



## Standard Test Method for Specular Gloss<sup>1</sup>

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This standard is issued under the fixed designation D 523; 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 approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

### 1. Scope

1.1 This test method covers the measurement of the specular gloss of nonmetallic specimens for glossmeter geometries of 60, 20, and 85° (1-7).<sup>2</sup>

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

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.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels<sup>3</sup>

D 3964 Practice for Selection of Coating Specimens for Appearance Measurements<sup>3</sup>

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials<sup>4</sup>

D 4039 Test Method for Reflection Haze of High-Gloss Surfaces<sup>3</sup>

E 97 Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry<sup>5</sup>

E 430 Test Method for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry<sup>3</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *relative luminous reflectance factor*—the ratio of the luminous flux reflected from a specimen to the luminous flux reflected from a standard surface under the same geometric conditions. For the purpose of measuring specular gloss, the

standard surface is polished glass.

3.1.2 *specular gloss*—the relative luminous reflectance factor of a specimen in the mirror direction.

### 4. Summary of Test Method

4.1 Measurements are made with 60, 20, or 85° geometry (8, 9). The geometry of angles and apertures is chosen so that these procedures may be used as follows:

4.1.1 The 60° geometry is used for intercomparing most specimens and for determining when the 20° geometry may be more applicable.

4.1.2 The 20° geometry is advantageous for comparing specimens having 60° gloss values higher than 70.

4.1.3 The 85° geometry is used for comparing specimens for sheen or near-grazing shininess. It is most frequently applied when specimens have 60° gloss values lower than 10.

### 5. Significance and Use

5.1 Gloss is associated with the capacity of a surface to reflect more light in some directions than in others. The directions associated with mirror (or specular) reflection normally have the highest reflectances. Measurements by this test method correlate with visual observations of surface shininess made at roughly the corresponding angles.

5.1.1 Measured gloss ratings by this test method are obtained by comparing the specular reflectance from the specimen to that from a black glass standard. Since specular reflectance depends also on the surface refractive index of the specimen, the measured gloss ratings change as the surface refractive index changes. In obtaining the visual gloss ratings, however, it is customary to compare the specular reflectances of two specimens having similar surface refractive indices. Since the instrumental ratings are affected more than the visual ratings by changes in surface refractive index, non-agreement between visual and instrumental gloss ratings can occur when high gloss specimen surfaces differing in refractive index are compared.

5.2 Other visual aspects of surface appearance, such as distinctness of reflected images, reflection haze, and texture, are frequently involved in the assessment of gloss (1), (6), (7). Test Method E 430 includes techniques for the measurement of both distinctness-of-image gloss and reflection haze. Test Method D 4039 provides an alternative procedure for measuring reflection haze.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.26 on Optical Properties.

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<sup>2</sup> The boldface numbers in parentheses refer to the list of references at the end of this test method.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>4</sup> Discontinued; see *1997 Annual Book of ASTM Standards*, Vol 06.01

<sup>5</sup> Discontinued; see *1992 Annual Book of ASTM Standards*, Vol 14.02.

5.3 Little information about the relation of numerical-to-perceptual intervals of specular gloss has been published. However, in many applications the gloss scales of this test method have provided discriminations between coated specimens that have agreed well with visual discriminations of gloss (10).

5.4 When specimens differing widely in perceived gloss or color, or both, are compared, nonlinearity may be encountered in the relationship between visual gloss difference ratings and instrumental gloss reading differences.

## 6. Apparatus

6.1 *Instrumental Components*—The apparatus shall consist of an incandescent light source furnishing an incident beam, means for locating the surface of the specimen, and a receptor located to receive the required pyramid of rays reflected by the specimen. The receptor shall be a photosensitive device responding to visible radiation.

**TABLE 1 Angles and Relative Dimensions of Source Image and Receptors**

	In Plane of Measurement			Perpendicular to Plane of Measurement		
	$\theta, ^\circ$	$2 \tan \theta/2$	Relative Dimension	$\theta, ^\circ$	$2 \tan \theta/2$	Relative Dimension
Source image	0.75	0.0131	0.171	2.5	0.0436	0.568
Tolerance $\pm$	0.25	0.0044	0.057	0.5	0.0087	0.114
60° receptor	4.4	0.0768	1.000	11.7	0.2049	2.668
Tolerance $\pm$	0.1	0.0018	0.023	0.2	0.0035	0.046
20° receptor	1.8	0.0314	0.409	3.6	0.0629	0.819
Tolerance $\pm$	0.05	0.0009	0.012	0.1	0.0018	0.023
85° receptor	4.0	0.0698	0.909	6.0	0.1048	1.365
Tolerance $\pm$	0.3	0.0052	0.068	0.3	0.0052	0.068

6.2 *Geometric Conditions*—The axis of the incident beam shall be at one of the specified angles from the perpendicular to the specimen surface. The axis of the receptor shall be at the mirror reflection of the axis of the incident beam. The axis of the incident beam and the axis of the receptor shall be within  $0.1^\circ$  of the nominal value indicated by the geometry. With a flat piece of polished black glass or other front-surface mirror in the specimen position, an image of the source shall be formed

at the center of the receptor field stop (receptor window). The length of the illuminated area of the specimen shall be not more than one third of the distance from the center of this area to the receptor field stop. The dimensions and tolerance of the source and receptor shall be as indicated in Table 1. The angular dimensions of the receptor field stop are measured from the receptor lens in a collimated-beam-type instrument, as illustrated in Fig. 1, and from the test surface in a converging-beam-type instrument, as illustrated in Fig. 2. See Fig. 1 and Fig. 2 for a generalized illustration of the dimensions. The tolerances are chosen so that errors in the source and receptor apertures do not produce an error of more than one gloss unit at any point on the scale (5).

6.2.1 The important geometric dimensions of any specular-gloss measurement are:

6.2.1.1 Beam axis angle(s), usually  $60, 20,$  or  $85^\circ$ .

6.2.1.2 Accepted angular divergences from principal rays (degree of spreading or diffusion of the reflected beam).

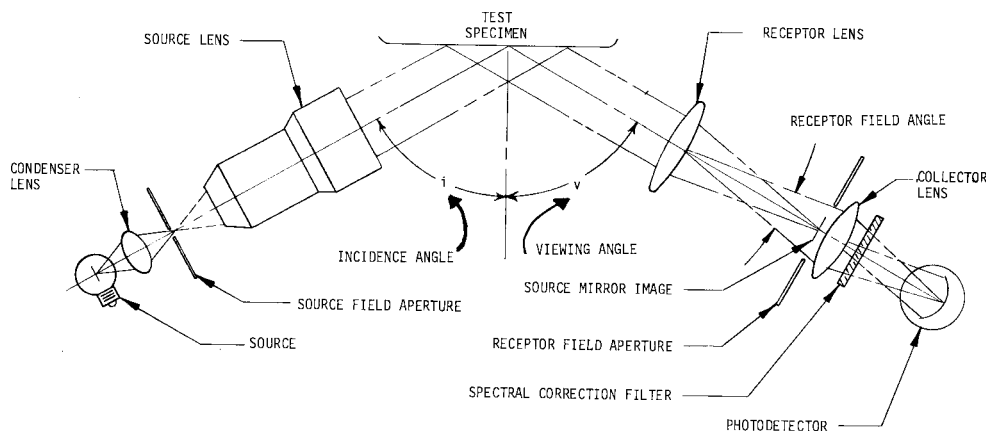
NOTE 1—The parallel-beam glossmeters possess the better uniformity of principle-ray angle of reflection, but the converging-beam glossmeters possess the better uniformity in extent of angular divergence accepted for measurement.

NOTE 2—*Polarization*—An evaluation of the impact of polarization on gloss measurement has been reported (11). The magnitude of the polarization error depends on the difference between the refractive indices of specimen and standard, the angle of incidence, and the degree of polarization. Because the specimen and standard are generally quite similar optically, measured gloss values are little affected by polarization.

6.3 *Vignetting*—There shall be no vignetting of rays that lie within the field angles specified in Table 1.

6.4 *Spectral Conditions*—Results should not differ significantly from those obtained with a source-filter photocell combination that is spectrally corrected to yield CIE luminous efficiency with CIE source C. Since specular reflection is, in general, spectrally nonselective, spectral corrections need to be applied only to highly chromatic, low-gloss specimens upon agreement of users of this test method.

6.5 *Measurement Mechanism*—The receptor-measurement mechanism shall give a numerical indication that is proportional to the light flux passing the receptor field stop with  $\pm 1\%$  of full-scale reading.



**FIG. 1 Diagram of Parallel-Beam Glossmeter Showing Apertures and Source Mirror-Image Position**

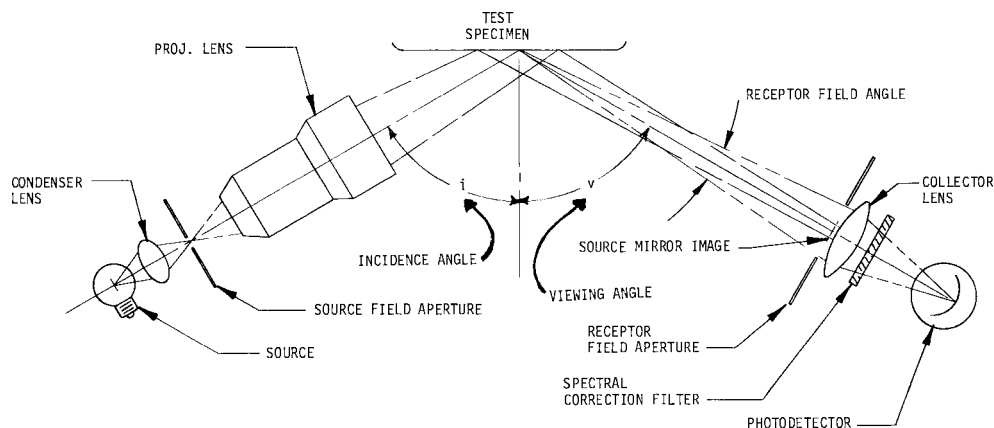


FIG. 2 Diagram of Converging-Beam Glossmeter Showing Apertures and Source Mirror-Image Position

## 7. Reference Standards

7.1 *Primary Standards*—Highly polished, plane, black glass with a refractive index of 1.567 for the sodium D line shall be assigned a specular gloss value of 100 for each geometry. The gloss value for glass of any other refractive index can be computed from the Fresnel equation (5). For small differences in refractive index, however, the gloss value is a linear function of index, but the rate of change of gloss with index is different for each geometry. Each 0.001 increment in refractive index produces a change of 0.27, 0.16, and 0.016 in the gloss value assigned to a polished standard for the 20, 60, and 85° geometries, respectively. For example, glass of index 1.527 would be assigned values of 89.2, 93.6, and 99.4, in order of increasing geometry.

NOTE 3—Polished black glass has been reported to change in refractive index with time largely due to chemical contamination (10). The original values can be restored by optical polishing with cerium oxide. A wedge of high-purity quartz provides a more stable reference standard than glass.

7.2 *Working Standards*—Ceramic tile, depolished ground opaque glass, emery paper, and other semigloss materials having hard and uniform surfaces are suitable when calibrated against a primary standard on a glossmeter known to meet the requirements of this test method. Such standards should be checked periodically for constancy by comparing with primary standards.

7.3 Store standards in a closed container when not in use. Keep them clean and away from any dirt that might scratch or mar their surfaces. *Never* place standards face down on a surface that may be dirty or abrasive. Always hold standards at the side edges to avoid getting oil from the skin on the standard surface. Clean the standards in warm water and a mild detergent solution brushing gently with a soft nylon brush. (Do not use soap solutions to clean standards, because they can leave a film.) Rinse standards in hot running water (temperature near 150°F (65°C)) to remove detergent solution, followed by a final rinse in distilled water. *Do not wipe standards.* The polished black glass high-gloss standard may be dabbed gently with a lint-free paper towel or other lint-free absorbent material. Place the rinsed standards in a warm oven to dry.

## 8. Preparation and Selection of Test Specimens

8.1 This test method does not cover preparation techniques. Whenever a test for gloss requires the preparation of test

specimens, use the procedures given in Practice D 823.

NOTE 4—To determine the maximum gloss obtainable from a test material, such as a paint or varnish, use Methods B or C of Practice D 823.

8.2 Select specimens in accordance with Practice D 3964.

## 9. Instrument Calibration

9.1 Operate the glossmeter in accordance with the manufacturer's instructions.

9.2 Verify the instrument zero by placing a black cavity in the specified position. If the reading is not within  $\pm 0.1$  of zero, subtract it algebraically from subsequent readings or adjust the instrument to read zero.

9.3 Calibrate the instrument at the start and completion of every period of glossmeter operation, and during the operation at sufficiently frequent intervals to assure that the instrument response is practically constant. To calibrate, adjust the instrument to read correctly the gloss of a highly polished standard, properly positioned and oriented, and then read the gloss of a working standard in the mid-gloss range. If the instrument reading for the second standard does not agree within one unit of its assigned values, check cleanliness and repeat. If the instrument reading for the second standard still does not agree within one unit of its assigned value, repeat with another mid-range standard. If the disparity is still more than one unit, do not use the instrument without readjustment, preferably by the manufacturer.

## 10. Procedure

10.1 Position each specimen in turn beneath (or on) the glossmeter. For specimens with brush marks or similar texture effects, place them in such a way that the directions of the marks are parallel to the plane of the axes of the incident and reflected beams.

10.2 Take at least three readings on a 3 by 6-in. (75 by 150-mm) area of the test specimen. If the range is greater than two gloss units, take additional readings and calculate the mean after discarding divergent results as in the section on Test for Outliers of Practice D 3980. For larger specimens, take a proportionately greater number of readings.

## 11. Diffuse Correction

11.1 Apply diffuse corrections only upon agreement between the producer and the user. To apply the correction,

subtract it from the glossmeter reading. To measure the correction, illuminate the specimen perpendicularly and view at the incident angle with the receiver aperture specified in 6.2 for the corresponding geometry. To compute the correction, multiply the 45°, 0° directional reflectance of the specimen, determined in accordance with Test Method E 97, by the effective fraction of the luminous flux reflected by the perfect diffuse reflector and accepted by the receiver aperture. The luminous flux entering the receiver aperture from the perfect white diffusor would give the following gloss indications for each of the geometries:

Geometry, °	Gloss of Perfect White Diffuser
60	2.5
20	1.2
85	0.03

## 12. Report

12.1 Report the information following:

12.1.1 Mean specular gloss readings and the geometry used.

12.1.2 If uniformity of surface is of interest, the presence of any specimen that exhibits gloss readings varying by more than 5 % from their mean.

12.1.3 Where preparation of the test specimen has been necessary, a description or identification of the method of preparation.

12.1.4 Manufacturer's name and model designation of the glossmeter.

12.1.5 Working standard or standards of gloss used.

## 13. Precision

13.1 On the basis of studies of this test method by several laboratories in which single determinations were made on different days on several ceramic tiles and painted panels differing in visually perceived gloss, the pooled within-laboratory and between-laboratories standard deviations were found to be those shown in Table 2. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

13.1.1 *Repeatability*—Two results, each of which are single determinations obtained on the same specimen by the same operator, should be considered suspect if they differ by more

TABLE 2 Standard Deviation of Gloss Determinations

Type of Gloss, °	No. of Ceramic Tiles	Degrees of Freedom		Standard Deviations	
		Within-Laboratory	Between-Laboratories	Within-Laboratory <sup>A</sup>	Between-Laboratories <sup>B</sup>
20	4	40	34	0.4	1.2
60	4	40	34	0.3	1.2
85	2	16	6	0.2	0.6

Type of Gloss, °	No. of Painted Panels	Degrees of Freedom		Standard Deviations	
		Within-Laboratory	Between-Laboratories	Within-Laboratory <sup>A</sup>	Between-Laboratories <sup>B</sup>
20	8	80	72	0.6	2.2
60	22	220	136	0.3	1.2
85	6	48	18	0.3	2.4

<sup>A</sup>Single determinations.

<sup>B</sup>For means of three determinations.

than the maximum acceptable differences given in Table 3.

TABLE 3 Maximum Acceptable Differences for Two Results

Type of Gloss, °	Repeatability (Within Laboratories) <sup>A</sup>		Reproducibility (Between Laboratories) <sup>B</sup>	
	Ceramic Tiles	Painted Panels	Ceramic Tiles	Painted Panels
20	1.1	1.7	3.5	6.4
60	0.9	0.9	3.4	3.5
85	0.6	0.8	2.0	7.2

<sup>A</sup>Single determinations.

<sup>B</sup>For means of three determinations.

13.1.2 *Reproducibility*—Two results, each the mean of three determinations, obtained on the same specimen by different laboratories should be considered suspect if they differ by more than the maximum acceptable differences given in Table 3. This does not include variability due to preparation of panels in different laboratories.

NOTE 5—For some types of paint, particularly semi-gloss, the measured gloss is affected by method of film preparation and drying conditions so that the reproducibility of results from such materials may be poorer than the values given in Table 3.

## 14. Keywords

14.1 appearance; directional reflectance factor; gloss; gonio-photometry; high gloss; relative luminous reflectance factor; specular gloss

## REFERENCES

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- (2) Hunter, R. S., and Judd, D. B., "Development of a Method of Classifying Paint According to Gloss," *ASTM Bulletin*, No. 97, March 1939, p. 11. A comparison is made of several geometrically different photometric scales for separating paint finishes for gloss. The geometric conditions of test later incorporated in Test Method D 523 are recommended.
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New York, 1975, Chapter 6, "Scales for Gloss and Other Geometric Attributes," and Chapter 13, "Instruments for the Geometric Attributes of Object Appearance."

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(Hunter), evaluation of low-gloss finishes with 85° sheen measurements (Schreckendgust), and gloss standards and glossmeter standardization (Hammond).

- (10) Billmeyer, F. W., Jr., O'Donnell, F. X. D., "Visual Gloss Scaling and Multidimensional Scaling Analysis of Painted Specimens," *Color Research and Application*, Vol 12, 1987, pp 315–326. Compares visual difference ratings with instrumental measurements of specular gloss, distinctness of image gloss, and haze for series of black, gray, and white painted specimens. The data are analyzed by multidimensional scaling.
- (11) Budde, W., "Stability Problems in Gloss Measurements," *Journal of Coatings Technology*, Vol 52, June 1980, pp. 44–48.

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