Designation: E 809 – 02

Standard Practice for Measuring Photometric Characteristics of Retroreflectors[1]

This standard is issued under the fixed designation E 809; 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 This practice describes the general procedures for instrumental measurement of the photometric characteristics of retroreflective materials and retroreflective devices.

1.2 This practice is a comprehensive guide to the photometry of retroreflectors but does not include geometric terms that are described in Practice E 808.

1.3 This practice describes the parameters that are required when stating photometric measurements in specific tests and specifications for retroreflectors.

1.4 *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:*

E 284 Terminology of Appearance[2]

E 308 Practice for Computing the Colors of Objects by Using the CIE System[2]

E 808 Practice for Describing Retroreflection[2]

2.2 *CIE Documents:*

CIE Publication No. 54.2, Retroreflection—Definition and Measurement[3]

CIE Publication No. 17.4, International Lighting Vocabulary[3]

CIE Publication No. 69-1987, Methods of Characterizing Illuminance Meters and Luminance Meters[3]

3. Terminology

3.1 Terms and definitions in Terminology E 284 and E 808 are applicable to this practice. In general, the terminology in this practice agrees with that in CIE Publications 17.4 and 54.2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *retroreflectometer aperture angles* —the maximum angular diameter of the pencil of light (see Fig. 1).

3.2.1.1 *Discussion*—In practice the illumination arrives at the retroreflector center within a narrow pencil of light surrounding the illumination axis and the light reflected to the photoreceptor is contained within another narrow pencil. The distribution of light within such pencils is the "aperture" function and the maximum angular diameter of the pencil is the "aperture angle." It is generally assumed that the aperture functions are rotationally symmetrical and even uniform, but this is often false, especially for illumination.

3.2.2 *retroreflector aperture surface*—the aperture surface of a retroreflector is given by the retroreflector itself, or by a diaphragm enclosing part of the retroreflector.

3.2.3 *retroreflector (or specimen) aperture*—angular dimensions from the source point of reference to the aperture surface of the retroreflector (or specimen).

3.2.3.1 *Discussion*—As the source and receiver are generally close to each other, distinction is not made between aperture angles seen from the source and receiver. When using collimated optics where the source and receiver are at virtual infinity, the retroreflector aperture is virtually naught. The retroreflector aperture describes the maximum variation of the entrance angle of the aperture surface of the retroreflector.

3.2.4 *circular aperture*—the angular diameter of a circular aperture surface.

3.2.5 *annular aperture*—the difference between the angular diameters of the external boundary circle and the internal boundary circle.

3.2.6 *rectangular aperture*—the angular height and width of a rectangular aperture surface.

3.2.6.1 *Discussion*—The orientation of the sides of the rectangular aperture surface should be supplied together with the angular height and width.

3.2.7 *source aperture*—angular dimensions from the retroreflector center to the exit aperture stop or pupil of the light source.

3.2.8 *receiver aperture*—angular dimensions from the retroreflector center to the entrance aperture or pupil of the receiver.

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[1] This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.10 on Retroreflection.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Available from USNC/CIE Publications Office; TLA Lighting Consultants, Inc., 77 Pond St., Salem, MA 01970.

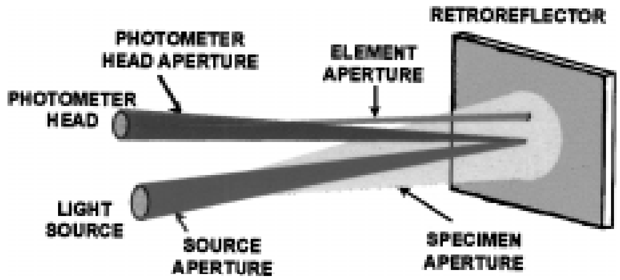

FIG. 1 Illustration of Apertures used in Retroreflection Measurement

3.2.9 *retroreflector element aperture*—angular dimension of the aperture surface of a retroreflective element as seen from the receiver's center.

3.2.9.1 *Discussion*—The element aperture quantifies an error source in the setting of the observation angle. This is a critical feature for testing large retroreflective elements or at short distances. When using collimated optics, placing the source and receiver at virtual infinity, the retroreflector element aperture is virtually zero.

3.2.10 *goniometer*—an instrument for measuring or setting angles.

3.2.11 *photopic receiver*—a receiver of radiation with a spectral responsivity which conforms to the $V(\lambda)$ distribution of the CIE Photopic Standard Observer that is specified in Practice E 308.

3.2.12 *reflected illuminance, E_r*—illuminance at the receiver measured on a plane perpendicular to the observation axis.

3.2.12.1 *Discussion*—This quantity is used in the calculation of the coefficient of luminous intensity, R_I: $R_I = (I/E_\perp) = (E_r d^2)/E_\perp$, where d is the distance from the retroreflector to the receptor.

4. Summary of Practice

4.1 The fundamental procedure described in this practice involves measurements of retroreflection based on the ratio of the retroreflected illuminance at the observation position to the incident illuminance measured perpendicular to the illumination axis at the retroreflector. From these measurements, along with the geometry of test, various photometric quantities applicable to retroreflectors can be determined.

4.2 Also described are methods of comparative testing where unknown specimens are measured relative to an agreed-upon standard retroreflector (a substitution test method).

5. Significance and Use

5.1 This practice describes procedures used to measure photometric quantities that relate to the visual perception of retroreflected light. The most significant usage is in the relation to the nighttime vehicle headlamp, retroreflector, and driver's eye geometry. For this reason the CIE Standard Source A is used to represent a tungsten vehicle headlamp and the receptor has the photopic, $V(\lambda)$, spectral responsivity corresponding to the light adapted human eye. Although the geometry must be specified by the user, it will, in general, correspond to the relation between the vehicle headlamp, the retroreflector, and the vehicle driver's eye position.

6. Uses and Applications

6.1 *Coefficient of Retroreflection*— This quantity is used to specify the performance of retroreflective sheeting. It considers the retroreflector as an apparent point source whose retroreflected luminous intensity is dependent on the area of the retroreflective surface involved. It is a useful engineering quantity for determining the photometric performance of such retroreflective surfaces as highway delineators or warning devices. The coefficient of retroreflection may also be used to determine the minimum area of retroreflective sheeting necessary for a desired level of photometric performance.

6.2 *Coefficient of Luminous Intensity*—This term is used to specify the performance of retroreflective devices. It considers the retroreflected luminous intensity as a function of the perpendicular illuminance incident on the device. It is recommended for use in describing performance of RPMs, taillight reflex reflectors and roadway delineators.

6.3 *Coefficient of Line Retroreflection (of a Reflecting Stripe)*—This term may be used to describe the retroreflective performance of long narrow strips of retroreflective materials, when the actual width is not as important as is the reflectivity per unit length.

6.4 *Reflectance Factor (of a Plane Reflecting Surface)*—This is a useful term for comparing surfaces specifically designed for retroreflection to surfaces which are generally considered to be diffuse reflectors. Since almost all natural surfaces tend to retroreflect slightly, materials such as $BaSO_4$ can have a reflectance factor much higher than one (as much as four) at small observation angles. Such diffuse reflectance standards should be used for calibration only at large observation angles, for example, 45°.

6.5 *Coefficient of Retroreflected Luminance* (also called *Specific Luminance*)—This term considers the retroreflector as a surface source whose projected area is visible as an area at the observation position. The coefficient of retroreflected luminance relates to the way the effective retroreflective surface is focused on the retina of the human eye and to the visual effect thereby produced. It is recommended for describing the performance of highway signs and striping or large vehicular markings which are commonly viewed as discernible surface areas.

6.6 *Coefficient of Luminous Flux per Unit Solid Angle, R_Φ*—This measurement is used to evaluate retroreflectors on the basis of flux ratios. It is numerically very nearly equal to the coefficient of retroreflected luminance at small entrance angles. It is recommended for use in the design of retroreflectors but not for specification purposes.

7. Requirements When Measuring Retroreflectors

7.1 When describing photometric measurements of retroreflectors, items in paragraphs 7.1.1-7.1.11 must be included. Refer to Fig. 2 for a diagram of measurement geometry terminology.

7.1.1 Retroreflective photometric quantity, such as: coefficient of luminous intensity (R_I), coefficient of retroreflected luminance (R_L) (also called specific luminance), coefficient of

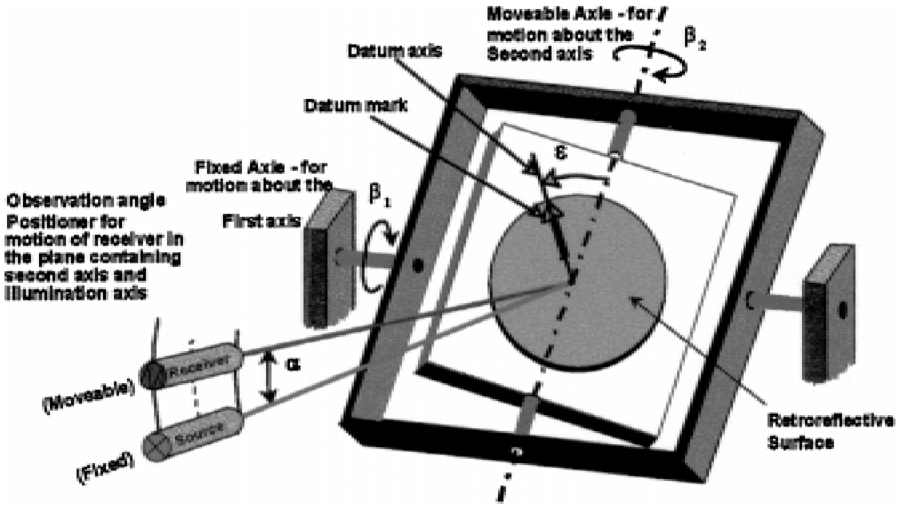

FIG. 2 View of Test Geometer for Measuring Retroreflection

retroreflection (R_A), coefficient of line retroreflection (R_M), reflectance factor (R_F), or coefficient of luminous flux per unit solid angle (R_Φ).

7.1.1.1 In specifications, a minimum acceptable quantitative value is usually established.

7.1.2 Units in which each quantity is to be measured (for example $cd \cdot lx^{-1} \cdot m^{-2}$).

7.1.3 Observation angle.

7.1.4 Components of the entrance angle, (β_1 and β_2).

7.1.4.1 When both β_1 and β_2 are near zero, care must be taken to prevent specular reflection from entering the photoreceptor.

7.1.4.2 Entrance angle β equals $\cos^{-1}(\cos\beta_1\cos\beta_2)$.

7.1.5 Rotation angle and the datum mark position shall be specified if random rotational orientation of the test specimen is not suitable.

7.1.6 Test distance or minimum test distance.

7.1.7 Test specimen size and shape.

7.1.8 Photoreceptor angular aperture.

7.1.9 Source angular aperture.

7.1.10 Retroreflector center.

7.1.11 Retroreflector axis. The retroreflector axis is usually perpendicular to the surface of retroreflective sheeting. In such complex devices as automobile or bicycle reflectors, the retroreflector axis and retroreflector center may be defined with respect to the illumination direction.

8. Apparatus

8.1 *General*—The apparatus shall consist of a photoreceptor, a light projector source, a specimen goniometer, an observer goniometer, (sometimes known as the observation angle positioner), and a photometric range.

8.1.1 Aperture angles are a very important consideration when measuring retroreflectors as Fig. 1 illustrates. The tolerances recommended in the following paragraphs are to be used generally, but materials may differ and in certain cases greater restriction on these aperture angles are necessary. See Table 1 for recommendations for maximum angular aperture of optical elements.

TABLE 1 Optical Element Angular Apertures[A]

Standard apertures	0.05°	0.−1°	0.167°	0.333°
Angular aperture of an individual retroreflective element, °	0.01° max	0.02° max	0.04° max	0.08° max

[A]Optical element angular aperture maximum requirements apply to all non-collimating instruments.

8.2 *Photoreceptor*—The photoreceptor shall be equipped as follows:

8.2.1 *Photopic Filter*—The photoreceptor shall be equipped with a light filter such that the spectral responsivity of the receptor should match the *V* (λ) response of the CIE Standard photopic observer with an f_1' tolerance no greater than 3 %. Spectral correction filters to the *V* (λ) function may be used provided that they are determined on material which has been previously measured by spectroradiometric means and closely corresponds in their spectral coefficient of retroreflection to the specimen under test. See Annex A1 for uncertainty tests and compensation.

8.2.2 *Photoreceptor Stability and Linearity*—The stability and linearity of the photometric scale reading must be within 1 % over the range of values to be measured (see Annex A2). The responsivity and range of the photoreceptor should be sufficient such that readings of the projector light source and the retroreflector under test will have a resolution of at least 1 part in 50.

8.2.3 *Photoreceptor Angular Aperture* —The photoreceptor must be equipped with a means to limit the angular collection of retroreflective luminous flux. This may be accomplished with an objective lens and field aperture or with light baffling. The field of view shall be limited such that the effect of stray light is negligible. The field of view should be limited to the smallest aperture that includes the entire test specimen or the illuminated area when testing horizontal coating materials. When an objective lens is used, it shall be capable of focusing at the test distance. Angular apertures for the photoreceptor are specified in degrees subtended at the specimen. The responsivity across the aperture shall be uniform.

8.3 *Light Projector Source*—The light source shall be a projector type capable of uniformly illuminating the specimen