Designation: D1003 – 13

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

This standard is issued under the fixed designation D1003; 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.*
*This test method replaces 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 E2387.

1.2 The values stated in SI units are to be regarded as 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 D1044.

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]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1044 Test Method for Resistance of Transparent Plastics to Surface Abrasion
E259 Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries
E284 Terminology of Appearance
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E2387 Practice for Goniometric Optical Scatter Measurements

2.2 *ISO Standards:*[3]

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 D883 and E284.

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

[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.

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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, http://www.ansi.org.

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

of Section 5. The use of a spectrophotometer for haze measurement of plastics can provide valuable diagnostic data on the origin of the haze,[4] 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 Sampling shall be statistically adequate to ensure that the specimens were obtained and produced by a process in statistical control. 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.) 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.

NOTE 3—Specimen type and preparation can influence the actual haze of the materials being tested.

## 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 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 40 h prior to test, in accordance with Procedure A of Practice D618. In case of disagreements, the tolerances shall be ±1°C (1.8°F) and ±5 % relative humidity.

6.2 *Test Conditions*—Set up the test apparatus in an atmosphere maintained at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % 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.[5,6]

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 4—It is important to verify whether the unobstructed-beam diameter and centering at the exit port are maintained, especially if the

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

[5] 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.

[6] 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.

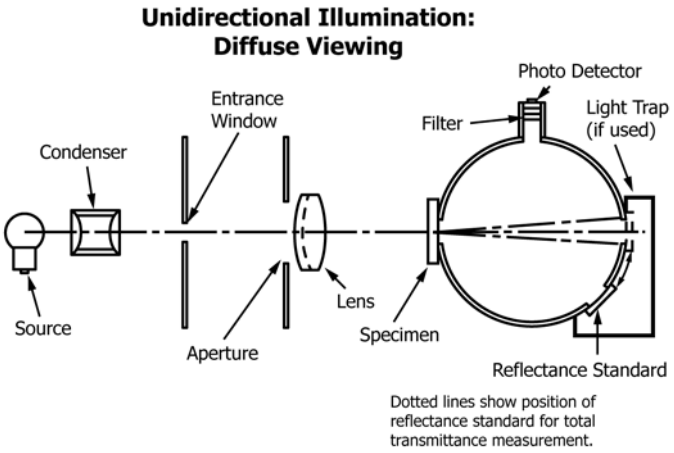


**FIG. 1 Schematic of Hazemeter**

source aperture and focus are changed.

NOTE 5—The tolerance stated on the annulus of 0.002 rad (0.1°) corresponds to an uncertainty of ±0.6 % in a haze reading.[7] 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.[8]

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;[5,7] however, these are not known to be commercially available. In their absence, wide-angle-plastic standards[9,6] may be used, but these are less sensitive to the size and centering of the annulus described by Billmeyer and Chen[4] and Weidner and Hsia,[8] and particular attention should be paid to Note 1 when only plastic haze standards are used.

7.2 *Procedure:*

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 |

**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 |

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*[10]:

7.3.1 Calculate total transmittance, $T_t$ (Note 6), equal to $T_2/T_1$.

7.3.2 Calculate diffuse transmittance, $T_d$ (Note 6), 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 6—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,

7.4.1.2 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*[11]:

7.5.1.1 Table 1 and Table 2 are based on a round robin conducted in 1985, in accordance with Practice E691, 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] Weidner, V. R., and Hsia, J. J., "NBS Reference Hazemeter: Its Development and Testing," *Applied Optics*, Vol 18, 1979, pp. 1619–1626.

[8] Highly reflective matte barium sulfate paint or pressed polytetrafluoroethylene powder are excellent for this purpose. See Practice E259.

[9] 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.

[10] See Appendix X1 for derivation of formulas.

[11] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1180.

**TABLE 2 Summary of 1985 Procedure A (Hazemeter) Luminous Transmittance Round Robin Involving Eleven Laboratories**

| Material | Average | *S(r)* | *S(R)* | *r* | *R* |
|---|---|---|---|---|---|
| 2 | 83.6 | 0.25 | 1.21 | 0.69 | 3.42 |
| 4 | 84.8 | 0.15 | 1.06 | 0.42 | 3.02 |
| 1 | 86.4 | 0.08 | 1.08 | 0.22 | 3.06 |
| 3 | 87.5 | 0.20 | 1.07 | 0.57 | 3.02 |
| 6 | 88.5 | 0.14 | 2.10 | 0.38 | 5.93 |
| 5 | 88.6 | 0.35 | 2.23 | 0.99 | 6.32 |

**TABLE 3 Summary of 1991 Procedure A (Hazemeter) Total Haze Round Robin Involving Six Laboratories**

| Material | Average | *S(r)* | *S(R)* | *r* | *R* |
|---|---|---|---|---|---|
| LDPE | | | | | |
| A | 0.58 | 0.031 | 0.133 | 0.086 | 0.372 |
| B | 1.89 | 0.029 | 0.216 | 0.080 | 0.604 |
| C | 2.08 | 0.021 | 0.200 | 0.058 | 0.568 |
| PET | | | | | |
| D | 2.69 | 0.042 | 0.313 | 0.117 | 0.075 |
| E | 5.74 | 0.031 | 0.395 | 0.086 | 1.106 |
| F | 8.06 | 0.049 | 0.566 | 0.137 | 1.584 |
| G | 12.68 | 0.050 | 0.490 | 0.140 | 1.372 |
| H | 28.57 | 0.091 | 1.042 | 0.256 | 2.9918 |

**TABLE 4 Summary of 1991 Procedure B (Spectrophotometer) Total Haze Round Robin Involving Seven Laboratories**

| Material | Average | $S(r)^A$ | $S(R)^B$ | $r^C$ | $R^D$ |
|---|---|---|---|---|---|
| LDPE | | | | | |
| A | 0.55 | 0.076 | 0.186 | 0.213 | 0.522 |
| B | 1.77 | 0.087 | 0.658 | 0.244 | 1.019 |
| C | 1.01 | 0.042 | 0.397 | 0.175 | 1.112 |
| PET | | | | | |
| D | 2.51 | 0.115 | 0.331 | 0.323 | 0.927 |
| E | 5.05 | 0.081 | 0.596 | 0.227 | 1.669 |
| F | 6.55 | 0.189 | 1.138 | 0.305 | 3.186 |
| G | 11.35 | 0.137 | 1.289 | 0.385 | 3.610 |
| H | 25.45 | 0.158 | 3.020 | 0.443 | 8.455 |

[A] $S_r$ is the within laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories:

$$S_r = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$$

[B] $S_R$ is the between laboratories reproducibility, expressed as standard deviation:

$$S_R = [s_r^2 + s_L^2]^{1/2}$$

where: $s_L$ = standard deviation of laboratory means.

[C] $r$ is the within-laboratory critical interval between two test results = 2.8 × $S_r$.
[D] $R$ is the between-laboratories critical interval between two test results = 2.8 × $S_R$.

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). (**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 method should apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 7.5.1.3 – 7.5.1.7 would then be valid for such data.)

7.5.1.3 For the purpose of compiling summary statistics, a test result has been defined to be the average of three replicate measurements of a property for a material in a laboratory, as specified in this test method. Summary statistics are given in Tables 1-3. In each table, for the material indicated, *S(r)* is the pooled within-laboratory standard deviation of a test result, *S(R)* is the between-laboratory standard deviation of a test result, $r = 2.83 \times S(r)$ (see 7.5.1.4), and $R = 2.83 \times S(R)$ (see 7.5.1.5).

7.5.1.4 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material. "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

7.5.1.5 *Reproducibility*—Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the "*R*" value for that material. "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

7.5.1.6 Judgments made as described in 7.5.1.3 and 7.5.1.4 will be correct in approximately 95 % of such comparisons.

7.5.1.7 For further information, see Practice E691.

7.5.2 *Bias*—Measurement biases cannot be determined since there are no accepted referee methods for determining these properties.

## 8. Procedure B (Spectrophotometer)

8.1 *Apparatus:*

8.1.1 The instruments used for measurement shall meet the geometric and spectral requirement of this section.

8.1.2 The instrument shall be capable of computing from the spectral data the 1931 CIE tristimulus values and related color coordinates for CIE standard Illuminant C or alternatively Illuminant A.

8.1.3 The instrument shall utilize a hemispherical optical measuring system, with an integrating sphere, in which the specimen can be placed flush against the sphere port. The surfaces of the interior of the integrating sphere, baffles, and reflectance standards shall be matte, of substantially equal reflectance and highly reflecting throughout the visible wavelengths.

8.1.4 Two geometries can be used: unidirectional illumination with diffuse viewing and diffuse illumination with unidirectional viewing. Using diffuse illumination with unidirectional viewing, the following apply:

8.1.4.1 Use an integrating sphere to illuminate the specimen diffusely; 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 specimen and light trap ports of the sphere shall be centered on the same great circle of the sphere, and there shall be at least 2.97 rad (170°) of arc between their centers. The light trap port shall subtend an angle of 0.14 rad (8°) at the center of the specimen port along the viewing beam. With the

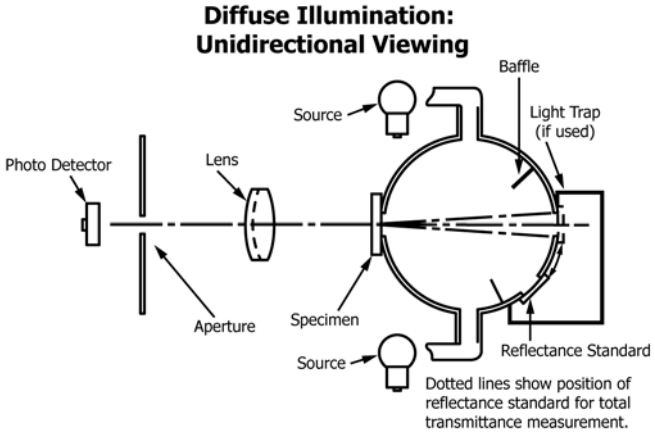


**FIG. 2 Spectrophotometer With Diffuse Illumination**

light trap in position, without specimen the axis of the viewing beam shall pass through the centers of the specimen and light trap ports.

8.1.4.2 View the specimen along an axis defined 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.

8.1.4.3 When the specimen is in place, the angle between the specimen normal and the line connecting the centers of the specimen and the light trap ports shall not exceed 0.14 rad (8°).

8.1.4.4 With no specimen in place, the viewed area at the exit port shall be approximately circular, sharply defined concentric within the light trap port, leaving an annulus of 0.023 ± 0.002 rad (1.3 ± 0.01°) subtended at the specimen port.

NOTE 7—Note 4 and Note 5 apply. It should be noted that it may be difficult, but is critical, to meet this requirement.

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

8.1.6 A schematic drawing of a spectrophotometer with unidirectional illumination and diffuse viewing is shown in Fig. 2.

NOTE 8—It is strongly recommended that conformance to the intent of this test method be confirmed through use of properly calibrated haze standards due to the difficulty of confirming conformance to this test method when using a drill spectrophotometer.

8.2 *Procedure*—Follow the manufacturer's instructions for the measurement of haze, and if none available, use Section 8.

8.3 *Calculation*—Most spectrophotometers are computer driven and values for luminous transmission and haze are automatically calculated. If values are not computed use calculation method in Section 9.

8.4 *Report:*

8.4.1 Report the following data:

8.4.1.1 Source and identity of specimen,

8.4.1.2 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.

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

8.4.1.4 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) when specifically requested, and

8.4.1.5 Diffuse luminous transmittance, $T_d$, to the nearest 0.1 % (indicate the average when reporting average values) when specifically requested.

8.5 *Precision and Bias*[11]:

8.5.1 *Precision:*

8.5.1.1 Precision data in Table 4 is based on a round robin conducted in 1991 involving eight materials and seven laboratories. For comparison purposes the same materials were measured on six regular hazemeters during the same round robin. The data from the regular hazemeter round robin is included in Table 3. (**Warning—**The following explanations of $r$ and $R$ (8.5.1.2 – 8.5.1.6) are intended to present only a meaningful way of considering the approximate precision of this test method. The data in Tables 1-4 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 method should apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 8.5.1.2 – 8.5.1.6 would then be valid for such data.)

8.5.1.2 For the purpose of compiling summary statistics, a test result has been defined to be the average of three replicate measurements of a property for a material in a laboratory, as specified in this test method. Summary statistics are given in Table 4. In each table, for the material indicated, $S(r)$ is the pooled within-laboratory standard deviation of a test result, $S(R)$ is the between-laboratory standard deviation of a test result, $r = 2.83 \times S(r)$ (see 8.5.1.3), and $R = 2.83 \times S(R)$ (see 8.5.1.4).

8.5.1.3 *Repeatability*—In comparing two mean values of the same material, obtained by the same operator using the same equipment on the same day, the means should be judged not equivalent if they differ by more than the $r$ value for that material.

8.5.1.4 *Reproducibility*—In comparing two mean values for the same material obtained by different operators using different equipment on different days, either in the same laboratory or in different laboratories, the means should be judged not equivalent if they differ by more than the $R$ value for that material.

8.5.1.5 Judgments made as described in 8.5.1.3 and 8.5.1.4 will be correct in approximately 95 % of such comparisons.

8.5.1.6 For further information, see Practice E691.

8.5.2 *Bias*—Measurement biases cannot be determined since there are no accepted referee methods for determining these properties.

## 9. Referee Procedure

9.1 In case of dispute, Procedure A—Hazemeter will be the referee procedure measured with a standard hazemeter.

## 10. Keywords

10.1 haze; luminous transmittance; regular transmittance; transparent plastics

# APPENDIXES

**(Nonmandatory Information)**

## X1. DERIVATION OF FORMULAS FOR HAZE

X1.1 The derivation of the formula for haze for both procedures is as follows:

X1.1.1 Total luminous transmittance, $T_t$, is calculated as follows:

$$T_t = T_2 / T_1 \quad \text{(X1.1)}$$

where:

$T_2$ = total light transmitted by the specimen, and
$T_1$ = incident light.

X1.1.2 If $T_3$, the light scattered by the instrument, is zero, the diffuse luminous transmittance,$T_d$, is calculated as follows:

$$T_d = T_4/T_1 \quad \text{(X1.2)}$$

where:

$T_4$ = light scattered by the instrument and specimen.

X1.1.3 If $T_3$ is greater than zero due to light scattered by the instrument, the total scattered light,$T_4$, will be greater than the light scattered by the specimen by an amount proportional to$T_3$ and equal to$T_3$ times$T_2/T_1$. The corrected amount of light scattered by the specimen will then be the following:

$$T_4 - T_3(T_2/T_1) \quad \text{(X1.3)}$$

X1.1.4 The diffuse luminous transmittance, $T_d$, is then calculated as follows:

$$T_d = [T_4 - T_3(T_2/T_1)]/T_1 \quad \text{(X1.4)}$$

X1.1.5 Percent haze is then calculated from the ratio of diffuse, $T_d$, to total luminous transmittance, $T_t$, as follows:

$$\text{haze, \%} = (T_d/T_t) \times 100 \quad \text{(X1.5)}$$

$$= [(T_4 - T_3 (T_2/T_1)] / T_1 \div (T_2/T_1)] \times 100$$

$$= [(T_4 - T_3 (T_2/T_1)]/T_2) \times 100$$

$$= [(T_4/T_2) - (T_3/T_1)] \times 100$$

## X2. ALTERNATIVE HAZE (SHORTCUT) PROCEDURE

X2.1 Many commercial hazemeters have indicating systems and a means of adjusting the light scattered by the instrument to zero and the total light transmitted by the specimen to 100. For these instruments, the following is a shortcut method that can be used for determining haze.

NOTE X2.1—This shortcut procedure may produce erroneous values for highly absorbing samples, or those measured in a stopped-down beam mode (as for Taber abrasion haze). With such samples, instrument stray light may not be properly accounted for. It is recommended that in such situations a comparison be made of the standard procedure and the shortcut procedure using typical samples. In case of any disagreement, the standard procedure shall be considered to produce the correct values.

X2.1.1 With the hazemeter set to measure total transmittance, adjust the instrument output to read 100.0.

X2.1.2 With the hazemeter set to measure light scattered by the instrument, adjust the instrument output to read 0.0.

X2.1.3 With the hazemeter set to measure total transmittance, place the test specimen against the entrance port of the integrating sphere.

X2.1.4 Adjust the instrument output to read 100.0.

X2.1.5 Set the instrument to measure light scattered by the specimen and record the reading as percent haze.

## SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D1003 - 11$^{\varepsilon 1}$) that may impact the use of this standard. (November 15, 2013)

*(1)* Added Note 3.

*(2)* Renumbered subsequent notes.