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Standard Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials¹

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INTRODUCTION

This is a guide describing the selecting of geometric conditions of measurement of appearance attributes such as color, gloss, reflectance, opacity, and transmittance. It includes a selection of numerical scales for appearance attributes other than color.

In describing appearance, wavelength (or spectral) variability is primarily responsible for color, while geometric (or directional) selectivity is primarily responsible for gloss, luster, translucency, and like attributes. However, geometric conditions not only affect geometric variables such as gloss and transparency, but also affect color, diffuse reflectance, and transmittance. Likewise spectral conditions can affect the measurement of geometric attributes of appearance. Therefore both the spectral and geometric conditions of measurement must be identified in specifying an appearance attribute of a specimen.

This guide describes the selection of geometric conditions and as a consequence should help improve agreement in these measurements as well as providing useful guidance in resolving differences between spectral-type measurements that are related to geometry.

1. Scope

1.1 This guide is intended for use in selecting terminology, measurement scales, and instrumentation for describing or evaluating such appearance characteristics as glossiness, opacity, lightness, transparency, and haziness in terms of reflected or transmitted light. This guide does not consider the spectral variations responsible for color, but the geometric variables described herein can importantly affect instrumentally measured values of color. This guide is general in scope rather than specific as to instrument or material.

2. Referenced Documents

2.1 ASTM Standards:

- C 346 Test Method for 45-deg Specular Gloss of Ceramic Materials²
- C 347 Test Method for Reflectance, Reflectivity, and Coefficient of Scatter of White Porcelain Enamels³
- C 523 Test Method for Light Reflectance of Acoustical Materials by the Integrating Sphere Reflectometer⁴
- C 584 Test Method for Specular Gloss of Glazed Ceramic

Whitewares and Related Products⁵

- D 523 Test Method for Specular Gloss⁶
- D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics⁷
- D 1455 Test Method for 60-deg Specular Gloss of Emulsion Floor Polish⁸
- D 1494 Test Method for Diffuse Light Transmission Factor of Reinforced Plastics Panels⁹
- D 1746 Test Method for Transparency of Plastic Sheet⁷
- D 1834 Test Method for 20-deg Specular Gloss of Waxed Paper¹⁰
- D 4039 Test Method for Reflection Haze of High-Gloss Surfaces⁶
- D 4061 Test Method for Retroreflectance of Horizontal Coatings⁶
- E 97 Test Method for Directional Reflectance Factor, 45-deg, 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry⁴
- E 167 Practice for Goniophotometry of Objects and Materials⁶
- E 284 Terminology of Appearance⁶
- E 429 Test Method for Measurement and Calculation of

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² *Annual Book of ASTM Standards*, Vol 02.05.

³ Discontinued; see 1990 *Annual Book of ASTM Standards*, Vol 02.05.

⁴ Discontinued; see 1991 *Annual Book of ASTM Standards*, Vol 14.02.

⁵ *Annual Book of ASTM Standards*, Vol 15.02.

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

⁷ *Annual Book of ASTM Standards*, Vol 08.01.

⁸ *Annual Book of ASTM Standards*, Vol 15.04.

⁹ *Annual Book of ASTM Standards*, Vol 08.04.

¹⁰ *Annual Book of ASTM Standards*, Vol 05.01.

Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments⁶

E 430 Method for Measurement of Gloss of High Gloss Surfaces by Goniophotometry⁶

E 808 Practice for Describing Retroreflection⁶

E 809 Practice for Measuring Photometric Characteristics of Retroreflectors⁶

E 810 Test Method for Coefficient of Retroreflection of Retroreflective Sheeting⁶

E 811 Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions⁶

E 991 Practice for Color Measurement of Fluorescent Specimens⁶

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation⁶

E 1767 Practice for Specifying the Geometry of Observations and Measurements to Characterize the Appearance of Materials⁶

F 768 Method for Specular Reflectance and Transmittance Measurements of Optically Flat-Coated and Non-Coated Specimens¹¹

2.2 CIE Publications:¹²

CIE Publication No. 15.2, Colorimetry, second edition 1986

CIE Publication No. 17.4, International Lighting Vocabulary, fourth edition, 1987

CIE Publication No. 38, Radiometric and Photometric Characteristics of Materials and Their Measurement, 1977

3. Terminology

3.1 Definitions:

3.1.1 *flux (radiant)*, Φ —the time rate of flow of radiant energy; radiant power (Terminology E 284).

3.1.2 *incident flux*, Φ_i —flux incident on the specimen at a specified illumination angle and aperture angle.

3.1.3 *reflected flux*, Φ_r —flux reflected from the specimen at a specified viewing angle and aperture angle.

3.1.4 *reference reflected flux*, $\Phi_{r,r}$ —flux reflected from a reference standard of reflectance, illuminated and viewed in the same manner as the specimen under consideration.

3.1.5 *transmitted flux*, Φ_t —flux transmitted through the specimen at a specified viewing angle and field angle.

3.1.6 *reflectance*, ρ —ratio of the reflected flux to the incident flux defined as $\rho = \Phi_r / \Phi_i$.

3.1.7 *reflectance factor*, R —ratio of the reflected flux to the reference reflected flux defined as $R = \Phi_r / \Phi_{r,r}$.

3.1.8 *transmittance*, τ —ratio of the transmitted flux to the incident flux defined as $\tau = \Phi_t / \Phi_i$.

3.1.8.1 *Discussion*—A companion term, transmittance factor, is not normally used in the measurement of appearance attributes.

3.1.9 For other definitions see Terminology E 284 and CIE Publication Nos. 17.4 and 38.

4. Summary of Guide

4.1 When light impinges upon a material, several phenomena can occur. Part of the light may be reflected, part may be transmitted, and part may be absorbed. This guide deals with the reflected and transmitted light and the selection of geometric conditions for its measurement.

4.2 An idealization of the light reflected and transmitted by a material is shown in Fig. 1. Fig. 2 illustrates luminance distributions more like those actually encountered in practice.

5. Types of Measurement Scales

5.1 *Type of Scale*—The terms defined in 3.1.6–3.1.8 to may be further identified by a preceding adjective, such as specular, regular, diffuse, total, or directional, thereby identifying the basis for the measurement scale. The significance of each of these adjectives is as follows:

5.1.1 *regular*—indicates that only light that has been reflected or transmitted without scattering or diffusion is included for measurement. When a specimen scatters or diffuses the incident light on reflection or transmission, the values obtained will depend on the angular size of the illuminator and receiver used in the measurement.

5.1.2 *specular*—indicates that only the light that is mirror-reflected is included for measurement. The CIE prefers the modifier *regular* instead of *specular* although *specular* reflectance is recognized. *Specular* has also sometimes been used to refer to regular transmittance. This is a misnomer because specular refers to a mirror.

5.1.3 *diffuse*—indicates that only the light reflected or transmitted in directions other than the specular or regular direction is included in the measurement.

NOTE 1—The differences between the concepts of regular and diffuse components of reflection and transmission are shown in Table 1.

5.1.4 *total*—indicates that the light reflected or transmitted in all directions is included for measurement.

5.1.5 *directional*—indicates that the light reflected or transmitted in specified directions only is included for measurement. Directional values depend on the illumination and viewing angles and refer to light reflected or transmitted in directions that differ moderately from the centroid direction or axis of the beam.

6. Geometric Directions of Incidence and Viewing

6.1 Geometric directions may be identified by preceding the adjective with the angular directions, by including a detailed geometric description, or by placing after the symbols a subscript that represents the measurement condition.

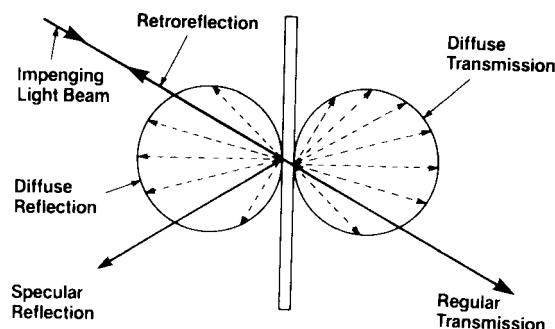


FIG. 1 Idealizations of Reflection and Transmission Phenomena, Showing Components

¹¹ Discontinued; see 1995 Annual Book of ASTM Standards, Vol 06.01.

¹² Information on how to obtain CIE documents should be requested from the U.S. National Committee, CIE, c/o Radiometric Physics Division, National Institute of Standards and Technology, Bldg. 220, Room B-306, Gaithersburg, MD 20899.