Designation: D8514/D8514M – 23

Standard Specification for Flexible, Retroreflective Sheeting for Use in High Visibility Vehicle Markings[1]

This standard is issued under the fixed designation D8514/D8514M; 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 specification covers flexible, retroreflective sheeting for use in high visibility markings to provide enhanced daytime and/or nighttime visibility for use on emergency response vehicles, utility vehicles, and similar vehicles.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus

B209/B209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate

B449 Specification for Chromates on Aluminum

D2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

D4956 Specification for Retroreflective Sheeting for Traffic Control

E284 Terminology of Appearance

E308 Practice for Computing the Colors of Objects by Using the CIE System

E808 Practice for Describing Retroreflection

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

E811 Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions

E991 Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method

E1247 Practice for Detecting Fluorescence in Object-Color Specimens by Spectrophotometry

E1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry

E2301 Test Method for Daytime Colorimetric Properties of Fluorescent Retroreflective Sheeting and Marking Materials for High Visibility Traffic Control and Personal Safety Applications Using 45°:Normal Geometry

E3165 Test Method for Nighttime Retroreflected Chromaticity of Retroreflective Sheeting

G7/G7M Practice for Natural Weathering of Materials

G147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G155 Practice for Operating Xenon Arc Lamp Apparatus for Exposure of Materials

2.2 *Other Standards and References:*

Publication No. 14/04 High Conspicuity Livery for Police Vehicles, by Paul Harrison, Published by Police Scientific Development Branch, UK Home Office, 2004

NFPA 1901 Standard for Automotive Fire Apparatus, 2016

49 CFR 571.108, Standard No. 108 Lamps, Reflective Devices, and Associated Equipment

Report FA-336 / December 2013 Emergency Vehicle Safety Initiative, U.S. Fire Administration, Federal Emergency Management Administration, 2013

Report FA-323 / August 2009 Emergency Vehicle Visibility and Conspiciuity Study, Federal Emergency Management Administration, 2009

[1] This specification is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.38 on Highway Traffic Control Materials.

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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.

Study of Protecting Emergency Responders on the Highways and Operation of Emergency Vehicles: A Review of Responder Agencies Who Have Adopted Emergency Lighting and Vehicle Conspicuity Technology, Cumberland Valley Volunteer Fireman's Association – Emergency Responder Safety Institute, June 2018
NFPA 1917 Standard for Automotive Ambulances, 2019
Olson, Paul L. et al., Performance Requirements for Large Truck Conspicuity Enhancements, University of Michigan Traffic Research Institute, Report UMTRI-92-8, February 1992

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms are as described in Terminology E284 (Appearance), and Practice E808 (Practice for Describing Retroreflection).

3.1.2 *Battenburg markings, n*—an alternating pattern of large, contrasting color blocks. See X1.15.1 and Fig. X1.2 for additional details.

3.1.3 *chevron markings, n*—an inverted V-shaped mark of an alternating pattern positioned at a 45° angle of two contrasting colors. See X1.15.2 and Fig. X1.3 for additional details.

3.1.4 *fluorescent material, n*—a material that absorbs light energy of visible and/or ultraviolet wavelengths, and which, in turn, reradiates some portion of that light energy, typically at longer wavelengths.

3.1.4.1 *Discussion*—This reradiation allows fluorescent colors to be brighter during the daytime than non-fluorescent colors having a similar chromaticity.

3.1.5 *perimeter markings, n*—retroreflective striping, typically 25 mm wide, used to outline the contours of a vehicle.

4. Significance and Use

4.1 High visibility markings are utilized on emergency response vehicles, utility vehicles, and similar vehicles that may be required to stop alongside an active roadway. Such high visibility markings are utilized in order to capture the attention of motorists to warn of potentially hazardous roadside activity or to alert of the possible presence of individuals working outside their vehicle. Chevron markings and Battenburg markings are two examples of such high visibility markings.

4.2 This document establishes a specification for a flexible, retroreflective sheeting with substantially higher coefficients of retroreflection than that provided by engineer grade sheeting, which is commonly defined by Specification D4956, Type I.

4.3 This specification only defines the minimum properties for a flexible, retroreflective sheeting for use in high visibility vehicle markings. The application guidelines provided in the appendixes are for reference purposes only. It is the responsibility of the user of this document to determine the appropriate choice of materials, coverage areas, colors, and application patterns to meet their specific needs.

4.4 This specification does not cover conspicuity tape as commonly applied to the contours of heavy trucks, trailers, buses, or similar large vehicles. Such conspicuity tape is covered by other industry standards and regulations, such as 49 CFR 571.108. Similarly, this specification does not cover retroreflective tape utilized to outline the edges of slow-moving vehicle warning triangles.

4.5 This specification does not address inks, overlays, or other imaging methods that may be applied to the retroreflective sheeting.

4.6 This specification provides minimum requirements for photometric and colorimetric properties for the retroreflective sheeting prior to its installation and in-service use on vehicles. Retroreflective sheeting, once installed as vehicle markings, are outside the scope of this document.

5. Description of Materials

5.1 Retroreflective sheeting shall consist of a white or colored sheeting having a smooth outer surface and essentially have the property of a retroreflector over its entire surface. The sheeting is supplied with a pressure-sensitive adhesive to allow application to a vehicle surface.

6. Ordering Information

6.1 The purchaser using this specification shall include the following information:

6.1.1 Reference to required conformance of this standard specification,

6.1.2 Color, and

6.1.3 Roll size.

7. Required Properties

7.1 Conformance of the retroreflective sheeting shall be evaluated using the corresponding test methods defined in Section 8.

TABLE 1 Minimum Coefficient of Retroreflection[A]

Observation Angle (α)	Entrance Angle (β)	White	Yellow	Orange	Red	Blue	Green	Fluor. Yellow-Green	Fluor. Yellow	Fluor. Orange
0.2°	–4°	350	255	150	66	25	56	290	225	120
0.2°	30°	150	110	62	28	12	24	120	95	50
0.2°	45°	60	44	25	11	4	9	49	38	20
0.5°	–4°	70	50	30	13	5	11	58	45	22
0.5°	30°	40	28	16	7	2.5	6	32	26	14
0.5°	45°	15	11	6	3	1	2	12	9	5

[A] Minimum coefficient of retroreflection (R_A) cd/fc/ft^2 [cd·lx–1·m–2].

7.2 *Minimum Coefficient of Retroreflection*—When tested in accordance with 8.3, the coefficient of retroreflection shall meet the requirements as provided in Table 1.

7.3 *Daytime Chromaticity and Luminance Factor (Y%)*—When tested in accordance with 8.4, the daytime chromaticity and daytime luminance factor (Y%) shall conform to the requirements of Table 2 and Table 3 respectively.

7.4 *Nighttime Chromaticity*—When tested in accordance with 8.5, the nighttime chromaticity shall conform to the requirements of Table 4.

7.5 *Accelerated Outdoor Weathering*—After weathering exposure in accordance with 8.6, the retroreflective sheeting shall conform to the following requirements.

NOTE 1—Supplementary Requirement S1 describes a method for artificial accelerated weathering, which users of this specification may employ for preliminary conformance to this requirement until outdoor weathering results are available. To follow this artificial accelerated weathering test method using Method I or III, the weathering exposure hours shall be 685 h; use of Method II shall require 1000 h of weathering exposure time.

NOTE 2—This accelerated outdoor weathering requirement is intended to be a minimum weathering requirement. Manufacturers may provide materials with weathering performance exceeding this minimum.

7.5.1 The retroreflective sheeting shall show no cracking, scaling, pitting, blistering, edge lifting, or curling, nor a dimensional change (shrinkage or expansion) of more than 1/32 in. [0.8 mm] in any direction.

7.5.2 *Retention of Coefficient of Retroreflection*—The coefficient of retroreflection measured at 0.2° observation and –4° and +30° entrance angles after weathering, when measured in accordance with 8.3.2, shall meet or exceed 80 % of the minimum coefficient of retroreflection requirements outlined in Table 1.

7.5.3 *Colorfastness*—After accelerated weathering exposure, the daytime chromaticity and daytime luminance factor, when measured in accordance with 8.4, shall continue to conform to the requirements of Table 2 and Table 3 respectively.

7.6 *Flexibility*—When tested in accordance with 8.7, the retroreflective sheeting shall show no signs of cracking.

7.7 *Liner Removal*—When tested in accordance with 8.8, the protective release liner shall be easily removed without the retroreflective sheeting showing signs of breaking, tearing, or peeling of its adhesive layer.

TABLE 3 Daytime Luminance Factor Requirements

Color	Y%	
	Minimum	Maximum
White	27	. . .
Yellow	15	45
Orange	10	30
Red	2.5	15
Blue	1.0	10
Green	3.0	12
Fluorescent Yellow-Green	50	. . .
Fluorescent Yellow	35	. . .
Fluorescent Orange	20	. . .

7.8 *Peel Adhesion*—When tested in accordance with 8.9, for each test panel substrate, the average 90° peel adhesion shall be greater than 2.5 lbf/in. [11.1 N/25 mm].

7.9 *Impact Resistance*—When tested in accordance with 8.10, the retroreflective sheeting shall show no signs of cracking or delamination outside the area of direct impact.

7.10 *Solvent Resistance*—When tested in accordance with 8.11, the retroreflective sheeting shall show no softening, blistering, distorting, discoloring, cracking, or dissolution. Further, after performing the solvent resistance test, the coefficient of retroreflection when measured at 0.2° observation and –4° entrance angles, when measured in accordance with 8.3.2, shall meet the requirements of Table 1.

7.11 *Corrosion Resistance*—When tested in accordance with 8.12, the retroreflective sheeting shall show no softening, blistering, distorting, dissolution, discoloring, or corrosion. Further, after performing the solvent resistance test, the coefficient of retroreflection when measured at 0.2° observation and –4° entrance angles, when measured in accordance with 8.3.2, shall meet the requirements of Table 1.

7.12 *Resistance to Manual Cleaning*—When tested in accordance with 8.13, the retroreflective sheeting shall show no signs of damage or delamination or separation from the test panel substrate.

TABLE 2 Daytime Chromaticity Specification Limits[A]

Color	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.303	0.300	0.368	0.366	0.340	0.393	0.274	0.329
Yellow	0.498	0.412	0.557	0.442	0.479	0.520	0.438	0.472
Orange	0.558	0.352	0.636	0.364	0.570	0.429	0.506	0.404
Red	0.565	0.346	0.629	0.281	0.735	0.265	0.648	0.351
Blue[B]	0.140	0.035	0.244	0.210	0.190	0.255	0.065	0.216
Green[B]	0.026	0.399	0.166	0.364	0.286	0.446	0.207	0.771
Fluor. Yellow-Green	0.387	0.610	0.369	0.546	0.428	0.496	0.460	0.540
Fluor. Yellow	0.479	0.520	0.446	0.483	0.512	0.421	0.557	0.442
Fluor. Orange	0.583	0.416	0.535	0.400	0.595	0.351	0.645	0.355

[A] The four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 Standard Colorimetric System measured with CIE Standard Illuminant D65 and standard observer 2°.
[B] The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors.

TABLE 4 Nighttime Chromaticity Specification Limits[A]

Color	1		2		3		4	
	x	y	x	y	x	y	x	y
White	0.475	0.452	0.360	0.415	0.392	0.370	0.515	0.409
Yellow	0.513	0.487	0.500	0.470	0.545	0.425	0.572	0.425
Orange	0.595	0.405	0.565	0.405	0.613	0.355	0.643	0.355
Red	0.650	0.348	0.620	0.348	0.712	0.255	0.735	0.265
Blue[B]	0.091	0.133	0.230	0.240	0.180	0.370	0.033	0.370
Green[B]	0.007	0.570	0.200	0.500	0.322	0.590	0.193	0.782
Fluor. Yellow-Green	0.480	0.520	0.473	0.490	0.523	0.440	0.550	0.449
Fluor. Yellow	0.554	0.445	0.526	0.437	0.569	0.394	0.610	0.390
Fluor. Orange	0.625	0.375	0.589	0.376	0.636	0.330	0.669	0.331

[A] The four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 Standard Colorimetric System measured with CIE Standard Illuminant A.
[B] The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors.

7.13 *Resistance to Power Spray Washing*—When tested in accordance with 8.14, the retroreflective sheeting shall show no signs of damage or delamination or separation from the test panel substrate.

7.14 *Detection of Fluorescence*—For fluorescent retroreflective sheeting only, the fluorescent properties shall be detected through either of the following test methods listed in 7.14.1 or 7.14.2. It is not necessary for the fluorescent properties to be detected through both methods. For certain fluorescent retroreflective sheetings, the fluorescent properties may only be detectable through one of the following test methods.

7.14.1 *Evaluation of Spectral Data*—When tested in accordance with 8.15, the percent reflectance shall exceed 100 % at one or more wavelengths between 400 nm and 700 nm.

7.14.2 *Filtered Colorimetry Measurements*—When testing in accordance with 8.16, the difference between the baseline daytime luminance factor ($Y\%_{baseline}$) and the filtered daytime luminance factor ($Y\%_{filtered}$) shall be at least 5 % of the baseline daytime luminance factor ($Y\%_{baseline}$).

8. Test Methods

8.1 *Test Conditions*—Unless otherwise specified in this specification, all materials should be conditioned for 24 h at a temperature of 73 ± 3 °F [23 ± 2 °C] and 50 ± 10 % relative humidity.

8.2 *Test Sample and Test Panel Preparation*—Sample the retroreflective sheeting according to Section 9. Prepare test samples or test panels as follows:

8.2.1 Unless otherwise specified, a test sample is prepared by cutting the retroreflective sheeting at a dimension of 8 by 8 in.

NOTE 3—It may not always be possible to test an 8 by 8 in. sample. In these cases, a composite of smaller sizes may be utilized or a smaller area may be utilized.

8.2.2 Unless otherwise specified, a test panel is prepared by removing the liner from the test sample and applying the test sample to an aluminum panel, as per the recommendations of the retroreflective material manufacturer. The aluminum panel shall be cut from Alloy 6061-T6 or 5052-H38, in accordance with Specification B209/B209M, and be of one of three thicknesses: 0.020 in. [0.508 mm], 0.040 in. [1.016 mm], or 0.063 in. [1.600 mm] in thickness, and a minimum of 8 by 8 in. The aluminum panel shall be prepared in accordance with Specification B449, Class 2 (or be degreased and lightly acid etched), before the test sample is applied. After the test sample is applied to the aluminum panel, the test panel shall be conditioned for 24 h at a temperature of 73 ± 3 °F [23 ± 2 °C] and 50 ± 10 % relative humidity prior to testing.

8.3 *Coefficient of Retroreflection:*

8.3.1 Take three samples according to Section 9.

8.3.2 Determine the coefficients of retroreflection in accordance with Test Method E810 where the entrance angles $\beta_1 = \beta°$ and $\beta_2 = 0°$. Based upon this method, report the average R_A value for each sample after taking the average across the two rotation angles of 0° and 90°.

8.3.3 The coefficients of retroreflection, computed as the average of the three samples, shall meet the minimum requirements identified in 7.2, and none of the samples shall have a coefficient of retroreflection less than 80 % of the values required in 7.2.

8.4 *Daytime Color*—Determine the chromaticity (x,y) and daytime luminance factor (Y%) for CIE Standard Illuminant D65 and the 1931 CIE 2° standard observer in accordance with Practice E308, Practice E991, Test Method E1349, and Test Method E2301, as applicable. For measurements, an annular instrument with a minimum measured diameter of 1 in. [2.54 cm] shall be used.

8.4.1 For fluorescent samples, it is necessary either that the physical illumination of the sample be a good approximation to CIE Standard Illuminant D65, requiring an instrument with an appropriately filtered light source, or else that a bispectral photometer conforming to Test Method E2301 be used.

8.5 *Nighttime Chromaticity*—Determine the chromaticity (x,y) in accordance with Test Method E3165 and further described in Practice E811 and evaluated using the CIE system in Practice E308. (The saturation limit shall be considered to extend to the boundary of the chromaticity locus of spectral colors.) Measure using CIE Illuminant A, observation angle of 0.33°, entrance angle of +5°, source and receiver apertures not to exceed 10 min of arc, and CIE 1931 (2°) standard observer.

8.6 *Accelerated Outdoor Weathering:*

8.6.1 *Test Specimens*—Prepare three replicate samples for each color. Each test specimen shall be a minimum of 4 in. by 12 in.

8.6.2 *Outdoor Weathering Conditions*—Conduct outdoor exposures in accordance with Practice G7/G7M. During exposure, test panels shall be open backed and oriented at an angle of 45° from the horizontal and facing the equator in accordance with Practice G7/G7M. Exposure location shall be South Florida. Panel labeling, and conditioning and handling of panels prior to exposure and during evaluation periods shall be in accordance with Practice G147.

8.6.3 *Exposure Time Frame*—The exposure time shall be twelve months.

8.6.4 *Washing and Drying of Panels After Weathering*—Gently wash the panels using a soft cloth or sponge and clean water or a dilute solution of a mild detergent (1 % by weight in water, maximum concentration). Then, rinse thoroughly with clean water and blot dry with a soft, clean cloth. Finally, condition the panels at 73 ± 3 °F for at least 2 h prior to conducting any property measurements.

8.6.5 *Report of Test Results*—For each test conducted after accelerated outdoor weathering, report the average measurement of the three replicate test samples for each color tested.

8.7 *Flexibility*—Bend the material, in 1 s, around a ⅛ in. [3.2 mm] mandrel with adhesive contacting the mandrel. The test specimen shall be 2.75 by 11 in. [70 by 229 mm]. The test specimen shall be conditioned for 24 h at 73 ± 3 °F prior to conducting the test.

NOTE 4—For ease of testing, spread talcum powder on the adhesive to prevent sticking to the mandrel.

8.8 *Liner Removal*—Condition the test sample for 4 h at 160 °F [71 °C] and under a weight of 2.5 psi [17.2 kPa]. Immediately after removal from this conditioning, attempt to remove the protective release liner.

8.9 *Peel Adhesion:*

8.9.1 *Test Panel Substrates*—Peel adhesion testing shall be conducted on two different test panel substrates as listed below. Each panel shall be cut to the proper size to fit within a 90° peel testing fixture.

8.9.1.1 *Aluminum Test Panel Substrate #1*—Prepare an aluminum panel as outlined in 8.2.2.

8.9.1.2 *Automotive Paint Test Panel Substrate #2*—Utilize a steel test panel prepared and coated to be representative of an OEM automotive white basecoat / clear coat paint surface. The test panel shall be made from cold roll steel of 0.032 in. thickness and consist of a white basecoat and a clear coat of polysiloxane chemistry.

NOTE 5—Formulation differences between available polysiloxane clear coat products may result in different peel adhesion results. When performing the peel adhesion testing, the identity of the polysiloxane clear coat should be recorded for future reference purposes.

8.9.2 *Preparation of Test Panels*—Cut a set of six different test strips from the center of the test samples. Each test strip shall be 1 in. by 12 in. [25 mm by 305 mm]. Using a rubber-coated steel roller applicator having a weight of 4.5 ± 0.1 lb, a diameter of 3.25 in., and approximately a ¼ in. rubber coating with a Shore A durometer between 75 and 85, apply three test strips to each of the two different test panel substrates. Only a single pass with the roller applicator shall be utilized to laminate the test strips to each panel substrate. Further, during application of the test strip, care should be taken not to exert any additional force or pressure during the application process other than what the steel roller applicator provides through its own weight.

8.9.3 Condition each panel for 24 h at a temperature of 73 ± 3 °F [23 ± 2 °C] and 50 ± 5 % relative humidity prior to testing. Using a 90° peel fixture on a tensile strength testing machine, measure the peel force required to remove each sample from each test panel substrate. Utilize a constant peel speed of 300 mm [11.8 in.] per minute and measure the peel force along a test distance of at least 50 mm [3.94 in.]. For each sample, record the average peel force across the test distance. For each test panel substrate, report the average of the three measurements.

8.10 *Impact Resistance*—Apply a test sample to an aluminum panel of 0.063 in. [1.600 mm] thickness according to 8.2.2. Utilizing the test instrument and procedures described in Test Method D2794, with the reflective sheeting side facing up, subject this test panel to the impact of a 2 lb [0.91 kg] weight dropped from a height necessary to generate an impact of 10 in.-lb [1.13 N-m] when striking with a ⅝ in. [15.8 mm] diameter rounded tip indentor. The indentation formed during this test shall be an intrusion, in which the panel is struck on the sheeting side and the panel is supported by a steel fixture having a cylindrical hole as described in subsection 6.3 of Test Method D2794.

8.11 *Solvent Resistance*—A test panel not less than 2 in. by 6 in. shall be immersed in a mixture of 70 % n-heptane and 30 % toluene (also known as toluol), by volume, for 1 min. After removal, the surface shall be wiped dry with a clean and soft cloth.

8.12 *Corrosion Resistance*—Following Practice B117, a test panel shall be exposed to a saline mist for two periods of exposure of 24 h each, separated by a 2 h interval during which the specimen dries. The saline mist shall be produced by atomizing a saline solution obtained by dissolving five parts by weight of sodium chloride in 95 parts of water. At the end of the test, the surface of the sample unit shall be cleaned with a clean and soft cloth to remove salt deposits from the saline mist.

8.13 *Resistance to Manual Cleaning*—A test sample smeared with a mixture of detergent lubricating oil and graphite shall be easily cleaned without damage to the retroreflective surface when wiped with a mild aliphatic solvent such as n-heptane, followed by washing with a neutral detergent.

8.14 *Resistance to Pressure Washing*—Subject the test panel to a continuous spraying action for 60 s on the test sample in its normal mounting conditions under the following setup parameters: (*1*) Water/wash solution pressure 8 ± 0.2 MPa; (*2*) Water/wash solution temperature 140 ± 9 °F [60 ± 5 °C]; (*3*) Water/wash solution flow rate 7 ± 1 l/min; (*4*) The tip of the cleaning wand to be positioned at distance of 24 ± 0.079 in. [600 ± 20 mm] away from the retroreflective surface; (*5*) Cleaning wand to be held at no greater angle than 45° from perpendicular to the retroreflective surface; and (*6*) 40° nozzle creating wide fan pattern.

8.15 *Detection of Fluorescence Through Evaluation of the Spectral Data*—Using an instrument capable of providing the spectral data, measure the daytime color in accordance with 8.4 to obtain the spectral data providing the percent reflectance as a function of wavelength. Review the spectral data to identify any wavelengths where the percent reflectance is greater than 100 %.

8.16 *Detection of Fluorescence Through Filtered Colorimetry Measurements*—Follow the sequence of steps provided below to determine the baseline daytime luminance factor ($Y\%_{baseline}$) and the filtered daytime luminance factor ($Y\%_{filtered}$) for CIE Standard Illuminant D65 and the 1931 CIE 2° standard observer in accordance with Practice E308, Practice E991, Test Method E1349, and Test Method E2301, as applicable.

8.16.1 *Setup*—This test method utilizes two different long-wavelength bandpass filters to determine the baseline daytime luminance factor ($Y\%_{baseline}$) and the filtered daytime luminance factor ($Y\%_{filtered}$). Prior to taking any measurements, instrumentation should be calibrated per the instrument manufacturer's instructions without either long-wavelength bandpass filter located between the illuminating source and any calibration standards.

8.16.1.1 Each bandpass filter shall be manufactured by the same supplier and be from the same product family from that manufacturer (that is, made from similar materials with similar properties). Additionally, each filter shall have the following performance requirements:

(1) Transmission in Pass-Through Wavelengths: >91 %

(2) Optical Density: >4.0

(3) Slope Factor of Cut-On Wavelengths: ±1 %

(4) Cut-On Wavelength Tolerance: ±1 %

8.16.1.2 When each bandpass filter is placed between the light source of the colorimeter and the sample, if the bandpass filter has a surface coating which functions as the wavelength filter, the coated side of the filter shall be positioned towards the light source of the colorimeter.

8.16.2 *Determination of Baseline Daytime Luminance Factor ($Y\%_{baseline}$)*—Determine the baseline daytime luminance factor ($Y\%_{baseline}$) by placing a 325 nm long-wavelength bandpass filter between the sample and the illuminating source of the colorimeter and then measure the total daytime luminance factor (Y%) per 8.4. Take eight measurements at random positions and rotations across each sample and report the average. The baseline daytime luminance factor ($Y\%_{baseline}$) shall be the average of these measurements.

8.16.3 *Determine the Cut-On Wavelength for the Second Long-Wavelength Bandpass Filter*—Determine the cut-on wavelength for the second long-wavelength bandpass filter by reviewing the spectral curve of the sample when the daytime color is measured in accordance with 8.4 without the use of any long-wavelength bandpass filters. By reviewing the spectral curve, identify the wavelength where the percent reflectance of the leading edge of the spectral curve is 10 %. The cut-on wavelength of the second long-wavelength bandpass filter shall be up to 25 nm less than the wavelength where the percent reflectance is 10 %. Fig. 1 provides an example spectral curve of a fluorescent yellow material and shows an appropriate range of cut-on wavelengths for the second long-wavelength bandpass filter for this specific sample.

8.16.4 *Determination of Filtered Daytime Luminance Factor ($Y\%_{filtered}$)*—Determine the filtered daytime luminance factor ($Y\%_{filtered}$) by placing the second long-wavelength bandpass filter (which has a cut-on wavelength within the range identified in 8.16.3) between the sample and the illuminating source of the colorimeter and then measuring the total daytime luminance factor (Y%) per 8.4. Take eight measurements at random positions and rotations across each sample and report the average. The filtered daytime luminance factor ($Y\%_{filtered}$) shall be the average of these measurements.

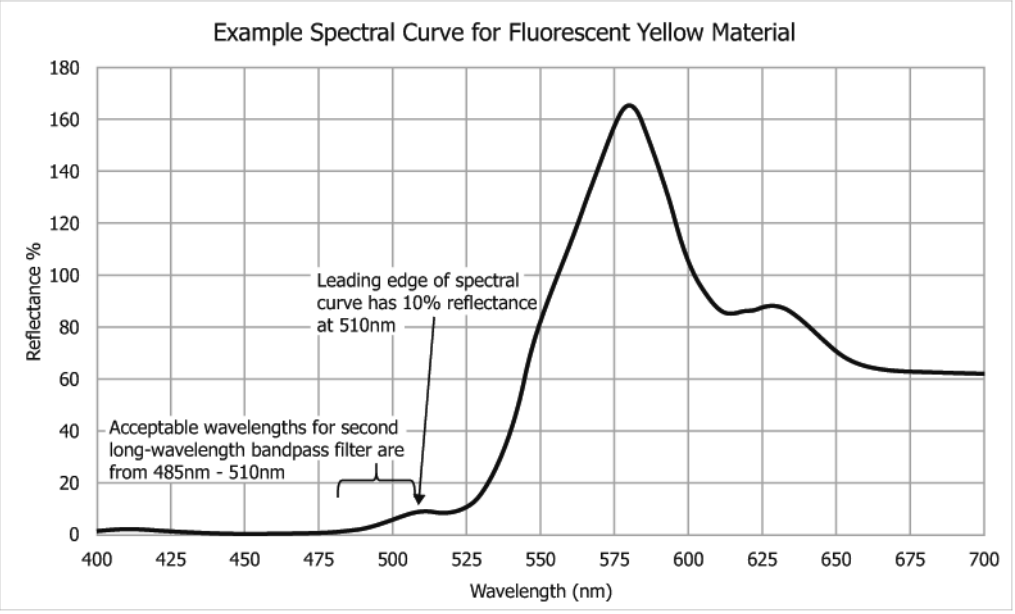

FIG. 1 Example Spectral Curve for Fluorescent Yellow Material

NOTE 6—This test methodology is based upon Practice E1247 for Detecting Fluorescence in Object-Color Specimens by Spectrophotometry. Appendix X2 provides background information and application information pertaining to the usage of this method.

9. Sampling

9.1 Retroreflective sheeting shall be sampled from commercially available channels and representative of the manufacturer's current production.

9.2 To determine conformance to the requirements for the coefficient of retroreflection:

9.2.1 Randomly obtain a sample at least 1 yd [0.914 m] long by the roll width of the material to represent the entire sheet, lot, or roll to be tested.

9.2.2 Three samples are taken from the selected specimen. The three samples shall be spaced evenly across (left, center, right) and spaced evenly down the length of the specimen.

9.3 For conformance to all other requirements, single samples taken at random shall be tested.

10. Packaging and Package Marking

10.1 The sheets or rolls manufactured under this specification shall be packaged in accordance with commercially acceptable standards. Each package shall be marked with the following:

10.1.1 Name, brand, or trademark,

10.1.2 Quantity,

10.1.3 Size,

10.1.4 Lot or run number, and

10.1.5 Part number.

11. Precision and Bias

11.1 The precision and bias for the test methods in Section 8 have not been determined.

12. Keywords

12.1 emergency vehicles; fluorescent; high visibility; retroreflective sheeting; vehicle markings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the purchase order or contract.

S1. Artificial Accelerated Weathering

S1.1 *Scope*—This supplementary test may be used for provisional qualification of retroreflective sheeting in the interim period until the results from accelerated outdoor weathering are available (see 8.6). The results from accelerated outdoor weathering shall supersede and take precedence over the results from artificial accelerated weathering tests.

S1.2 *Test Specimens*—Expose three replicate specimens. Each test specimen shall be a minimum of 2.5 in. by 2.5 in. [64 mm by 64 mm].

S1.3 *Test Conditions*—Conduct exposures in a xenon arc exposure apparatus to simulate direct exposure to solar radiation. Operate the exposure apparatus in accordance with the basic principles and operating procedures of Practice G155 for using xenon arc and water apparatus intended to reproduce the weathering effects that occur when materials are exposed to sunlight, heat, and moisture as rain or dew in actual use.

NOTE S1.1—Results from artificial accelerated weathering tests are best used to compare the relative stability of materials. Reproducibility between laboratories has been shown to be good when the stability of materials is evaluated in terms of performance ranking compared to a control material of similar composition and construction and known outdoor stability; therefore, exposure of a control material at the same time as the test material is strongly recommended (see Practice G151).

S1.3.1 *Simulation of Terrestrial Daylight*—The xenon arc shall be filtered to provide a simulation of terrestrial daylight. The spectral power distribution of the filtered xenon arc shall conform to the Relative Ultraviolet Spectral Power Distribution Specification for Xenon Arc with Daylight Filters in Practice G155, Table 1.

S1.3.2 *Exposure Test Methods*—Three methods are provided for testing to determine conformance to provisional weathering requirements. These methods correspond to international practices for artificial accelerated weathering. Method I is equivalent to ISO 4892-2:2013 Cycle B4, Method II is equivalent to Practice G155 Cycle 1, and Method III is equivalent to ISO 4892-2:2013 Cycle 1. Control the exposure conditions according to the exposure set point parameters in Table S1.1.

NOTE S1.2—The operational fluctuations given in Table S1.1 do not imply that the user is allowed to program a set point higher or lower than the exact set point specified. They refer to allowable deviations from the set point in the reading observed at the control sensor during equilibrium operating conditions. These deviations are the result of normal operational variations in apparatus. If the operational fluctuation is greater than the maximum allowable specified in Table S1.1, discontinue the test until the problem is resolved.

S1.3.2.1 Results obtained using any of the methods shall be accepted for showing conformance to this supplementary requirement.

NOTE S1.3—Method III meets the requirements of EN12899-1:2007. The historical practice within CEN and ISO has been to specify the Black Standard Thermometer for controlling temperature in xenon arc apparatus.

S1.3.3 *Xenon Arc Irradiance Setting*—The recommended irradiance set point is 0.51 W/(m^2·nm) at 340 nm. However, to accommodate testing in xenon arc machines set at 0.35 W/(m^2·nm) at 340 nm specified for other types of specimens being tested at the same time, the option is given to test retroreflective sheeting at the lower irradiance level. Therefore, the test duration is specified in terms of radiant exposure rather than time in order to provide equivalent radiant exposures at the different irradiance levels.