Designation: E 1501 – 99$^{\epsilon 1}$

Standard Specification for Nighttime Photometric Performance of Retroreflective Pedestrian Markings for Visibility Enhancement[1]

This standard is issued under the fixed designation E 1501; 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.

ϵ^1 NOTE—Editorial changes made throughout in September 2000.

INTRODUCTION

The use of appropriate retroreflective markings can significantly enhance the night visibility and safety of the user. As the first in a series addressing overall visibility for individual safety, this standard is intended to establish minimum retroreflective performance requirements and test methods for retroreflective pedestrian markings.

1. Scope

1.1 This specification covers the performance of retroreflective markings to be used on objects worn by pedestrians for the purpose of enhanced conspicuity. It addresses conspicuity from viewpoints around the entire object, and it allows for freedom of design of the markings so long as the minimum requirements are achieved. Objects include but are not limited to jackets, shirts, vests, trousers, socks, backpacks, hats, and footwear. An adjustment for the brightness/luminance ratio as a function of color is also made.

1.2 This specification applies only to nighttime viewing conditions in which the observer is positioned near a source of illumination. The most common example is that of a motor vehicle operator seeing by means of the light from the headlamps of the vehicle.

1.3 This specification describes the minimum retroreflective performance required for a reasonable level of nighttime conspicuity. It does not address potentially diminished performance of retroreflective markings that may be experienced with general storage, use, wear, and care.

1.4 SI (metric) units shall be used in referee decisions under this specification.

1.5 The following safety hazards caveat pertains to specifying materials by this standard specification. Although the markings described in this specification are intended to significantly enhance safety through increased conspicuity under most conditions of illumination and viewing of the type described in 1.2 above, they do not guarantee significantly enhanced conspicuity under all such conditions. Individuals exposed to adverse weather conditions or associated with high levels of vehicular or hazards exposure may require other types or amounts of retroreflective markings. *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 808 Practice for Describing Retroreflection[2]

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

E 811 Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions[2]

F 923 Guide Properties of High Visibility Materials Used to Improve Individual Safety[2]

2.2 *Other Standards:*

Publication CIE No. 54, Retroreflection—Definitions and Measurements, Central Bureau of the CIE, Vienna, 1982[3]

3. Terminology

3.1 *Definitions*—Definitions of terms relating to retroreflection in Terminology E 284, Practice E 808, and Guide F 923 are applicable to this specification.

3.1.1 *coefficient of luminous intensity, R_I, n*—of a retroreflector, ratio of the luminous intensity (I) of the retroreflector in the direction of observation to the illuminance ($E_\perp$) at the retroreflector on a plane perpendicular to the direction of the incident light, expressed in candelas per lux ($cd \cdot lx^{-1}$). $R_I = (I/E_\perp)$.

[1] This specification is under the jurisdiction of ASTM Committee E-12 on Color and Appearance and is the direct responsibility of Subcommittee E12.08 on High Visibility Materials for Individual Safety.

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

[3] Available from the USNC–CIE Publications Office, c/o Mr. Thomas M. Lemons, TLA-Lighting Consultants, 7 Pond Street, Salem, MA 01970-4819.

3.1.2 *conspicuity*, *n*—the characteristics of an object that determine the likelihood that it will come to the attention of an observer.

3.1.3 *observation angle*, α, *n*—*in retroreflection*, angle between the illumination axis and the observation axis.

3.1.3.1 *Discussion*—The observation angle is always positive and is restricted to small acute angles.

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

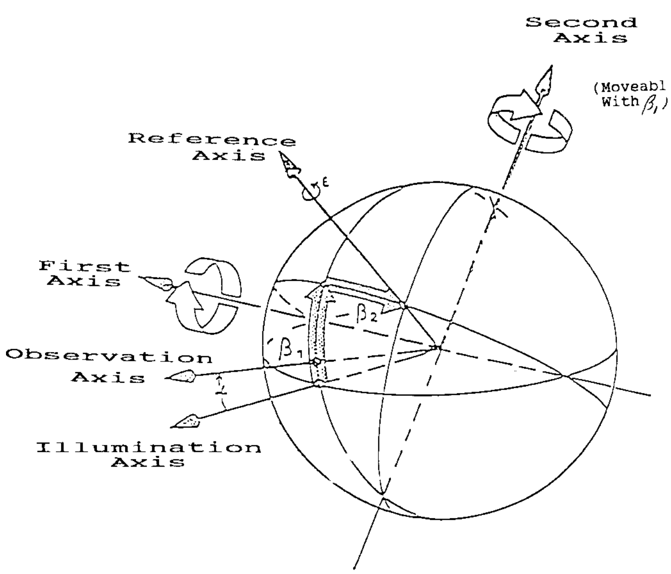
3.1.5 *pedestrian*, *n*—any person on foot (standing or moving) who is located on a highway or street. **F 923**

3.1.6 *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.

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

3.1.7.1 *Discussion*—This is sometimes called the reference axis (Fig. 1). It is used to establish a coordinate system fixed with respect to the retroreflector by which its location and angular orientation can be specified. When symmetry exists, the retroreflector axis usually coincides with the axis of symmetry of the retroreflector. This is the axis of maximum reflectivity. It is typically normal to the face of retroreflective sheeting. For injection-molded retroreflectors, its direction may vary, and must be defined as a result of testing or by consulting the manufacturer.

3.2 *Definitions of Terms Specific to This Standard:*



See Publication CIE No. 54. The principal fixed axis is the illumination axis. The first axis is perpendicular to the plane containing the observation axis and the illumination axis. The second axis is perpendicular to both the first axis and the reference axis. The reference axis is fixed with respect to the retroreflector or object but movable with the components β_1 and β_2 of the entrance angle. All axes, angles, and directions of rotation are shown positive.

FIG. 1 The CIE Angular Reference System for Specifying and Measuring Retroreflectors

3.2.1 *color factor* F_c, *n*—a chromatic adjustment to coefficient of luminous intensity R_I to account for the ratio of brightness to luminance.

3.2.2 *entrance angle component for object inclination*, β_1, *n*—angle from the illumination axis to the plane containing the object reference axis and the first axis for the object (see Fig. 1 and Fig. 2). Range: $-90°<\beta_1\leq 90°$.

3.2.3 *entrance angle component for object rotation*, β_2, *n*—angle from the plane containing the observation half-plane to the object reference axis (see Fig. 1 and Fig. 2). Range: $-180°< \beta_2\leq 180°$

3.2.4 *first axis for the object*,, *n*—axis through the approximate center of the object and perpendicular to the observation half-plane (see Fig. 1 and Fig. 2).

3.2.5 *marking*, *n*—that portion of an object that retroreflects.

3.2.6 *object*, *n*—the item worn by a pedestrian, to be marked for increased conspicuity under this specification.

3.2.7 *object reference axis*,, *n*—a designated line segment that extends outward from the approximate center of the object and is horizontial when the object is oriented in its usual upright position (see Fig. 1 and Fig. 2).

3.2.8 *retroreflective return*, R_R, *n*—the sum of the coefficients of luminous intensity, R_I, measured at two selected observation angles and adjusted for chromaticity.

3.2.8.1 *Discussion*—This quantity is used to describe the effective performance of the object. (See 6.6.)

3.2.9 *second axis for the object*, *n*—axis through the approximate center of the object, lying in the plane of the illumination axis and observation axis, and perpendicular to the object reference axis (see Fig. 1 and Fig. 2).

4. Classification of Objects

4.1 To facilitate testing objects, they are classified as follows:

4.1.1 *Type 1*—Coats, jackets, and coveralls. Sleeved garments with markings on front, back, and sleeves. A typical example is shown in Fig. 3.

4.1.2 *Type 2*—Vests. Sleeveless garments to cover front, back, and sides of upper torso. Markings are provided on the front and back. A typical example is shown in Fig. 4.

4.1.3 *Type 3*—Trousers (short or long), leg bands, leggings, socks (to be worn with short trousers), and other leg coverings. A typical example is shown in Fig. 5.

4.1.4 *Type 4*—School bags and backpacks. Back-carried using shoulder and/or front straps. Markings are on surfaces away from the body, including carrying straps. A typical example is shown in Fig. 6.

4.1.5 *Type 5*—Hats, helmets, head bands, and other head gear. Garments worn on the head for protection, warmth, or increased conspicuity. A typical example is shown in Fig. 7.

4.1.6 *Type 6*—Shoes and other footwear. Objects worn on the feet. A typical example is shown in Fig. 8.

4.2 Other types 4.1.1-4.1.6 are not limited to the example or marking placement shown in Figs. 3-8.

5. Performance Requirements

5.1 *Retroreflective return* (R_R):

5.1.1 For each distance simulation and each entrance angle

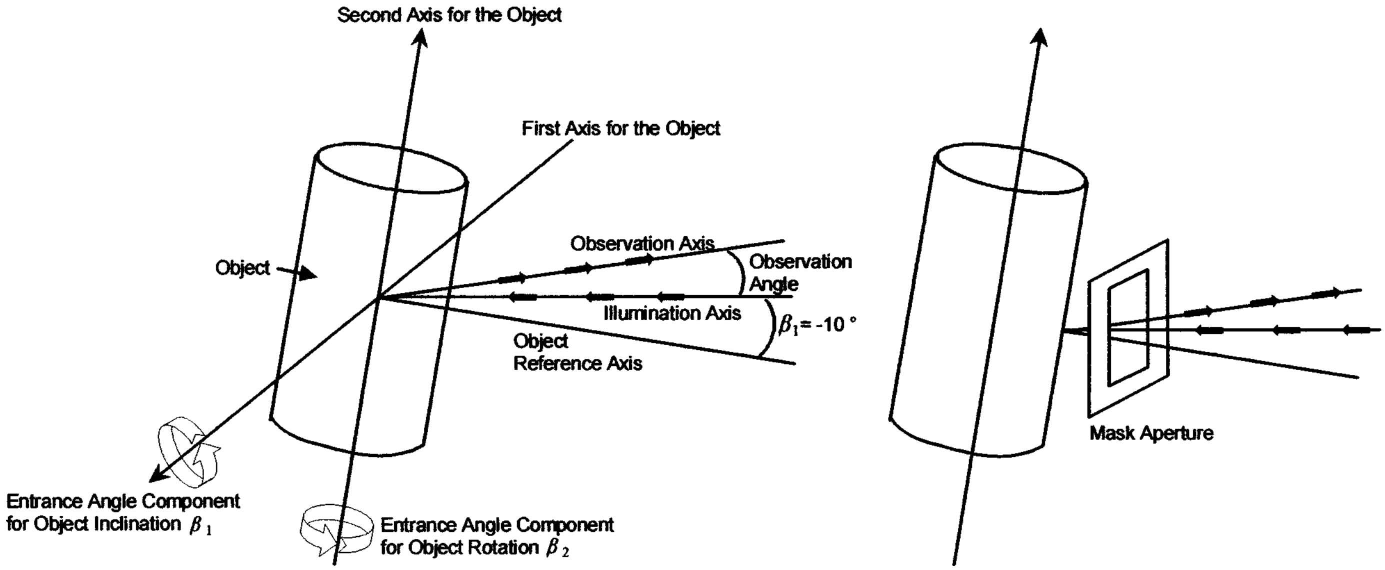


FIG. 2 The Angular Reference System Used in this Specification

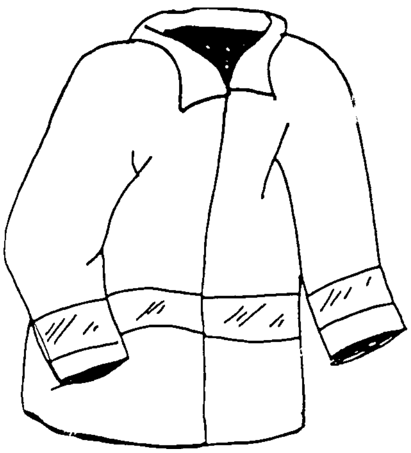


FIG. 3 A Type 1 Object (Coats, Jackets, and Coveralls) Showing Location of Markers

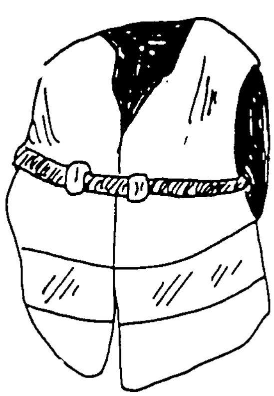


FIG. 4 A Type 2 Object (Vests) Showing Location of Markers

component for object rotation β_2 the retroreflective return, R_R is calculated by the following formula:

$$R_R = F_c\,[R_{I1} + R_{I2}]\,[A_0 / A]^{0.6} \tag{1}$$

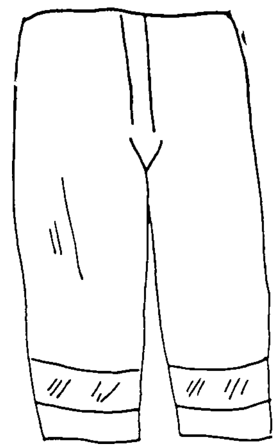


FIG. 5 A Type 3 Object (Trousers and Other Leg Coverings) Showing Location of Markers

where:

F_c = is the color factor for the markings as determined in 6.5,

F_c = is defined to be dimensionless, so R_R has the same physical dimensions as R_I,

R_{I1} = is the coefficient of luminous intensity, R_I measured through an aperture mask (see Section 6) at observation angle α_1 as given in Table 1,

R_{I2} = is the coefficient of the luminous intensity, R_I measured through an apertured mask (see Section 6) at observation angle α_2 as given in Table 1,

A_0 = is the minimum area for any mask aperture for each distance simulation as given in Table 1, and

A = is the sum of the areas of the apertures in the mask; the minimum dimensions for area A_0 and dimension D_0 of a mask aperture are given in Table 1.

5.1.2 For each of the two distance simulations and at each measurement point at 15° intervals of β_2 over a full 360° of rotation as the object is rotated about the second axis for the object with an entrance angle component for object inclination

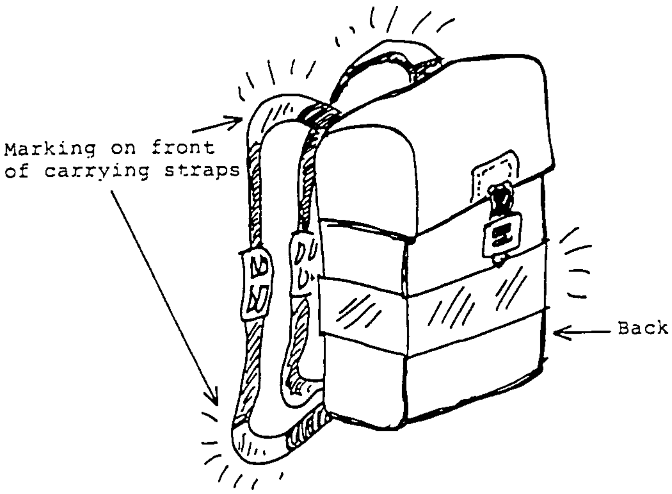


FIG. 6 A Type 4 Object (School Bags and Backpacks) Showing Location of Markers

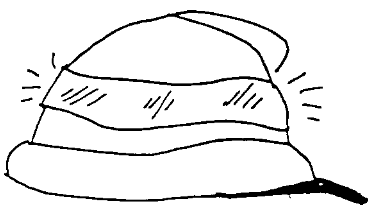


FIG. 7 A Type 5 Object (Hats and Other Headgear) Showing Location of Markers

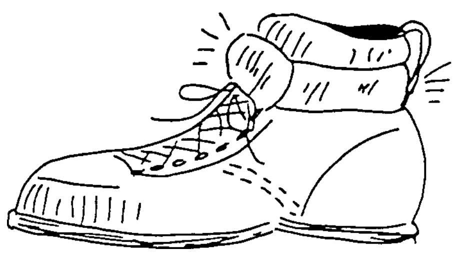


FIG. 8 A Type 6 Object (Shoes and Other Footwear) Showing Location of Markers

TABLE 1 Measurement Parameters for Determining R_R Which are Specific to Simulated Viewing Distances

Distance Simulated	Observation α_1	Angles α_2	Minimum Aperture Area A_0	Minimum Aperture Dimension D_0
70 m	1.1°	0.5°	0.005 m^2 (7.56 in.^{2})	0.07 m (2.75 in.)
230 m	0.3°	0.15°	0.053 m^2 (82 in.^{2})	0.23 m (9.06 in.)

β_1 of −10°, R_R shall be equal to or greater than the minimum value shown in Table 2. Since, within prescribed limits, the dimensions of the mask aperture(s) are to be specified by the object manufacturer in order to allow a particular design to be evaluated under conditions favorable to it, in cases of dispute it is up to the person claiming an object meets the specifications to define the mask(s) for the measurements that will be made to verify compliance. (See 6.2.1 for further discussion of masks.)

TABLE 2 Required Minimum Values of R_R

Distance	Minimum R_R
70 m	0.40 cd/lx
230 m	2.30 cd/lx

5.2 *Control of the Position of Test Objects When Tested for Retroreflective Return*:

5.2.1 Objects shall be selected according to the appropriate classification (Section 4), prepared by the corresponding preparation method (6.2.8), and tested according to the test methods of 6.2.5 and 6.2.6.

5.2.2 Objects shall be oriented in their usual upright positions, with no rotation about the object reference axis. Entrance angle components for object inclination (β_1) and object rotation (β_2) shall be set according to 6.2 .

6. Test Methods

6.1 *Summary of Test Methods*:

6.1.1 Retroreflective marking test geometries and procedures.

6.1.1.1 Mask. (See 6.2.1.)

6.1.1.2 Observation angles, α. (See 6.2.2.)

6.1.1.3 Entrance angle component for object inclination, β_1. (See 6.2.3.)

6.1.1.4 Entrance angle component for object rotation, β_2. (See 6.2.4.)

6.1.1.5 Seventy metre simulation test for coefficient of luminous intensity, R_I. (See 6.2.5.)

6.1.1.6 Two hundred-thirty metre simulation test for coefficient of luminous intensity, R_I. (See 6.2.6.)

6.1.1.7 Test preparation for pedestrian object by classification. (See 6.2.8.)

6.1.2 Retroreflectometer parameters for instrumental measurements of the performance characteristics of retroreflective markings. (See 6.3.)

6.1.3 Parameters for measuring colorimetric characteristics of retroreflective markings under nighttime conditions. (See 6.4.)

6.1.4 Calculating color factor, F_c. (See 6.5.)

6.1.5 Calculating retroreflective return, R_R. (See 5.1 and 6.6.)

6.2 *Retroreflective Marking Test Geometries*:

6.2.1 For each measurement of R_I a matte black mask must be placed immediately before the object. The mask must exclude from the measurement all but the selected marking(s) or portion(s) of the marking(s) that are to be included in determining whether R_R meets this specification.

TABLE 3 Conditions for Measurement of Coefficient of Luminous Intensity R_I

Condition	70 m Simulation	230 m Simulation
Observation Angle		
α_1	1.10°	0.30°
α_2	0.50°	0.15°
Entrance Angle Component for Object Inclination β_1	−10°	−10°
Entrance Angle Component for Object Rotation β_2	–165° to +180° in 15° steps	–165° to +180° in 15° steps

6.2.1.1 During measurement of R_I the mask shall be positioned perpendicular to the illumination axis and as close as possible to the object.

6.2.1.2 The same aperture sizes and positions must be used for both R_I measurements used to determine a given value of R_R. If desired, the mask may be moved around in any direction perpendicular to the illumination axis to search out the position yielding the highest combined R_I readings before the measurement data are recorded. The position and sizes of the apertures may be different for different entrance angle components for object rotation β_2 and distance simulations.

NOTE 1—The two R_I measurements used in a given determination of R_R simulate the simultaneous contributions to brightness by a pair of headlights, and thus, must be made under the same conditions.

6.2.1.3 The size and shape of the aperture(s) used are discretionary with the exception of the following limitations: Each aperture must be a square or rectangle(s) and at least D_0 in both dimensions. The values for D_0 for each distance simulation are given in Table 1. When more than one aperture is used simultaneously, as in measuring objects with multiple markings in view, the apertures may not be overlapping, although contiguous apertures are permitted. (See Appendix X1 for illustrations of apertures and suggestions for optimizing apertures.)

NOTE 2—Experiments conducted by E12.08 members indicated that conspicuity is governed by fields with retinal angles of approximately 1 milliradian. The values of D_0 were selected to take this into account.

6.2.2 The observation angles shall be α = 0.15°, 0.30°, 0.50° and 1.10°, each observation angle to be used as specified in 6.2.5 and 6.2.6.

6.2.3 The entrance angle component for object inclination, β_1, shall be set to −10°.

6.2.4 The entrance angle components for object rotation used (β_2 = –165° to 180° in 15° steps) simulate a pedestrian turning 360° about a near-vertical axis (β_1 = −10°).

NOTE 3—A pedestrian may be perceived by a vehicle driver in any orientation about its vertical axis. It is required that the conspicuity of the pedestrian or object be maintained over 360° of its rotation about a vertical axis. To test for this, measurements are taken at every 15° of this rotation.

6.2.5 To determine the coefficient of luminous intensity, R_I, for the 70 m simulation, the following tests will be performed with the test object at an entrance angle component for object inclination β_1 = −10°. Measurements of luminous intensity shall be made at observation angles of α_1 = 1.10° (simulating the right headlight) and α_2 = 0.50° (simulating the left headlight).

6.2.5.1 Separate measurements of luminous intensity shall be made at each specified observation angle.

6.2.5.2 The coefficient of luminous intensity, R_I is measured in accordance with Practice E 809.

6.2.6 To determine the coefficient of luminous intensity, R_I, for the 230 m simulation, the following tests will be performed with the test object at an entrance angle component for object inclination of β_1 = −10°. Measurements of luminous intensity shall be made at observation angles of α_1 = 0.30° (simulating the right headlight) and α_2 = 0.15° (simulating the left headlight).

6.2.6.1 Separate measurements of luminous intensity shall be made at each specified observation angle.

6.2.6.2 The coefficient of luminous intensity, R_I, is measured in accordance with Practice E 809.

6.2.7 Table 2 establishes the required retroreflected return, R_R. R_R is the coefficient of luminous intensity multiplied by the color factor, F_c. (See 5.1 and 6.6.)

6.2.8 *Test Preparation for Pedestrian Object by Classification*:

6.2.8.1 The following type-specific test procedures are provided for the control of the shape of the objects being tested.

6.2.8.2 *Type 1*—Coats, jackets, and coveralls. These shall be mounted on an appropriate mannequin such that the garment can be fastened easily without large wrinkles or folds. The test garment shall hang naturally from the mannequin without touching the ground. The test object shall be measured in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.3 *Type 2*—Vests. These shall be mounted on an appropriate mannequin such that the garment can be fastened easily without large wrinkles or folds. The mannequin shall be armless or have provision for moving or removing the arms so that they do not block the test illumination or the retroreflective return. The test object shall be tested in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.4 *Type 3*—Trousers. These shall be mounted on an appropriate leg-shaped form such that the garment can be fastened easily without large wrinkles or folds. The test garment shall hang naturally from the mannequin without touching the ground and shall be tested in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.5 *Type 4*—School bags and backpacks. These shall be mounted on an appropriate form and tested in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.6 *Type 5*—Hats. These shall be mounted on an appropriate form and tested in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.7 *Type 6*—Shoes and other footwear. These shall be mounted in pairs 3.8 cm (1.5 in.) apart, in parallel, on appropriate forms and tested in accordance with 6.2.5, 6.2.6, and 6.6.

6.2.8.8 When a mannequin is used to provide a human form, the entrance angle component for object inclination, β_1, is selected as −10°.

6.2.8.9 In all descriptions of orientations, the object is to be considered as being positioned as it would be worn by a pedestrian under ordinary circumstances.

6.3 *Retroreflectometer Parameters for Instrumental Measurements of the Performance Characteristics of Retroreflective Markings*:

6.3.1 The coefficient of luminous intensity, R_I of the test specimen described above shall be measured in accordance with Practice E 809 (modified with use of masks as described in 6.2.1) using the following parameters:

6.3.1.1 Minimum test distance: 15 m (50 ft).

6.3.1.2 Maximum photoreceptor angular aperture: 0.1°.

6.3.1.3 Angular aperture of the object: as determined by the masks specified in 6.2.1.3.

6.3.1.4 Source angular aperture: 0.1°.

6.3.1.5 Observation half-plane oriented upward and vertical.

6.4 *Chromaticity Coordinates*—Chromaticity coordinates need not be measured for achromatic markings or when the markings meet this specification with $F_c = 1$. The retroreflective marking material chromaticity coordinates shall be determined by testing flat samples of the marking materials used on the garment or object in accordance with Practice E 811 with the following parameters:

6.4.1 Observation angle: $\alpha = 0.33°$.

6.4.2 Entrance angle : $\beta_1 = -10°$.

6.4.3 Rotation angles: ϵ = five equally spaced (72° apart).

6.4.4 Observation distance: 15 m or greater.

6.4.5 Specimen size: rectangle 0.1 m (4 in.) by 0.3 m (12 in.). (If the marking is made using separate small retroreflectors, these shall be arranged closely spaced in an array falling within the dimensions given in 6.4.)

6.4.6 Receptor angular aperture: no greater than 0.2°.

6.4.7 Source angular aperture: no greater than 0.2°.

6.4.8 The retroreflector center shall be the geometric center of the specimen.

6.4.9 The retroreflector axis shall be perpendicular to the surface of the retroreflector.

6.5 *Color Factor for Adjustment Calculations, F_c*:

6.5.1 F_c may be set equal to 1 for achromatic markings and for other colored markings that meet this specification with $F_c = 1$.

6.5.2 For instrument parameters see 6.4.

6.5.3 The chromatic adjustment is obtained through the use of a multiplicative brightness–to–luminance ratio, F_c obtained as follows:

6.5.3.1 Calculate a color coordinate a normalized to $Y = 100$ for CIE Illuminant A and the CIE 1931 standard observer as:

$$a = 185\,[0.9105(x/y) - 1] \tag{2}$$

6.5.3.2 Calculate a color coordinate b normalized to $Y = 100$ for CIE Illuminant A and the CIE 1931 standard observer as:

$$b = 38\,[1 - 2.8131(z/y)] \tag{3}$$

6.5.3.3 Calculate F_c as:

$$F_c = 1 + (a^2 + b^2)^{1/2}/150 \tag{4}$$

NOTE 4—A highly chromatic retroreflector may appear brighter than an achromatic retroreflector with the same luminance, partially compensating for the lower luminance of the chromatic retroreflector. The values for R_I are adjusted by multiplication by F_c to take this into account.

NOTE 5—It is not the purpose of this specification to establish or imply that any certain color has a specific meaning in terms of pedestrian activities.

6.6 *Calculation of Retroreflected Return, R_R*:

6.6.1 The measured values of the coefficient of luminous intensity, R_I determined according to 6.2 and 6.3 and the value of F_c determined from 6.4 and 6.5 (or set equal to 1) shall be used to calculate R_R as described in 5.1 for each entrance angle component for object rotation β_2 and distance simulation.

$$R_R = F_c\,[(R_I \text{ at } \alpha = \alpha_1, \beta_2 = 0°) + (R_I \text{ at } \alpha = \alpha_2, \beta_2 = 0°)]\,[A_O / A]^{0.6} \tag{5}$$

and for β_2 = –165, –150, –135 ... +180°, giving 24 measurements in all, each the sum of two values of R_I at α_1 and α_2. Here F_c is the factor for adjustment for chromaticity, and R_I is the coefficient of luminous intensity. A_0 is the minimum area for any mask aperture for each distance simulation as given in Table 1. A is the sum of the areas of the apertures in the mask. (The minimum area A_0 and minimum dimension D_0 of the mask apertures are given in Table 1.) The specifications in Table 2 must be met. (See 5.1.)

6.6.2 If the values of R_R determined using $F_c = 1$ in 6.2 exceed those specified in Table 2, this specification can be considered to be met without need to determine the chromaticity adjustment.

7. Report

7.1 The report shall contain the following:

7.1.1 Sample identification.

7.1.2 Measured values of R_I used to meet this specification. (Measured values of R_I obtained only to position a mask need not be reported.)

7.1.3 The size, shape, approximate orientation, and approximate position of the mask apertures for each R_R determination (or set of R_R determinations using the same mask apertures and positions) shall be described in the report.

7.1.4 Calculations of retroreflected return, R_R. (See 6.6.)

7.1.5 Any deviation from the requirements of this specification.

8. Precision and Bias

8.1 The precision and bias for the test methods in 6 will be determined.

9. Keywords

9.1 conspicuity; high visibility materials; nighttime retroreflective performance; pedestrians; retroreflection/retroreflectors; retroreflective pedestrian markings; visibility

APPENDIXES

(Nonmandatory Information)

X1. DISCUSSION OF APERTURES IN MASKS

X1.1 Except as noted in 6.2.1.3, the size and shape of the apertures in the masks used to block extraneous reflections from the measurements is discretionary. In order to facilitate testing, the manufacturers of the pedestrian object must specify the masks. To obtain the highest R_R readings for a given marking the apertures should be filled with retroreflecting material and show a minimum of nonretroreflecting areas. The largest apertures meeting this condition will usually yield the highest calculated R_R values. (See Fig. X1.1 and Fig. X1.2.) When the marking material used will easily meet the specifications, there is an advantage to using an oversize aperture. It will simplify the testing and make it easier to automate. It will also make later verification measurements easier. (See example in Fig. X1.3.) Since the burden of proof is on the person claiming his markings meet the specification, it is a distinct advantage to him to produce markings with performance well above the required specifications because it makes the testing easier and offers the wearer of the object increased protection. If neither the minimum aperture over a "hot spot" in the marking nor an obviously good large aperture over most of the marking yields retroreflective return (R_R) values that pass the specification, it is usually wise to redesign the marking or use higher quality retroreflecting material, or both. This will make the test more easily met.

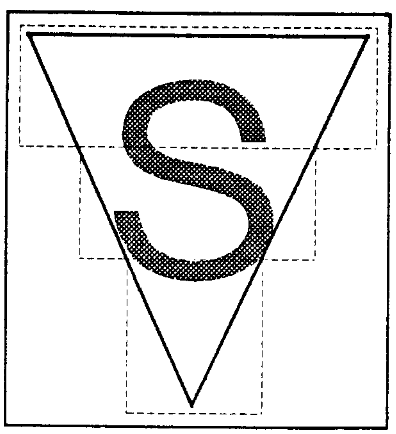
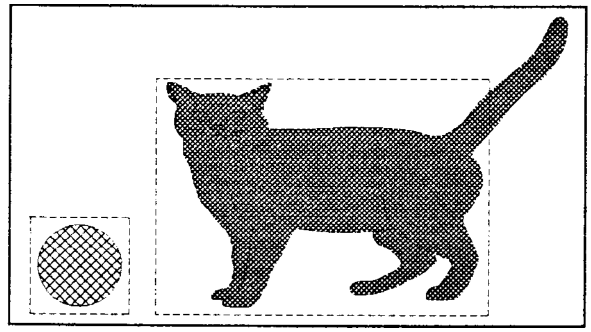
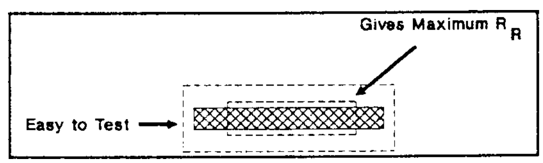


FIG. X1.1 Use of Three Contiguous Rectangular Apertures to Measure a Triangular "Superman" Logo



The cat's tail, while contributing to the design and conspicuity, should not be measured, since it is thinner than the minimum aperture dimension.

FIG. X1.2 Use of Two Apertures, One to Show the Cat and One to Show the Ball



The smaller aperture yields the higher retroreflective return (R_R), but the larger aperture allows the object to be measured at all object rotation angles without moving the aperture.

FIG. X1.3 Use of Two Different Apertures to Measure a Horizontal Stripe

X1.2 See Fig. X1.1, Fig. X1.2, and Fig. X1.3.

X2. RECOMMENDATIONS FOR DESIGN AND LAYOUT OF MARKINGS

X2.1 *Rationale for Marking*—This specification assures that from any position around the object at least one area in the marking will provide the proper level and concentration of retroreflected light to make the object conspicuous within normally encountered levels of background lighting. The specifications were arranged to allow a maximum of freedom in design. The ultimate goal of the markings is to increase the safety of individuals using the marked objects. The following suggestions will enhance the probability of achieving this goal:

X2.2 *Make Markings Appealing to Potential Users*—This is one of the most important factors in achieving safety through marking. In order to be protected, pedestrians must obtain and wear or carry marked items, and whatever encourages them to do so will advance the cause of safety.

X2.3 *Arrange Markings to Identify the Object as Being a Person* —Having a driver notice the object as a source of reflected light is only the first step towards providing pedestrian safety. Safety is greatly enhanced if a driver is assisted through the placement and design of the markings to discern that the marked object is not part of the background clutter. The following are suggestions: Arrange the markings in rows, bands, or other distinctive large groupings. Place markings on the ends of sleeves and on pants cuffs to provide motion characteristic of people. Arrange markings to provide outline characteristics of human beings such as "stick figures."

X2.4 *Place Markings for Maximum Exposure*—Try to arrange for markings to be clearly visible as much of the time as possible. The following are examples: On a vest or sleeveless shirt, the markings on the side should be placed low so as to have them hidden less by the wearer's arms. Avoid placing markings on a shirt so low that they might be obscured if the shirt is tucked into trousers. Place front markings on a hiker's jacket in the center so that they will not be obscured by the straps of a backpack, and place the rear markings on the back of the sleeves so that the pack itself will not obscure them.

X2.5 *Use Markings Beyond Those Required by the Specification* —The specification gives minimum values of retroreflective return for a single marking. Safety will be enhanced if the retroreflective return of a given measured area is greater than required in Table 1, or if more than one measured area at a time meets the specification when the object is viewed from a given direction. Also, safety can be enhanced by markings in addition to those that meet the specifications, even when the additional markings by themselves do not meet the specifications. For example, retroreflective piping to outline a garment might make its shape obvious after the specification marking has called attention to it, or a retroreflecting logo might provide a spot of additional reflected light that would move with the principal markings. Offsetting a higher consumer price due to such additional marking through truthful promotional statements such as, "Twice as much reflecting power as called for by ASTM E1501" or "Outlined with reflecting piping to enhance safety above ASTM E1501" is encouraged.

X3. BACKGROUND RESEARCH

X3.1 Members of Committee E12.08 researched the literature, performed calculations, and conducted experiments to establish a basis for the following:

X3.1.1 Observation angles.

X3.1.2 Required level of coefficient of luminous intensity, R_I.

X3.1.3 Mask to limit light to a specified angular aperture.

X3.1.4 Aperture placement during testing for R_I.

X3.1.5 This work is presently in preparation for publication.

X3.2 A Simple Retained Retroreflectivity Evaluation:

X3.2.1 A simple way to qualitatively check that the markings are still meeting expectations after use of the object is as follows:

X3.2.1.1 Place object with markings in a darkened room.

X3.2.1.2 Illuminate with and view directly over the top of a flashlight from 6 m (20 ft) away. (See Fig. X3.1.)

X3.2.1.3 Markings should appear easily distinguishable, particularly when compared to nonretroreflective material markings.

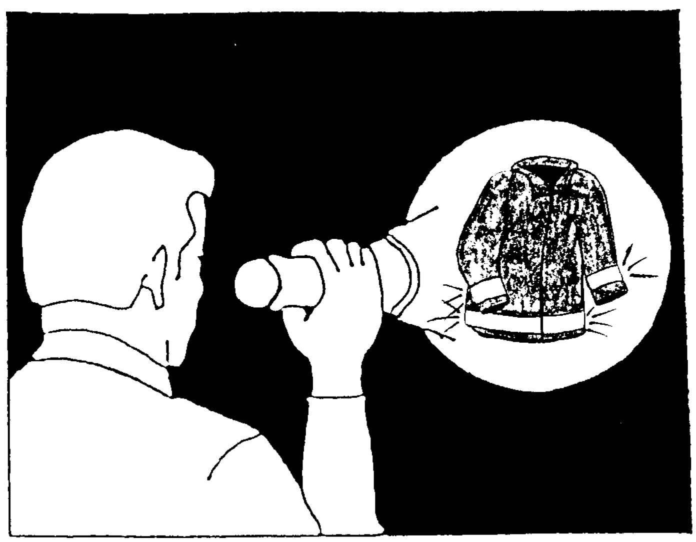


FIG. X3.1 Illumination and Viewing for a Simple Evaluation of Retained Retroreflectivity