~~Designation:D1003–00~~ Designation: D 1003 – 07

Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics[1]

This standard is issued under the fixed designation D 1003; 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.*~~

This test method has been approved for use by agencies of the Department of Defense to replace Method 3022 of Federal Test Method Standard 406.

1. Scope*

1.1 This test method covers the evaluation of specific light-transmitting and wide-angle-light-scattering properties of planar sections of materials such as essentially transparent plastic. Two procedures are provided for the measurement of luminous transmittance and haze. Procedure A uses a hazemeter as described in Section 5 and Procedure B uses a spectrophotometer as described in Section 8. Material having a haze value greater than 30 % is considered diffusing and should be tested in accordance with Practice E 167.

1.2 The values stated in SI units are to be regarded as ~~the~~ standard.

NOTE 1—For greater discrimination among materials that scatter a high percent of light within a narrow forward angle, such as is the case with abraded transparent plastics, adjust the hazemeter and perform measurements in accordance with Test Method D 1044.

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 2—This test method is not equivalent to ISO 13468–1 and ISO/DIS 14782.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 618~~Practice for Conditioning Plastics and Electrical Insulating Materials for Testing~~ Practice for Conditioning Plastics for Testing

D 883 Terminology Relating to Plastics

D 1044 Test Method for Resistance of Transparent Plastics to Surface Abrasion

D 1898~~Practice for Sampling of Plastics~~[2] Practice for Sampling of Plastics[3]

E 167 Practice for Goniophotometry of Objects and Materials

E 259~~Practice for Preparation of Reference White Reflectance Standards~~[3] Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries

E 284 Terminology of Appearance

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

2.2 *ISO Standards:*[4]

ISO 13468–1 Plastics—Determination of the Total Luminous Transmittance of Transparent Materials

ISO/DIS 14782 Plastics—Determination of Haze of Transparent Materials

3. Terminology

3.1 *Definitions*—Terms applicable to this test method are defined in Terminologies D 883 and E 284.

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[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.40 on Optical Properties .

~~This test method has been approved for use by agencies of the Department of Defense to replace Method3022 of Federal Test Method Standard406.~~

~~Current edition approved June 10, 2000. Published July 2000. Originally published as D1003–49T. Last previous edition D1003–97$^{\epsilon 1}$.~~

Current edition approved Nov. 1, 2007. Published November 2007. Originally approved in 1949. Last previous edition approved in 2000 as D 1003 - 00.

[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* ~~, Vol 08.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

~~[4] Annual Book of ASTM Standards, Vol 14.02.~~

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *haze*, *n*—in transmission, the scattering of light by a specimen responsible for the reduction in contrast of objects viewed through it. The percent of transmitted light that is scattered so that its direction deviates more than a specified angle from the direction of the incident beam.

3.2.1.1 *Discussion*—In this test method, the specified angle is 0.044 rad (2.5°).

3.2.2 *luminous*, *adj*—weighted according to the spectral luminous efficiency function V() of the CIE (1987).

3.2.3 *luminous transmittance*, *n*—the ratio of the luminous flux transmitted by a body to the flux incident upon it.

4. Significance and Use

4.1 Light that is scattered upon passing through a film or sheet of a material can produce a hazy or smoky field when objects are viewed through the material. Another effect can be veiling glare, as occurs in an automobile windshield when driving into the sun.

4.2 Although haze measurements are made most commonly by the use of a hazemeter, a spectrophotometer may be used, provided that it meets the geometric and spectral requirements of Section 5. The use of a spectrophotometer for haze measurement of plastics can provide valuable diagnostic data on the origin of the haze,[5] and Procedure B is devoted to the use of a spectrophotometer.

4.2.1 Procedure A (hazemeter) test values are normally slightly higher and less variable than Procedure B (spectrophotometer) test values.

4.3 Regular luminous transmittance is obtained by placing a clear specimen at some distance from the entrance port of the integrating sphere. However, when the specimen is hazy, the total hemispherical luminous transmittance must be measured by placing the specimen at the entrance port of the sphere. The measured total hemispherical luminous transmittance will be greater than the regular luminous transmittance, depending on the optical properties of the sample. With this test method, the specimen is necessarily placed at the entrance port of the sphere in order to measure haze and total hemispherical luminous transmittance.

4.4 Haze data representative of the material may be obtained by avoiding heterogeneous surface or internal defects not characteristic of the material.

4.5 Haze and luminous-transmittance data are especially useful for quality control and specification purposes.

4.6 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, 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. Test Specimens

5.1 Sample the material in accordance with Practice D 1898. Obtain specimens that are free of defects not characteristic of the material unless such defects constitute variables under study.

5.2 Cut each test specimen to a size large enough to cover the entrance port of the sphere. A disk 50 mm ~~(2 in.)~~[2 in.] in diameter, or a square with sides of the same dimensions, is suggested. The specimen shall have substantially plane-parallel surfaces free of dust, grease, scratches, and blemishes, and it shall be free of visibly distinct internal voids and particles, unless it is specifically desired to measure the contribution to haze due to these imperfections.

5.3 Prepare three specimens to test each sample of a given material unless specified otherwise in the applicable material specification.

6. Conditioning

6.1 *Conditioning*—Unless otherwise required in the appropriate materials specification or agreed between customer/supplier, condition the test specimens at 23 ± 2°C ~~(73.4~~[73.4 ± ~~3.6°F)~~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. In case of disagreements, the tolerances shall be ±1°C ~~(1.8°F)~~[1.8°F] and ±2 % relative humidity.

6.2 *Test Conditions*—Set up the test apparatus in an atmosphere maintained at 23 ± 2°C ~~(73.4~~[73.4 ± ~~3.6°F)~~3.6°F] and 50 ± 5 % relative humidity.

7. Procedure A—Hazemeter

7.1 *Apparatus*:

7.1.1 The instrument used for measurement shall meet the geometric and spectral requirements of this section.[6,7]

~~[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.~~

[5] Billmeyer, F. W., Jr., and Chen, Y., "On the Measurement of Haze," *Color Research and Application*, Vol 10, 1985, pp. 219–224.

~~[6] Billmeyer, F. W., Jr., and Chen, Y., "On the Measurement of Haze," *Color Research and Application*, Vol 10, 1985, pp. 219–224.~~

[6] The sole source of supply of the hazemeter known to the committee at this time is BYK-Gardner USA 9104 Guilford Road Columbia, MD 21046.

~~[7] Hazemeters made by BYK-Gardner, Inc., 2435 Linden Lane, Silver Spring, MD 20910, meet these requirements. Other manufacturers of this equipment, which meet the requirements, may exist but have not been identified.~~

7.1.2 A light source and a photodetector shall be supplied, and the combination shall be filtered to provide an output corresponding to the luminosity response of the 1931 CIE Standard Colorimetric Observer with CIE Standard Illuminant C or, alternatively, Illuminant A. The output shall be proportional to within 1 % to the incident flux over the range of flux used. The photometric stability for source and detector must be constant throughout the test of each specimen.

7.1.3 Use an integrating sphere to collect transmitted flux; the sphere may be of any diameter as long as the total port areas do not exceed 4.0 % of the internal reflecting area of the sphere. The entrance and exit ports shall be centered on the same great circle of the sphere, and there shall be at least 2.97 rad (170°) of arc between centers. The exit port shall subtend an angle of 0.14 rad (8°) at the center of the entrance port. With the light trap in position, without the specimen, the axis of the irradiating beam shall pass through the centers of the entrance and exit ports. For a hazemeter, position the photocell or photocells on the sphere 1.57 ± 0.17 rad (90 ± 10°) from the entrance port and baffle it from direct exposure to the entrance port. In the pivotable modification where the interior wall adjacent to the exit port is used as the reflectance reference, the angle of rotation of the sphere shall be 0.140 ± 0.008 rad (8.0 ± 0.5°).

7.1.4 Illuminate the specimen by a substantially unidirectional beam; the maximum angle that any ray of this beam may make with the beam axis shall not exceed 0.05 rad (3°). This beam shall not be vignetted at either port of the sphere.

7.1.5 When the specimen is placed against the entrance port of the integrating sphere, the angle between the perpendicular to the specimen and a line connecting the centers of entrance and exit ports shall not exceed 0.14 rad (8°).

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

NOTE 3—It is important to verify whether the unobstructed-beam diameter and centering at the exit port are maintained, especially if the source aperture and focus are changed.

NOTE 4—The tolerance stated on the annulus of 0.002 rad (0.1°) corresponds to an uncertainty of ±0.6 % in a haze reading.[8] This is relevant for assessing the precision and bias of this test method.

7.1.7 The surfaces of the interior of the integrating sphere, baffles, and reflectance standard, if used, shall be of equal reflectance, matte, and highly reflecting throughout the visible spectrum.[9]

7.1.8 A light trap shall be provided that will absorb the beam completely when no specimen is present, or the instrument design shall obviate the need for a light trap.

7.1.9 A schematic drawing of the optics of a hazemeter with unidirectional illumination and diffuse viewing is shown in Fig. 1.

7.1.10 A series of calibrated haze standards is required for periodic verification of the accuracy of instrumental response. Ideally, if the haze of narrow-angle-scattering specimens (such as plastic films) is to be measured, narrow-angle-scattering glass standards should be used;[6,8] however, these are not known to be commercially available. In their absence, wide-angle-plastic standards[10,7] may be used, but these are less sensitive to the size and centering of the annulus described by Billmeyer and Chen[5] and Weidner and Hsia,[9] and particular attention should be paid to Note 1 when only plastic haze standards are used.

7.2 *Procedure*:

[7] 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, which you may attend.

[8] Weidner, V. R., and Hsia, J. J., "NBS Reference Hazemeter: Its Development and Testing," *Applied Optics*, Vol 18, 1979, pp. 1619–1626.

[9] Highly reflective matte barium sulfate paint or pressed polytetrafluoroethylene powder are excellent for this purpose. See Practice E 259.

[10] Calibrated plastic haze standards are available from BYK-Gardner, Inc., 2435 Linden Lane, Silver Spring, MD 20910.

[10] The sole source of supply of the calibrated plastic haze standards known to the committee at this time is BYK-Gardner USA 9104 Guilford Road Columbia, MD 21046.

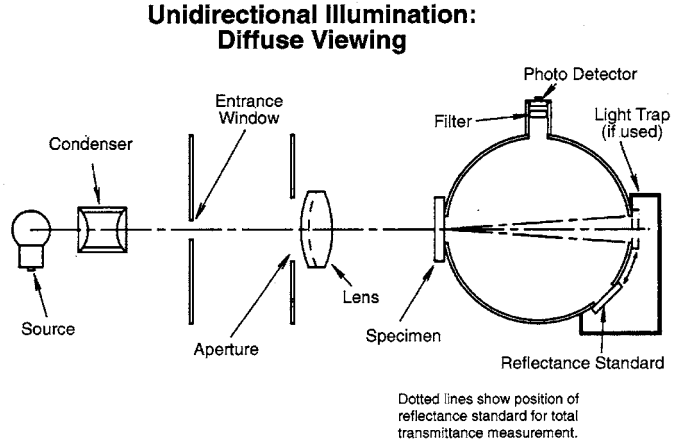

FIG. 1 Schematic of Hazemeter

7.2.1 Determine the following four readings:

Reading Designation	Specimen in Position	Light Trap in Position	Reflectance Standard in Position	Quantity Represented
T_1	no	no	yes	incident light
T_2	yes	no	yes	total light transmitted by specimen
T_3	no	yes	no	light scattered by instrument
T_4	yes	yes	no	light scattered by instrument and specimen

7.2.2 Repeat readings for T_1, T_2, T_3, and T_4 with additional specified positions of the specimen to determine uniformity.

7.3 *Calculation*[11]*:*

7.3.1 Calculate total transmittance, T_t (Note 5), equal to T_2 / T_1.

7.3.2 Calculate diffuse transmittance, T_d (Note 5), as follows:

$$T_d = [T_4 - T_3 (T_2 / T_1)] / T_1 \quad (1)$$

7.3.3 Calculate percent haze as follows:

$$\text{haze} = T_d / T_t \times 100 \quad (2)$$

NOTE 5—To obtain the greatest accuracy in luminous transmittance measurement when using a single-beam instrument, it is necessary to use a standard, calibrated with a double-beam instrument, because insertion of the sample in the single-beam instrument changes the efficiency of the sphere. This change may result in spuriously high readings for clear, colorless samples and significant errors for dark or highly saturated colors. In these cases, the photometer should be used as a comparison instrument with a standard of known transmittance similar to that of the specimen. For greatest accuracy of luminous transmittance measurement, compare the transmittance of the specimen with that of a calibrated standard of similar luminous transmittance.

7.4 *Report*:

7.4.1 Report the following data:

7.4.1.1 Source and identity of specimen,

~~7.4.1.2Nominal thickness of specimen to the nearest 0.025 mm,~~

7.4.1.2 Nominal thickness of specimen to the nearest 0.0025 mm or better for specimens less than 0.25 mm in thickness and to the nearest 0.025 mm or better for specimens greater than 0.25 mm in thickness,

7.4.1.3 Total luminous transmittance, T_t, to the nearest 0.1 % (indicate the average when reporting average values and specify whether CIE Illuminant C or A is used),

7.4.1.4 Diffuse luminous transmittance, T_d, to the nearest 0.1 % (indicate the average when reporting average values), and

7.4.1.5 Percent haze, to the nearest 0.1 % (indicate the average when reporting average values).

7.5 *Precision and Bias—Hazemeter* :

7.5.1 *Precision*:

7.5.1.1 Table 1 and Table 2 are based on a round robin conducted in 1985, in accordance with Practice E 691, involving six film materials tested by 11 laboratories. In the round robin, each laboratory that measured a property made eight replicate measurements of the property for each of the six materials listed as 1 to 6 in Table 1 and Table 2.

7.5.1.2 Table 3 is based on a round robin conducted in 1991 involving eight materials and six laboratories. This table can be directly compared to Table 4 ~~(Spectrophotometer).~~

~~NOTE6—~~**~~Caution:~~**(Spectrophotometer). (**Warning—**The following explanations of *r* and *R* (7.5.1.3-7.5.1.7) are intended to present only a meaningful way of considering the approximate precision of this test method. The data in Tables 1-3 should not be applied rigorously 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

[11] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.40 on Optical Properties . Current edition approved Nov. 1, 2007. Published November 2007. Originally approved in 1949. Last previous edition approved in 2000 as D 1003 - 00.

TABLE 1 Summary of 1985 Procedure A (Hazemeter) Total Haze Round Robin Involving Eleven Laboratories

Material	Average	*S(r)*	*S(R)*	*r*	*R*
3	3.8	0.10	0.33	0.28	0.94
1	8.7	0.18	0.42	0.50	1.18
2	13.5	0.08	0.40	0.23	1.12
4	18.0	0.27	0.61	0.76	1.72
5	21.0	0.41	1.68	1.16	4.74
6	26.5	0.35	1.13	0.98	3.19