Standard Test Method for
Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry[1]

1. Scope

1.1 This test method describes an 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, and may specify the rotation angles.

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. The testing apparatus must be able to achieve the coplanar geometry.

1.4 Portable and bench retroreflection measuring equipment may be used to determine R_A values provided the geometry and appropriate substitution standard reference panels, measured in accordance with this test method, are utilized. In this case the methods of Procedure B in Practice E 809 apply. Additional information on the use of portable retroreflectometers may be found in Test Method E 1709.

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:* [2]

E 284 Terminology of Appearance

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

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 808 Practice for Describing Retroreflection

E 809 Practice for Measuring Photometric Characteristics of Retroreflectors

E 1709 Test Method for Measurement of Retroreflective Signs Using a Portable Retroreflectometer

2.2 *Other Document:*

CIE Publication No 54 Retroreflection—Definition and Measurement[3]

3. Terminology

3.1 The terms and definitions in Terminology E 284 and Practice E 808 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) to the area (A), expressed in candelas per lux per square metre (cd·lx^{-1}·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 (cd·fc^{-1}·ft^{-2}). The SI and inch pound units are numerically equal, because the units of R_A reduce to 1/sr. 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 (cd·lx^{-1}·m^{-2}) 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 extensively in the specification of retroreflective sheeting.

3.2.2 *coplanar geometry, n*—retroreflection geometry in which the retroreflector axis, illumination axis, and observation axis lie in one plane.

3.2.2.1 *Discussion*—In the coplanar geometry: the second entrance angle component, β_2, is equal to 0°; presentation angle, γ, is equal to either 0° or 180°; orientation angle, ω_s, is equal to either the rotation angle, ϵ, or to $\epsilon + 180°$ or $\epsilon - 180°$.

3.2.3 *datum axis*, *n*—a designated half-line from the retroreflector center perpendicular to the retroreflector axis.

3.2.4 *datum mark*, *n*— an indication on the retroreflector, off the retroreflector axis, that establishes the direction of the datum axis.

3.2.5 *entrance angle,* β, *n*—the angle between the illumination axis and the retroreflector axis.

3.2.5.1 *Discussion*—The entrance angle is usually no larger than 90°, but for completeness its full range is defined as $0° \leq \beta \leq 180°$. In the CIE (goniometer system) β is resolved into two components β_1 and β_2. Since by definition β is always positive, the common practice of referring to the small entrance angles that direct specular reflections away from the photoreceptor as a negative value is deprecated by ASTM. The recommendation is to designate such negative values as belonging to β_1.

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

3.2.7 *illumination axis*, *n*—the half-line from the retroreflector center through the source point.

3.2.8 *observation angle,* α, *n*—the angle between the illumination axis and the observation axis.

3.2.8.1 *Discussion*—The observation angle is never negative and is almost always less than 10° and usually no more than 2°. The full range is defined as $0° \leq \alpha < 180°$.

3.2.9 *observation axis*, *n*—the half-line from the retroreflector center through the observation point.

3.2.10 *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.

3.2.11 *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]

3.2.12 *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).

3.2.13 *retroreflective sheeting*—a retroreflective material preassembled as a thin film ready for use.

3.2.14 *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]

3.2.15 *retroreflector axis*, *n*—a designated half-line from the retroreflector center.

3.2.15.1 *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. The retroreflector axis usually coincides with the axis of symmetry of the retroreflector. For retroreflective sheeting the normal to the surface is chosen as the retroreflector axis.

3.2.16 *retroreflector center*, *n*—the point on or near a retroreflector that is designated to be the location of the device.

3.2.17 *rotation angle,* ε, *n*—the angle in a plane perpendicular to the retroreflector axis from the observation half-plane to the datum axis, measured counterclockwise from a viewpoint on the retroreflector axis.

3.2.17.1 *Discussion*— Range: $-180° < \epsilon \leq 180°$. The definition is applicable when entrance angle and viewing angle are less than 90°. More generally, rotation angle is the angle from the positive part of second axis to the datum axis, measured counterclockwise from a viewpoint on the retroreflector axis.

3.2.17.2 *Discussion*—Rotation of the sample about the retroreflector axis while the source and receiver remain fixed in space changes the rotation angle (ε) and the orientation angle (ω_s) equally.

3.2.18 *rotationally uniform*, *adj*—having substantially constant R_A, when rotated about the retroreflector axis, while the source, receiver, retroreflector center and retroreflector axis all remain in a fixed spatial relation.

3.2.18.1 *Discussion*—The degree of rotational uniformity can be specified numerically.

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

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·lx^{-1}· m^{-2}, but for values less than 1 cd·lx^{-1}· 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 An unpolarizing light source shall be used.

6.1.3 The source aperture shall be a standard circular aperture as defined in Practice E 809. For measurements at observation angles (α) of $0.2° \leq \alpha \leq 2.0°$, the exit aperture of the source shall be uniformly radiant, circular and 26 mm (± 2 mm) in diameter. This corresponds to 0.1° angular aperture at 15 m test distance. For measurements at observation angles (α) of $0.1° \leq \alpha < 0.2°$, the exit aperture of the source shall be uniformly radiant, circular and 13 mm (± 1 mm) in diameter. This corresponds to 0.05° angular aperture at 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·lx^{-1}·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 The receiver aperture shall be a standard circular aperture as defined in Practice E 809. For measurements at observation angles (α) of $0.2° \leq \alpha \leq 2.0°$, the receiver shall be provided with an entrance aperture 26 mm (± 2 mm) in diameter. This corresponds to 0.1° angular aperture at 15 m test distance. For measurements at observation angles (α) of $0.1° \leq \alpha < 0.2°$, the receiver shall be provided with an entrance aperture 13 mm (± 1 mm) in diameter. This corresponds to a 0.05° angular aperture at 15 m test distance. The size of the entrance aperture stop 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 must hold a 200 mm square specimen and 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 β_1 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 $\pm 0.005 \times 60° = \pm 0.3°$). 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).
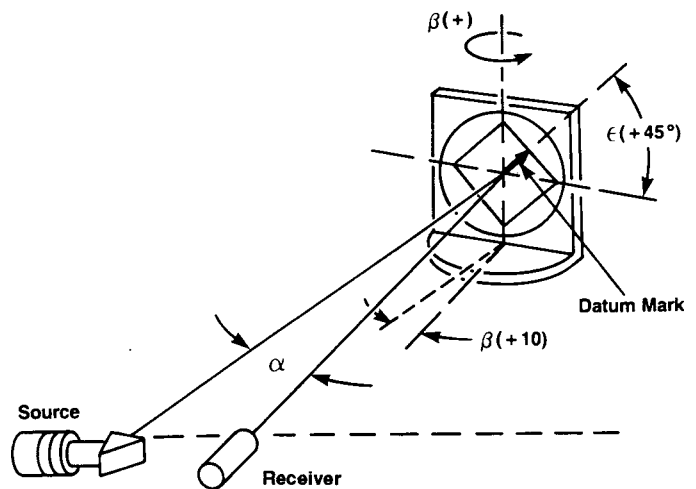
Note 1—This view shows the source-receiver in a horizontal plane and the entrance angle β (= β_1) as a rotation about a vertical axis. The rotation angle ϵ is shown at +45° for illustration purposes— default position is $\epsilon = 0°$.

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