Designation: E 810 – 94 (Reapproved 2000)

Standard Test Method for Coefficient of Retroreflection of Retroreflective Sheeting[1]

This standard is issued under the fixed designation E 810; 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 test method describes the instrument measurement of the retroreflective performance of retroreflective sheeting.

1.2 The user of this test method must specify the entrance and observation angles to be used.

1.3 This test method is intended as a laboratory test and requires a facility that can be darkened sufficiently so that stray light does not affect the test results.

1.4 Portable and bench retroreflection measuring equipment may be used to determine R_A values provided the appropriate substitutional standard reference panels, measured in accordance with this test method, are used. In this case the methods of Procedure B in Practice E 809 apply.

1.5 *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 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

E 808 Practice for Describing Retroreflection[2]

E 809 Practice for Measuring Photometric Characteristics of Retroreflectors[2]

2.2 *Other Document:*

CIE Publication No 54 Retroreflection—Definition and Measurement[4]

3. Terminology

3.1 The terms and definitions in Terminology E 284 apply to this test method.

3.2 *Definitions:*

3.2.1 *coefficient of retroreflection, R_A—of a plane retroreflecting surface*, the ratio of the coefficient of luminous intensity (R_I) of a plane retroreflecting surface to its area (A), expressed in candelas per lux per square metre ($cd \cdot lx^{-1} \cdot m^{-2}$). $R_A = R_I/A$.

3.2.1.1 *Discussion*—The equivalent inch–pound units for coefficient of retroreflection are candelas per foot candle per square foot. The SI and inch pound units are numerically equal. An equivalent term used for coefficient of retroreflection is specific intensity per unit area, with symbol SIA or the CIE symbol R′. The term coefficient of retroreflection and the symbol R_A along with the SI units of candelas per lux per square meter are recommended by ASTM.

3.2.1.2 *Discussion*—R_A is a useful engineering quantity for determining the photometric performance of such retroreflective surfaces as highway delineators or warning devices. R_A may also be used to determine the minimum area of retroreflective sheeting necessary for a desired level of photometric performance. R_A has been used intensively in the specification of retroreflective sheeting.

3.2.2 *datum mark, n—in retroreflection,* an indication on the retroreflector that is used to define the orientation of the retroreflector with respect to rotation about the retroreflector axis.

3.2.2.1 *Discussion*—The datum mark must not lie on the retroreflector axis.

3.2.3 *entrance angle, n— in retroreflection*, angle between the illumination axis and the retroreflector axis.

3.2.3.1 *Discussion*—The entrance angle is usually no larger than 90°, but for completeness its full range is defined as $0° \leq \beta \leq 180°$. To completely specify the orientation, this angle is characterized by two components, β_1 and β_2.

3.2.4 *goniometer, n*—an instrument for measuring or setting angles.

3.2.5 *illumination axis, n— in retroflection*, a line from the centroid of the effective source aperture to the retroreflector center.

3.2.6 *observation angle, n*—angle between the axes of the incident beam and the observed (reflected) beam (*in retroreflection*, α, between the illumination axis and the observation axis).

3.2.6.1 *Discussion*—The observation angle is always positive and in the context of retroreflection is restricted to small acute angles. Range: $0° \leq \alpha < 180°$.

3.2.7 *observation axis, n— in retroreflection,* a line from the

[1] This method 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] *Annual Book of ASTM Standards*, Vol 14.02.

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

centroid of the effective receiver aperture to the retroreflector center.

3.2.8 *receiver, n*— the portion of a photometric instrument that receives the viewing beam from the specimen, including a collector such as an integrating sphere, if used, often the monochromator or spectral filters, the detector, and associated optics and electronics.

3.2.9 *retroreflection*, *n*—reflection in which the reflected rays are preferentially returned in directions close to the opposite of the direction of the incident rays, this property being maintained over wide variations of the direction of the incident rays. [CIE][B]

3.2.10 *retroreflective device*, *n*—deprecated term; use *retroreflector*.

3.2.11 *retroreflective material*, *n*—a material that has a thin continuous layer of small retroreflective elements on or very near its exposed surface (for example, retroreflective sheeting, retroreflective fabrics, transfer films, beaded paint, highway surface signs, or pavement striping).

3.2.12 *retroreflective sheeting*—a retroreflective material preassembled as a thin film ready for use. Retroreflective sheeting is a commonly used surfacing material for highway signs.

3.2.13 *retroreflector, n*—a reflecting surface or device from which, when directionally irradiated, the reflected rays are preferentially returned in directions close to the opposite of the direction of the incident rays, this property being maintained over wide variations of the direction of the incident rays. [CIE, 1982][B]

3.2.14 *retroreflector axis, n*—a designated line segment from the retroreflector center that is used to describe the angular position of the retroreflector.

3.2.14.1 *Discussion*—The direction of the retroreflector axis is usually chosen centrally among the intended directions of illumination; for example, the direction of the road on which or with respect to which the retroreflector is intended to be positioned. In testing horizontal road markings the retroreflector axis is usually the normal to the test surface.

3.2.15 *retroreflector center*, *n*—a point on or near a retroreflector that is designated to be the center of the device for the purpose of specifying its performance.

3.2.16 *rotation angle,* ϵ, *n*—in retroreflection, angle indicating the orientation of the specimen when it is rotated about the retroreflector axis.

3.2.16.1 *Discussion*—The rotation angle is the dihedral angle from the half-plane originating on the retroreflector axis and containing the positive part of the second axis to the half plane originating on the retroreflector axis and containing the datum mark. Range: $-180° \leq \epsilon \leq 180°$.

3.2.17 *source*, *n*—an object that produces light or other radiant flux.

3.2.18 *viewing angle,* ν, *n*—in retroreflection, the angle between the retroreflector axis and the observation axis.

4. Summary of Test Method

4.1 This test method involves the use of a light projector source, a receiver, a device to position the receiver with respect to the source and a test specimen holder in a suitable darkened area. The specimen holder is separated from the light source by 15 m.

4.2 The general procedure involved is to determine the ratio of the light retroreflected from the test surface to that incident on the test surface.

4.3 The photometric quantity, coefficient of retroreflection, is calculated from these measurements.

5. Significance and Use

5.1 Measurements made by this test method are related to visual observations of retroreflective sheeting as seen by the human eye when illuminated by tungsten-filament light sources such as a motor vehicle headlamp.

5.2 The values determined relate to the visual effects for a given geometric configuration as specified by the user of the test method. This test method has been found useful for tests at observation angles between 0.1 and 2.0° (observation angles between 0.1° and 0.2° may be achieved by careful design of source and receiver aperture configuration), and at entrance angles up to 60°. It has been used to determine coefficient of retroreflection values as low as 0.1 $cd \cdot lx^{-1} \cdot m^{-2}$, but for values less than 1 $cd \cdot lx^{-1} \cdot m^{-2}$ special attention must be given to the responsivity of the receiver and to the elimination of very small amounts of stray light.

6. Apparatus

6.1 *Light Source*—The light source shall be of the projector type and shall meet the following requirements (an illuminance at the 15-m specimen distance of about 10 lx is commonly available within these restrictions):

6.1.1 The spectral energy distribution of the source shall be proportional to CIE standard Source A (a correlated color temperature of 2856 K, see Practice E 308). The projection lamp together with the projection optics shall be operated such that it illuminates the test specimen with this spectral power distribution.

6.1.2 A nonpolarizing light source shall be used.

6.1.3 At observation angles between 0.2° and 2.0°, the exit aperture of the source shall be circular and 26 mm (±5 %) in diameter. This corresponds to 0.1° angular aperture at the 15 m test distance. At observation angles between 0.1° and 0.2°, the exit aperture of the source shall be circular and 13 mm (±5 %) in diameter. This corresponds to 0.05° angular aperture at the 15 m test distance.

6.1.4 The illumination at the sample produced by the projector shall be such that the test specimen and only a minimum of the background is illuminated. This is commonly accomplished by placing a restrictive aperture in the projector slide port.

6.1.5 The source shall be regulated such that the illuminance at the test surface does not change by more than ±1 % for the duration of the test.

6.1.6 The illuminance produced on the sample surface shall be uniform within ±5 % of the average illuminance normal to the source at the distance of 15 m.

6.2 *Receiver*—The receiver shall meet the requirements that follow. (In this test, for 10 lx incident upon a 1 $cd \cdot lx^{-1} \cdot m^{-2}$ retroreflective sheeting test specimen with area of 0.04 m^2, the incident normal illuminance at the receiver will be about 1.8×10^{-3} lx).

6.2.1 The responsivity and range of the receiver shall be sufficient so that readings of both the incident normal illuminance (at the specimen) and the retroreflected light at the observation position can be measured with a resolution of at least 1 part in 50 on the readout scale.

6.2.2 The spectral responsivity of the receiver shall match that of the 1931 CIE Standard Photopic Observer (see Annex A1 of Practice E 809).

6.2.3 The receiver shall be insensitive to the polarization of light.

6.2.4 The linearity of the photometric scale over the range of readings to be taken shall be within ±1 %. Correction factors may be used to ensure a linear response. Linearity verification tests must be made utilizing the entire receiver readout device including the detector, load, range selection system and readout display device.

6.2.5 The stability of the receiver shall be such that readings from a constant source do not vary any more than 1 % for the duration of the test.

6.2.6 The field of view shall be limited by use of light baffles or a field aperture on the instrument so that the entire test sample is fully within the field of view, rejecting stray light as much as practical. A background light level m_b less than 5 % of the smallest m_1 reading is acceptable.

6.2.7 For measurements at observation angles between 0.2° and 2.0°, the receiver shall be provided with an entrance aperture 26 mm (±5 %) in diameter. This is equivalent to 0.1° angular aperture at 15 m. For measurements at observation angles between 0.1° and 0.2°, the receiver shall be provided with an entrance aperture 13 mm (±5 %) in diameter. This is equivalent to 0.05° angular aperture at 15 m. The physical size of the entrance aperture must be small so that the receiver may be positioned physically close to the source exit aperture without shadowing any of the illuminating light beam.

6.3 *Test Specimen Goniometer (Test Specimen Holder)*—The specimen holder, commonly custom built to hold up to a 0.3-m^2 test specimen (recommended test specimen size is 0.2 by 0.2 m), must meet the following requirements (see Fig. 1):

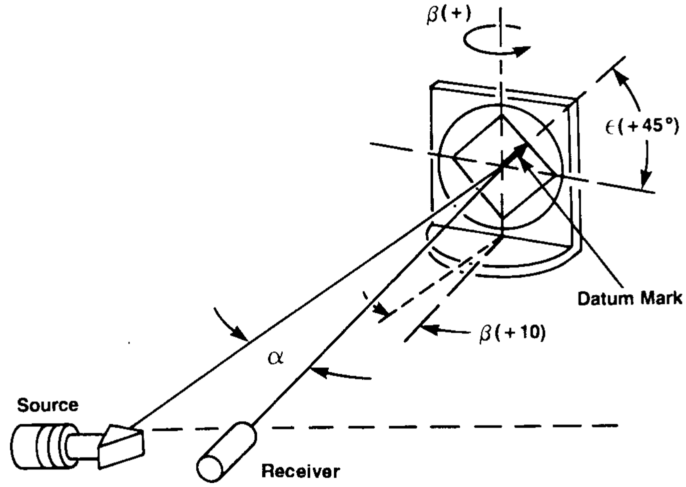
6.3.1 A means must be provided to rotate the specimen on an axis contained in the plane of the specimen surface if several entrance angles are to be used.

6.3.1.1 The entrance angle component is used to set the goniometer when no specific component is specified (see Practice E 808).

6.3.2 The specimen surface must be positionable so that the entrance angle is accurate to within 0.5 % of its complement (that is, for a 30° entrance angle this angle must be accurately set to± 0.005 by 60° = ±0.3°). This is obtainable by providing an accurate optical means to align the test surface to the "0 degree" entrance angle and then adjusting the angular setting (within the required tolerance).

6.3.3 The specimen holder must be provided with a means of eliminating reflections from the edges of the specimen and the holder itself must be nonreflective (usually painted with a flat black paint).

6.3.4 The specimen holder should be constructed such that



NOTE 1—This view shows the source-receiver in a horizontal plane and the entrance angle β (= β_1) as a rotation about a vertical axis. The rotation angle ε is shown at +45° for illustration purposes— default position is ε = 0°.

FIG. 1 Pictorial View of a Goniometer—Specimen Holder Assembly

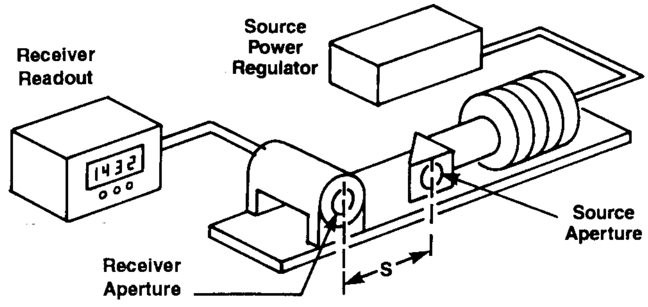
the receiver can easily be substituted for the specimen (required when incident light measurements are taken).

6.4 *Observer Goniometer (Device for Receiver/Light Source Separation)*—A device (sometimes called an observation angle positioner) must be provided to adequately support and separate the receiver from the source at the observation position. It must allow the observation angle to be varied (see Fig. 2). The usual range is at least 0.2° to 2.0°.

6.4.1 The accuracy of separation of the source exit aperture from the receiver entrance aperture is dependent on the test sample. For most materials, a positioning accuracy of ±0.1 mm (or ±0.5 % of the receiver angular subtense) at 15-m distance is adequate. A common method of fixing this distance is to provide a bar with holes machined in it at separations corresponding to the desired observation angles.

6.4.2 In this test method the minimum practical observation angle is approximately 0.2° using a receiver with an entrance aperture 26 mm (±5 %) in diameter. If an observation angle between 0.1° and 0.2° is to be used, a smaller aperture is needed as explained in 6.2.7.

6.5 *Photometric Range*—Sufficient working space is required so that the projector and sample can be separated by a 15-m distance.



NOTE 1—The distance *s* is adjusted to correspond to the desired observation angle.

FIG. 2 Pictorial View of Observation Angle Positioning Device