Designation: D 1044 – 99

Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion[1]

This standard is issued under the fixed designation D 1044; 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 describes a procedure for estimating the resistance of transparent plastics to one kind of surface abrasion by measurement of its optical effects.

1.2 Abrasive damage is judged by that percentage of transmitted light which, in passing through the abraded track, deviates from the incident beam by forward scattering. For the purpose of this test method, only light flux deviating more than 0.044 rad (2.5°) on the average is considered in this assessment of abrasive damage.

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

NOTE 1—Recent attempts to employ the Taber Abraser for volume loss determinations of various plastics, like earlier ones,[2] have been unsuccessful because of excessively large coefficients of variation attributed to the data. Insufficient agreement among the participating laboratories has rendered the use of volume loss procedure inadvisable as an ASTM test method.

NOTE 2—For determining resistance to abrasion of plastics by measurement of volume loss, reference should be made to Test Methods D 1242.

NOTE 3—For determining the resistance to abrasion of organic coatings by weight loss, reference is made to Test Method D 4060. This test method uses more aggresive CS-10 or CS-17 abrasive wheels. It suffers from poor reproducibility between laboratories when numerical abrasion resistance values are used. Interlaboratory agreement improves significantly when ranking a series of coatings for their abrasion resistance.

NOTE 4—This test method is similar to ISO 3444 and ISO 4586/2. Their technical content is somewhat different. This test method and ISO 9352-89 are not technically equivalent.

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.* For a specific precautionary statement, see 8.1.2.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[3]

D 1242 Test Methods for Resistance of Plastic Materials to Abrasion[3]

D 2240 Test Method for Rubber Property—Durometer Hardness[4]

D 4000 Classification System for Specifying Plastic Materials[5]

D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[6]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[7]

2.2 *ISO Standards:*

ISO 3444 Paper and Board Determination of Abrasion Resistance[8]

ISO 4586/2 Abrasion Resistance of Decorative Laminated Sheets[8]

ISO 9352–89 Plastics—Determination of Resistance to Wear Abrasive Wheels[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *abrasion*—abrasive wear caused by displacement or rearrangement of a softer material due to rubbing or scuffing against hard sharp particles.

3.1.2 *haze*—See definitions in Test Method D 1003.

3.1.3 *reface*—preparation of an abrasive wheel on a conditioning stone prior to use in testing.

3.1.4 *wheel*—an abrasive wheel consisting of hard particles (aluminum oxide) embedded in rubber.

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[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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[2] Supporting data are available from ASTM Headquarters. Request RR:D20-48 and RR:D20-1090.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 06.01.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

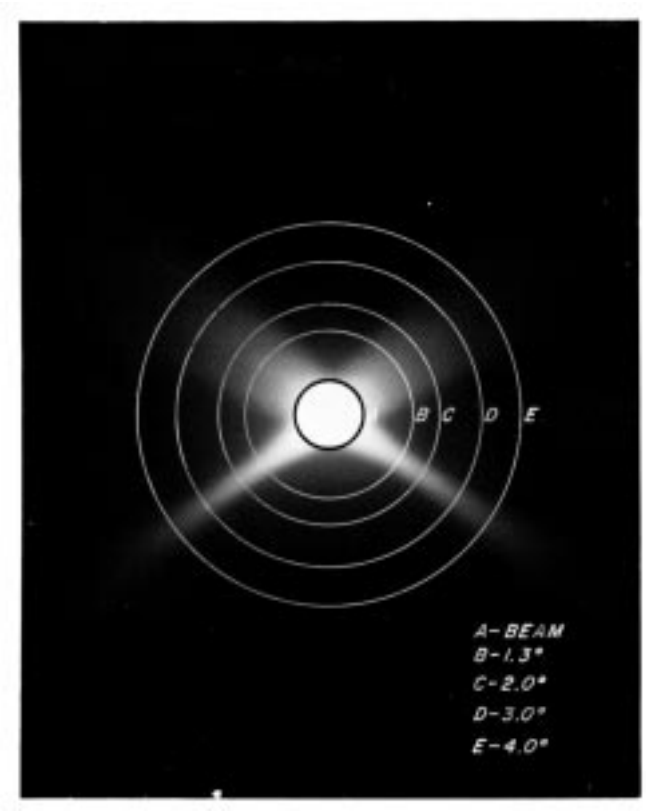
***A Summary of Changes section appears at the end of this standard.**

4. Significance and Use

4.1 Transparent plastic materials, when used as windows or enclosures, are subject to wiping and cleaning; hence the maintenance of optical quality of a material after abrasion is important. It is the purpose of this test method to provide a means of estimating the resistance of such materials to this type and degree of abrasion.

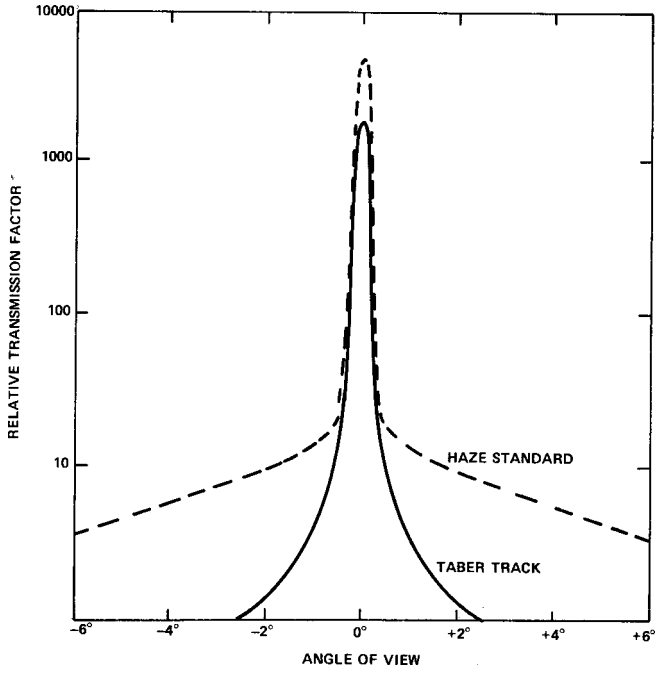
4.2 Although this test method does not provide fundamental data, it is suitable for grading materials relative to this type of abrasion in a manner which correlates with service.

4.3 Comparison of interlaboratory data or the specification of a "haze" value has no significance if the hazemeter requirements given in Section 4 are not used. This is because light diffused from the surface of a Taber track is scattered at a narrow angle (Fig. 1 and Fig. 2) while light diffused internally by a specimen is scattered at a wide angle. In many hazemeters, when a diaphragm is inserted to limit the light beam to the width of the abraded track, the specular beam at the exit port becomes smaller. The dark annulus will then be greater than the 0.023 ± 0.002 rad (1.3 ± 0.1°) requirements of Test Method D 1003. Since a large percentage of the narrow-angle forward-scattered light will not impinge on the sphere wall," haze" readings become smaller. For hazemeters that have not been properly adjusted, the magnitude of this reduction is dependent both on the integrating sphere diameter and the reduction of the entrance beam.



NOTE 1—This photograph shows light pattern of the scattering from the surface of a Taber abraded specimen. The circles show how increasing the 1.3° dark annulus dramatically changes the amount of light impacting the sphere wall.

FIG. 1 Light Scattering from Surface of Abraded Tracks (Photograph)



NOTE 1—This graph shows goniophotometric curves for Taber abraded tracks. The specular angle of transmission is at 180°.

FIG. 2 Light Scattering from Surface of Abraded Tracks (Graph)

4.4 For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification System D 4000 lists the ASTM materials standards that currently exist.

5. Apparatus

5.1 *Abrader*—The Taber abraser or its equivalent, so constructed that wheels of several degrees of abrasiveness may be readily used. Loads of 250, 500, or 1000 g on the wheels may be obtained by use of changeable weights or counterweights.

5.2 *Refacing Stone*—An ST-11 refacing stone shall be used for truing the abrasive wheels.

5.3 *Abrasive Wheels*—The grade of "Calibrase" wheel designated CS-10F shall be used. The "Calibrase" wheel shall meet the following requirements at the time of the test (Note 3):

5.3.1 The wheel shall not be used after the date stamped on it, and

5.3.2 The durometer hardness of the wheel shall be measured in accordance with Test Method D 2240, on at least four points equally spaced on the center of the abrading surface and one point on each side surface of the wheel. The test on the abrading surface shall be made with the pressure applied vertically along a diameter of the wheel, and the reading taken 10 s after full application of the pressure. Each wheel shall have a durometer hardness of D 72 ± 5 at all measured points.

NOTE 5—The abrasive quality of the "Calibrase" wheels varies with

hardness which changes with age.

5.4 *Abraser Turntable*—The turntable of the abraser shall rotate substantially in a plane with a deviation at a distance of 1.6 mm (1/16 in.) from its periphery of not greater than ±0.051 mm (±0.002 in.). The typical rotation speed is 72 r/min.

5.5 *Photometer*—An integrating sphere photoelectric photometer, described in Test Method D 1003, shall be used to measure the light scattered by the abraded track. The photometer shall have the image of its entrance window focused at and concentric with the exit port of the integrating sphere.

5.6 *Stops*—Either an aperture or a field stop (diaphragm) shall be inserted in the optical beam of the apparatus, so that the light beam to the abraded area is limited in size. The light beam shall be of any regular shape but shall have a maximum dimension along the radial axis of the sample, of 7 ± 1 mm.

5.6.1 When the reduced light beam is unobstructed by a specimen, its cross section at the exit port shall be approximately circular, sharply defined, uniformly bright, and concentric within the exit port, leaving an annulus of 0.023 ± 0.002 rad (1.3 ± 0.1°) subtended at the entrance port (Fig. 3).

NOTE 6—Uniformity of the light intensity is usually checked by observing the beam through thin bond paper placed at the exit port.

NOTE 7—Forward-scattering glass standards[9] can be used to check that the optical system of the hazemeter is properly adjusted.

5.7 *Specimen Holder*—A suitable holder shall be used to permit positioning the abraded specimen so that the light beam is centered in the abraded track.

[9] Suitable standards are available from Gardner Laboratory, Inc., 5521 Landy Lane, Bethesda, MD 20014, and Hunter Associates Laboratory, Inc., 9529 Lee Highway, Fairfax, VA 22030.

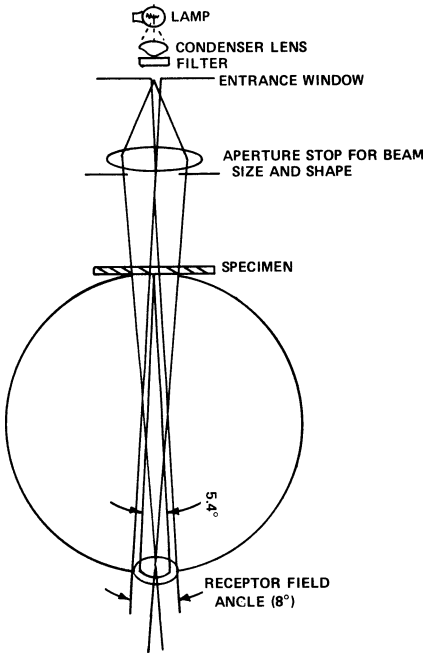


FIG. 3 Modified Hazemeter for Measuring Forward-Scattering Specimens Showing Aperture Stop Location and Annulus at the Exit Port

6. Test Specimens

6.1 The test specimens shall be clean, transparent disks 102 mm (4 in.) in diameter or plates 102 mm (4 in.) square, having both surfaces substantially plane and parallel. They may be cut from sheets or molded in thicknesses up to 12.7 mm (½ in.). A 6.3-mm (¼–in.) hole shall be centrally drilled in each specimen. Three such specimens shall be tested per sample, except for interlaboratory or specification tests when ten specimens shall be tested.

7. Conditioning

7.1 *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 for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±2 % relative humidity.

7.2 *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 in the test method. In cases of disagreements, the tolerances shall be ±1°C (±1.8°F) and ±2 % relative humidity.

8. Procedure

8.1 Mount the pair of "Calibrase" wheels to be used on their respective flange holders, taking care not to handle them by their abrasive surfaces. Select the load to be used and affix it to the abraser. Mount an ST-11 refacing stone, fine side up, on the turntable.

8.1.1 The use of a vacuum cleaner is recommended to remove residue. If used, lower the vacuum nozzle and adjust its height to within 0.8 to 1.6 mm (1/32 to 1/16 in.) of the refacing stone. Set the vacuum to a position of 50 or greater.

8.1.2 Reface new wheels for 100 cycles. Reface previously used wheels for 25 cycles. Reface the wheels for 25 cycles before abrading each specimen. In each case brush the residue from the stone during the process. **Caution**: Do not touch the surface of the wheels after they are refaced.

8.1.3 Discard the ST-11 refacing stone when grooves or ridges first become evident.

8.2 Mount the specimen on the specimen holder and subject it to abrasion for a selected number of cycles. Use an abrasion of 100 cycles with the 500-g load, unless otherwise specified. Use a soft camel's hair brush or compressed air to remove residue from the specimen after abrasion.

NOTE 8—For plotting curves of light scattering versus cycles of abrasion, 10, 25, 50, and 100 cycles are recommended.

8.3 Using an integrating sphere photometer that has been properly adjusted, place the specimen in the holder and measure the percentage of the transmitted light that is diffused by the abraded track on at least four equally spaced intervals along the track. The abraded track should be against the entrance window of the photometer. The specimen holder should be positioned so that no portion of the light beam is within 1 mm of the inside or outside edge of the track.

NOTE 9—The specimen may be supported free to rotate on a 6.3-mm (¼-in.) pin, so positioned as to center the light beam on the abraded area.

The specimen may be automatically rotated and an integrated value thus obtained.

NOTE 10—Subjective comparisons may be made by visually comparing abraded specimens with a measured, abraded standard.

9. Report

9.1 Report the following information:

9.1.1 Percentage of the transmitted light that is scattered by the abraded specimens, averaged for the specimens tested,

9.1.2 Number of specimens tested,

9.1.3 Load and the number of cycles used, if other than specified in 7.2,

9.1.4 Plot of the percentage of light scattered versus cycles abraded, if more than one number of cycles is used, and

9.1.5 Description of the integrating sphere photometer including: sphere geometry; exit light beam diameter with and without the diaphragm inserted; and location of the diaphragm in the light beam.

10. Precision and Bias

10.1 Table 1 and Table 2 are based on a round robin conducted in 1983, involving six materials tested by six laboratories. Each laboratory made fourteen determinations for each material and cycle combination.

10.2 The data in Table 1 was calculated to apply to the case where three determinations are made for each test result. Table 2 is for ten determinations (see 6.1).

10.2.1 In Table 1 or Table 2, for the materials indicated:

S_r = pooled within-laboratories standard deviation of the mean for three or ten specimens,

S_R = total among-laboratories standard deviation of the mean for three or ten specimens,

$I_r = 2.83\ S_r$ (see 10.3), and

$I_R = 2.83\ S_R$ (see 10.4).

Other materials may give somewhat different results.

10.3 *Repeatability*—In comparing two averages (of three or ten specimens each) for the same material, obtained by the same operator using the same equipment on the same day, the average should be judged not equivalent if they differ by more than the I_r value for that material and condition.

10.4 *Reproducibility*—In comparing two averages (of three or ten specimens each) for the same material, obtained by different operators using different equipment, the averages should be judged not equivalent if they differ by more than the I_R value for that material and condition.

10.5 The judgments in accordance with 10.3 and 10.4 will be corrected in approximately 95 % of such comparisons.

10.6 For further information on the methodology used in this section, see Practice E 691.

10.7 *Bias*—No statement is made about bias of this test method, as there is no absolute method available as a referee method.

11. Keywords

11.1 abrasion; haze; hazemeter; surface abrasion; Taber abraser

TABLE 1 Precision Statement Based on Three Replicates

Material	Number of Cycles	Mean	Values in Units of Percent Haze			
			S_r	S_R	I_r	I_R
Polystyrene	10	43.05	1.80	5.79	5.09	16.38
Polystyrene	50	79.17	0.83	9.36	2.35	26.51
Acrylic	25	14.88	0.43	4.48	1.22	12.68
Acrylic	100	27.98	0.61	4.20	1.73	11.90
Polycarbonate	25	28.85	0.77	2.59	2.18	7.32
Polycarbonate	100	42.12	0.96	4.53	2.72	12.82
Coated acrylic	200	2.58	0.25	1.48	0.71	4.19
Coated acrylic	1000	12.79	1.17	4.48	3.31	12.67
Coated polycarbonate	100	4.27	0.56	1.37	1.58	3.88
Coated polycarbonate	500	27.06	1.99	12.13	5.63	34.34
Cellulose acetate butyrate	10	14.92	0.46	3.04	1.30	8.62
Cellulose acetate butyrate	50	37.89	1.07	5.51	3.03	15.60

TABLE 2 Precision Statement Based on Ten Replicates

Material	Number of Cycles	Mean	Values in Units of Percent Haze			
			S_r	S_R	I_r	I_R
Polystyrene	10	43.05	0.99	5.58	2.80	15.81
Polystyrene	50	79.17	0.46	9.34	1.30	26.44
Acrylic	25	14.88	0.24	4.47	0.68	12.64
Acrylic	100	27.98	0.33	4.17	0.93	11.81
Polycarbonate	25	28.85	0.42	2.50	1.19	7.09
Polycarbonate	100	42.12	0.52	4.46	1.47	12.62
Coated acrylic	200	2.58	0.14	1.47	0.40	4.15
Coated acrylic	1000	12.79	0.64	4.36	1.81	12.36
Coated polycarbonate	100	4.27	0.31	1.29	0.88	3.64
Coated polycarbonate	500	27.06	1.09	12.02	3.08	34.02
Cellulose acetate butyrate	10	14.92	0.25	3.02	0.71	8.55
Cellulose acetate butyrate	50	37.89	0.59	5.44	1.67	15.40

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D-20 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 1044–99: (*1*) Added Note 4.