

# Plastics — Determination of hardness —

## Part 2: Rockwell hardness

The European Standard EN ISO 2039-2:1999 has the status of a British Standard

**IMPORTANT NOTE.** Before reading this method it is essential to read BS 2782-0, Introduction, issued separately.

ICS 83.080.01

## Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Plastics and Rubber Standards Policy Committee (PRM/-) to Technical Committee PRM/21, upon which the following bodies were represented:

British Plastics Federation  
 British Steel Industry  
 British Telecommunications plc  
 British Textile Confederation  
 Department of Trade and Industry (National Physical Laboratory)  
 EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)  
 Electrical and Electronic Insulation Association (BEAMA Ltd.)  
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 Ministry of Defence  
 PIRA  
 Packaging and Industrial Films Association  
 Plastic Industrial Containers Association  
 Plastics and Rubber Institute  
 RAPRA Technology Ltd.  
 Yarsley Technical Centre Ltd.

This British Standard, having been prepared under the direction of the Plastics and Rubber Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 28 February 1992

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The following BSI references relate to the work on this standard:

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### Amendments issued since publication

Amd. No.	Date	Comments
10694	May 2000	Renumbering BS 2782-3:Method 365C:1992 as BS EN ISO 2039-2:2000

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## National foreword

This British Standard is the official English language version of EN ISO 2039-2:1999. It is identical to ISO 2039-2:1987. It is dual numbered as BS 2782-3:Method 365C:1992.

This method has been prepared under the direction of the Plastics and Rubber Standards Policy Committee and is identical with ISO 2039-2:1987 "*Plastics — Determination of hardness — Part 2 : Rockwell hardness*", published by the International Organization for Standardization (ISO).

It supersedes BS 2782: Method 365C:1986 which is withdrawn.

### Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index" or by using the "Find" facility of the BSI Standards Electronic Catalogue.

The Technical Committee has reviewed the provisions of ISO 48:1979 to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

**WARNING NOTE.** This British Standard method, which is identical with ISO 2039-2, does not necessarily detail all the precautions necessary to meet the requirements of the Health and Safety at Work etc. Act 1974. Attention should be paid to any appropriate safety precautions and the method should be operated only by trained personnel.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN ISO title page, the EN ISO foreword, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

English version

## Plastics — Determination of hardness — Part 2: Rockwell hardness

(ISO 2039-2:1987)

Plastiques — Détermination de la dureté —  
Partie 2: Dureté Rockwell  
(ISO 2039-2:1987)

Kunststoffe — Bestimmung der Härte —  
Teil 2: Rockwellhärte  
(ISO 2039-2:1987)

This European Standard was approved by CEN on 6 May 1999.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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### CEN

European Committee for Standardization  
Comité Européen de Normalization  
Europäisches Komitee für Normung

**Central Secretariat: rue de Stassart 36, B-1050 Brussels**

## Foreword to EN ISO 2039-2:1999

The text of the International Standard from Technical Committee ISO/TC 61, Plastics, of the International Organization for Standardization (ISO) has been taken over as a European Standard by Technical Committee CEN/TC 249, Plastics, the Secretariat of which is held by IBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 1999, and conflicting national standards shall be withdrawn at the latest by December 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

## 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- $\alpha$  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, Rubber, vulcanized — Determination of hardness (Hardness between 10 and 100 IRHD)<sup>1)</sup>.

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 — Determination of hardness — Part 1: Ball indentation method.*

## 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 indenter 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 indenter. 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 *indenter* with its associated fittings;
- a *device* for applying the appropriate loads to the indenter without impact.

**4.2** The indenter comprises a polished hardened steel ball which rolls freely in its housing. The ball shall not deform during the test or show damage after a test. The diameter of the indenter depends upon the Rockwell scale in use (see 4.5).

**4.3** The indenter is equipped with a dial gauge or other suitable device to measure the depth of penetration of the indenter 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). Alternative means of measurement of penetration and display of data may be used, provided that the accuracy is at least equal to that of the dial gauge.

<sup>1)</sup> At present at the stage of draft. (Revision of ISO 48:1979, ISO 1400:1975 and ISO 1818:1975.)

**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 indenter. 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 hand-book 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 indenter to the anvil. The major load shall be 980,7 N for this calibration.

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

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

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 indenter on the supported surface after a test.

**5.2** When specimens of the minimum thickness specified in 5 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 indenter diameter are correct for the Rockwell hardness scale in use (see 4.5). Discard the first reading after changing a ball adjustment, as the indenter does not properly seat by hand-adjustment in the housing chuck. The full pressure of the major loads is required to seat the indenter shoulder into the chuck.

NOTE See 4.7 for periodic calibration of the apparatus.

**7.3** Place the test specimen on the platform. Check that the surface of the test specimen and that of the indenter 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  $15 + \frac{1}{0}$  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).

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

$$\sigma = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n-1}}$$

where

- $\sigma$  is the standard deviation (estimated);
- $x$  is the individual value of Rockwell hardness;
- $\bar{x}$  is the arithmetic mean of the results;
- $n$  is the number of 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 A Determination of Rockwell- $\alpha$ hardness

(This annex forms an integral part of the Standard.)

### A.0 Introduction

The Rockwell hardness test as described in this International Standard determines the hardness of plastics as a function of indenter 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 indenter 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- $\alpha$  test. The only suitable Rockwell scale for determining the Rockwell- $\alpha$  hardness of plastics is the R scale, that is, 12,7 mm diameter indenter and 588,4 N major load.

### A.1 Procedure

**A.1.1** Use the 12,7 mm diameter indenter 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 place 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- $\alpha$  hardness using 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- $\alpha$ hardness and ball indentation hardness of ISO 2039-1

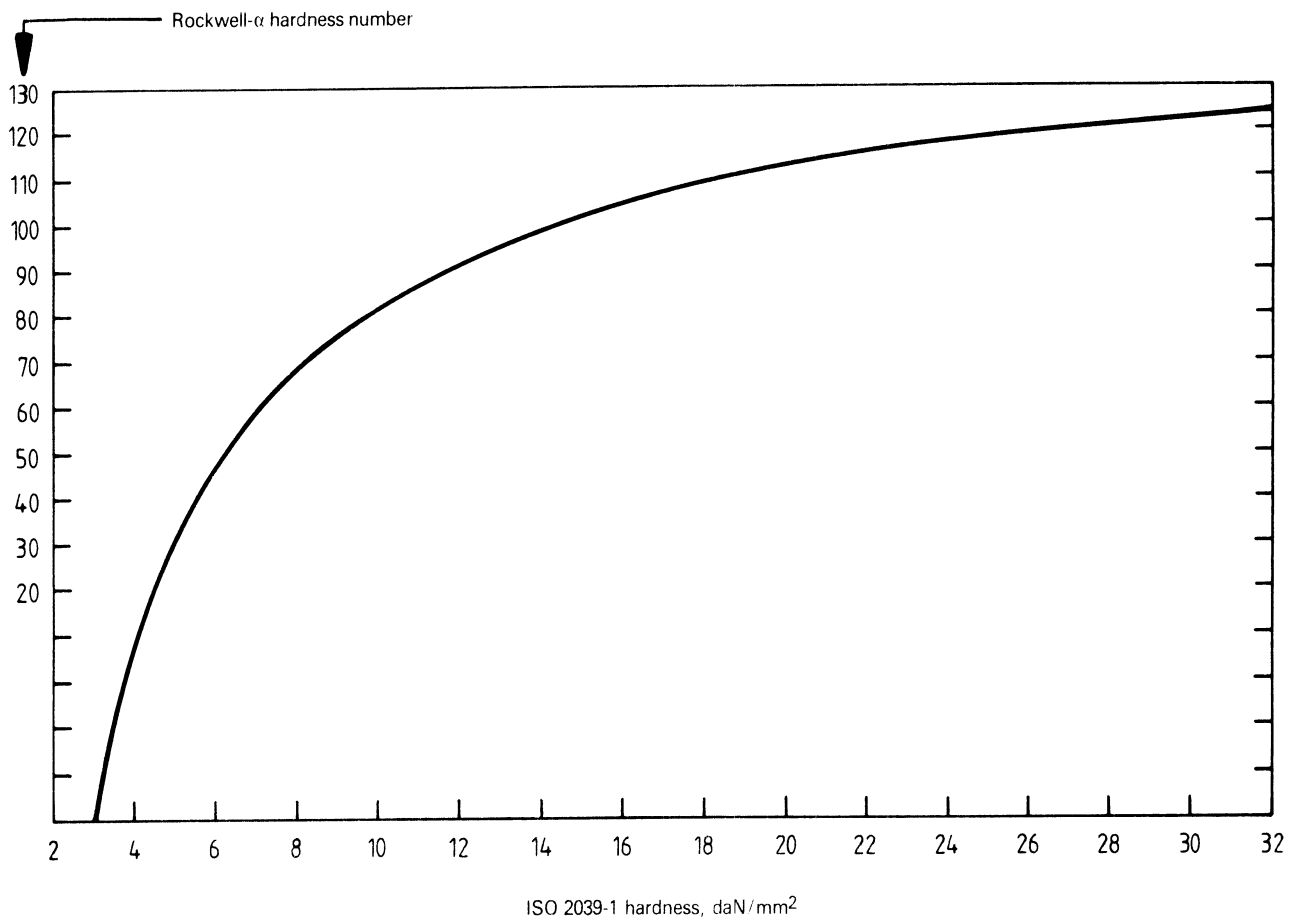
Fett[2] established the mathematical relationship between Rockwell- $\alpha$  hardness and the ball indentation hardness of ISO 2039-1 and demonstrated that the mathematical relationship holds good in practice for both thermosetting and thermoplastic materials over the range of Rockwell- $\alpha$  hardness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

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

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 follows 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- $\alpha$  hardness ASTM D 785 and ball indentation hardness DIN 53456, *Materialprüfung*, Vol. 14, No. 5, pp. 151-153.

**Annex ZA (normative)****Normative references to international publications with their relevant European publications**

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

Publication	Year	Title	EN	Year
ISO 291	1997	<i>Plastics — Standard atmospheres for conditioning and testing</i>	EN ISO 291	1997
ISO 868	1985	<i>Plastics and ebonite — Determination of indentation hardness by means of a dirometer (Shore hardness)</i>	EN ISO 868	1997
ISO 2039-1	1993	<i>Plastics — Determination of hardness — Part 1: Ball indentation method</i>	EN ISO 2039-1	1996



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