



Standard Test Methods for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry¹

This standard is issued under the fixed designation E 430; 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.

1. Scope

1.1 These test methods cover the measurement of the reflection characteristics responsible for the glossy appearance of high-gloss surfaces. Two test methods, A and B, are provided for evaluating such surface characteristics at specular angles of 30° and 20°, respectively. These test methods are not suitable for diffuse finish surfaces nor do they measure color, another appearance attribute.

1.2 As originally developed by Tingle and others (see Refs 1 and 2),² the test methods were applied only to bright metals. Recently they have been applied to high-gloss automotive finishes and other nonmetallic surfaces.

2. Referenced Documents

2.1 ASTM Standards:

D 523 Test Method for Specular Gloss³

D 2457 Test Method for Specular Gloss of Plastic Films and Solid Plastics⁴

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials⁵

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflectance and Transmission Properties of Materials³

E 284 Terminology of Appearance³

E 308 Practice for Computing the Colors of Objects by Using the CIE System³

E 1347 Test Method for Color and Color-Difference Measurement of Object-Color Specimens by Tristimulus (Filler) Colorimetry³

3. Terminology

3.1 Definitions:

3.1.1 Reflectance and Related Terms:

3.1.1.1 *reflectance*, ρ , n —ratio of the reflected radiant or luminous flux to the incident flux in the given conditions. (E 284)

¹ These test methods are under the jurisdiction of ASTM Committee E-12 on Appearance and are the direct responsibility of Subcommittee E 12.03 on Geometry. Current edition approved July 10, 1997. Published September 1997. Originally published as E 430 – 71. Last previous edition E 430 – 91.

² The boldface numbers in parentheses refer to the list of references at the end of this method.

³ *Annual Book of ASTM Standards*, Vol 06.01.

⁴ *Annual Book of ASTM Standards*, Vol 08.02.

⁵ *Annual Book of ASTM Standards*, Vol 15.09.

(1) *Discussion*—The term *reflectance* is often used in a general sense or as an abbreviation for *reflectance factor*. Such usage is not assumed in this method. The definition may require that the term be modified by adjectives denoting the spectral and geometric conditions of measurement.

3.1.1.2 *reflectance factor*, R , n —ratio of the flux reflected from the specimen to the flux reflected from the perfect reflecting diffuser under the same spectral and geometric conditions of measurement. (E 284)

3.1.1.3 *gloss reflectance factor*, R_s , n —ratio of the specularly reflected part of the (whole) flux reflected from the specimen to the flux reflected from a specified gloss standard under the same geometric and spectral conditions of measurement.

(1) *Discussion*—The gloss standard may be a black glass or a mirror, and may be assigned one of a variety of scale values G_s as specified. (E 284)

3.1.2 Gloss and Types of Gloss:

3.1.2.1 *gloss*, n —angular selectivity of reflected light, responsible for the degree to which reflected highlights or images of objects may be seen as superimposed on a surface. (E 284)

(1) *Discussion*—Gloss is responsible for the object's glossy appearance, not for an observer's perception of the appearance. At least six types or characteristics of gloss may be observed depending upon the character of the surface and the spatial distribution of the reflected light (3).

3.1.2.2 *specular gloss*, n —ratio of flux reflected in specular direction to incident flux for a specified angle of incidence and source and receptor angular apertures. (E 284)

3.1.2.3 *distinctness-of-image gloss*, n —aspect of gloss characterized by the sharpness of images of objects produced by reflection at a surface. (E 284)

3.1.2.4 *sheen*, n —the specular gloss at a large angle of incidence for an otherwise matte specimen. (The usual angle for measurement is 85°.) (E 284)

3.1.3 Terms Relating to Surface Characteristics:

3.1.3.1 *directionality*, n —perceived, the degree to which the appearance of a surface changes as the surface is rotated in its own plane, under fixed conditions of illumination and viewing. (E 284)

3.1.3.2 *texture*, n —the visible surface structure depending on the size and organization of small constituent parts of a material; typically, the surface structure of a woven fabric. (E 284)

3.1.4 Other Terms:

3.1.4.1 *aperture angle, 2_{κ} , n* —angle subtended at a point on a specimen by the maximum dimension of the illuminator or receiver, within which the flux in a directional beam is contained.

(1) *Discussion*—In optics, the symbol κ is used for the half angle; hence the recommended symbol here is 2_{κ} . (E 284)

3.1.4.2 *goniophotometer, n* —instrument that measures flux as a function of angles of illumination or observation. (E 284)

3.2 Terms Specific to This Test Method:

3.2.1 Terms Relating to Reflection Haze:

3.2.1.1 *reflection haze, H , n* —for a specified specular angle, ratio of flux reflected at a specified angle (or angles) from the specular direction to the flux similarly reflected at the specular angle by a specified gloss standard.

(1) *Discussion*—Modifiers may be used to specify the angles at which the haze is measured (for example, 2° or 5°); whether H or a logarithmic form is to be stated; or whether H is to be compensated for the luminance of the specimen by multiplication by Y_{specimen}/Y_n , where n denotes the reference white; or any combination of these.

3.2.2 Terms Relating to Metallic Reflection:

3.2.2.1 *metallic brightness, n* —freedom of a metal surface from diffuse haze or texture.

3.2.3 Terms Relating to Specimen Directionality:

3.2.3.1 *'with-machine' direction, n* —the axis of a specimen that is parallel to the direction of mill rolling or extrusion, or other surface-finish texture.

3.2.3.2 *'across-machine' direction, n* —the perpendicular to 'with-machine' direction.

3.3 Other appearance terms and definitions in Terminology E 284 are applicable to this test method.

4. Summary of Test Method

4.1 Several geometrically different measures of light reflected by a surface are proposed for use in describing its gloss appearance. In Test Method A, gloss reflectance factor is measured at 30° to the specimen normal using narrow illuminator and receiver aperture angles (0.5° wide maximum). Distinctness-of-image gloss is measured at 29.7 or 30.3° or both. Narrow-angle (2°) reflection haze is measured at 28 or 32° or both, and wide-angle (5°) reflection haze at 25 or 35° or both. The ratio of reflectance factors for 28 or 32° or both, perpendicular and parallel to the machine direction of the specimen, is computed as a measure of directionality. In Method B, specular gloss is measured at 20° according to Test Method D 523, and narrow-angle reflection haze is measured at 18.1 and 21.9° . For additional information on the selection of geometric conditions, see Guide E 179.

5. Significance and Use

5.1 The gloss of metallic finishes is important commercially on metals for automotive, architectural, and other uses where these metals undergo special finishing processes to produce the appearances desired. It is important for the end-products which use such finished metals that parts placed together have the same glossy appearance.

5.2 It is also important that automotive finishes and other high-gloss nonmetallic surfaces possess the desired finished

appearance. The present method identifies by measurements important aspects of finishes. Those having identical sets of numbers normally have the same gloss characteristics. It usually requires more than one measurement to identify properly the glossy appearance of any finish (see Refs 3 and 4).

6. Apparatus

6.1 The apparatus shall be either an abridged goniophotometer (see Fig. 1 and Fig. 2) or a full goniophotometer (see Fig. 3) that can be set to the specified specular, off-specular, and aperture angles given in Table 1 and Table 2. The abridged goniophotometer may have a fixed angle of incidence (for Test Method A, 30° ; for Test Method B, 20°) and specific fixed directions of view at which the flux from the specimen is measured (see Table 1 and Table 2).⁶

6.1.1 *Geometric Conditions for Test Method A*—The direction of incidence shall be 30° . The directions of view shall be opposite the direction of incidence at 30° for specular reflectance, 29.7 or 30.3° for distinctness of image comparisons, 28 or 32° for narrow-angle haze comparisons, and 25 or 35° for wide-angle haze comparisons. The angular dimensions of the mirror reflected image of the source slit in the plane of measurement and the angular dimensions of the receiver windows in this plane of measurement shall be as shown in Table 1.

6.1.2 *Geometric Conditions for Test Method B*—The direction of incidence shall be $20 \pm 0.1^{\circ}$. The directions of view shall be opposite the direction of incidence, at 20° for specular gloss measurement and at 18.1 and 21.9° for narrow-angle reflection haze measurement. The angular dimensions of the specularly reflected image of the source slit in the plane of measurement and the angular dimensions of the receiver windows in this plane of measurement shall be as shown in Table 2.

6.1.3 *Spectral Conditions*—The measurement shall be made with visible light to give results in accordance with the CIE spectral luminous efficiency function $V(\lambda)$ identical with \bar{y} in the CIE 1931 standard observer and CIE standard illuminant C (see Practice E 308 and Test Method E 1347). If another illuminant A, is used, this shall be specified in the report.

6.1.4 *Polarization*—The incident flux shall be unpolarized and the receiver shall be insensitive to the state of polarization of the reflected luminous flux.

6.1.5 *Clamp*—For Test Method A, a rotatable clamp of the type shown in Fig. 4 may be used for flattening and positioning the specimen during measurement.

7. Standards

7.1 Three calibrated standards of good planarity shall be available in either a set of metals or a set of nonmetals, depending upon which type of surface is measured.

7.2 High-Gloss Standards:

⁶ The sole source of supply of the apparatus known to the committee at this time for Method A is Hunter Associates Laboratory, Reston, VA, and for Method B is BVK-Gardner USA, Columbia, MD. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

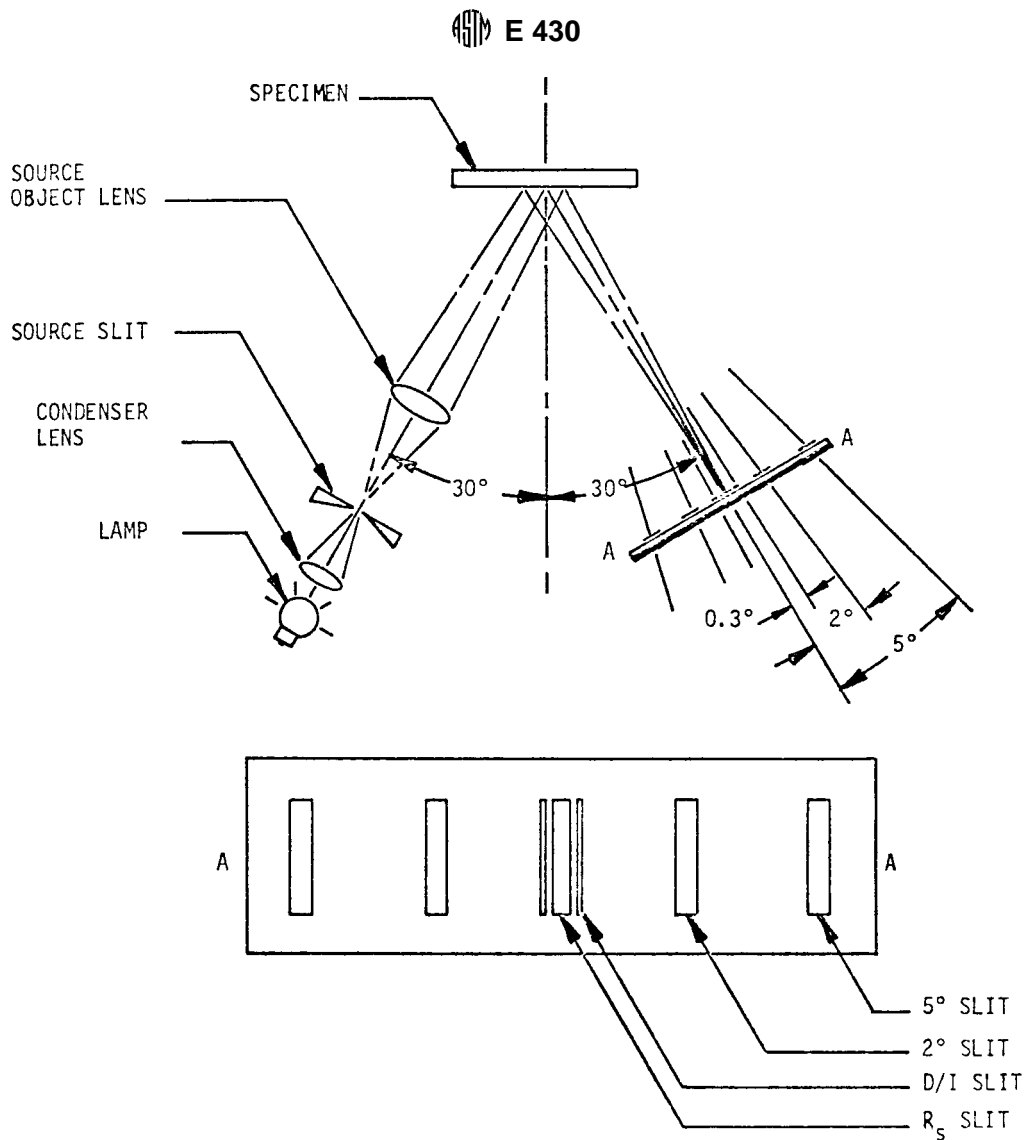


FIG. 1 Optical Diagram of the Abridged Goniophotometer

7.2.1 *High-Gloss Standard for Metals* shall be of aluminum, evaporated onto glass and covered with a protective coating of silicon monoxide, and calibrated for specular gloss and distinctness-of-image gloss.

7.2.2 *High-Gloss Standard for Nonmetals* shall be of highly polished black glass with a refractive index of approximately $n_D = 1.527$, calibrated for specular gloss and reflection haze, and assigned a scale value of $G_s = 89.4$ for a specular angle of 30° (Test Method A) or $G_s = 89.2$ for a specular angle of 20° (Test Method B).

NOTE 1—To determine the scale value, calculate the first-surface (Fresnel) reflectance (Test Method D 2457, Section 5.1) for $n_D = 1.567$ and the specular angle of interest; for 30° it is 5.0436 % and for 20° it is 4.9078 %. Assign this a scale value of 100 (Test Method D 523, Section 7.1). Repeat the calculation for $n_p = 1.527$ and the same specular angle; the result for 30° is 4.5069 % and for 20° , 4.3769 %. The new scale value for 30° is $100 \times (4.5069/5.0436) = 89.4$, and for 20° , $100 \times (4.3769/4.9078) = 89.2$. (The latter value is also given in Test Method D 523.)

7.3 Intermediate Standards:

7.3.1 *Intermediate Standard for Metals* shall be of either chromium evaporated onto glass and covered with a protective coating of silicon monoxide, or of bright sheet aluminum with

protective coating and calibrated for specular gloss and distinctness-of-image gloss.

7.3.2 *Intermediate Standard for Nonmetals* shall be of a ceramic material, such as porcelain enamel on steel, and calibrated for specular gloss and distinctness-of-image gloss.

7.4 *Diffuse Standards* shall have a reflectance factor substantially constant over the angular range of the instrument.

7.5 *Care of Standards*—It is essential that the standards be kept clean and free of scratches as well as from contact with contaminating materials. The cleaning method specified by the instrument manufacturer shall be followed and the standards should be checked at regular intervals against reference standards held in reserve.

8. Specimens

8.1 Specimens shall be obtained from test samples by selecting areas that are plane and representative of each sample being tested. Every specimen must be at least $2\frac{3}{4}$ in. (70 mm) in the smallest dimension. Specimens may be larger so long as it is possible to insert them and flatten them properly for measurement.

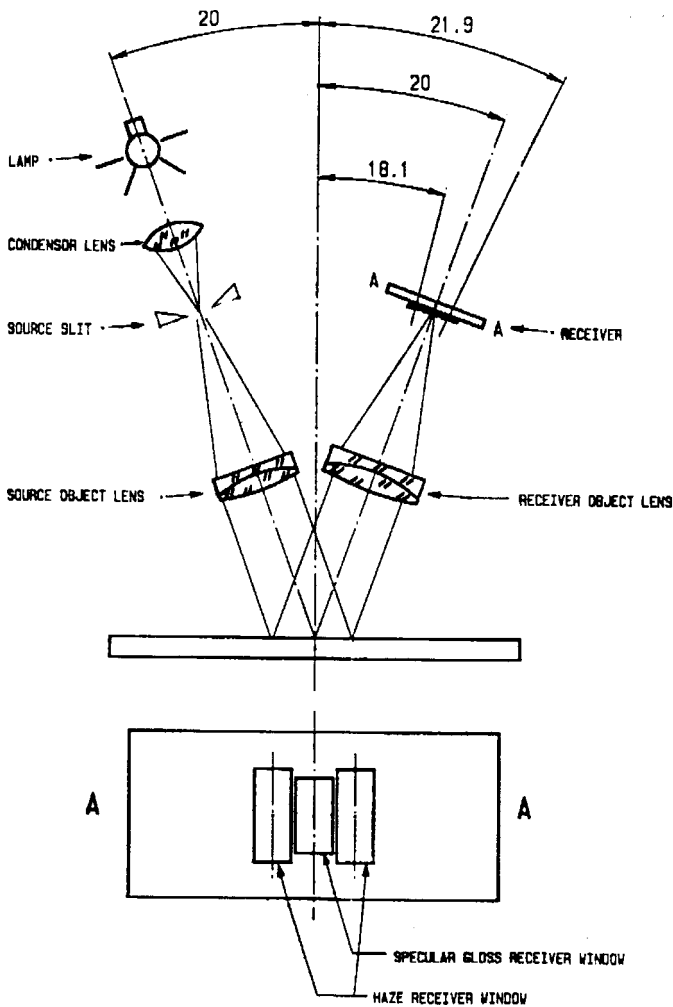


FIG. 2 Optical Diagram of the Apparatus for Method B

9. Preparation and Standardization of Apparatus

9.1 The instrument must be used in a clean dry area free of drafts. Standard laboratory conditions are recommended (see Section 2 of Specification E 171). Voltage regulation to $\pm 0.01\%$ must be incorporated in the instrument, or supplied separately. Follow manufacturer’s recommendations for instrument warmup.

9.2 *Standardization*—Adjust the instrument to read the same gloss reflectance factor for the intensity of light reflected from the diffuse standard through the specular, distinctness-of-image, and haze apertures. Adjust the instrument to read values of specular gloss and distinctness-of-image gloss assigned the aluminum mirror if metal surfaces are being measured; or the black gloss standard if nonmetal surfaces are being measured. If the instrument does not then read the appropriate intermediate standard within the limits set by the instrument manufacturer, refocus or restandardize following the manufacturer’s instructions.

10. Procedure

10.1 Bring the specimen to the instrument for measurement. Be sure the specimen is flat.

10.2 For Test Method A, be certain that the specular sensor is centered on the specimen-reflected specular light beam. The

full goniophotometer, shown in Fig. 3, identifies the specular direction by the peak of the goniophotometric curve.

10.3 Rotate the specimen in its own plane to find the orientation, giving the maximum specular signal. This specimen orientation is called the “machine direction” because it generally coincides with the direction of travel of a sheet or film material through a processing machine.

10.4 Record the following quantities:

10.4.1 For Test Method A, readings of (a) gloss reflectance factor (specular gloss), $R_{s,30}$ at 30° ; (b) distinctness-of-image gloss; (c) 2° reflection haze, H_2 ; and (d) 5° reflection haze, H_5 . The quantities in (b), (c), and (d) may be either gloss reflectance factors or values of H , which are their ratios to the specular gloss reflectance factor recorded in (a).

10.4.2 For Test Method B, readings of (a) the 20° specular gloss, $R_{s,20}$; (b) the reflection haze, H ; and (c) the luminous reflectance, Y .

10.5 Measure at least three areas of each specimen.

10.6 From these same areas, read 2° haze for the “across-machine direction,” being careful to flatten the test surface and orient the specular beam in each case.

10.7 Take readings on the standards at the end of the series of observations to ensure that the instrument has remained in calibration throughout the operation.

11. Calculation

11.1 For Test Method A, calculate the mean of three readings for each specimen for:

- 11.1.1 Specular gloss, $R_{s,30}$, at 30° .
- 11.1.2 Distinctness-of-image gloss, $100 \times (1 - H_{0.3})$, evaluated at 0.3° on either or both sides of the specular angle.
- 11.1.3 2° Reflection haze, $100 H_2$, evaluated at 2° on either or both sides of the specular angle.
- 11.1.4 5° Reflection haze, $100 H_5$, evaluated at 5° on either or both sides of the specular angle.
- 11.1.5 Directionality, $100 \times (H_{2, \text{across-machine}} / H_{2, \text{with-machine}})$, evaluated at 2° on either or both sides of the specular angle.

11.2 For Test Method B, calculate the mean of three readings of each specimen for:

- 11.2.1 Specular gloss, $R_{s,20}$ at 20° .
- 11.2.2 One or more of the following, as required:
 - 11.2.2.1 Reflection haze, H_{20} .
 - 11.2.2.2 Logarithmic reflection haze, $H_{20, \log} = 1285 \log[(H_{20}/20) + 1]$.
 - 11.2.2.3 Compensated reflection haze, $H_{20, \text{comp}} = H_{20, \text{specimen}} - (H_{20, n} \times Y_{\text{specimen}}/Y_n)$.

NOTE 2— $H_{20, \log}$ may also be calculated as a compensated quantity by using $H_{20, \text{comp}}$ in place of H_{20} in 11.2.2.2. Compensated quantities shall be used when comparing specimens with different values of Y .

12. Report

12.1 The report for Test Method A shall contain the following:

- 12.1.1 The specular gloss $R_{s,30}$,
- 12.1.2 The distinctness-of-image gloss,
- 12.1.3 The 2° haze, H_2 ,
- 12.1.4 The 5° reflection haze, H_5 ,
- 12.1.5 The directionality.

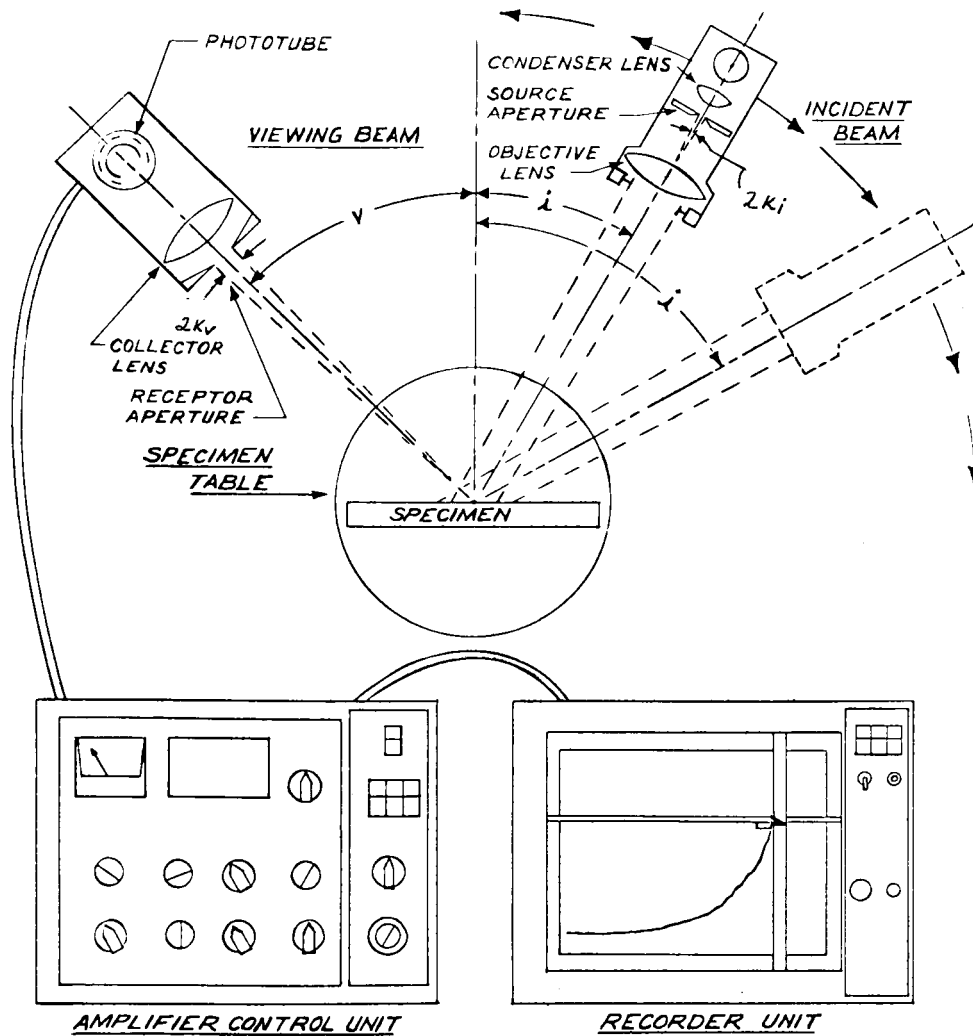


FIG. 3 Recording Goniophotometer Showing Viewing Angle, v , Incidence Angle, i , and Their Respective Field Angles, $2K_v$, and $2K_i$

TABLE 1 Dimensions of the Mirror Image of the Source-Slit, and of the Receptor Windows Measured in the Plane of the Receiving Windows (see Fig. 1)

	Source-Slit Mirror Image, °	Specular Receiver Window, °	Distinctness-of-Image (± 0.29) Receiver Window, °	Haze Receiver Windows, °
Angle of center of window (measured from perpendicular to specimen surface)	30	30	30.3 and 29.7	28 and 32 or 25 and 35
Width (in the plane of the angle of reflection)	0.44 ± 0.01	0.4 ± 0.01	0.14 ± 0.01	0.4 ± 0.1 or 0.5 ± 0.1
Length (across the plane of the angle of reflection)	5.0 ± 1	3.0 ± 1	3.0 ± 1	3.0 ± 1

12.2 The report for Test Method B shall contain the following:

12.2.1 The specular gloss $R_{s,20}$,

12.2.2 Either the logarithmic reflection haze or the compensated logarithmic reflection haze.

12.3 The report for both methods shall contain the following:

12.3.1 Identification of instrument used by model and serial number,

12.3.2 Identification of gloss standards by number and scale value assigned, and

12.3.3 Identification of any specimens whose values on any

scale differ by more than 3.0 in individual readings from the averages reported.

13. Precision and Bias

13.1 Test Method A:

13.1.1 An indication of the sensitivity of this test method is shown in Table 3 by the values of Spearman rank correlation coefficients. The data were obtained with a set of 20 aluminum and stainless steel specimens selected for a wide range of reflectance characteristics. Visual evaluations were compared with measurements using (1) the abridged goniophotometer, (2) a full goniophotometer, and (3) other instruments. A more

TABLE 2 Dimensions of the Specular Image of the Source-Slit and of the Receptor Windows Measured in the Plane of the Receiving Windows (see Fig. 2)

	Source-Slit Specular Image, °	Specular Gloss Receiver Window, °	Haze Receiver Window, °
Angle of center of window (measured from perpendicular to specimen surface)	20.0 ± 0.1	20.0 ± 0.1	18.1 ± 0.1 and 21.9 ± 0.1
Width (in the plane of the angle of reflection)	0.75 ± 0.1	1.8 ± 0.05	1.8 ± 0.1
Length (across the plane of the angle of reflection)	2.5 ± 0.25	3.6 ± 0.1	5.5 ± 0.25

complete report of these findings appears in Ref (5).

13.1.2 *Instrument Reproducibility*—Five panels of anodized

TABLE 4 Instrument Reproducibility Data

	Root-Mean-Square Differences from Goniophotometer Assigned Values	
	30° Specular Reflectance	Distinctness-of-Reflected Image
One instrument with receptor windows filled with optical fibers	1.4	1.5
Average, two instruments with segmented silicon photocell light receivers	2.2	1.1

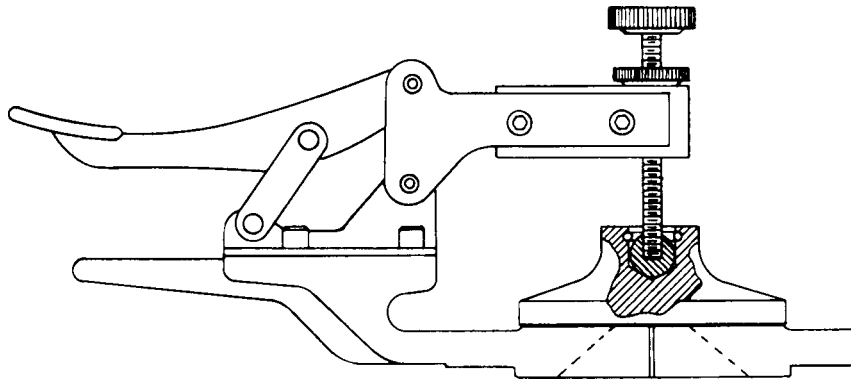


FIG. 4 A Rotatable Clamp Suggested for Flattening the Specimen and Positioning It During Measurement

TABLE 3 Rank Correlation Coefficients of Distinctness-of-Image and Haze Between the Dorigon Abridged Goniophotometer and Other Instruments, and with Visual Judgments

Dori-Gon Versus	Distinctness-of-Image ^A	Haze ^B	
		2°	5°
Visual	0.91	0.82	0.96
D10-5 Gonio	0.93	...	0.96
Alcoa DORI	0.87
Alcoa Abridged Gonio	0.98
D36B Distinctness-of-Image Glossmeter	0.94

^A Visual judgments of rank were made by sighting in the “with” machine direction only, whereas instrumental “with” and “across” directions were averaged.

^B Visual judgments of haze were made by ranking the specimens according to the amount of near specular reflectance (milkyiness) adjacent to the image of a concentrated light source. Correlation between the Dorigon and the D10-5 Gonio and between the Dorigon and the Alcoa Abridged Gonio at 2° were equivalent to those at 5°.

aluminum sheet, ranging from 12 to 77 in specular reflectance and from 24 to 97 in distinctness-of-image gloss, were calibrated with the full goniophotometer, then measured with three abridged goniophotometers. One of the abridged goniophotometers had optical fibers filling the receptor windows and two instruments had receptor windows of segmented silicon photocells. The results of the full goniophotometer calibration are given in Table 4.

13.2 *Test Method B:*

13.2.1 Precision and Bias will be determined.

REFERENCES

- (1) Tingle, W. H., and Potter, F. R., "New Instrument Grades for Polished Metal Surfaces," *Product Engineering*, Vol 27, March 1961.
- (2) Tingle, W. H., and George, D. J., "Measuring Appearance Characteristics of Anodized Aluminum Automotive Trim," Report No. 650513, Society of Automotive Engineers, May 1965.
- (3) Hunter, R. S., "Gloss Evaluation of Materials," *ASTM Bulletin 186*, ASTBA, December 1952.
- (4) Christie, J. S., "Instruments for Metallic Appearance," *Appearance of Metallic Materials, ASTM STP 478*, Am. Soc. Testing Mats., ASTTA, 1971.
- (5) Christie, J. S., "An Instrument for the Geometric Attributes of Metallic Appearance," *Applied Optics*, Vol. 8, No. 9, September 1969.

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