Designation: E1809 – 01

Standard Test Method for Measurement of High-Visibility Retroreflective-Clothing Marking Material Using a Portable Retroreflectometer[1]

This standard is issued under the fixed designation E1809; 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 covers the measurement of the retroreflective properties of high visibility pedestrian garments, such as vests, using a portable retroreflectometer that can be used in the field. The portable retroreflectometer is a hand-held instrument with a defined standard geometry that can be placed in contact with retroreflective marking material to measure the retroreflection. The measurements can be compared to minimum requirements to determine the need for replacement of the retroreflective material.

1.2 This test method is designed for measuring retroreflective marking materials that have an area equal to or greater than that of the aperture of the retroreflectometer.

1.3 This test method is intended to be used for field measurement of retroreflective marking materials, but may be used to measure the performance of materials before placing the clothing in use.

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:*[2]

E284 Terminology of Appearance

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E808 Practice for Describing Retroreflection

E809 Practice for Measuring Photometric Characteristics of Retroreflectors

E810 Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry

3. Terminology

3.1 The terminology used in this test method, in general, agrees with that used in Terminology E284.

3.2 *Definitions*—The delimiting phrase *in retroreflection* applies to each of the following definitions when used outside the context of this or other retroreflection standards.

3.2.1 *coefficient of retroreflection, R_A, n—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·lx $^{-1}$· m^{-2}).

$$R_A = R_I/A \quad (1)$$

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

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

3.2.4 *entrance half-plane*, *n*—the half-plane that originates on the line of the illumination axis and contains the retroreflector axis.

3.2.5 *instrument standard*, *n*—a working standard used to standardize the portable retroreflectometer.

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

3.2.7 *observation half-plane*, *n*—the half-plane that originates on the line of the illumination axis and contains the observation axis.

3.2.8 *orientation angle,* ω_s, *n*—the angle in a plane perpendicular to the retroreflector axis from the entrance half-plane to the datum axis, measured counter-clockwise from the viewpoint of the source.

[1] This test 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.9 *portable retroreflectometer*, *n*—a hand-held instrument that can be used in the field or in the laboratory to measure retroreflection.

3.2.9.1 *Discussion*—In this test method, *portable retroreflectometer* refers to a hand-held instrument that can be placed in contact with retroreflective marking material to measure the coefficient of retroreflection in a standard geometry.

3.2.10 *presentation angle,* γ, *n*—the dihedral angle from the entrance half-plane to the observation half-plane, measured counter-clockwise from the viewpoint of the source.

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.

3.2.12 *rotation angle,* ε, *n*—the angle in a plane perpendicular to the retroreflector axis from the observation half-plane to the datum axis, measured counter-clockwise from the viewpoint of the source.

3.3 Definitions of entrance angle components β_1 and β_2, as well as other geometrical terms undefined in this test method, may be found in Practice E808.

4. Summary of Test Method

4.1 This test method involves the use of commercial portable retroreflectometers for determining the retroreflectivity of retroreflective marking material(s) on garments.

4.2 The entrance angle shall be nominally –4.0° and the observation angle shall be 0.2°.

4.3 The portable retroreflectometer uses an instrument standard for standardization.

4.4 After standardization, the retroreflectometer is placed in contact with the retroreflective marking material, ensuring that only the area to be tested is within the measurement area of the instrument. The retroreflective marking material and garment must be laid flat as a reading can be taken only on a planar surface.

4.5 The reading displayed by the retroreflectometer is recorded. The retroreflectometer is then moved to another position on the same retroreflective marking material and the measured value at this location is recorded. For each type and color of retroreflective marking material, for each side (front, back, left, and right) of the garment under test, a minimum of five readings shall be taken and their average value reported.

5. Significance and Use

5.1 Measurements made by this test method are related to the night time brightness of retroreflective marking materials approximately facing the driver of a mid-sized automobile equipped with tungsten filament headlights at about 200 m distance.

5.2 Retroreflective marking material used for pedestrian safety can degrade with time, exposure to sunlight, wear and cleaning, and the material requires periodic measurement to ensure that the performance of the retroreflective material provides adequate safety to the wearer.

5.3 This test method is not intended to be used for the measurement of retroreflective marking material for pedestrian safety at observation and entrance angles other than those specified herein.

5.3.1 For most materials, the values for the coefficient of retroreflection obtained at –4° entrance angle and 0.2° observation angle using this test method will be nearly the same as the values corresponding to +5° entrance angle and 0.2° observation angle, a geometry that is specified in some high-visibility clothing standards.

6. Apparatus

6.1 *Portable Retroreflectometer*:

6.1.1 The retroreflectometer shall be portable with the capability of being placed at various locations on the retroreflective marking material.

6.1.2 The retroreflectometer shall be constructed so that its placement on the retroreflective marking material will prevent stray light from entering the measurement area of the instrument and affecting the reading.

6.2 Instrument standard or standards of desired color(s) and material(s) are required.

6.3 *Light Source Requirements*:

6.3.1 The projection optics shall be such that the illuminance at any point over the measurement area shall be within 10 % of the average illuminance.

6.3.2 The aperture angle of the source, as determined from the center of the measurement area, shall be no greater than 0.1°.

6.4 *Receiver Requirements*:

6.4.1 The receiver shall have sufficient sensitivity and range to accommodate coefficient of retroreflection values from 0.1 to 1999 candelas per lux per square metre (cd lx^{-1} m^{-2}).

6.4.2 The combined spectral distribution of the light source and the spectral responsivity of the receiver shall match the combined spectral distribution of CIE Illuminant *A* and the $V(\lambda)$ spectral luminous efficiency function according to the following criterion: For any choice of plano-parallel colored absorptive filter mounted in front of a white retroreflective sample, the ratio of the R_A measured with the filter to the R_A measured without the filter shall be within 10 % of the Illuminant *A* luminous transmittance of an air-spaced pair of two such filters.

6.4.2.1 The filter should be mounted with a tilt (for example, 1.0°) to avoid specular reflection into the receiver of the retroreflectometer.

6.4.3 The instrument may be either a point instrument or an annular instrument, depending on the shape of the receiver aperture (see Fig. 1). Point and annular instruments make geometrically different measurements of R_A, which may produce values differing on the order of 10 %. Both measurements are valid for most purposes, but the user should learn the type of instrument from its specifications and be aware of certain differences in operation and interpretation. For both instrument types, the up position of the instrument shall be known.

6.4.3.1 The point instrument makes an R_A measurement virtually identical to an R_A measurement made on a range instrument following the procedure of Test Method E810. The denoted –4° entrance angle would be set on a range instrument

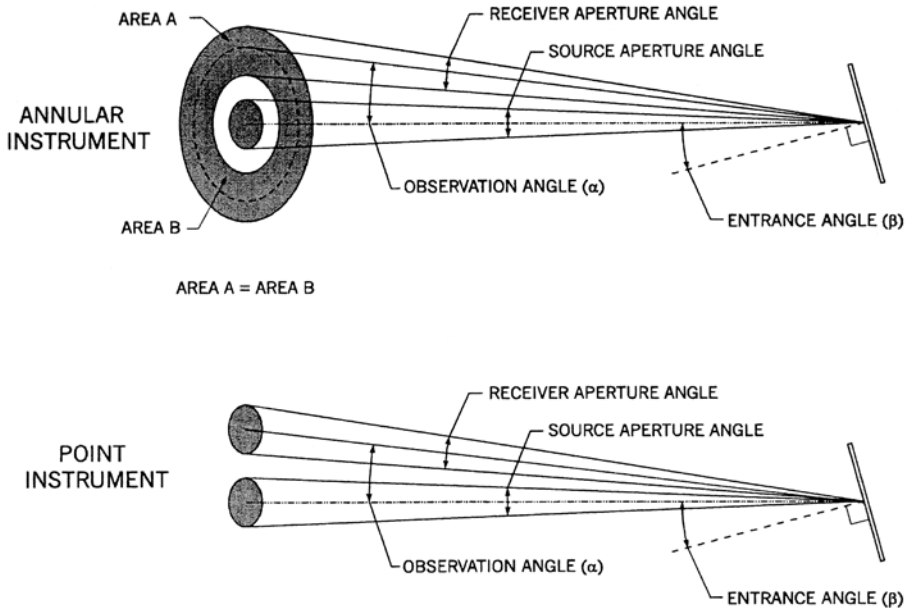


FIG. 1 Annular and Point Aperture Instrument Angles

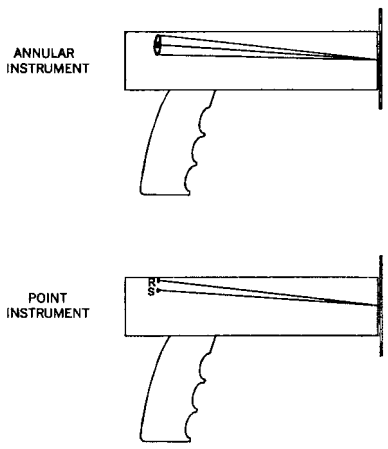
by setting $\beta_1 = -4°$; $\beta_2 = 0°$. The rotation angle (ε) for the point instrument is determined by the angular position of the instrument on the retroreflective marking. Assuming the retroreflector's datum axis to be upward, the rotation angle equals 0° when the instrument is upright. Clockwise rotation of the instrument on the retroreflective marking increases the rotation angle.

6.4.3.2 For the point instrument the up marking shall be opposite the entrance half-plane. It shall be in the observation half-plane (see Fig. 2).

6.4.3.3 The annular instrument makes an R_A measurement similar to an average of a great number of R_A measurements on a range instrument with presentation angle (γ) varying between −180° and +180°. For the denoted −4° entrance angle the range instrument would include the β_1 and β_2 settings indicated in Table 1. Table 1 includes the setting $\beta_1 = -4°$; $\beta_2 = 0°$, among others. There is no definite rotation angle (ε) for the annular instrument. All values from −180° to +180° are subsumed in the measurement.

TABLE 1 Laboratory Emulation of Annular Instrument Geometry

α	β_1	β_2	ε
0.2°	3.86°	−1.03°	−165°
0.2°	3.47°	−2.00°	−150°
0.2°	2.83°	−2.83°	−135°
0.2°	2.00°	−3.46°	−120°
0.2°	1.04°	−3.86°	−105°
0.2°	0.00°	−4.00°	−90°
0.2°	−1.04°	−3.86°	−75°
0.2°	−2.00°	−3.46°	−60°
0.2°	−2.83°	−2.83°	−45°
0.2°	−3.47°	−2.00°	−30°
0.2°	−3.86°	−1.03°	−15°
0.2°	−4.00°	0.00°	0°
0.2°	−3.86°	1.03°	15°
0.2°	−3.47°	2.00°	30°
0.2°	−2.83°	2.83°	45°
0.2°	−2.00°	3.46°	60°
0.2°	−1.04°	3.86°	75°
0.2°	0.00°	4.00°	90°
0.2°	1.04°	3.86°	105°
0.2°	2.00°	3.46°	120°
0.2°	2.83°	2.83°	135°
0.2°	3.47°	2.00°	150°
0.2°	3.86°	1.03°	165°
0.2°	4.00°	0.00°	180°



NOTE 1—For each instrument type, the illumination beam is 4° downward. For the point instrument, receiver is above source.

FIG. 2 Upright Optical Schematics

6.4.3.4 For the annular instrument the up marking shall be opposite the entrance half-plane (see Fig. 2).

6.4.3.5 For both instrument types, the orientation angle (ω_s) is determined by the angular position of the instrument on the retroreflective marking. It is the rotation angle (ε) rather than the orientation angle (ω_s) which primarily affects retroreflection measured at the small 4° entrance angle.

6.4.3.6 Rotationally insensitive materials, such as glass bead materials, have R_A values that are nearly independent of the rotation angle. Accordingly, the point and annular instruments will make practically identical measurements of R_A for retroreflective markings made with such materials.