Designation: D 1054 – 02 (Reapproved 2007)

Standard Test Method for Rubber Property—Resilience Using a Goodyear-Healey Rebound Pendulum[1]

This standard is issued under the fixed designation D 1054; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of impact resilience and penetration of rubber by means of the Goodyear-Healey rebound pendulum, see Fig. 1.

1.1.1 The term rubber, used within this method, shall refer to those substances classified as thermoplastic elastomers, vulcanized (thermoset) rubber, elastomeric materials, and cellular materials.

1.2 All materials, instruments, or equipment used for the determination of mass, force, direction, temperature or dimension shall have traceability to the National Institute for Standards and Technology, or other internationally recognized organization parallel in nature.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. Many of the stated dimensions in SI are direct conversions from the U.S. Customary System to accommodate the instrumentation, practices and procedures that existed prior to the Metric Conversion Act of 1975.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets

D 3183 Practice for Rubber—Preparation of Product Pieces for Test Purposes from Products

D 4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens

2.2 *ASTM Adjuncts:*

Goodyear-Healey Rebound Pendulum Drawings and Parts List[3]

3. Summary of Test Method

3.1 *Impact Resilience*—A freely falling pendulum hammer that is dropped from a given height impacts a test specimen, imparting a certain amount of energy. A portion of that energy is returned by the specimen to the pendulum and may be measured by the extent to which the pendulum rebounds. Since the energy of the pendulum is proportional to the vertical component of the displacement of the pendulum, it may be expressed as 1 – cos (of the angle of displacement) and impact resilience, *RB*, is readily determined from the equation.

$$RB = \frac{1 - \cos(\text{angle of rebound})}{1 - \cos(\text{original angle})} \times 100 \quad (1)$$

3.1.1 The value *RB* is commonly called percentage rebound.

3.2 *Penetration*—Dynamic stiffness is a factor that influences impact resilience. A convenient index of stiffness is the depth to which the penetration striker penetrates the test specimen upon impact.

4. Significance and Use

4.1 The Goodyear-Healey[3] rebound pendulum is designed to measure percent resilience of a rubber compound as an

[1] This test method is under the jurisdiction of ASTM Committee D11 on Rubber and is the direct responsibility of Subcommittee D11.14 on Time and Temperature-Dependent Physical Properties.

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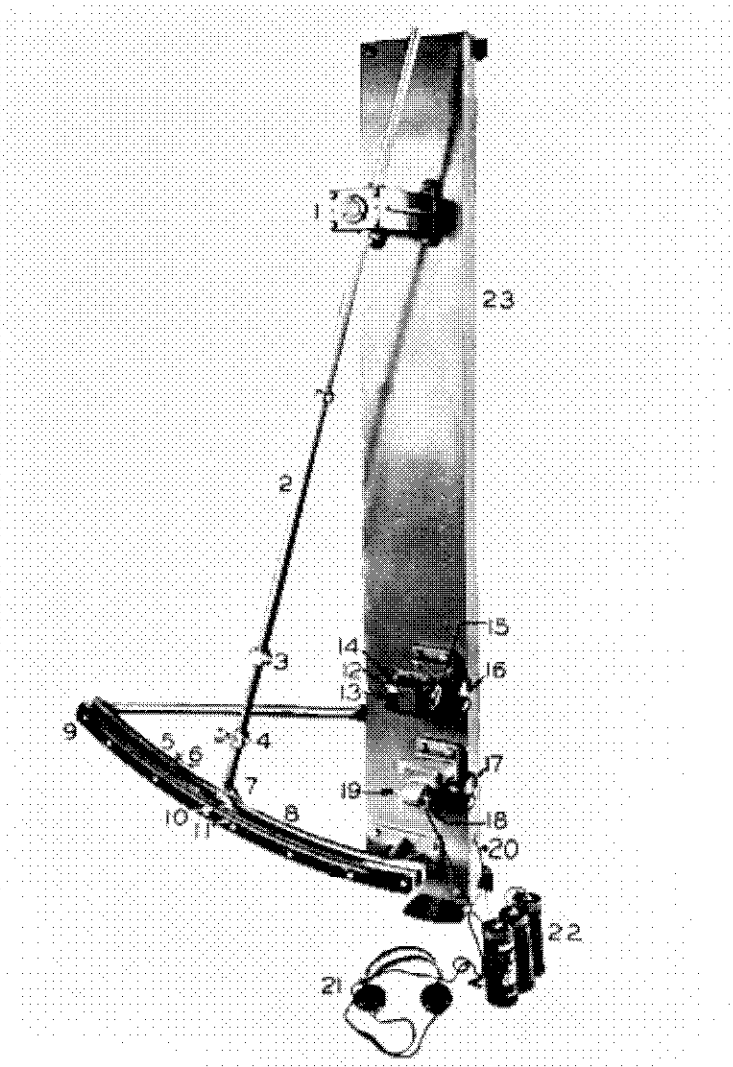
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The rebound pendulum is no longer available from the Goodyear Tire and Rubber Co., Process Engineering and System Designs, Dept. 109 E, 1144 East Market Street, Akron, OH 44316. Technical and engineering drawings for its manufacture and the reproduction of replacement parts are available at a nominal cost from ASTM International Headquarters. Order Adjunct No. ADJD1054. Original adjunct produced in 2000.



NOTE—Except where rough finish is indicated, all surfaces shall be machined to a smooth finish within the dimensions and tolerances indicated. Boiler-plate steel is suitable material.

FIG. 1 Goodyear-Healey Rebound Pendulum

indication of hysteretic energy loss that can also be defined by the relationship between storage modulus and loss modulus. The percent rebound measured is inversely proportional to the hysteretic loss.

4.2 Deflection is determined by measuring the depth of penetration of the rebound ball into the rubber block under test.

4.3 Percent resilience and deflection are commonly used in quality control testing of polymers and compounding chemicals, especially reinforcing material.

5. Apparatus

5.1 *Rebound Pendulum*—The Goodyear-Healey rebound pendulum (see Fig. 1) shall consist of the following:

5.1.1 Ball bearings (1), which support the pendulum,

5.1.2 Free swinging pendulum (2),

5.1.3 Penetration striker (3),

5.1.4 Contact for the indentation reading (4),

5.1.5 Release device (5 and 6),

5.1.6 Pawls (7),

5.1.7 Pawl rack (8),

5.1.8 Pointer (10),

5.1.9 Anvil (12),

5.1.10 Quadrant with an angular scale (11),

5.1.11 Specimen holder (14),

5.1.12 Penetration micrometer (16, 17, and 18),

5.1.13 Headphones (21) and a dry battery circuit (22), or other suitable power supply, attached to the penetration micrometer for determining when the moment of contact of the contact for the indentation reading (4), and

5.1.14 Vertical base (23).

5.2 The steel pendulum bar (2) shall conform to the following dimensions:

	mm	in.
Length of pendulum bar, overall (2)	1825 ± 2	72.80 ± 0.08
Diameter of pendulum bar (2)	23.17 ± 0.13	0.912 ± 0.005
Diameter of penetration striker (3)	22.22 ± 0.13	0.875 ± 0.005
Length from center of bearing to center of penetration striker (1, 3)	1070 ± 1	42.125 ± 0.04
Length from center of bearing to center of the indentation contact (1, 4)	1280 ± 1	50.40 ± 0.04
Distance from center of gravity of pendulum to center of bearing	560 ± 1	22.05 ± 0.04
Mass of pendulum assembly, complete	6675 ± 10 g	14.72 ± 0.02 lb

NOTE 1—To clarify the similarity in nomenclature: the penetration striker (3) is also referred to as the striking hammer or ball-nosed striker, where the contact for the indentation reading (4) is also referred to as the Penetration Striker Pin.

5.3 *Situating the Goodyear-Healey Instrument*:

5.3.1 The instrument shall be rigidly mounted to a solid support that is free from vibration. Examples of a suitable supporting structure are a concrete and steel building column or a vertical steel beam encased in concrete and rigidly mounted in a concrete foundation.

5.3.2 The mounting bolts used to secure the instrument to the supporting structure shall be tightened to the maximum torque specified for the bolts.

5.3.3 The plumb and level of the instrument shall be verified upon mounting and routinely checked using instruments designed for this purpose.

5.3.4 The specimen holder and anvil shall be free from play to eliminate vibration.

5.3.5 The instrument shall be mounted so that the pendulum, with pawls up, indicates "zero" on the scale.

5.3.6 There shall be no contact between the pendulum and the quadrant at point during the movement of the pendulum.

5.3.7 The instrument shall be operated at the standard laboratory temperature, 23 ± 2°C (73.4 ± 3.6°F) where it shall remain free from atmospheric conditions that may adversely affect test determinations. When it is known that the specimens being tested are sensitive to relative humidity (RH) the relative humidity shall be maintained at 50 ± 5 % for the duration of the tests.

6. Test Specimens

6.1 The test specimens shall be rectangular blocks, 25 ± 0.5 × 25 ± 0.5 × 50 ± 1 mm (1 ± 0.02 × 1 ± 0.02 × 2 ± 0.04 in.).

6.2 The specimens shall be prepared from sheets of uncured compounded rubber approximately 2 mm (0.85 in.) in thickness.

6.3 *Specimen Preparation*:

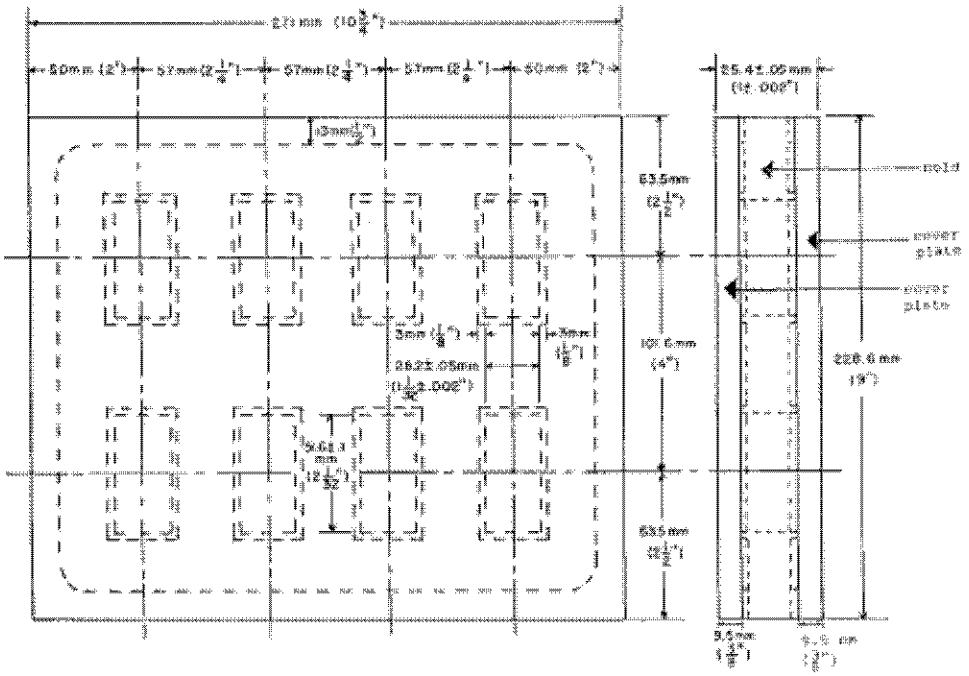
6.3.1 Cut the uncured sheet into rectangles of approximately 22 × 48 mm (0.9 × 1.9 in.) with the grain in a longitudinal direction, when the grain direction is known.

6.3.2 Ply the rectangles, longitudinally and grain-wise, to a thickness sufficient to fill the mold cavity (see Fig. 2) and to allow for appropriate overflow and compensate for voids and shrinkage.

6.3.3 Specimen thickness affects the required cure time. Cure the specimens in a mold (see Fig. 2) allowing sufficient time to compensate for the thickness of the specimens, that is, beyond the time normally allotted to equivalent unplied specimens of the same material.

6.3.4 Identification marks shall be placed only upon the top or bottom of the specimen, those being the surfaces with the largest square area. An identification pocket, when integral to the mold, shall be placed similarly, beyond the area that is to be tested so as not to affect the test determinations.

6.3.5 Preparation and conditioning of the specimens shall be in accordance with Practices D 3182 and D 3183.



NOTE—Dimensions unless otherwise specified are to be ±0.05 mm (±0.002 in.).

FIG. 2 Mold for Test Specimens

6.3.5.1 When evaluating compound ingredients, the specimen preparation and conditioning procedures may be determined by the participants in the evaluation.

6.3.6 When it is necessary to test the specimen at an elevated temperature (Hot Percentage Rebound), it shall be prepared as follows:

6.3.6.1 At an ambient temperature of 23 ± 2°C (73.4 ± 3.6°F), bring distilled water to a gentle boil.

6.3.6.2 Place the specimen in the container of boiling distilled water for no less than 1 h, during which time the distilled water shall be maintained at a gentle boil and shall be stirred gently to avoid lengthy contact of the specimen with the container.

6.3.6.3 The specimen may be alternatively heated to an equivalent temperature for an equivalent period in an oven of the types described in Specification E 145, providing that this is shown to give equivalent results to the conditioning described in 6.3.6.1 and 6.3.6.2.

6.3.6.4 Once the specimen is conditioned for the Hot Percentage Rebound test, it shall be dried, where appropriate to do so, using a material that will absorb the residual moisture from the surface of the specimen and leave no visible trace of the absorbing material. This shall be performed expediently to minimize the loss of heat from the specimen.

6.3.6.5 When it is possible, the specimen holder should be conditioned in the manner described in 6.3.6.2 and 6.3.6.3 and placed in the retainer in an expedient fashion. This will further minimize the heat loss of the specimen and enhance repeatability and reproducibility.

7. Procedure

7.1 The test shall be conducted at the standard laboratory temperature, 23 ± 2°C (73.4 ± 3.6°F) in an atmosphere free from conditions that may adversely affect test determinations. When it is known that the specimens being tested are sensitive to relative humidity, it shall be maintained at 50 ± 5 % for the duration of the tests.

7.1.1 The prepared specimens shall be conditioned as described in 7.1 for no less than 1 h prior to testing. Refer to 6.3.6.

7.2 Place the specimen in the specimen holder so that the longitudinal edge faces the penetration striker. Identifying marks on the specimens shall face the operator, refer to 6.3.4.

7.3 Tighten the specimen holder sufficiently, without visible deformation, to prevent movement of the specimen during the test.

7.4 A minimum of three specimens shall be tested.

7.5 *Percentage Rebound Test:*

7.5.1 Adjust the specimen holder, by means of the dial, so that the test specimen just touches the penetration striker with the pendulum at exactly "zero."

7.5.2 Adjust the setting of the contact pin, by means of the micrometer dial, until contact is made with the specimen. Contact is determined by use of the headphones.

7.5.3 Record the reading on the dial as the initial penetration "zero" point.

7.5.4 Set the pendulum holding clamp to position the pendulum at 15.00 degrees. Move the deflection indicator out of range.

7.5.5 Make ten impacts beginning from the 15° angle to equilibrate the specimen. These impacts may be made with the pawls up, which will require the operator to manually stop the pendulum on each upward stroke.

7.5.6 Make three test determinations (impacts), with the pawls in place (refer to 7.5.7). Record the highest of the three angles of rebound to within the nearest 0.05 degrees.

7.5.7 When making the three test determinations with the pawls up, the results will be slightly higher and should not be compared to those performed with the pawls in place. Record the highest of the three angles of rebound to within the nearest 0.05 degrees.

7.6 *Deflection Test:*

7.6.1 Determine deflection by advancing the deflection indicator until contact is made with the specimen, beginning from the 15° angle. Contact is determined by use of the headphones.

7.6.2 Record the reading on the indicator as the initial penetration "zero" point.

7.6.3 Back the deflection indicator off slightly and perform a test determination (impact) beginning from the 15° angle.

7.6.4 Repeat the determinations, advancing the deflection indicator incrementally 0.02 mm (0.001 in.) for each of five determinations over the final 0.1 mm (0.005 in.).

7.6.5 Read the deflection indicator to the nearest 0.02 mm (0.001 in.) and record.

7.6.6 Determine the final penetration "zero" point in the same manner as the initial penetration "zero" point and record.

8. Calculation

8.1 *Percentage Rebound*—Calculate the percentage rebound as follows:

$$RB = \frac{1 - \cos(\text{angle of rebound})}{0.03408} \times 100 \quad (2)$$

where:

RB = rebound percentage, and

0.03408 = $1 - \cos 15° = 1 - 0.96592$.

8.1.1 Percentages of rebound calculated for angles of rebound from 8° to 13° are given in Table 1.

8.2 *Penetration*—Calculate the deflection as follows:

8.2.1 Subtract the average of the initial penetration "zero" point and the final penetration "zero" point from the observed deflection.

8.2.2 Multiply this value by 0.837 to compensate for the difference in pendulum length at the point of measurement of deflection and at the point of actual penetration of the specimen.

8.2.3 Report this result in mm.

9. Report

9.1 Report the following information:

9.1.1 Date and time of the test,

9.1.2 Identification of the test specimen,

9.1.3 Specimen cure date, if known, or history of the specimen,

9.1.4 Temperature of the test specimen at the time of the test,

TABLE 1 Rebound Percentages, 15° Angle Drop

Angle of Rebound	8°	9°	10°	11°	12°	13°
0.00	28.6	36.1	44.6	53.9	64.1	75.2
0.05	28.9	36.6	45.1	54.4	64.6	75.7
0.10	29.3	37.0	45.5	54.9	65.1	76.3
0.15	29.6	37.4	46.0	55.4	65.7	76.9
0.20	30.0	37.8	46.4	55.9	66.2	77.5
0.25	30.3	38.2	46.9	56.4	66.8	78.1
0.30	30.7	38.6	47.3	56.9	67.3	78.7
0.35	31.1	39.0	47.8	57.4	67.8	79.3
0.40	31.5	39.4	48.2	57.9	68.4	79.9
0.45	31.9	39.8	48.7	58.4	69.0	80.5
0.50	32.2	40.3	49.1	59.0	69.6	81.1
0.55	32.6	40.7	49.9	59.5	70.1	81.7
0.60	32.9	41.1	50.1	60.0	70.7	82.3
0.65	33.3	41.6	50.6	60.5	71.2	83.0
0.70	33.7	42.0	51.0	61.0	71.8	83.6
0.75	34.1	42.4	51.5	61.5	72.3	84.2
0.80	34.5	42.8	52.0	62.0	72.9	84.8
0.85	34.9	43.3	52.5	62.5	73.5	85.4
0.90	35.3	43.7	53.0	63.1	74.0	86.0
0.95	35.7	44.2	53.5	63.6	74.6	86.6
1.00	36.1	44.6	53.9	64.1	75.2	87.2

9.1.4.1 Specimens that prepared, as described in 6.3.6 Hot Percentage Rebound, shall be reported as having a temperature of 100°C nominal.

9.1.5 Percentage Rebound as calculated in accordance with 8.1, and

9.1.6 Deflection as calculated in accordance with 8.2.

10. Precision and Bias

10.1 The interlaboratory test program to determine precision for this standard was conducted prior to the adoption of Practice D 4483. The original raw data is not available. Table 2 gives the precision results, presented in the format described in Practice D 4483, that were obtained from the within and between laboratory standard deviations as they appeared in a previous version of this test method. Please refer to Practice D 4483 for terminology and other testing and statistical concepts.

10.2 Cured rubber specimens of three different compounds, ranging in rebound percentage from 30 to 87 were prepared in one laboratory and sent to eight participating laboratories. The laboratories conducted duplicate tests on each of the specimens on three different days. The precision results are based upon the average of the two tests.

TABLE 2 Type 1 Precision—Percentage Rebound (RB)

Materials	Mean Level (*RB*)	Within Laboratories			Between Laboratories		
		Sr	*r*	(*r*)[A]	*SR*	*R*	(*R*)[A]
3 Unknown Compounds	30 to 87 %	0.8	2.36	3.8	3.9	11.0	16.4

[A] Estimated (*r*) and (*R*), only approximate.

10.3 The precision results in this Precision and Bias section give an estimate of the precision of this test method with the materials (rubbers) used in the particular interlaboratory program as described above. The precision parameters should not be used for acceptance or rejection testing, or both, of any group of materials without documentation that they are applicable to those particular materials and the specific testing protocols that include this test method.

10.4 *Precision*—The precision of this test method may be expressed in the format of the following statements which use as appropriate value *r*, *R*, (*r*), or *R*, that is, that value to be used in decisions about test results (obtained with the test method). The appropriate value is that value of *r* or *R* associated with a mean level in Table 2 closest to the mean level under consideration (at any given time, for any given material) in routine testing operations.

10.5 *Repeatability*—The repeatability, *r*, of these test methods has been established as the appropriate value tabulated in Table 2. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or non-identical sample populations.

10.6 *Reproducibility*—The reproducibility, *R*, of these test methods has been established as the appropriate value tabulated in Table 2. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* (for any given level) must be considered to have come from different or non-identical sample populations.

10.7 Repeatability and reproducibility are expressed as a percentage of the mean level, (*r*) and (*R*), have equivalent application statements as above for *r* and *R*. For the (*r*) and (*R*) statements, the difference in the two single test results is expressed as a percentage of the arithmetic mean of the two test results.

10.8 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by this test method. Bias, therefore cannot be determined.

11. Keywords

11.1 deflection; Goodyear-Healey; pendulum; percentage rebound; RB; rebound; resilience