Designation: E 1743 – 96

Standard Practice for Selection and Use of Portable Retroreflectometers for the Measurement of Pavement Marking Materials[1]

This standard is issued under the fixed designation E 1743; 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 covers the selection and use of portable retroreflectometers for the measurement at a prescribed geometry of the retroreflective properties of horizontal pavement marking materials containing glass spheres, such as traffic stripes and surface symbols.

1.2 The entrance and observation angles provided in the retroreflectometer greatly affect the test results and must be a major consideration in the selection of the instrument. Information on the relationship between instrument geometry and viewing geometry is provided in Section 5. Information on viewing geometry is provided in Table 1. Information on the relationship between viewing geometry and coefficient of retroreflected luminance, R_L is given in Fig. 1.

1.3 This practice is intended to be used for selection of portable retroreflectometers for field measurement of pavement markings but may also be used to select portable retroreflectometers to measure the performance of materials on sample panels before placing the marking material in the field.

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:*

D 4061 Test Method for Retroreflectance of Horizontal Coatings[2]

E 284 Terminology of Appearance[2]

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

E 1710 Test Method for the Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer[2]

TABLE 1 Examples of Viewing Geometry at Centerline for a Typical American Car and Driver

Distance, m	Left Headlight			Right Headlight		
	Entrance Angle, °	Co-entrance Angle,°	Observation Angle, °	Entrance Angle,°	Co-entrance Angle, °	Obser vation Angle, °
15	87.53	2.47	2.09	87.55	2.45	4.57
30	88.76	1.24	1.05	88.76	1.24	2.31
50	89.26	0.74	0.63	89.26	0.74	1.39
80	89.53	0.47	0.39	89.53	0.47	0.87
120	89.69	0.31	0.26	89.69	0.31	0.58

3. Terminology

3.1 The terminology used in this practice, agrees with that used in Terminology E 284.

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

3.2.1 *coefficient of retroreflected luminance*, R_L—ratio of the luminance, L, of a projected surface to the normal illuminance, $E_{\perp}$, at the surface on a plane normal to the incident light, expressed in candelas per square meter per lux ($cd \cdot m^{-2} \cdot lx^{-1}$).

3.2.1.1 *Discussion*—Because of the low luminance of pavement markings, the units commonly used are millicandelas per square meter per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$).

3.2.2 *co-entrance angle*, β_c—the complement of the entrance angle (90° − β).

3.2.3 *co-viewing angle*, v_c—the complement of the viewing angle (90° − v).

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

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

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

3.2.7 *portable retroreflectometer*—a hand-held instrument that can be used in the field or in the laboratory for measurement of retroreflectance.

3.2.7.1 *Discussion*—In this practice, "portable retroreflectometer" refers to a hand-held instrument that can be placed

[1] This practice is under the jurisdiction of ASTM Committee E-12 on Appearance and is the direct responsibility of Subcommittee E12.10 on Retroreflection.

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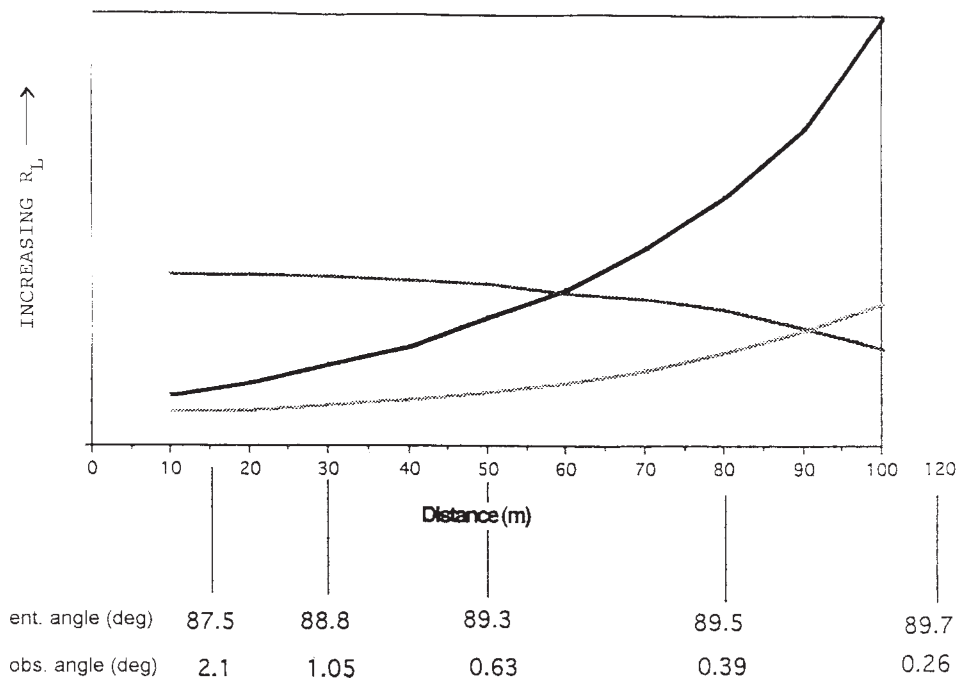
[2] *Annual Book of ASTM Standards*, Vol 06.01.



NOTE 1—Observation and entrance angles at indicated viewing distances are examples based upon a typical car and driver and may change if either the car or driver is changed.

FIG. 1 Curve of R_L versus Viewing Distance for Three Different Types of Markings

over roadway delineation to measure the coefficient of retroreflected luminance with a prescribed geometry.

3.2.8 *presentation angle,* γ—angle between the observation half-plane and the half-plane that originates on the illumination axis and that contains the retroreflector axis.

3.2.9 *retroreflection*—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.

3.2.10 *viewing angle*, *v*—the angle between the retroreflector axis and the receiver axis.

3.2.10.1 *Discussion*—The retroreflector axis for pavement markings is normal to the marking.

4. Summary of Practice

4.1 This practice involves the selection and use of commercial portable retroreflectometers for measurement at a prescribed geometry of the coefficient of retroreflected luminance of horizontal coating materials used in pavement markings.

4.2 The entrance angle used in such instruments is generally between 85.0° and 89.5°.

4.3 The observation angle used in such instruments is generally between 0.5° and 2.0°.

4.4 The instrument shall be selected so that the observation and entrance angles provided in the instrument conform to the angles specified by the pertinent agency or, if there is no specification for angles, the instrument shall be selected with attention to the general information provided in Section 5, Table 1, and Fig. 1.

4.5 The portable retroreflectometers may use either a built-in reference white for standardization or an external panel of known coefficient of retroreflected luminance.

4.6 General practice is to place the retroreflectometer directly over the pavement marking to be measured making sure that the measurement area of the retroreflectometer fits within the width of the stripe. The reading displayed by the retroreflectometer shall be recorded.

4.7 General practice is to then move the retroreflectometer to a number of other positions on the pavement marking and record and average the readings.

4.8 For a centerline, readings are generally taken and averaged in each direction.

4.9 Because of the extreme range of entrance and observation angles available in commercial instruments it should not be anticipated that there will be any correlation between instruments except for those using identical entrance and observation angles. This caution is true even when the instruments are standardized using as a standard, materials having the same glass bead indices, penetration, binder index, etc.

5. Significance and Use

5.1 The quality of the stripe is determined by the coefficient of retroreflected luminance and depends on the materials used, the age, and the wear pattern. These conditions should be observed and noted by the user.

5.2 Under the same conditions of illumination and viewing, larger values of R_L correspond to higher levels of visual performance.

5.3 Retroreflectivity of pavement (road) markings degrades with traffic wear and requires periodic measurement to ensure that sufficient line visibility is provided to drivers.

5.4 The relative visibility rankings of two different pavement markings may vary with the distance at which the markings are viewed. The material with the higher visibility ranking at short distance may have the lower visibility ranking at a larger distance (see Fig. 1).

5.5 For a given viewing distance, measurements of R_L made with a retroreflectometer having a geometry corresponding to that viewing distance are a good indicator of the visual ranking of material measured.

5.6 For most pavement marking materials the correlation between the R_L values measured by retroreflectometers with distinctly different measurement geometries generally will be inadequate for practical use.

5.7 It is the responsibility of the user to employ an instrument that is appropriate for the viewing distance established, as being important in meeting driver needs. For the convenience of the user, viewing geometry for centerline markings at various distances from a typical car and driver is illustrated in Fig. 2 and tabulated in Table 1. The measurement geometry of available portable retroreflectometers is listed in Table X1.1 of Appendix X1.

6. Apparatus

6.1 *Portable Retroreflectometer*:

6.1.1 The retroreflectometer shall be portable with the capability of being placed on various horizontal pavement markings in different locations.

6.1.2 The retroreflectometer shall be constructed so that placement on the highway pavement markings will preclude any stray light (daylight) from entering the measurement area of the instrument and affecting the reading.

6.1.3 For the convenience of the user, an arrow shall be placed on the instrument to enable it to be aligned with the direction of traffic.

6.2 *Light Source Requirements*:

6.2.1 The projection optics shall be such that the distribution of the illuminance over the measurement area should be within 10 % of the average illuminance.

6.2.2 The aperture angle of the light source as determined from the center of the measurement area shall be not greater than 10 min of arc (0.17°).

6.3 *Receiver Requirements*:

6.3.1 The receiver shall have sufficient sensitivity and range to accommodate coefficient of retroreflected luminance values expected in use, typically 1 to 2000 millicandelas per square meter per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$).

6.3.2 If the retroreflectometer is intended to be used for measurement of marking materials other than white, 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 luminosity 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_L measured with the filter to the R_L measured without the filter shall be within 10 % of the Illuminant *A* luminous transmittance of an air-spaced pair of two such filters.

6.3.3 The aperture angle of the receiver as determined from the center of the measurement area shall be not greater than 10 min of arc (0.17°).

6.3.4 Instruments with annular apertures are not recommended for measuring pavement markings.

6.3.5 The combined stability of the output of the light source and receiver shall be such that readings do not change

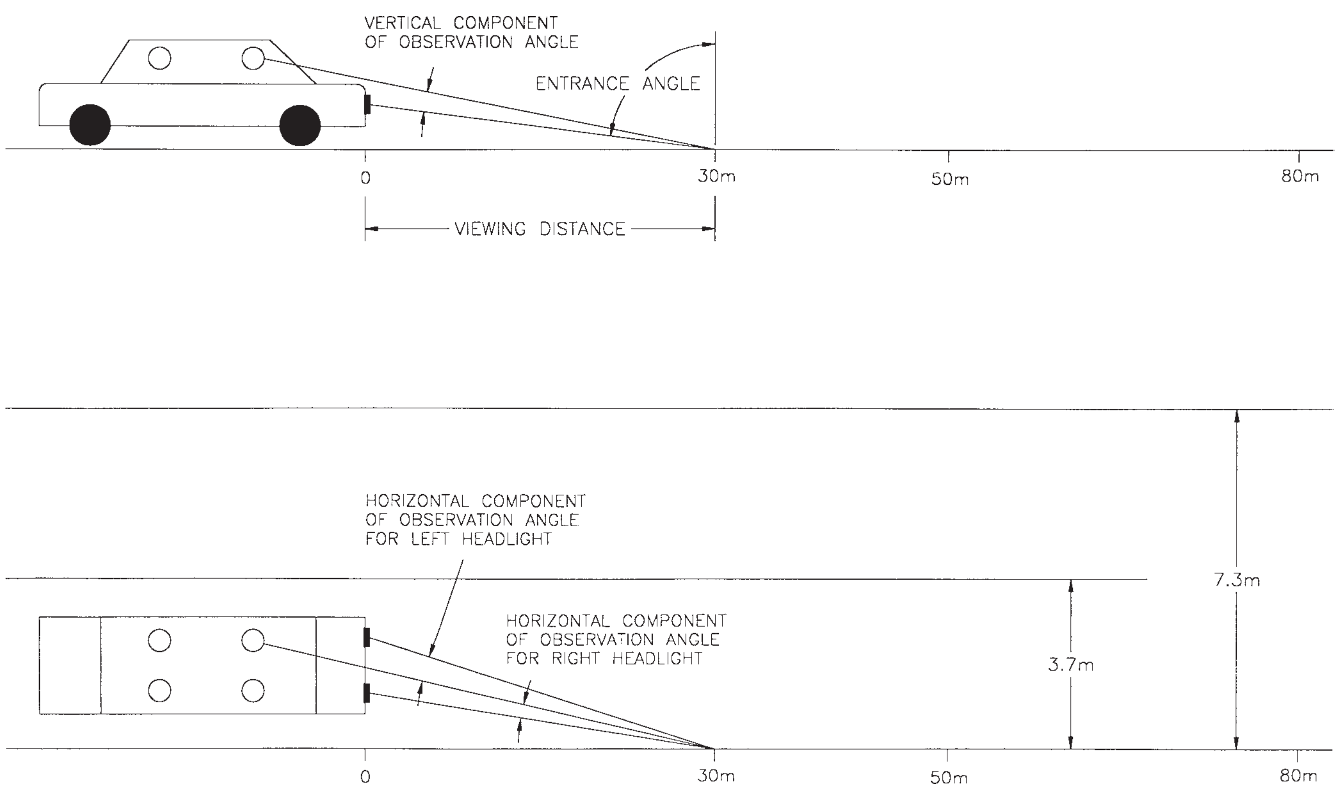


FIG. 2 Relationship Between Observation Angle and Viewing Distance

more than ±1 % after 10 s when the retroreflectometer is in contact with the pavement marking and ready to measure.

6.3.6 The linearity of the retroreflectometer photometric scale over the range of readings expected, shall be within 2 %. Correction factors may be used to ensure a linear response. A method for determining linearity is found in Annex A2 of Practice E 809.

6.4 *Measurement Geometry*:

6.4.1 The light source and receiver may be either at optical infinity or at a finite distance from the measurement area.

6.4.2 The observation angle and entrance angle of the retroreflectometer shall be selected on the basis of existing specifications or on the basis of the viewing distance considered most important in meeting driver needs (see Table 1 and Fig. 2).

6.4.3 For the geometry recommended for a viewing distance of 30 m, see Test Method E 1710.

6.4.4 The presentation angle of the retroreflectometer shall be 0° and shall be stated in the instrument specifications.

6.4.5 For a diagram of the optics geometry, see Fig. 3 .

7. Sampling

7.1 The number of readings to be taken at each test location and the spacing between test locations shall be specified by the user.

7.2 Recommendations as to the number of readings and spacing will be made in a later revision of this standard.

8. Standardization

8.1 The retroreflectometer shall be standardized using an instrument standard consisting of a separate panel of marking material with a known and reproducible coefficient of retroreflected luminance at the same geometry as the retroreflectometer. The instrument standard shall be standardized in accordance with Test Method D 4061 with the datum mark indicated on the standard. The instrument standard shall have a coefficient of retroreflected luminance, R_L, within the expected pavement marking range. The standardization values shall be maintained by checking against other standards or using Test Method D 4061 sufficiently often to ensure no large uncertainties in the measurement can occur.

8.2 Subsequent to this standardization, an internal or secondary reference surface, either diffuse white or retroreflecting surface, may be used to maintain the standardization of the instrument during brief periods of transport to the test site area.

8.3 Note that transporting the instrument from an air conditioned area to the test site may result in fogging of lenses or mirrors (if any) in the instrument. If there is any doubt about the standardization or if the readings are not constant, allow the instrument to reach ambient conditions and restandardize with the instrument standard.

9. Procedure

9.1 Use the manufacturer's instructions for operation of the retroreflectometer. In general, use the following procedure:

9.1.1 Ambient temperature shall be not less than 4°C (40°F).

9.1.2 The surface of the marking material shall be clean and dry.

9.1.3 Turn on the retroreflectometer and allow it to reach equilibrium following the manufacturer's instructions.

9.1.4 If the retroreflectometer has a zero-adjust control, set the display to 0 ± 2 in the least significant digit with the instrument placed on a very black, low retroreflectance panel.

9.1.5 If an instrument standard is used, standardize the retroreflectometer by placing the retroreflectometer on the instrument standard and setting the standardization control to the standardized value for that geometry.

9.1.6 For instruments with an internal reference surface, insert that surface into the light path and read the signal from the display. Record this reading.

9.1.7 Place the retroreflectometer squarely on the pavement marking material, making sure that the measurement area of the retroreflectometer fits within the width of the stripe. The reading direction of the retroreflectometer shall be placed in the direction of traffic. For centerlines, take readings for each direction of traffic and averaged separately.

9.1.8 Record the retroreflectometer reading and then move to other locations on the same sample set separated sufficiently to provide meaningful data (typically one meter) and record the results.

9.1.9 At intervals of 1 h or less, check the standardization and readjust the setting if the reading of either the internal standard or instrument standard has changed by more than 5 %.

10. Report

10.1 Report the following information:

10.1.1 The test date,

10.1.2 For traffic lane lines the average of the readings at each test location expressed as millicandelas per square meter

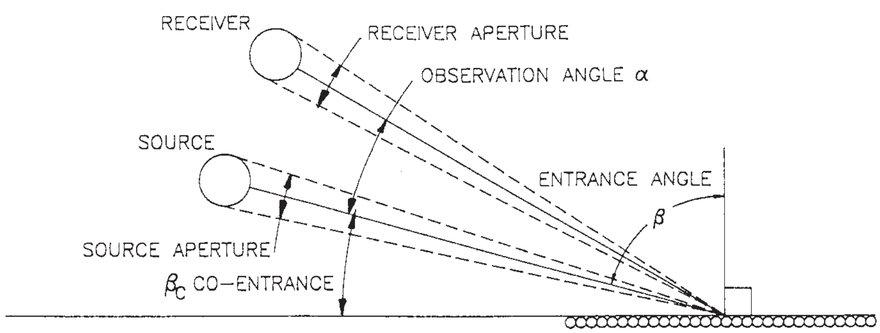


FIG. 3a Angles and apertures for non-collimating portable retroreflectometer.

FIG. 3 Optics Geometry Diagram for Portable Road Marking Retroreflectometer

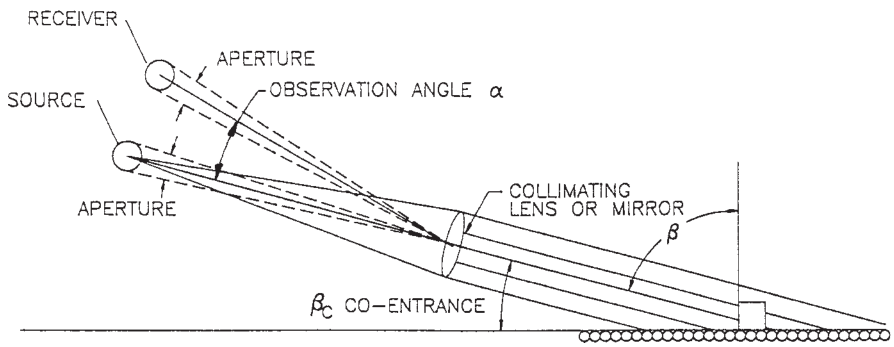


FIG. 3b Angles and apertures for collimating optics portable retroreflectometer.

FIG. 3 *(continued)*

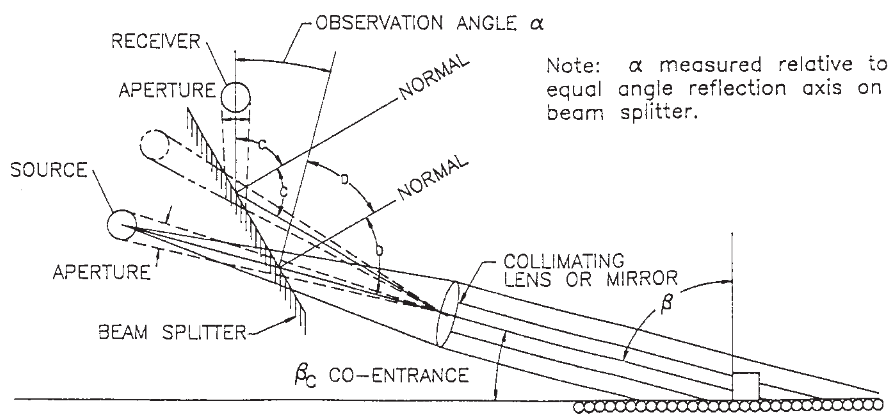


FIG. 3c Angles and apertures for portable retroreflectometer with collimating and beam splitter design.

FIG. 3 *(continued)*

per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$) for each sample set. For centerlines the average of the readings shall be reported for each traffic direction,

10.1.3 The geographical location of the test site including distance and direction from the nearest permanent site identification such as a mileage marker or crossroad,

10.1.4 Identification of the pavement marking material tested: type, color, age, transverse location on road (edge line, first line, second line, center),

10.1.5 Identification of the instrument used,

10.1.6 Value and date of standardization of the instrument standard used,

10.1.7 The entrance, viewing and observation angles used to obtain the readings,

10.1.8 Remarks as to overall condition of the line, such as rubber skid marks, carry over of asphalt, snow plow damage, and other things that may affect the retroreflection measurement, and

10.1.9 Ambient temperature.

11. Sources of Error

11.1 There are many factors that cause high variability when taking readings in the field, some of these are as follows:

11.1.1 Retroreflectometers with differing entrance angles or observation angles, or both, will give different readings,

11.1.2 Slight changes in the position of the retroreflectometer on the traffic line may give different readings,

11.1.3 Transverse lines may give less uniform readings than longitudinal lines. Transverse lines have high wear in the wheel track area and less wear in non-wheel track area,

11.1.4 The refractive index of the glass spheres and their depth of embedment as well as population on the pavement marking material will affect the readings,

11.1.5 The pigment loading of the binder, road films, dirt, salt, dust, water, etc. will also affect the readings, and

11.1.6 The entrance angle with respect to the specimen plane will be affected by the physical characteristics of the specimen.

12. Keywords

12.1 pavement markings; portable retroreflectometers; retroreflection

APPENDIX

(Nonmandatory Information)

X1. MEASUREMENT GEOMETRIES OF AVAILABLE PORTABLE RETROREFLECTOMETERS FOR PAVEMENT MARKING MATERIALS

X1.1 It should be the responsibility of the user to select an instrument based upon the visibility needs of drivers. Beyond that, cost, convenience of use, durability, etc., may influence the choice of instrument.

X1.2 Instrument makers are not identified. It is suggested that the user obtain measurement geometry specifications from manufacturers.

X1.3 Listed in Table X1.1 are the observations, co-entrance, and entrance angles used in portable retroreflectometers known to be available May, 1994.

TABLE X1.1 Measurement Geometry of Available Portable Retroreflectometers in Degrees

NOTE 1—Most known portable instruments have fixed measurement geometries.

	Observation Angle	Co-entrance Angle	Entrance Angle
Instrument 1	0.63	0.7	89.3
Instrument 2	1.0	3.5	86.5
Instrument 3	1.0	1.5	88.5
Instrument 4	1.05	1.24	88.76
Instrument 5	1.5	3.5	86.5