Designation: D 785 – 03

Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[1]

This standard is issued under the fixed designation D 785; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers two procedures for testing the indention hardness of plastics and related plastic electrical insulating materials by means of the Rockwell hardness tester.

1.2 The values stated in SI units are to be regarded as the standard. The values given in brackets are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This test method and ISO 2039-2 are equivalent. Procedure A of this test method is equivalent to the test method in the main body of ISO 2039-2. Procedure B of this test method is equivalent to the test method in the integral annex part of ISO 2039-2.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 618 Practice for Conditioning Plastics for Testing

D 883 Terminology Relating to Plastics

D 2240 Test Method for Rubber Property—Durometer Hardness

D 4000 Classification System for Specifying Plastic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standards*[3]

ISO 2039-2 Plastics—Determination of Hardness—Part 2: Rockwell Hardness

3. Terminology

3.1 Definitions used in this test method are in accordance with Terminology D 883.

4. Significance and Use

4.1 A Rockwell hardness number is a number derived from the net increase in depth impression as the load on an indenter is increased from a fixed minor load to a major load and then returned to a minor load (Procedure A). A Rockwell alpha (α) hardness number represents the maximum possible remaining travel of a short-stroke machine from the net depth of impression, as the load on the indenter is increased from a fixed minor load to a major load (Procedure B). Indenters are round steel balls of specific diameters. Rockwell hardness numbers are always quoted with a scale symbol representing the indenter size, load, and dial scale used. This test method is based on Test Methods E 18. Procedure A (Section 11) yields the indentation of the specimen remaining 15 s after a given major load is released to a standard 10-kg minor load. Procedure B (Section 12) yields the indentation of the indenter into the specimen after a 15-s application of the major load while the load is still applied. Each Rockwell scale division represents 0.002-mm [0.00008-in.] vertical movement of the indenter. In practice, the Rockwell hardness number is derived from the following relationship:

$$HR = 130 - e \quad (1)$$

where:

HR = the Rockwell hardness number, and

e = the depth of impression after removal of the major load, in units of 0.002 mm. This relation only holds for the E, M, L, R, and K scales.

4.2 A Rockwell hardness number is directly related to the indentation hardness of a plastic material, with the higher the reading the harder the material. An α hardness number is equal to 150 minus the instrument reading. Due to a short overlap of

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard.**

Rockwell hardness scales by Procedure A, two different dial readings on different scales may be obtained on the same material, both of which may be technically correct.

4.3 For certain types of materials having creep and recovery, the time factors involved in applications of major and minor loads have a considerable effect on the results of the measurements.

4.4 The results obtained by this test method are not generally considered a measure of the abrasion or wear resistance of the plastic materials in question.

4.5 Indentation hardness is used as an indication of cure of some thermosetting materials at room temperature. Generally, an uncured specimen has a hardness reading below normal.

4.6 Each Rockwell hardness scale in Table 1 is an extension of the proceeding less severe scale, and while there is some overlap between adjacent scales, a correlation table is not desirable. Readings on one material may be satisfactory for such a table, but there is no guarantee that other plastic materials will give corresponding readings because of differences in elasticity, creep, and shear characteristics.

4.7 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, and/or testing parameters covered in the materials specification shall take precedence over those mentioned in this test method. If there are no material specifications, then the default conditions apply.

5. Factors Affecting Reproducibility and Accuracy

5.1 Rockwell hardness readings have been found reproducible to ±2 divisions for certain homogeneous materials with a Young's modulus in compression over 3400 MPa [5×10^5 psi]. Softer plastics and coarse-filled materials will have a wider range of variation. A large ball indenter will distribute the load more evenly and decrease the range of test results (Note 2). The sensitivity of the instrument decreases with an increase in the dial reading and becomes very poor for readings of 100 and over due to the shallow indentation of the steel ball. It is desirable to use the smallest ball and highest load that is practical because of this loss of sensitivity. Rockwell hardness readings over 115 are not satisfactory and shall not be reported. Readings between zero and 100 are recommended, but readings to 115 are permissible. For comparison purposes, it may be desirable to take readings higher than 115 or lower than zero on any single scale. In such cases, Rockwell hardness readings may be reported, but the corresponding correct readings shall follow in parentheses, if possible. Such alternate readings are not always feasible when the specimen is subjected to constantly changing conditions or irreversible reactions.

NOTE 2—Molded specimens containing coarse fiber fillers, such as woven glass fabric, will influence the penetration obtained. These variations in hardness may be reduced by testing with the largest ball indenter consistent with the overall hardness of the material.

5.2 If the bench or table on which a Rockwell hardness tester is mounted is subject to vibration, such as is experienced in the vicinity of other machines, the tester should be mounted on a metal plate with sponge rubber at least 25 mm [1 in.] thick, or on any other type of mounting that will effectually eliminate vibration from the machine. Otherwise the indenter will indent further into the material than when such vibrations are absent.

5.3 Dust, dirt, grease, and scale or rust should not be allowed to accumulate on the indenter, as this will affect the results. Steel ball indenters that have nicks, burrs, or are out of round shall not be used.

5.4 The condition of the test equipment is an important factor in the accuracy of the test results. Dust, dirt or heavy oil act as a cushion to the load supporting members of the test equipment and cause erroneous readings of the instrument dial. The shoulders of the instrument housing, indenter chuck, ball seat in the instrument housing, capstan, capstan screw, and anvil shoulder seat should be kept clean and true. The capstan and screw should be lightly oiled. Pitted anvil surfaces may be refinished with 600 grit paper.

5.5 Surface conditions of the specimen have a marked effect on the readings obtained in a test. Generally, a molded finish will give a higher Rockwell reading than a machined face due to the high resin content or filled materials or better orientation and lower plasticizer content of unfilled plastic materials. Tubular or unsupported curved specimens are not recommended for plastic hardness testing. Such curved surfaces have a tendency to yield with the load and produce an unsymmetrical indentation pattern.

5.6 Many plastic materials have anisotropic characteristics which cause indentation hardness to vary with the direction of testing. In such cases, the hardest face is generally that one perpendicular to the molding pressure. Specimens with flashing on the side supported by the anvil also may give erroneous results.

5.7 Ambient temperature variations can significantly affect hardness for many materials.

5.8 Rockwell hardness tests of the highest accuracy are made on pieces of sufficient thickness so that the Rockwell reading is not affected by the supporting anvil. A bulge, change in color, or other marking on the under surface of the test specimen closest to the anvil is an indication that the specimen is not sufficiently thick for precision testing. Stacking of thin specimen is permitted provided they are flat, parallel, and free from dust or burrs. The precision of the test is reduced for

TABLE 1 Rockwell Hardness Scales

Rockwell Hardness Scale (Red Dial Numbers)	Minor Load, kg	Major Load, kg[A]	Indenter Diameter	
			in.	mm
R	10	60	0.5000 ± 0.0001	12.700 ± 0.0025
L	10	60	0.2500 ± 0.0001	6.350 ± 0.0025
M	10	100	0.2500 ± 0.0001	6.350 ± 0.0025
E	10	100	0.1250 ± 0.0001	3.175 ± 0.0025
K	10	150	0.1250 ± 0.0001	3.175 ± 0.0025

[A] This major load is not the sum of the actual weights at the back of the frame but is a ratio of this load, depending on the leverage arm of machine. One make and model has a 25 to 1 leverage arm.

stacked specimens, and results should not be compared to a test specimen of standard thickness.

6. Apparatus

6.1 *Rockwell Hardness Tester,* in accordance with the requirements of Section 7. A flat anvil at least 50 mm [2 in.] in diameter shall be used as a base plate for flat specimens.

6.2 For Rockwell hardness testing, it is necessary that the major load, when fully applied, be completely supported by the specimen and not held by other limiting elements of the machine. To determine whether this condition is satisfied, the major load should be applied to the test specimen. If an additional load is then applied, by means of hand pressure on the weights, the needle should indicate an additional indentation. If this is not indicated, the major load is not being applied to the specimen, and a long-stroke (PL) machine or less severe scale should be used. For the harder materials with a modulus around 5500 MPa [8×10^5 psi] or over, a stroke equivalent to 150 scale divisions, under major load application, may be adequate; but for softer materials the long-stroke (250 scale divisions under major load) machine is required.

7. Test Specimen

7.1 The standard test specimen shall have a minimum thickness of 6 mm [¼ in.]. The specimen may be a piece cut from a molding or sheet. Care should be taken that the test specimen has parallel flat surfaces to ensure good seating on the anvil and thus avoid the deflection that may be caused by poor contact. The specimen shall be at least 25 mm [1 in.] square if cut from sheet stock, or at least 6 cm^2 [1 $in.^2$] in area if cut from other shapes. The minimum width shall be 13 mm [½ in.] plus the width of the indentation resulting from the conduct of a test using the chosen indenter.

NOTE 3—Specimen with a thickness other than 6 mm may be used if it has been verified that, for that thickness, the hardness values are not affected by the supporting surface and that no imprint shows under the surface of the specimen after testing. The specimen may be composed of a pile-up of several pieces of the same thickness, provided that precaution is taken that the surfaces of the pieces are in total contact and not held apart by sink marks, burrs from saw cuts, or other protrusions and provided the hardness values are not affected by the stacking of thin specimens.

8. Calibration

8.1 Check the Rockwell hardness tester periodically with a small machinist's level along both horizontal axes from a flat anvil for correct positioning. Minor errors in leveling are not critical, but correct positioning is desirable.

8.2 The adjustment of speed-of-load application is of great importance. Adjust the dashpot on the Rockwell tester so that the operating handle completes its travel in 4 to 5 s with no specimen on the machine or load applied by the indenter to the anvil. The major load shall be 100 kg for this calibration. When so adjusted, the period taken for the mechanism to come to a stop with the specimen in place will vary from 5 to 15 s, depending upon the particular specimen, the indenter, and the load used. The operator should check the instrument manual for this adjustment.

8.3 Select a standardized test block as near as possible to the hardness of the material being tested. If more than one hardness scale is used in testing, choose a standardized test block for each scale used (Note 4). Make five impressions on the test surface of the block. Compare the average of these five tests against the hardness calibration of the blocks. If the error is more than ±2 hardness numbers, bring the machine into adjustment as described in 8.4 or in 5.3 and 5.4. If adjustment can not be achieved, more extensive servicing of the instrument may be needed.

NOTE 4—Standard test blocks for the R, L, E, K, and M scales are available from Wilson Instruments, 100 Royal Street, Canton, Ma 02021 (A Division of Instron Corporation).

8.4 Check the index lever adjustment periodically and make adjustments if necessary. To adjust the index lever, place a specimen (plastic with low creep or soft metal) on the anvil and turn the knurled elevating ring to bring the specimen in contact with the indenter. Keep turning the ring to elevate the specimen until positive resistance to further turning is felt, which will be after the 10-kg load is encountered. When excessive power would have to be used to raise, the specimen higher, set the dial so that the set position is at the top and take note of the position of the pointer on the dial. If the pointer is between B 50 and B 70 on the red scale, no adjustment is necessary; if the pointer is between B 45 and B 50, adjustment is advisable; and if the pointer is anywhere else, adjustment is imperative. As the pointer revolves several times when the specimens is elevated, the readings mentioned above apply to the revolution of the pointer which occurs either as the reference mark on the gage stem disappears into the sleeve or as the auxiliary hand on the dial passes beyond the zero setting on the dial. The object of this adjustment is to determine if the elevation of the specimen to the minor load does not cause even a partial application of the major load. Apply the major load only through the release mechanism.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C [73.4 ± 3.6°F] and 50 ±5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, unless otherwise specified by contract or relevant material specification, or unless it has been shown that conditioning is not necessary. In cases of disagreement, the tolerances shall be 1°C [1.8°F] and ±2 % relative humidity.

9.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C [73.4 ± 3.6°F] and 50 ± 5 % relative humidity, unless otherwise specified by the contract or relevant material specification. In cases of disagreements, the tolerances shall be 1°C [1.8°F] and ±2 % relative humidity.

NOTE 5—Operation of this test equipment above the below normal temperature is not recommended due to the change in viscosity of the dashpot oil and the close tolerance of the gage.

10. Number of Tests

10.1 At least five hardness tests shall be made on isotropic materials. For anisotropic materials, at least five hardness tests shall be made along each principal axis of anisotropy, provided the sample size permits.

11. Procedure A

11.1 Chose the correct scale for the specimen under test. Rockwell hardness values are reported by a letter to indicate the scale used and a number to indicate the reading. The choice of scales shall be governed by the considerations concerned with the total indentation readings and the final scale reading for a particular material and scale (see Table 1 and 5.1, 6.2, and 11.5) The Rockwell hardness scale used shall be selected from those listed in Table 1, unless otherwise noted in individual methods or specifications.

11.2 Discard the first reading after changing a ball indenter, as the indenter does not properly seat by hand adjustment in the housing chuck. The full pressure of the major load is required to seat the indenter shoulder into the chuck.

NOTE 6—The operation of the test instrument as described in this procedure may differ in detail from that of automated electronic instruments. Refer to the manufacturer's instructions for the instruments for the instrument in use for the specifics of operating that instrument.

11.3 With the specimen in place on the anvil, turn the capstan screw until the small pointer is at a zero position and the large pointer is within ±5 divisions of B 30 or the "set" position on red scale. This adjustment applies without shock a minor load of 10 kg, which is built into the machine. Final adjustment of the gage to "set" is made by a knurled ring located on some machines just below the capstan hand wheel. If the operator should overshoot his "set" adjustment, another trial shall be made in a different test position of the specimen; under no circumstances should a reading be taken when the capstan is turned backward. Within 10 s after applying the minor load, and immediately after the "set" position is obtained, apply the major load by releasing the trip lever (Note 7). Remove the major load 15 (+1, -0) s after its application. Read the Rockwell hardness on the red scale to the nearest full-scale division 15 s removing the major load.

NOTE 7—The application of the minor load starts when the gage pointer starts to move; this is not the point of final zero adjustment.

11.4 Record the readings as follows: Count the number of times the needle passes through zero on the red scale on the application of the major load. Subtract from this the number of times the needle passes through zero upon the removal of this load. If this different is zero, record the value as the reading plus 100. If the difference is 1, record the reading without change, and, if the difference is 2, record the reading as the scale reading minus 100 (Note 8). Softer plastic materials, requiring a less severe scale than the R scale, shall be tested by Test Method D 2240.

NOTE 8—Example—With a difference of two revolutions and a scale reading of 97, indentation hardness values should be reported as -3 = (97-100).

11.5 Determine the total indentation, with the major load applied, by the number of divisions the pointer travels from the zero set position during the 15 s from the time the lever is tripped.

11.6 If the total indentation, reading with the major load applied, for a particular scale exceeds the limits of the test machine used (150 divisions for regular machines and 250 divisions for PL machines), use the next less severe scale. Thus, if the M scale indentation (with the major load) is 290 divisions use the L Rockwell scale.

11.7 Do not make the tests so near the edge of the specimen that the indenter will crush out the edge when the major load is applied. In no case shall the clearance be less than 6 mm [¼ in.] to the edge of the specimen. Neither should tests be made too close to each other, as the plastic surface is damaged from the previous indentation. Never make duplicate tests on the opposite face of a specimen; if a specimen is turned over and retested on the opposite face, the ridges on the first face will contribute to a softer reading on the second face.

12. Procedure B

12.1 Use the R scale with a 12.7 mm [½ –in.] indenter and 60-kg major load in this test.

NOTE 9—This is the only scale approved for plastics testing by Procedure B.

12.2 Determine the "spring constant" or correlation factor of the machine as follows: Place a soft copper block, of sufficient thickness and with plane parallel surfaces, on the anvil in the normal testing position. Raise the sample and anvil by the capstan screw to the 12.7 mm [½-in.] indenter until the small pointer is at the starting dot and the large pointer reads zero on the black scale. Apply the major load by tripping the load release lever. The dial gage will then indicate the vertical distance of indentation plus the spring of the machine frame and any other elastic compressive deformation of the indenter spindle and indenter. Repeat this operation several times without moving the block, but resetting the dial to zero after each test while under minor load, until the deflection of the dial gage becomes constant, that is, until no further indentation takes place and only the spring of the instrument remains. This value, in terms of dial divisions, is the correction factor to be used in 12.4.

12.3 Following the machine adjustment described in 8.2 and 8.4, place the test specimen in position on the anvil. With the specimen in place, apply the minor load of 10 kg and make the zero setting within 10 s; apply the major load immediately after the zero setting has been completed (Note 10). Observe and record the total number of divisions that the pointer of the dial gage passes through during 15 s of major load application. It is to be noted that the numbers shown on the standard dial gage are not be used, but the actual scale divisions representing indentation shall be counted. For this reason, the black scale is recommended. A full revolution of the needle represents 100 divisions (Note 11). The limitations of 6.2 still apply to this procedure.

NOTE 10—Materials subject to excessive creep are not suitable for this procedure.

NOTE 11—The total indentation equals the number of revolutions × 100 + the reading on the black scale.

12.4 The total scale divisions that are indicated by the dial gage, as observed in 12.3, represent the indentation produced plus the spring constant correction of the test instrument. Subtract this correction factor (12.2) from the observed reading and record the difference as the total indentation under load.

12.5 The hardness determined by this procedure shall be known as the alpha, α, Rockwell hardness number and shall be calculated as follows:

$$\alpha \text{ Rockwell hardness number} = 150 - \text{total indentation under load} \quad (2)$$

NOTE 12—Examples—With a total indentation of 30 divisions, obtained as described in 12.3 and 12.4, the value is α 120; or if the total indentation is 210, the value is -α 60.

13. Calculation

13.1 Calculate the arithmetic mean for each series of tests on the same material and at the same set of test conditions. Report the results as the "average value" rounded to the equivalent of one dial division.

13.2 Calculate the standard deviation (estimated) as follows, and report it to two significant figures:

$$s = \sqrt{(\Sigma X^2 - n\bar{X}^2) / (n-1)} \quad (3)$$

where:

s = estimated standard deviation,
X = value of a single observation,
$\bar{X}$ = arithmetic mean of a set of observations, and
n = number of observations in a set.

14. Report

14.1 Report the following information:

14.1.1 Material identification,

14.1.2 Filler identification and particle size, if possible

14.1.3 Total thickness of specimen,

14.1.4 The number of pieces in the specimen and the average thickness of each piece,

14.1.5 Surface conditions, for example, molded or machined

14.1.6 The procedure used (Procedure A or Procedure B),

14.1.7 The direction of testing (perpendicular or parallel to molding or anisotropy),

14.1.8 A letter indicating the Rockwell hardness scale used,

14.1.9 An average Rockwell hardness number calculated by Procedure A or Procedure B,

14.1.10 The standard deviation, and

14.1.11 The testing conditions.

15. Precision and Bias

15.1 Table 2 is based on a round robin[4] conducted in 1988 in accordance with Practice E 691, involving six materials tested by 12 laboratories. For each material, all the samples were prepared at one source, but the individual specimens were prepared at the laboratories which tested them. Each test results was the average of five individual determinations. Each laboratory obtained four test results for each material.

TABLE 2 Precision[A]

Materials	Rockwell Hardness Scale	Values in Rockwell Units					Number of Laboratories
		Average	S_r	S_R	r	R	
Polypropylene	R	76.8	1.30	3.03	3.64	8.48	12
Polypropylene	R	102.5	0.68	2.10	1.90	5.88	12
ABS	L	74.9	1.32	2.58	3.70	7.22	11
Modified Acrylic	L	78.3	0.91	2.96	2.55	8.29	11
ABS	M	31.8	2.47	7.68	6.92	21.50	11
Acrylic	M	93.4	0.76	2.97	2.13	8.32	12

[A] S_r = the within-laboratory standard deviation of the average.
S_R = the between-laboratories standard deviation of the average.
r = 2.8 S.
R = 2.8 S.

15.2 *Concept of r and R*—**Warning—**The following explanations of r and R (15.2 through 15.2.3) are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Table 2 should not be rigorously applied to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories. Users of this test method should apply the principles outlines in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 15.2 through 15.2.3 would then be valid for such data.

Used is S_r, and S_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens.

15.2.1 *Repeatability, r*—Comparing two test results for the same material, obtained by the same operator using the same equipment on the same day. The two test results should be judged not equivalent if they differ by more than the r value for the material.

15.2.2 *Reproducibility, R*—Comparing two test results for the same material, obtained by different operators using different equipment on different days. The two test results should be judged not equivalent if they differ by more than the R value for that material.

15.2.3 Any judgement in accordance with 15.2.1 or 15.2.2 would have an approximate 95 % (0.95) probability of being correct.

15.3 *Bias*—There are not recognized standards by which to estimate the bias of this test method.

16. Keywords

16.1 electrical insulating materials; indentation hardness; plastic molding; plastic sheets; Rockwell alpha hardness; Rockwell hardness; Rockwell hardness number

[4] Supporting data available from ASTM Headquarters. Request RR:D20-1152.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes or reasons for the changes, or both.

D 785–03:
(*1*) Revised Note 1 to improve clarity.
(*2*) Removed reference to Test Method D 617 in subsection 2.1 since it has been withdrawn.
(*3*) Deleted paragraph 4.6.
(*4*) Added a statement to the end of paragraph 4.1 to improve clarity.
D 785–98:
(*1*) Added ISO equivalency statement.
(*2*) Removed reference to solid rod specimen and fixtures for same.
(*3*) Added note to follow manufacturer's instructions for operation of electronic instruments.
(*4*) Added terminology section.
(*5*) Revised statements in significance and use and conditioning sections to indicate precedence of contracts and material specifications.