentor are free of dust, dirt, grease and scale and that the test specimen surface is normal to the direction of the applied load.

Apply the minor load and set the dial gauge to zero. Within 10 s of applying the minor load, apply the major load (see 4.4). Remove the major load $15\,^{+1}_{\ 0}$ s after the start of applying the major load. During this operation, avoid jerking the machine mechanism. Read the dial gauge to the nearest scale division 15 s after the start of removing the major load.

NOTE — If the machine is directly calibrated in Rockwell hardness numbers, it is convenient to proceed as follows : Count the number of times the needle passes through zero on the red scale after application of the major load. Subtract this from the number of times the needle passes through zero upon the removal of the major load. If this difference is zero, record the hardness number as the reading plus 100. If the difference is 1, record the reading as the scale reading without change and, if the difference is 2, record the reading as the scale reading minus 100. If in doubt, consult the manufacturer's handbook for the machine.

7.4 Make five measurements on the same surface of the test specimen. No measurement shall be made within 10 mm of any edge of the test specimen, and no two measurements shall be made less than 10 mm apart.

7.5 Ideally, Rockwell hardness numbers should lie between 50 and 115; values above this range are inaccurate and the determination shall be repeated using the next severest scale.

NOTE — If a less severe scale than the R scale is required, the Rockwell test is not suitable and the material should be tested in accordance with ISO 868 (Shore hardness).

8 Expression of results

8.1 Express the Rockwell hardness as a number prefixed by the scale letter.

8.2 If the Rockwell hardness tester is directly calibrated in hardness numbers, record the Rockwell hardness after each test (see the note in 7.3).

8.3 If necessary, calculate the Rockwell hardness number (see 3.2).

8.4 When required, calculate the estimated standard deviation as follows :

$$\sigma = \sqrt{\frac{\Sigma x^2 - n\,\overline{x}^2}{n - 1}}$$

where

σ is the standard deviation (estimated);

x is the individual value of Rockwell hardness;

$\overline{x}$ is the arithmetic mean of the results;

n is the number of the results.

9 Test report

The test report shall include the following particulars :

a) reference to this International Standard;

b) complete identification of the material tested;

c) description, dimensions and manner of preparation of the test specimen;

d) conditioning and conditions under which the test is carried out;

e) number of tests;

f) Rockwell hardness scale (either M, L or R);

g) Rockwell hardness numbers, individual values and average value;

h) estimated standard deviation of the results, if required.

Annex

Determination of Rockwell-α hardness

A.0 Introduction

The Rockwell hardness test as described in this International Standard determines the hardness of plastics as a function of indentor depth of penetration after allowing for elastic recovery of the test specimen. As such, the Rockwell hardness on the L, M and R scales cannot be related to the ball indentation hardness of ISO 2039/1 since this derives hardness from the depth of penetration of the indentor under load (that is, not allowing for any elastic recovery of the material). However, the Rockwell apparatus may be used to determine hardness from the depth of penetration under load and this has been standardized[1] as the Rockwell-α test. The only suitable Rockwell scale for determining the Rockwell-α hardness of plastics is the R scale, that is, 12,7 mm diameter indentor and 588,4 N major load.

A.1 Procedure

A.1.1 Use the 12,7 mm diameter indentor and 588,4 N major load.

A.1.2 Determine the spring constant of the testing machine as follows : Place a soft copper block (at least 6 mm thick) on the platform and apply the minor load. Set the depth-indicating device to zero and apply the major load. Maintain the major load until the depth indicator is stationary. Note the reading, remove the major load and reset the depth indicator to zero. Repeat this sequence of operations until the reading of the depth indicator is constant after each application of the major load. This represents the point at which no further penetration of the copper block takes places and therefore the constant depth reading is the movement of the depth-indicating device due to the spring of the apparatus. Note this constant reading and record it as the number of 0,002 mm units (d_s).

A.1.3 Replace the copper block by the test specimen and proceed as in 7.3 except that after the application of the minor load the depth indicator shall be set to zero within 10 s and the major load immediately applied. During 15 s of application of the major load, observe and record the depth of penetration in units of 0,002 mm (d_h = depth of penetration at 15 s).

A.2 Expression of results

Calculate the Rockwell-α hardness from the equation

$$R\,\alpha = 150 - (d_h - d_s)$$

where

$R\,\alpha$ is the Rockwell hardness number;

d_s and d_h are as defined in A.1.2 and A.1.3.

A.3 Relationship between Rockwell-α hardness and ball indentation hardness of ISO 2039/1

Fett[2] established the mathematical relationship between Rockwell-α hardness and the ball indentation hardness of ISO 2039/1 and demonstrated that the mathematical relationship holds good in practice for both thermosetting and thermoplastic materials over the range of Rockwell-α hardness between − 20 and 100. This relationship is given with sufficient accuracy by the equation

$$R\,\alpha = 150 - 122{,}5\left[\left(\frac{60}{0{,}086\,H_k}\right)^{0{,}813} - \left(\frac{10}{0{,}086\,H_k}\right)^{0{,}813}\right] \quad \ldots (1)$$

where

$R\,\alpha$ is the Rockwell-α hardness number;

H_k is the ISO 2039/1 hardness, expressed in kilograms-force per square centimetre.

ISO 2039/1 now requires that the hardness be expressed in decanewtons per square millimetre. Converting equation (1) to SI units,

$$R\,\alpha = 150 - 122{,}5\left[\left(\frac{60}{8{,}771\,9\,H}\right)^{0{,}813} - \left(\frac{10}{8{,}771\,9\,H}\right)^{0{,}813}\right] \quad \ldots (2)$$

where H is the ISO 2039/1 hardness, expressed in decanewtons per square millimetre.

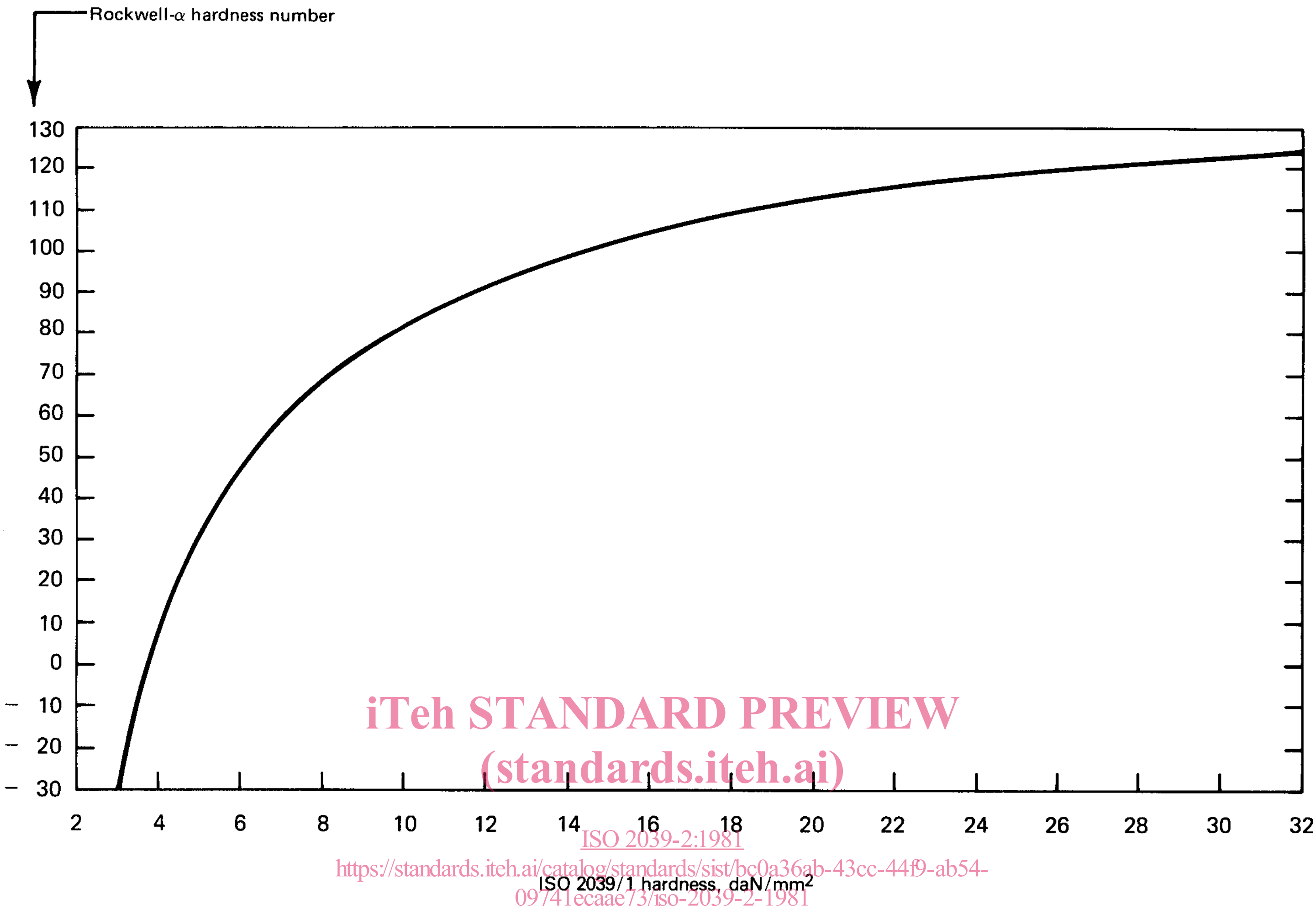
Equation (2) can be simplified to

$$R\,\alpha = 150 - \left(\frac{448{,}6}{H^{0{,}813}}\right)$$

or

$$H = \left(\frac{448{,}6}{150 - R\,\alpha}\right)^{1{,}23}$$

A graph of $R\,\alpha$ versus H in the range of $R\,\alpha$ from − 30 to 130 is shown below for ease of conversion.



Bibliography

[1] ASTM D 785-65, *Standard test method for Rockwell hardness of plastics and electrical insulating materials.*

[2] FETT, THEO, Relation between Rockwell-α hardness ASTM D 785 and ball indentation hardness DIN 53456, *Materialprüfung*, Vol. 14, No. 5, pp. 151-153.