Designation: D2228 – 04 (Reapproved 2009)

Standard Test Method for Rubber Property—Relative Abrasion Resistance by Pico Abrader Method[1]

This standard is issued under the fixed designation D2228; 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 U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the abrasion resistance of vulcanized (thermoset) rubbers, thermoplastic elastomers, and elastomeric and similar materials to a standardized reference system. A standardized set of reference compounds is used to calculate relative abrasion resistance. These reference compounds are also used to determine the relative performance, within a permissible range, of the cutting knives used in performing the test.

1.2 All materials, instruments, or equipment used for the determination of mass, force, or dimension shall have traceability to the National Institute for Standards and Technology,[2] 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.

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:*[3]

D618 Practice for Conditioning Plastics for Testing

D3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets

D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

3. Summary of Test Method

3.1 In this test method, a pair of tungsten carbide cutting knives of a specified geometry and configuration are used to abrade the surface of the specimen. The knives are lowered onto a circular test specimen, or button, which is rotated under controlled conditions of speed, time, and force on the cutting knives. A dusting powder is used as an interface between the cutting knives and the specimen to engulf the abraded rubber particles and to maintain the cutting knives relatively free from oils, resins, and the like, which may be present in the specimen and may interfere with the abrasion assessment. A series of five calibration compounds are used to determine that the sharpness of the knives and hence, the calibration of the instrument, are within the specified limits, and additionally, as reference standards to which the abrasion resistance, determined by volumetric loss, of a subject material may be compared.

4. Significance and Use

4.1 This test method may be used to estimate the relative abrasion resistance of subject materials as described in 1.1. No correlation between this accelerated test and service performance is given or implied, due, in part, to the widely varying nature of service conditions.

4.2 The formulas, for which the mixing and curing specifications are given in Annex A1, once prepared, are referred to as calibration compounds. These calibration compounds may be used to determine the performance status of the cutting knives as described in this test method.

4.3 The performance of the cutting knives may also be determined by periodically determining their dimensions as described in 6.1.7.

4.4 The calibration compounds are used as reference standards to which the abrasion resistance, determined by volume loss of a subject material, may be compared.

4.5 Once the resistance to abrasion is established, using this methodology, for a specific material, the results achieved may

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[1] This test method is under the jurisdiction of ASTM Committee D11 on Rubber and is the direct responsibility of Subcommittee D11.15 on Degradation Tests.

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[2] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

[3] 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.

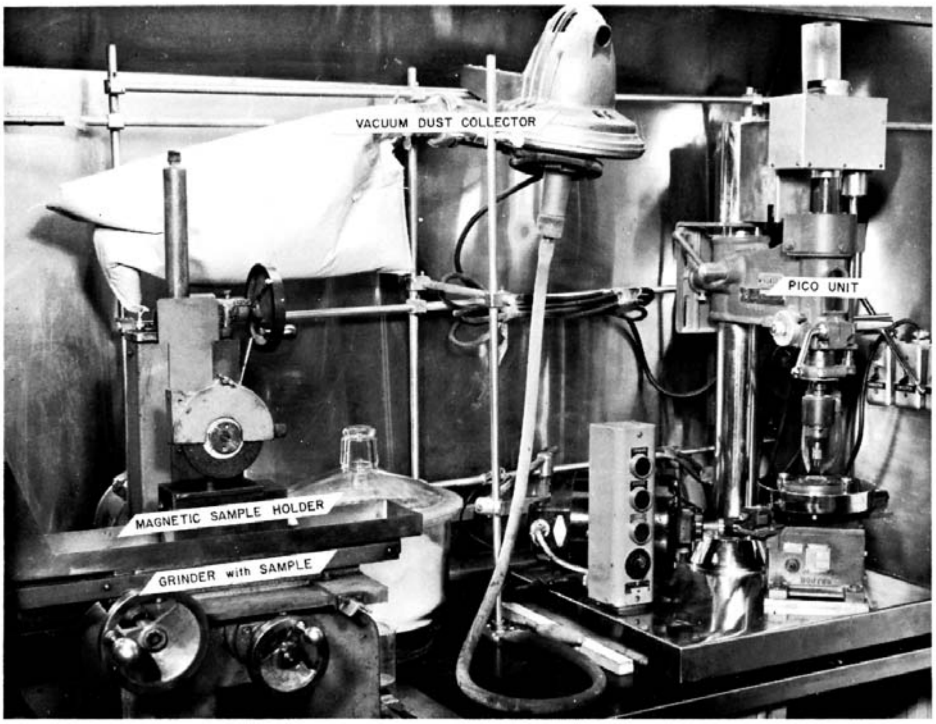

FIG. 1 Typical Pico Tester

be used as a basis for future comparative analysis of identical materials, either as agreed upon between laboratories, or between customer and supplier.

5. Interference

5.1 This test method is conducted under controlled conditions, except for the sharpness of the cutting knives. The behavior of the materials, as described in 1.1, yield varying results with respect to the cutting knives. This variation can be minimized by maintaining the knives in accordance with recommendations outlined in Section 9.

6. Apparatus

6.1 *Pico Tester,* the apparatus is illustrated in Fig. 1.

6.1.1 *Turntable,* on which the test specimen is mounted and rotated, having the capability of maintaining 1.00 ± 0.03 Hz (rps) throughout the duration of a test cycle (see Section 10).

6.1.2 *Instrument Frame,* with armature assembly that holds and lifts the cutting knives. Mounted on top of the assembly is a "dead-weight load box" in which masses (weights) may be placed to regulate the force on the cutting knives (see Section). The assembly moves freely in a bearing housing that permits vertical motion but counteracts the reaction torque on the cutting knives, thus preventing rotation. Vertical travel, once knives have been lowered onto the test specimen, is restricted by an arm lock.

6.1.3 *Drive Motor,* with forward, reverse, and stop controls to govern the operation of the turntable.

6.1.4 *Dusting Powder Reservoir* and *Feeder Tubes*, capable of supplying a uniform flow of dusting powder at the rate of 5 mg/s to the interface of the cutting knives and test specimen during operation (see Section 10).

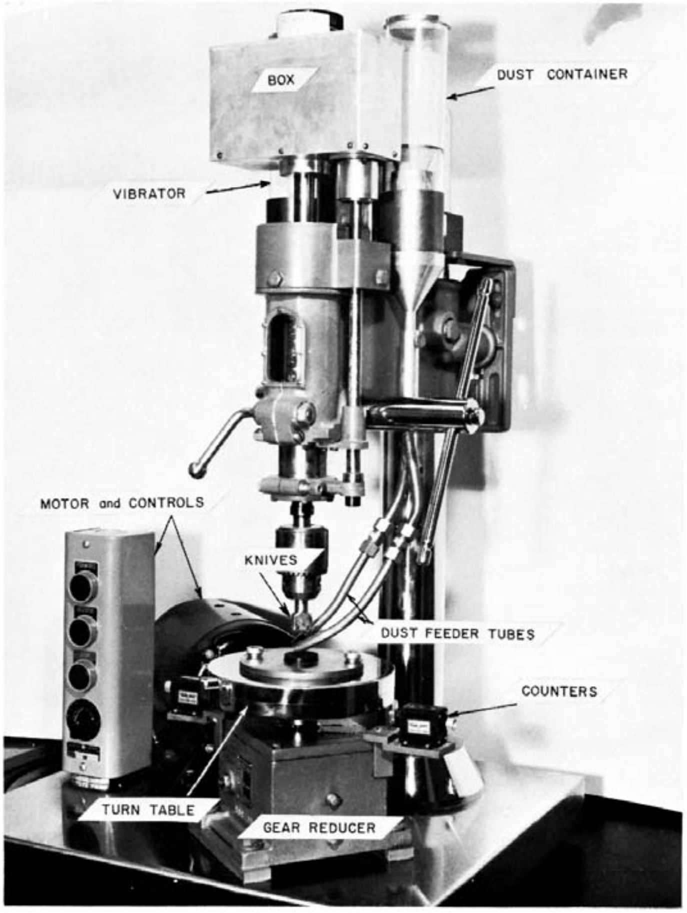

FIG. 1 Typical Pico Tester *(continued)*

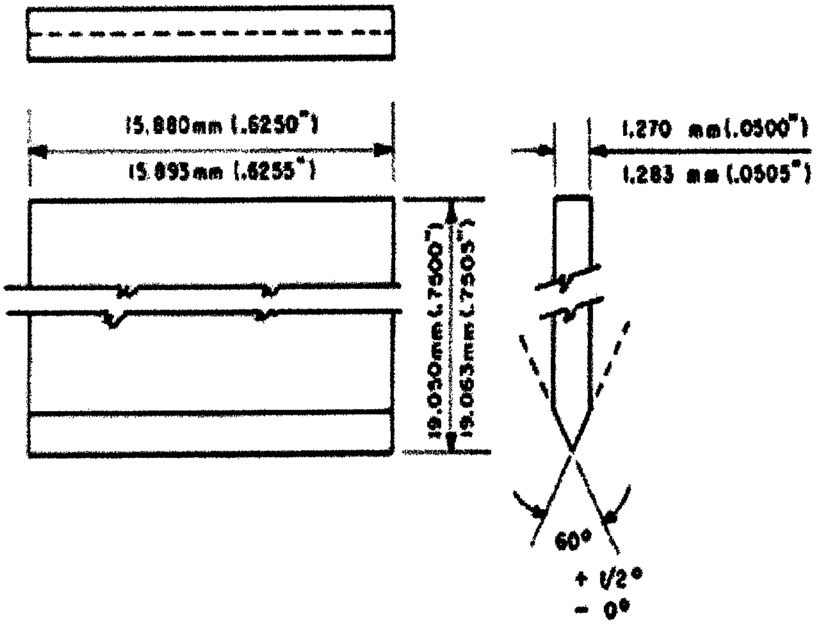

FIG. 2 Pico Cutting Knives

6.1.5 *Vacuum Dust Collector,* with vacuum sweeper hose of rubber tubing capable of rapid removal of the dusting powder and debris from the specimen and cutting knife interface.

6.1.6 *Digital Counters,* a pair mounted diametrically opposed to one another on the turntable support, capable of displaying a total count of no less than 80 and determining the rotations of the turntable to within 1.00 ± 0.03 Hz (rps) throughout the duration of a test cycle (see Section 10).

6.1.7 *Cutting Knives,* tungsten carbide knives manufactured to the specifications in Fig. 2 of Grade 831 Carboloy or an equivalent material, at the time of manufacture or resharpening.

6.1.7.1 The cutting knives shall have a "cutting edge" formed by the angle of the two bevels. The apex of the angle shall have a blunted edge, or "flat," with a width of 10 ± 5 µm.

6.1.7.2 At the time of manufacture or resharpening, the "cutting edge" may be less than 10 ± 5 µm. The blunted edge, or "flat," shall then be produced by the end user, manufacturer, or resharpening service supplier, by dulling with a diamond dust, or other suitable method to 10 ± 5 µm prior to first use.

NOTE 1—The supplier shall notify the end user of new or resharpened cutting knives of the final specifications of the cutting edges and other dimensional specifications.

6.1.7.3 The width of the blunted edge, or "flat," shall be verified either by standard microscopy techniques or scanning electron microscopy.[4,5]

6.1.7.4 The beveled surfaces shall have a finish equivalent to a No. 4-µm finish at the time of manufacture or resharpening.

6.1.7.5 The cutting knives, at the time of manufacture or resharpening, shall be matched in pairs so that the overall dimensions of each of the three major axes have a difference between them individually no greater than 0.013 mm (0.0005 in.) and that they are parallel to within ±0.0065 mm (0.00025 in.).

6.2 *Grinder,* for preparing the surfaces of test specimens. The grinder shall be equipped with:

6.2.1 A magnetic plate for holding the specimen in place,

6.2.2 A micrometer adjustment capable of controlling the vertical movement of the abrasive wheel in 0.025-mm (0.001-in.) increments,

6.2.3 A handwheel for traversing the specimen,

6.2.4 An electric motor with a spindle having a rotational frequency of 95 ± 3 Hz (rps) and equipped with an arbor to secure the abrasive wheel (see Section 10), and

6.2.5 An abrasive wheel with a diameter of no less than 100 mm (4 in.) and 12.5 mm (0.5 in.) in width, when new, and a center mounting hole of 12.7 mm (0.5 in.) in diameter. The grit of the wheel shall be equivalent to Carborundum C30LB.

6.3 *Balance,* accurate to ±0.0001 g.

7. Auxiliary Materials

7.1 *Dusting Powder:*

7.1.1 The dusting powder used shall be a blend of equal parts by weight of aluminum oxide and diatomaceous earth. The diatomaceous earth should first be passed through a No. 200 (75-µm) screen and the retained material discarded.[5,6]

7.1.2 A mixture of the two materials, in equal parts, shall be thoroughly blended, densed, and screened. When preparing small quantities, the following procedure is satisfactory:

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[4] The sole source of supply of the scanning electron microscopy (SEM) verification of cutting knife dimensions known to the committee at this time is BF Goodrich Research and Development, Brecksville, OH.

[5] If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[6] The sole source of supply of the Alon-C undensed aluminum oxide known to the committee at this time is Cabot Corp., Boston, MA.

TABLE 1 Calibration Compound (Reference Compound) Specifications

	Compound Designation				
	A	B	C	D	E
Nominal index	76	86	106	113	128
Permissible range	69 to 83	81 to 91	95 to 117	105 to 121	116 to 140

7.1.2.1 Into a sturdy ceramic, wide mouth, 4-dm^3 jar, place 100 g of each of the two materials.

7.1.2.2 Blend thoroughly by agitation.

7.1.2.3 Add 1000 g of 4.76 mm (3⁄16 in.) steel balls and place the closed jar on a roller for approximately 8 h at about 0.33 Hz (rps).

7.1.2.4 Remove the steel balls.

7.1.2.5 Scrape the densed dust out of the jar and pass through a No. 30 (600 µm) screen with the aid of a brush.[5,7]

7.2 *Calibration Compounds:*

7.2.1 The formulas and the mixing and curing specifications for the five calibration compounds are given in Annex A1. A brief description of the five compounds in terms of rubber and black types is as follows:

Compound	Rubber	Black
A	Styrene-Butadiene	Industry Reference
B	Styrene-Butadiene	Industry Reference
C	Natural Rubber	Industry Reference
D	Styrene-Butadiene Polybutadiene Blend	Industry Reference
E	Styrene-Butadiene Polybutadiene Blend	Intermediate Surface Abrasion Furnace Black

NOTE 2—The compounds listed in 7.2.1, 9.1, and Annex A1 have been modified from the 1982 compounds, due to the unavailability of some ingredients. The new compounds will not give equivalent results and new "Nominal Indices" and "Permissible Ranges" (see Table 1) are being developed. During the interim period of development, the previous (1982) calibration, or reference compounds, which can be prepared, shall be prepared and used as described in this test method.

7.2.2 The calibration compounds given in Annex A1 are compounds developed in 2000. These compounds have been modified from the 1982 compounds (see Note 2). The 2000 calibration compounds were not intended to give equivalent index results to the calibration compounds described prior to 2000. The "Nominal Indices" of the 2000 calibration compounds, however, have been developed based on the qualification in 5.1, and the "Permissible Ranges" are being established based on the specifications for the cutting knives as delineated in 6.1.7.

7.2.3 The five calibration compounds[5,8] are used to verify the operational status of the instrument. If within the "Permissible Ranges" described in Table 1, the subject materials are then tested and compared with the test results of the calibration compounds. In essence, once it has been determined that the tester is in calibration, the calibration compounds act as reference compounds and, where applicable, either of the two terms will be used.

8. Test Specimen

8.1 The standard test specimen shall be molded to the dimensions shown in Fig. 3, and shall be regarded as the standard test specimen.

8.2 An alternative specimen may be used in which a disk of the test material, not less than 1.59 mm (0.062 in.) in thickness and of the same diameter as the standard specimen, is cemented to a previously used specimen, or one that has been buffed down to accommodate the thickness of the disk. The disk may be cut from a product or from a laboratory cured sheet.

8.3 When testing conveyor belt covers or similar items, a specimen may be prepared as described in 8.2 or by cutting cylindrical specimens through the belt and cementing these to buffed down standard specimens with either the top or bottom cover being the surface to be tested. Covers shall be at least 0.79 mm (0.032 in.) thick.

8.4 In all tests, a minimum of two separately cured test specimens per material shall be tested. If replicate determinations are required, they may be rebuffed and retested providing the minimum specified thickness is maintained and noted in Section 12.

9. Calibration

9.1 The calibration of the Pico Abrader shall be verified at least once for every 30 specimens tested, or when using reformulated, remixed, or recured calibration compounds.

NOTE 3—Industry Reference Black No. 5 was used in Compounds A through D when these nominal indices were determined; Compound E contains an ISAF Black. The most recent IRB allotment (No. 6; 1986) does not match its predecessor of 1982 in physical properties performance of vulcanized compounds. The nominal indices of Compounds A through

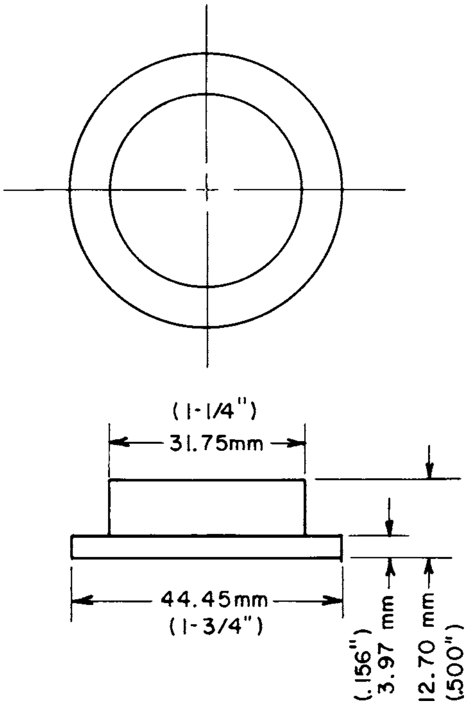

FIG. 3 Standard Test Specimen

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[7] The sole source of supply of a preblended mixture of these pigments known to the committee at this time is Ferry Industries, Inc., Stow, OH.

[8] Cured specimens will be available from Corporate, Consulting Service and Instruments, Inc. (CCSi) and Akron Rubber Development Laboratory, Inc. (ARDL), both of Akron, OH.

D maintain their relative values with respect to one another with the new black allotment but Compound E is forced to a higher nominal index (148). See Section 8.

9.1.1 The calibration shall be accomplished by testing each of the five calibration compounds enumerated in Table 1.[7]

9.1.1.1 The calibration shall be performed as described in Section 10, and under the conditions described in Section 11.

9.1.1.2 The results shall be calculated as described in 9.2 – 9.4 and shall be within the permissible range indicated in Table 1.

9.2 Calculate the volume loss for each calibration compound by subtracting the final mass from the initial mass and dividing the result by the density of the rubber:

$$L_x = \frac{M_i - M_f}{D} \qquad (1)$$

where:

L_x = volume loss in cm^3 of calibration compound X,
M_i = initial mass in g,
M_f = final mass in g, and
D = density, in mg/m^3.

9.3 Multiply the volume loss for each calibration compound by its nominal index, add these products together, and divide by 500 as follows:

$$\text{Standard volume loss} = \qquad (2)$$

$$\frac{(L_A \times 76) + (L_B \times 86) + (L_C \times 106) + (L_D \times 113) + (L_E \times 128)}{5 \times 100}$$

where: L_A, L_B, L_C, L_D, *and* L_E = volume loss, in cm^3, for Calibration Compounds A, B, C, D, and E, respectively.

9.4 Divide the standard volume loss resulting from the calculation of Eq 2 by the individual volume losses of each calibration compound to give the index value for each.

9.4.1 *Example*—The following volume losses, in cm^3, were obtained:

$$L_A = 0.0395 \qquad (3)$$

$$L_B = 0.0337$$

$$L_C = 0.0272$$

$$L_D = 0.0254$$

$$L_E = 0.0235$$

$$\text{Standard volume loss} = \qquad (4)$$

$$\frac{(0.0395 \times 76) + (0.0337 \times 86) + (0.0272 \times 106) + (0.0254 \times 113) + (0.0235 \times 128)}{5 \times 100} = 0.0293$$

Index for calibration compound A = $(0.0293/0.0395) \times 100 = 74$
Index for calibration compound B = $(0.0293/0.0337) \times 100 = 87$
Index for calibration compound C = $(0.0293/0.0272) \times 100 = 108$
Index for calibration compound D = $(0.0293/0.0254) \times 100 = 115$
Index for calibration compound E = $(0.0293/0.0235) \times 100 = 125$

9.5 During routine use, the cutting knives will become dull, affecting test determinations. The cutting knives may be routinely examined (see 6.1.7.3) so that they have, at the apex of the angle formed by the two bevels, a blunted edge, or "flat," with a width no greater than 20 µm.

9.5.1 When, during use, the cutting knives are routinely examined, they shall be removed from service if the blunted edge, or "flat," has a width greater than 20 µm.

9.5.2 When the effectiveness of the cutting knives is determined by reliance upon their comparative performance to the calibration compounds enumerated in Table 1, they shall be removed from service when a test determination falls outside of the "permissible range" for any of the calibration compounds given in Table 1.

9.6 In the event that the cutting knives are found to be within the previously enumerated dimensional specifications and tests performed on the calibration compounds do not fall within their respective "permissible range" enumerated in Table 1, the calibration compounds shall be remixed, recured, and retested.

9.7 When the procedure described in 9.6 fails to yield the desired results within a laboratory, between laboratories, between customer and supplier, or for the purposes of referee testing, the following shall occur:

9.7.1 Prepared test specimens, obtained from third party commercial sources (see Note 2), shall be tested following the procedures in Sections 9 and 10 using new or resharpened cutting knives adhering to the specifications in 6.1.7 (see Fig. 2).

10. Procedure

10.1 The calibration procedures and frequency described in Section 9 are required to be performed prior to conducting tests on subject materials.

10.2 *Preparing the Test Specimen:*

10.2.1 Buff the surface of the specimen on a surface grinder described in 6.2.

10.2.1.1 Set the abrasive wheel for an abraded depth of 0.13 mm (0.005 in.) to remove the mold skin.

10.2.1.2 Follow with a finishing depth of 0.025 mm (0.001 in.), then without changing the micrometer setting, give the surface of the specimen a finish grind.

10.2.1.3 The dwell time per pass under the abrasive wheel should be approximately 1 s.

10.2.1.4 Remove all loose rubber particles and debris from the buffed specimen.

10.2.2 When successive tests are made on a previously tested specimen (see 8.2), buff off the abrasion pattern produced on the specimen as given in 10.2.

10.2.3 Different volume losses will be obtained depending on the time specimens are allowed to equilibrate, that is, to remain in the atmospheric condition specified, after buffing, for specimen conditioning (see Section 11).

10.3 *Preparing the Apparatus:*

10.3.1 Close the power switch for the motor control unit. Allow the thymatrol tubes to warm up for two minutes before starting the motor. After the motor warms up, it can be started, stopped, and reversed as needed.

10.3.2 Direct current drive motors with SCR controls may be used, in which case 10.3.1 can be disregarded.

10.3.3 The rotational frequency of the turntable shall be 1.00 ± 0.03 Hz (rps).

10.3.4 The conditions described in 10.3.3 and 10.3.6 shall be regarded as standard. If varying severity tests are desired, it is recommended that the following alternative conditions be employed:

	Rotational Frequency, Hz (rps)	Force, N
Low severity	0.50	24.50
High severity	1.83	88.20

10.3.5 The number of revolutions remains the same, that is, a total of 80 (see 10.4.10).

10.3.6 The force on the knives shall be 44 ± 0.44 N. The tare of the shaft, chuck, knife holder, knives, and box is stamped on each tester; add the appropriate mass to attain the specified force.

10.3.7 These conditions may be modified if agreed upon between laboratories or between supplier and user and are so reported (see Section 12).

10.4 *Performing the Test:*

10.4.1 Tests shall be conducted in accordance with the conditions in Section 11.

10.4.2 Determine the mass of the specimen on a balance, recording results to the nearest 0.0001 g.

10.4.3 Mount the specimen onto the turntable.

10.4.4 Start the duster and adjust so that an even flow of 5 mg/s of dusting powder is established.

10.4.5 Push the forward button.

10.4.6 Lower the knives gently onto the specimen within the first revolution.

10.4.7 After the twentieth revolution, stop the tester within one quarter of a revolution.

10.4.8 Stop the duster and lift the knives from the specimen.

10.4.8.1 A cylindrical receptacle may be placed around the test specimen and filled with a sufficient supply of dusting powder so that the knives do not have to be lifted upon change of rotational direction.

10.4.8.2 Volume losses obtained by this test method may not be as great, but as long as all test specimens and calibration compounds are tested similarly, similar index results will be attained.

10.4.8.3 If this procedure is employed, it shall be reported (see Section 12).

10.4.9 Vacuum the dusting powder and the abraded rubber particles from the specimen.

10.4.10 Repeat 10.4.4 – 10.4.8, reversing the direction of rotation of the turntable each time, for three more increments of 20 revolutions (test cycle), for a total of 80 revolutions (one test), 40 revolutions in each direction.

10.4.10.1 Electronic controls, designed to automate 10.4.10.2 through 10.4.10.7, are permissible.

10.4.11 Remove the specimen, remove all loose powder and abraded rubber with a stiff brush.

10.5 *Calculation:*

10.5.1 Determine the mass of the specimen on a balance, recording results to the nearest 0.0001 g.

10.5.2 Calculate the volume loss from the mass loss and density of the tested material. As done in 9.2 – 9.4, express the result in an index number obtained by dividing the standard volume loss of the reference compounds, tested in the same series, by the volume loss of the tested material and multiplying the quotient by 100.

10.5.3 Calculate the index of the tested material against any one of the reference compounds as described in 10.5.2. This method is particularly useful when employing non-standard severity conditions.

11. Laboratory Atmosphere, Instrument and Test Specimen Conditioning

11.1 Tests shall be conducted in the standard laboratory atmosphere, as defined in Practice D618.

11.2 The instrument shall be maintained in the standard laboratory atmosphere, as defined in Practice D618, for 24 h prior to performing calibration or tests.

11.3 The specimen shall be conditioned in accordance with Condition 24/23/50 as described in Practice D618, and within the tolerances specified in Practice D618, Section 3, and stated as Condition 24/23/50, T–23–50.

where:

24 = the number of hours of conditioning,
23 = the temperature in degrees Celsius, ±2°C (73.4 ± 3.6°F), and
50 = the relative humidity in %, ±5 %.

and tested under the same conditions, described in Practice D618 as T–23–50,

where:

T = test conditions of 23° ± 2°C, and 50 % relative humidity ±5 %.

11.4 No conclusive evaluation has been made on Pico Abrasion calibrations or tests under conditions other than those stated in 11.1. Conditioning or testing at temperatures other than the above may cause variations in calibration or test results.

11.5 These procedures may be modified if agreed upon between laboratories or between supplier and user and are in accordance with alternative procedures identified in Practice D618.

12. Report

12.1 Report the following information:

12.1.1 Type of specimen, standard or alternative, as described in Section 8,

12.1.2 Identification of the tested specimens,

12.1.3 Cure time and temperature,

12.1.4 Force on knives used, in N, as described in 10.3.4 or 10.3.6, 12.1.5 Rotational frequency used, in Hz, as described in 10.3.4 or 10.3.6,

TABLE 2 Type 1—Precision

NOTE 1—
S_r = within laboratory standard deviation,
r = repeatability (in measurement units),
(r) = repeatability (in percent),
S_r = between laboratory standard deviation,
R = reproducibility (in measurement units), and
(R) = reproducibility (in percent)

Com-pound	Test Level Average	Part A—Volume Loss, cm^3 Within Laboratories			Between Laboratories		
		Sr	*r*	(*r*)	*Sr*	*R*	(*R*)
E	0.017	0.0005	0.0014	8.32	0.0037	0.0105	61.6
C	0.017	0.0006	0.0017	10.0	0.0038	0.010	63.3
D	0.019	0.0006	0.0017	8.95	0.0036	0.0102	53.6
B	0.025	0.0012	0.0034	13.6	0.0069	0.0195	78.1
A	0.036	0.0011	0.0031	8.61	0.0043	0.0122	33.8
		Part B—Abrasion Index					
A	71.4	6.37	18.0	25.3	7.61	21.5	30.1
B	96.9	5.28	14.9	15.4	4.97	14.1	14.6
C	114.2	4.26	12.1	10.6	...	...	...
D	119.3	6.70	19.0	15.9	5.03	14.2	11.9
E	140.7	6.70	19.0	13.5	14.1	39.9	28.4

12.1.6 Type of dusting, as described in 10.4.8.1, Standard Feed or Cylinder Contained,

12.1.7 Initial specimen mass, M_i, as calculated in 9.2, Eq 1,

12.1.8 Final specimen mass, M_f , as calculated in 9.2, Eq 1,

12.1.9 Specimen mass loss, $M_i - M_f$, as calculated in 9.2, Eq 1,

12.1.10 Density, *D*, as calculated in 9.2, Eq 1,

12.1.11 Specimen volume loss, L_x, as calculated in 9.2, Eq 1, and

12.1.12 Abrasion index with the test method used to calculate the index as described in 10.5.2 or 10.5.3 (see 9.3, Eq 2, and 9.4, Example 1).

13. Precision and Bias[9]

13.1 These precision statements have been prepared in accordance with Practice D4483. Please refer to this practice for terminology and other testing and statistical concept explanations.

13.2 *Type 1*—Precision data have been compiled, which excludes the compounding variation among laboratories (see Table 2).

13.3 The statements were developed from interlaboratory testing of the five new calibration compounds (A–E). These five compounds were mixed in a B Banbury internal mixer with curatives added on a mill. All specimens of the same compound were cured from the same mix.

13.4 The precision statements are based on the testing of five samples by six laboratories on two days.

13.5 A test result is defined to be the average of two separately cured specimens.

13.6 Precision statements were prepared for both volume loss and abrasion index. Volume loss is the measure of the physical differences among the interlaboratory testers and index is a measure of the test method in general.

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

13.8 *Repeatability*—The repeatability, *r*, of this test method has been established as the *appropriate value* tabulated in the precision tables. 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.

13.9 *Reproducibility*—The reproducibility, *R*, of this test method has been established as the *appropriate value* tabulated in the precision tables. 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.

13.10 Repeatability and reproducibility expressed as a percentage of the mean level, (*r*) and (*R*), have equivalent application statements as 13.8 and 13.9 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.

13.11 *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 the test method. Bias, therefore, cannot be determined.

14. Keywords

14.1 abrasion; abrasion resistance; knife abrasion; Pico abrader; Pico abraser; rubber articles; rubber products

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[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D11-1022.

ANNEX

(Mandatory Information)

A1. FORMULAS AND MIXING AND CURING SPECIFICATIONS FOR THE CALIBRATION COMPOUNDS

A1.1 Calibration Compounds

A1.1.1 The formulas for the calibration compounds are given in Table A1.1.

A1.2 Methods of Mixing

A1.2.1 The compounds are mixed in a B Banbury internal mixer in accordance with Practice D3182. Initial temperature of the mixing chamber is 50°C (120°F). Batch size is 70 % of total chamber volume capacity. The curatives are added on a mixing mill having rolls between 250 and 258-mm (9.8 to 10.2-in.) outside diameter and an operating temperature of 65°C (150°F).

Note A1.1—The standard mill has rolls between 150 and 155-mm (5.9 to 6.1-in.) outside diameter. If this mill is used to add curatives, the batch may be divided into three equal portions. The mixing cycle may have to be adjusted to obtain comparable results.

A1.2.2 The mixing cycles for the calibration compounds are given in Table A1.2. Mixing is accomplished by following the time specifications. No provisions are made for preconditioning of the carbon black.

A1.2.3 Sheet the compound off the mill at an approximate thickness of 2.1 mm (0.08 in.) and cool on a flat dry clean metal surface.

A1.2.4 Die cut disks of the required diameter and stack the disks to the required height.

TABLE A1.2 Mixing Cycles for Calibration Compounds

Step	Compound, min				
	A	B	C	D	E
B Banbury:					
Add rubber	0:00	0:00	0:00	0:00	0:00
Add fillers	0:30	0:30	0:30	0:30	0:30
Ram sweep	2:00	1:45	2:10	2:00	2:00
Add oil	2:30	2:10	2:55	2:25	2:30
Ram scrape	3:10	3:00	3:50	3:15	3:15
Dump	4:15	3:50	5:05	4:00	4:15
Probe temperature at dump, °C, (°F)	143 (290)	152 (305)	160 (320)	138 (280)	138 (280)
Mill:					
Band material	0:00	0:00	0:00	0:00	0:00
Add curatives	0:30	0:40	0:45	0:40	0:40
End pass	2:30	2:15	3:00	2:15	2:00
Take off	6:15	6:30	6:15	5:30	5:30

A1.3 Recommended Cures

A1.3.1 Cures for the calibration compounds, in the form of the molded specimens required for the test, are given in Table A1.3.

A1.3.2 The size of the molded specimen is such that a lag time or incubation time of approximately five minutes is involved in the cure. It is recommended that cures of experimental materials be increased by this amount over the cure that

TABLE A1.1 Formulas for Calibration Compounds

Ingredient	Industry Trade Name or Reference Supplier	Designation				
		A	B	C	D	E
Natural rubber[A]	SMR L	0.00	0.00	100.0	0.00	0.00
Polybutadiene[B]	TAKTENE 220	0.00	0.00	0.00	50.00	50.00
SBR 1502[C]	SBR 1502	0.00	100.00	0.00	0.00	0.00
SBR 1712[C]	SBR 1712	137.50	0.00	0.00	68.75	68.75
Stearic acid[D]	Stearic Acid IRM 021a	1.50	1.50	2.00	1.50	1.50
Zinc oxide[E]	Zinc Oxide IRM 91a	5.00	5.00	5.00	5.00	5.00
IRB[F]	IRB #7	60.00	40.00	45.00	80.00	0.00
ISAF black[G]	N220	0.00	0.00	0.00	0.00	80.00
Process oil[E,H]	SUNDEX 8125	5.00	10.00	5.00	27.50	27.50
Dimethyl butylphenyl phenylenediamine[I]	SANTOFLEX 13	1.50	1.50	1.00	1.50	1.50
Trimethyldihydroquinoline[I]	FLECTOL H	1.50	1.50	1.50	1.50	1.50
TBBS[J,K]	TBBS IRM 003	1.00	1.00	0.60	1.20	1.20
Sulfur[D]	Sulfur IRM 031a	2.00	2.00	2.50	2.00	2.00
	Totals	215.00	162.50	162.60	238.95	238.95

[A] Available from H.A. Astlett, Toronto, Ontario.

[B] Available from Bayer Canada, Toronto, Ontario.

[C] SBR 1502 and SBR 1712 are available from synthetic rubber suppliers in various quantities.

[D] Available from Akron Rubber Development Laboratory, Akron, OH.

[E] Available from R.E. Carroll, Akron, OH.

[F] Industry Reference Black #7 is available in 22.68 kg (50 lb) bags from carbon black suppliers.

[G] This replaces N234, which is no longer commercially available.

[H] This replaces Sundex 7260T, which is no longer commercially available.

[I] Available from Harwick, Akron, OH.

[J] N- *tert*-butyl-2-benzothiazole sulfenamide.

[K] Available from Akrochem, Akron, OH.

is established for sheets approximately 2 mm (0.08 in.) thick.

TABLE A1.3 Recommended Cures for Calibration Compounds

Compound	Time, min	Temperature, °C (°F)
A	65	150 (302)
B	65	150 (302)
C	60	140 (284)
D	65	150 (302)
E	65	150 (302)

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