Designation: D 4956 – 04

Standard Specification for Retroreflective Sheeting for Traffic Control[1]

This standard is issued under the fixed designation D 4956; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers flexible, non-exposed glass bead lens and microprismatic, retroreflective sheeting designed for use on traffic control signs, delineators, barricades, and other devices.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 7, of this specification. *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]

B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate

B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]

B 449 Specification for Chromates on Aluminum

D 523 Test Method for Specular Gloss

E 284 Terminology of Appearance

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

E 808 Practice for Describing Retroreflection

E 810 Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry

E 991 Practice for Color Measurement of Fluorescent Specimens

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation

E 1247 Practice for Detecting Fluorescence in Object-Color Specimens by Spectrophotometry

E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus (Filter) Colorimetry

E 1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry

E 2152 Practice for Computing the Colors of Fluorescent Objects from Bispectral Photometric Data

E 2153 Practice for Obtaining Bispectral Photometric Data for Evaluation of Fluorescent Color

E 2301 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

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G 152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

3. Terminology

3.1 *Definitions*—Definitions of terms are as described in Terminology E 284 and Practice E 808.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *reboundable sheeting, n*—retroreflective material intended to be attached to flexible impact resistant plastic devices, such as traffic drum-like channelizing devices.

4. Classification

4.1 Retroreflective sheeting shall consist of a white or colored sheeting having a smooth outer surface and that essentially has the property of a retroreflector over its entire surface. There are ten types and five classes of retroreflective sheeting. Types are determined by conformance to the retroreflectance, color, and durability requirements listed in 6.1 and may be of any construction providing that those requirements

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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.

are met. Type designation is provided as a means for differentiating functional performance. Typical examples of applications are provided for descriptive information only and are not intended to be limitations or recommendations. Common identifiers for each type are listed in 4.2.

4.1.1 The typical applications for the retroreflective sheeting addressed in this specification are:

Type	Typical Application
I	Highway signing, construction-zone devices, and delineators
II	Highway signing, construction-zone devices, and delineators
III	Highway signing, construction-zone devices, and delineators
IV	Highway signing, construction-zone devices, and delineators
V	Delineators
VI	Temporary roll-up signs, warning signs, traffic cone collars, and post bands
VII	Highway signing, construction-zone devices, and delineators
VIII	Highway signing, construction-zone devices, and delineators
IX	Highway signing, construction-zone devices, and delineators
X	Highway signing, construction-zone devices, and delineators

4.2 Retroreflective sheeting shall be classified as follows (the type sequence is not indicative of performance level):

4.2.1 *Type I*—A medium-intensity retroreflective sheeting referred to as "engineering grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.2 *Type II*—A medium-high-intensity retroreflective sheeting sometimes referred to as "super engineer grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.3 *Type III*—A high-intensity retroreflective sheeting, that is typically encapsulated glass-bead retroreflective material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.4 *Type IV*—A high-intensity retroreflective sheeting. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.5 *Type V*—A super-high-intensity retroreflective sheeting. This sheeting is typically a metallized microprismatic retroreflective element material. This sheeting is typically used for delineators.

4.2.6 *Type VI*—An elastomeric high-intensity retroreflective sheeting without adhesive. This sheeting is typically a vinyl microprismatic retroreflective material. This sheeting is typically used for orange temporary roll-up warning signs, traffic cone collars, and post bands.

4.2.7 *Type VII*—A super-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at long and medium road distances as determined by the R_A values of Table 1 at 0.1° and 0.2° observation angles. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.8 *Type VIII*—A super-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at long and medium road distances as determined by the R_A values of Table 2 at 0.1° and 0.2° observation angles. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.9 *Type IX*—A very-high-intensity retroreflective sheeting having highest retroreflectivity characteristics at short road distances as determined by the R_A values of Table 3 at 1° observation angle. This sheeting is typically an unmetallized microprismatic retroreflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.10 *Type X*—A super-high intensity retroreflective sheeting having highest retroreflective characteristics at medium road distances as determined by the R_A values of Table 4 at 0.1° and 0.2° observation angles. This sheeting is typically an unmetallized microprismatic element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

NOTE 1—All retroreflective sheetings, but especially microprismatic sheetings, may have unique performance characteristics outside of the range of the standard geometries presented in the tables that define the types. Certain applications may require the use of a particular product within a particular type in order to achieve a desired level of retroreflectivity in a given situation. In these cases, information concerning additional performance characteristics must be obtained.

4.3 *Backing Classes*—The backing required for retroreflective sheeting Types I through X shall be classified as follows:

4.3.1 *Class 1*—The adhesive backing shall be pressure-sensitive, require no heat, solvent, or other preparation for adhesion to smooth, clean surfaces.

4.3.2 *Class 2*—The adhesive backing shall have an adhesive that shall be activated by applying heat and pressure to the material. The temperature necessary to form a durable permanent bond shall be a minimum of 150°F (66°C).

4.3.2.1 The Class 2 material shall be repositionable under normal shop conditions and at substrate temperatures up to

TABLE 1 Type VII Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	1000	750	375	100	200	45	800	600	300
0.1°[B]	+ 30°	570	430	215	57	115	26	460	340	170
0.2°	− 4°	750	560	280	75	150	34	600	450	230
0.2°	+ 30°	430	320	160	43	86	20	340	260	130
0.5°	−4°	240	180	90	24	48	11	190	145	72
0.5°	+ 30°	135	100	50	14	27	6.0	110	81	41

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx⁻¹·m⁻²).
[B] Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 2 Type VIII Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	1000	750	375	100	150	60	30	800	600	300
0.1°[B]	+30°	460	345	175	46	69	28	14	370	280	135
0.2°	−4°	700	525	265	70	105	42	21	560	420	210
0.2°	+30°	325	245	120	33	49	20	10	260	200	95
0.5°	−4°	250	190	94	25	38	15	7.5	200	150	75
0.5°	+30°	115	86	43	12	17	7	3.5	92	69	35

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx⁻¹·m⁻²).
[B] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 3 Type IX Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	660	500	250	66	130	30	530	400	200
0.1°[B]	+30°	370	280	140	37	74	17	300	220	110
0.2°	−4°	380	285	145	38	76	17	300	230	115
0.2°	+30°	215	162	82	22	43	10	170	130	65
0.5°	−4°	240	180	90	24	48	11	190	145	72
0.5°	+30°	135	100	50	14	27	6.0	110	81	41
1.0°	−4°	80	60	30	8.0	16	3.6	64	48	24
1.0°	+30°	45	34	17	4.5	9.0	2.0	36	27	14

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx⁻¹·m⁻²).
[B] Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 4 Type X Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	800	600	300	80	120	40	24	640	480	240
0.1°[B]	+30°	400	300	150	40	60	20	12	320	240	120
0.2°	−4°	560	420	210	56	84	28	17	450	340	170
0.2°	+30°	280	210	105	28	42	14	8.4	220	170	84
0.5°	−4°	200	150	75	20	30	10	6.0	160	120	60
0.5°	+30°	100	75	37	10	15	5.0	3.0	80	60	30

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx⁻¹·m⁻²).
[B] Values for 0.1° observation angle are supplementary requirements that shall only apply when specified by the purchaser in the contract or order.

100°F (38°C) and without damage to the material. The Class 2 material may be perforated to facilitate removal of air in heat-vacuum laminators, but the perforations must be of a size and frequency such that they do not cause objectionable blemishes when the sheeting is printed.

4.3.3 *Class 3*—The adhesive backing shall have a positionable low-tack pressure-sensitive adhesive that requires no heat, solvent, or other preparation for adhesion to smooth, clean surfaces. It shall be repositionable up to a temperature of 100°F (38°C) without damage to the material.

4.3.4 *Class 4*—The adhesive backing shall have a low-temperature pressure-sensitive adhesive that permits sheeting applications at temperatures down to + 20°F (−7°C) without the aid of heat, solvent, or other preparation for adhesion to smooth, dry, clean surfaces.

4.3.5 *Class 5*—This shall be a nonadhesive backing made of material commercially used for self-supporting products such as traffic cone collars, temporary roll-up warning signs, and post bands.

5. Ordering Information

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

5.1.1 ASTM designation (D 4956),

5.1.2 Classification type (see Section 4),

5.1.3 Adhesive class (see 4.3),

5.1.4 Daytime color (see 6.3),

5.1.5 Length and width of sheets (see 8.1),

5.1.6 Length and width of rolls (see 8.2),

5.1.7 Supplementary information, if required by the purchaser, including:

5.1.7.1 Compliance with the minimum coefficient of retroreflection for 0.1° observation angle is a supplementary requirement which shall apply only when specified. An observation angle of 0.1° may be specified where the long distance performance of a sheeting is to be a requirement,

5.1.7.2 Fungus-resistance testing requirements (see Supplementary Requirement S1), and

5.1.7.3 Reboundable sheeting requirements (see Supplementary Requirement S2),

5.1.8 Indication that the sheeting is intended for work zone use, if applicable, to determine which weathering requirements apply, and

5.1.9 Any additional information.

6. Performance Requirements

6.1 This is a summary of the minimum performance requirements for each type of retroreflective sheeting.

6.1.1 *Type I*—Minimum Coefficient of Retroreflection—Table 5; Outdoor Weathering—24 months, see 6.4; Daytime Luminance Factor—Table 6; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.2 *Type II*—Minimum Coefficient of Retroreflection—Table 7; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 6; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.3 *Type III*—Minimum Coefficient of Retroreflection—Table 8; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 6; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.4 *Type IV*—Minimum Coefficient of Retroreflection—Table 9; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 10 and Table 14; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.5 *Type V*—Minimum Coefficient of Retroreflection—Table 11; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 12; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.6 *Type VI*—Minimum Coefficient of Retroreflection—Table 13; Outdoor Weathering—6 months, see 6.4; Daytime Luminance Factor—Table 6 and Table 14.

6.1.7 *Type VII*—Minimum Coefficient of Retroreflection—Table 1; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 10 and Table 14; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.8 *Type VIII*—Minimum Coefficient of Retroreflection—Table 2; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 10 and Table 14; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.9 *Type IX*—Minimum Coefficient of Retroreflection—Table 3; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 10 and Table 14; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.1.10 *Type X*—Minimum Coefficient of Retroreflection—Table 4; Outdoor Weathering—36 months, see 6.4; Daytime Luminance Factor—Table 10 and Table 14; Other requirements: When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

6.2 *Coefficient of Retroreflection*—The coefficient of retroreflection shall meet or exceed the minimum requirements for the appropriate type of sheeting (see Tables 1-5, Tables 7-9, Table 11, and Table 13) as specified in 7.3.

TABLE 5 Type I Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.2°	−4°	70	50	25	9.0	14	4.0	1.0
0.2°	+ 30°	30	22	7.0	3.5	6.0	1.7	0.3
0.5°	− 4°	30	25	13	4.5	7.5	2.0	0.3
0.5°	+ 30°	15	13	4.0	2.2	3.0	0.8	0.2

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx^{-1}·m^{-2}).

TABLE 6 Daytime Luminance Factor (*Y* %)[A]

Color	Minimum	Maximum
White	27	...
Yellow	15	45
Orange	14	30
Green	3.0	9.0
Red	2.5	12
Blue	1.0	10
Brown	4.0	9.0

[A] For Sheeting Types I, II, III, and VI.

TABLE 7 Type II Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.2°	−4°	140	100	60	30	30	10	5.0
0.2°	+ 30°	60	36	22	10	12	4.0	2.0
0.5°	− 4°	50	33	20	9.0	10	3.0	2.0
0.5°	+ 30°	28	20	12	6.0	6.0	2.0	1.0

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx^{-1}·m^{-2}).

TABLE 8 Type III Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.1°[B]	−4°	300	200	120	54	54	24	14
0.1°[B]	+ 30°	180	120	72	32	32	14	10
0.2°	− 4°	250	170	100	45	45	20	12
0.2°	+ 30°	150	100	60	25	25	11	8.5
0.5°	−4°	95	62	30	15	15	7.5	5.0
0.5°	+ 30°	65	45	25	10	10	5.0	3.5

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft²(cd·lx^{-1}·m^{-2}).
[B] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

6.3 *Daytime Color*—The color of the sheeting shall conform to requirements of Table 17, and one of the following: Table 6, Table 10, Table 12, or Table 14 when tested in accordance with 7.4. Daytime and nighttime color shall have substantially the same hue. Daytime color requirements were developed for a limited set of retroreflective sheetings and a limited set of measurement devices. Measurement techniques appropriate for a wider range of optical technologies and instruments are under development. Some sheeting may require visual assessment to determine the acceptability of daytime appearance.

6.4 *Accelerated Outdoor Weathering Requirements*—The retroreflective sheeting shall be weather resistant and show no appreciable cracking, scaling, pitting, blistering, edge lifting, or curling, or more than 1/32-in. (0.8-mm) shrinkage or expansion when tested in accordance with 7.6. Conduct retroreflectivity measurements after outdoor weathering at 0.2° observation and −4° and +30° entrance angles. The minimum coefficient of retroreflection (R_A) after weathering is specified in Table 15.

NOTE 2—Supplementary Requirement S3 describes a method for artificial accelerated weathering, which users of this specification may employ for preliminary judgment until outdoor weathering results are available.

6.5 *Colorfastness*—After the specified outdoor weathering, the specimen shall conform to the requirements of Table 17,

265 285
180 178
48 50
48 50
21 17.5 22
17

TABLE 9 Type IV Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	500	380	200	70	90	42	25	400	300	150
0.1°[B]	+ 30°	240	175	94	32	42	20	12	185	140	70
0.2°	− 4°	360	270	145	50	65	30	18	290	220	105
0.2°	+ 30°	170	135	68	25	30	14	8.5	135	100	50
0.5°	−4°	150	110	60	21	27	13	7.5	120	90	45
0.5°	+ 30°	72	54	28	10	13	6	3.5	55	40	22

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft^2(cd·lx^{-1}·m^{-2}).
[B] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 10 Daytime Luminance Factor (*Y* %)[A]

Color	Minimum	Maximum
White	40	...
Yellow	24	45
Orange	12	30
Green	3.0	12
Red	3.0	15
Blue	1.0	10
Brown	1.0	6.0

[A] (Typically Non-Metalized Microprismatic Material) For Sheeting Types IV, VII, VIII, IX, and X.

TABLE 11 Type V Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue
0.1°[B]	−4°	2000	1300	800	360	360	160
0.1°[B]	+ 30°	1100	740	440	200	200	88
0.2°	− 4°	700	470	280	120	120	56
0.2°	+ 30°	400	270	160	72	72	32
0.5°	−4°	160	110	64	28	28	13
0.5°	+ 30°	75	51	30	13	13	6.0

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft^2(cd·lx^{-1}·m^{-2}).
[B] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 12 Daytime Luminance Factor (*Y* %)[A]

Color	Minimum	Maximum
White	15	...
Yellow	12	30
Orange	7.0	25
Green	2.5	11
Red	2.5	11
Blue	1.0	10
Brown	1.0	9.0

[A] (Typically Metalized Microprismatic Delineator Material) For Sheeting Type V.

and one of the following: Table 6, Table 10, Table 12, or Table 14 when tested in accordance with 7.4 and 7.7.

6.6 *Shrinkage*—The retroreflective sheeting shall not shrink in any dimension more than 1/32 in. (0.8 mm) in 10 min or more than 1/8 in. (3.2 mm) in 24 h when tested in accordance with 7.8.

6.7 *Flexibility*—The sheeting shall be sufficiently flexible to show no cracking when tested in accordance with 7.9.

6.8 *Liner Removal*—The liner, when provided, shall be easily removed without soaking in water or other solutions, and shall not break, tear, or remove adhesive from the sheeting. (See 7.10.)

6.9 *Adhesion*—When tested in accordance with 7.5, the adhesive backing of the retroreflective sheeting shall produce a bond that will support a 1¾-lb (0.79-kg) weight for adhesive classes 1, 2, and 3 or a 1-lb (0.45-kg) weight for adhesive class 4 for 5 min, without the bond peeling for a distance of more than 2 in. (51 mm).

6.10 *Impact Resistance*—Retroreflective sheeting shall show no cracking or delamination outside of the actual area of impact when subjected to the impact test in accordance with 7.11.

6.11 *Specular Gloss*—The retroreflective sheeting shall have a specular gloss of not less than 40 when tested in accordance with 7.12.

7. Test Methods

7.1 *Test Conditions*—Unless otherwise specified in this specification, condition all adhesively bonded and unbonded test samples and specimens at a temperature of 73 ± 3°F (23 ± 2°C) and 50 ± 5 % relative humidity for 24 h prior to testing.

7.2 *Panel Preparations*—Unless otherwise specified in this specification, when tests are to be performed using test panels, apply the specimens of retroreflective material to smooth aluminum cut from Alloy 6061-T6 or 5052-H38, in accordance with Specification B 209 or B 209M. The sheets shall be 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. (200 by 200 mm). Prepare the aluminum in accordance with Specification B 449, Class 2, or degrease and lightly acid etch before the specimens are applied. Apply the specimens to the panels in accordance with the recommendations of the retroreflective sheeting manufacturer.

7.3 *Coefficient of Retroreflection*—Determine the coefficients of retroreflection in accordance with Test Method E 810.

7.4 *Daytime Color*:

7.4.1 Determine the chromaticity and luminance factor *Y* (%) for CIE standard illuminant D65 and the 1931 CIE 2° standard observer in accordance with Practice E 308, Test Methods E 1347, E 1349, and E 2301, and Practices E 991, E 1164, E 2152, and E 2153, as applicable. The luminance factor is the sum of the reflectance luminance factor and the fluorescence luminance factor. Bispectral measurement provides the individual factors, while measurement with simulated D65 provides their sum.

7.4.1.1 For fluorescent specimens, it is necessary either that the physical illumination of the specimen be a good approximation to illuminant D65, requiring an instrument with an appropriately filtered light source, or else that a bispectral photometer conforming to Test Method E 2301 be used.

TABLE 13 Type VI Sheeting[A]

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1°[B]	−4°	750	525	190	90	105	68	600	450	300
0.1°[B]	+ 30°	300	210	75	36	42	27	240	180	120
0.2°	− 4°	500	350	125	60	70	45	400	300	200
0.2°	+ 30°	200	140	50	24	28	18	160	120	80
0.5°	−4°	225	160	56	27	32	20	180	135	90
0.5°	+ 30°	85	60	21	10	12	7.7	68	51	34

[A] Minimum Coefficient of Retroreflection (R_A) cd/fc/ft^2(cd·lx^{-1}·m^{-2}).
[B] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 14 High Conspicuity Daytime Luminance Factor (*Y* %)[A]

Color	Minimum	Maximum
Fluorescent Yellow-Green	60	none
Fluorescent Yellow	45	none
Fluorescent Orange	25	none

[A] The luminance factors shown in this table consist of the sum of a reflectance luminance factor and fluorescence luminance factor. The luminance factor may be determined using a good approximation to illuminant D65, requiring an instrument with an appropriately filtered light source, or else that a bispectral photometer conforming to Test Method E 2301 be used.

TABLE 15 Outdoor Weathering Photometric Requirements for All Climates

Type	Months[A]	Minimum Coefficient of Retroreflection, R_A
I	24[B]	50 % of Table 5
II	36[B]	65 % of Table 7
III	36[B]	80 % of Table 8
IV	36[B]	80 % of Table 9
V	36[B]	80 % of Table 11
VI	6	50 % of Table 13
VII	36[B]	80 % of Table 1
VIII	36[B]	80 % of Table 2
IX	36[B]	80 % of Table 3
X	36[B]	80 % of Table 4

[A] Testing at shorter intervals may be done to gather additional information.
[B] When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

TABLE 16 Climate Types for Use in Outdoor Exposures of Retroreflective Sheetings

Climate Type[A,B]	Mean Monthly Temperature, °C		Representative Example of a Typical Location
	Warmest Month	Coldest Month	
Tropical summer rain	28 to 34	18 to 22	Miami, FL
Desert	28 to 34	10 to 17	Phoenix, AZ
(optional, but recommended)			
Climate mutually agreed upon between the purchaser and the seller[C]			

[A] Climate classification is in accordance with the Koppen reformed classification system.
[B] Outdoor exposure results from Miami, FL and Phoenix, AZ are recognized internationally as benchmarks for evaluating durability of many different types of material and products.
[C] Outdoor exposures of retroreflective sheeting materials are conducted in locations representative of several different climates by the National Transportation Product Evaluation Program (NTPEP) run by AASHTO.

7.4.2 There are three types of 45/0 (0/45) instruments: annular, circumferential, and uniplanar (see Fig. 1). Measurement of prismatic sheeting with circumferential instruments may require multiple measurements. Measurement of prismatic sheeting with uniplanar instruments definitely requires multiple measurements.

7.4.2.1 If the measurement geometry is circumferential, then the testing laboratory must verify that the apertures in the ring are sufficiently close for acceptable approximation to an annular measurement. This may depend on the optical construction of the specimen, and must be determined by the testing laboratory. Multiple measurements of the same specimen area at different rotations may be averaged to improve the approximation to an annular measurement.

7.4.2.2 If the measurement geometry is uniplanar, then a sequence of measurements shall be made on the same specimen area at incremental rotations, and the measurement values shall be taken as averages over all the rotations. The number of rotations shall be large enough for acceptable approximation to an annular measurement. The number depends on the optical construction of the specimen and must be determined by the testing laboratory.

7.4.3 Instruments (spectrophotometers, colorimeters) used to measure daytime color shall have 45/0 or 0/45 illumination and viewing geometry. The referee instrument shall have 10° apertures for both illumination and viewing. Use of aperture sizes deviating from these may affect the measurement results.

7.5 *Adhesion*—Apply the sheeting to a test panel, 0.040 in. (1.016 mm) minimum thickness, prepared as specified in 7.2. Bond 4 in. (102 mm) of a 1 by 6-in. (25.4 by 152-mm) specimen to a test panel. Condition (see 7.1) and then attach the weight to the free end and allow it to hang free at an angle of 90° to the panel surface for 5 min.

7.6 *Outdoor Weathering*—Conduct outdoor exposures in accordance with Practice G 7. 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 G 7. Expose two panels per location for the number of months specified in Table 15. Conduct exposures in locations with the climate types shown in Table 16. Panel labeling, and conditioning and handling of panels prior to exposure and during evaluation periods shall be in accordance with Practice G 147.

7.6.1 *Specimen Mounting for Type VI Sheetings*—Clamp the ends of 100 by 300-mm specimens between 25 by 200 by 2-mm 6061T6 aluminum bars, and attach these bars to mounting strips on the outdoor exposure rack. Expose the specimens so that the long axis is parallel to the ground so that bolts used to clamp specimen ends do not interfere with attachment to the test rack. Fig. 2 is a diagram showing the arrangement of the clamping bars and the test specimen.

TABLE 17 Color Specification Limits (Daytime)[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
Green[B]	0.026	0.399	0.166	0.364	0.286	0.446	0.207	0.771
Red	0.648	0.351	0.735	0.265	0.629	0.281	0.565	0.346
Blue[B]	0.140	0.035	0.244	0.210	0.190	0.255	0.065	0.216
Brown	0.430	0.340	0.610	0.390	0.550	0.450	0.430	0.390
Fluorescent Yellow-Green	0.387	0.610	0.369	0.546	0.428	0.496	0.460	0.540
Fluorescent Yellow	0.479	0.520	0.446	0.483	0.512	0.421	0.557	0.442
Fluorescent 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.

[B] The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors.

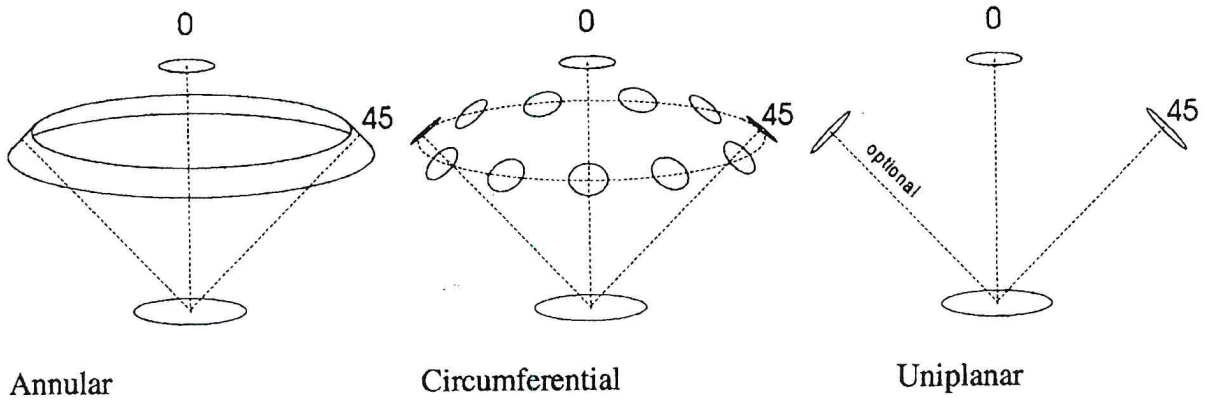

FIG. 1 Three Types of 0/45 (45/0) Instrument

7.6.2 *Washing Panels After Exposure*—Following exposure, 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). After washing, rinse thoroughly with clean water, and blot dry with a soft clean cloth. After washing and drying, condition the panels at room temperature for at least 2 h prior to conducting any property measurements.

7.6.3 *Measurement of Coefficient of Retroreflection*—After panels have been washed, dried, and conditioned in accordance with 7.6.2, measure retroreflectance at 0.2° observation and –4° and 30° entrance angles. Report the average of the coefficient of retroreflection measured at each geometry on the two panels from each exposure location.

7.7 *Colorfastness*—Use one of the outdoor weathered specimens to test for colorfastness. Wash, dry, and condition panels in accordance with 7.6.2 and test as specified in 7.4.

7.8 *Shrinkage*—Condition a 9 by 9-in. (229 by 229-mm) retroreflective sheeting specimen with liner, a minimum of 1 h at standard test conditions (see 7.1). Remove the liner and place the specimen on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 h, measure the specimen to determine the amount of dimensional change.

7.9 *Flexibility*—Bend the sheeting, in 1 s, around a ⅛-in. (3.2-mm) mandrel with adhesive contacting the mandrel. For ease of testing, spread talcum powder on the adhesive to prevent sticking to the mandrel. The test specimen shall be 2¾ by 11 in. (70 by 229 mm). The test temperature shall be 73 ± 3°F (23± 2°C).

7.10 *Liner Removal*—The protective liner, if any, shall be easily removed following accelerated storage for 4 h at 160°F (71°C) under a weight of 2.5 psi (17.2 kPa).

7.11 *Impact Resistance*—Apply the retroreflective sheeting to a 3 by 5 by 0.040-in. (76 by 127 by 1.016-mm) 6061-T6 aluminum test panel as specified in 7.2 and test condition as specified in 7.1. Subject the sheeting to the impact of a 2-lb (0.91-kg) weight, with a ⅝-in. (15.8-mm) diameter rounded tip, dropped from the height necessary to generate an impact of 10 in.-lb (1.13 N-m).

7.12 *Specular Gloss*—Determine the specular gloss of the retroreflective sheeting in accordance with Test Method D 523 at an angle of 85°.

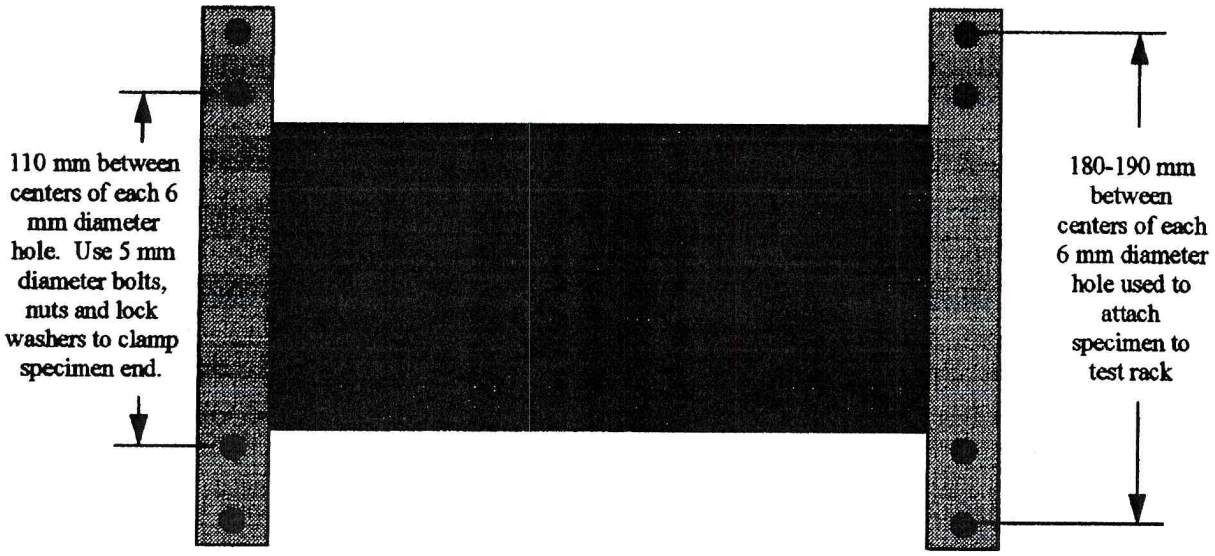

FIG. 2 Diagram Showing Clamping Bars Used for Attaching Type VI Sheeting Specimens to Test Rack for Outdoor Exposure

8. General Requirements

8.1 *Sheets*—When the retroreflective material is in sheet form, the design, dimension, and tolerances shall be as specified by the purchaser.

8.2 *Rolls*—When ordered in rolls, the retroreflective material shall be evenly wound on a core of sufficient rigidity to prevent distortion of the roll. The maximum number of splices shall be 4/50-yd (46-m) roll. Each splice shall be visible at the edge of the roll. The length and width will be specified by the purchaser.

8.3 *Color Processing*—The sheeting shall permit color processing with compatible transparent and opaque process colors in accordance with the sheeting manufacturer's recommendation at temperatures between 60 to 100°F (16 to 38°C) and relative humidity at 20 to 80 %.

9. Precision and Bias

9.1 The precision and bias for the test methods in Section 7 have not been determined.

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:

Name, Brand, or Trademarks
Quantity
Size
Lot or Run Number
Part Number

11. Keywords

11.1 barricades; delineators; highway signing; reboundable sheeting; retroreflective sheeting; traffic control

SUPPLEMENTARY REQUIREMENTS

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

S1. Fungus Resistance

S1.1 *Scope*—This supplementary specification covers fungus-resistance testing.

S1.2 *Test Requirements and Test Methods:*

S1.2.1 *Test Conditions*—Unless otherwise specified in this specification, all adhesively bonded and unbonded test samples and specimens shall be conditioned at a temperature of 73 ± 3°F (23 ± 2°C) and 50 ± 5 % relative humidity for 24 h prior to testing.

S1.2.2 *Panel Preparations*—Unless otherwise specified in this specification, when tests are to be performed using test panels, the specimens of retroreflective material shall be applied to smooth aluminum cut from Alloy 6061-T6, in accordance with Specification B 209 or B 209M, sheets in 0.020-in. (0.508-mm) thickness. The aluminum shall be prepared in accordance with Specification B 449, Class 2 or degreased and lightly acid etched before the specimens are applied. The specimens shall be applied to the panels in accordance with the recommendations of the retroreflective sheeting manufacturer.

S1.3 *Fungus Resistance:*

S1.3.1 For use in areas where fungus growth on retroreflective sheeting may be a problem, fungus resistance shall be determined as specified herein.

S1.3.2 After inoculation with the test organism, *Aspergillus niger*, and incubation for 14 days, the retroreflective material shall show no appreciable formation of fungus growth. Any formation of fungus growth shall be noninjurious to the retroreflective material and shall be removable by wiping with a soft cloth.

S1.3.3 *Test Organism*—The test organism used in this test shall be *Aspergillus niger*, ATCC Number 6275.[3] Cultures of this organism shall be carefully maintained on a potato-dextrose agar medium and promptly renewed if there is evidence of contamination. The stock cultures may be kept for not more than 4 months in a refrigerator at a temperature between 3 to 10°C (37 to 50°F). Subcultures incubated between 28 to 30°C (82.4 to 86°F) for 10 to 14 days shall be used in preparing the inoculum.

S1.3.4 *Culture Medium*—The culture medium shall have the following composition:

$NaNO_3$	3.0 g
K_2HPO_4	1.0 g
$MgSO_4 \cdot 7H_2O$	0.5 g
KCl	0.25 g
Agar	15.0 g
Distilled water to make 1000 mL.	

S1.3.5 The pH shall be 5.5 to 6.5: if otherwise, adjust to that range with HCl or NaOH. After mixing, the ingredients shall be sterilized by autoclaving for 15 min at 15 psi (103 kPa) at 248°F (120°C). Under sterile conditions, the medium shall be poured into six petri dishes (150 by 20 mm), about 2.2 oz (65 ml) per dish, and allowed to harden.

S1.3.6 *Inoculum*—Add about 0.34 oz (10 ml) of sterile, distilled water containing about 0.005 % of nontoxic wetting agent to a subculture (10 to 14 days old) of the test organism in a ripe, fruiting condition. The spores shall be forced into suspension with a sterile camel's hair brush (or other suitable means) and diluted to 3.4 oz (100 ml) with sterile, distilled water.

S1.3.7 *Preparation of Specimens*—Cut three 3 by 3-in. (76 by 76-mm) specimens from the sample and apply to test panels with the retroreflective surface up. Completely immerse the test specimens in a leaching tank of continuously flowing water for 24 h and then remove and dry. The leaching tank shall be large enough to hold an amount of water weighing not less than 50 times the weight of the specimens. The water entering the tank shall not fall directly on the specimens and shall flow at a rate of 1.3 to 2.6 gal/h (5 to 10 L/h). The pH of the water shall be in the range of 6.0 to 8.0.

S1.3.8 *Inoculation*—Under aseptic conditions, dip each specimen in 70 % ethanol for a few seconds, rinse in distilled water, and place firmly on the surface of the solidified agar medium contained in the petri dishes. Place specimens with the retroreflective surface facing up, one specimen to each dish. With a sterile pipette, distribute 0.03 to 0.05 oz (1.0 to 1.5 ml) of inoculum over the surface of each specimen and the surrounding medium.

[3] Available from the American Type Culture Collection (ATCC), 12301 Parklawn Dr., Rockville, MD 20852, or Mycology Laboratory, PRL, U.S. Army Natick Laboratories, Natick, MA 01760.

S1.3.9 *Incubation Period*—The period of incubation shall be 14 days at a temperature between 84.2 to 89.6°F (28.9 to 32°C) and 85 to 90 % relative humidity.

S1.3.10 *Control*—Test three control specimens of untreated, porous-grade filter paper with the specimens of the retroreflective material to check the viability of the inoculum. At the end of the incubation period, the controls should be covered with fungus growth.

S1.3.11 *Test Results*—Upon completion of the incubation period, examine the specimens visually for fungus growth. Wipe the specimens with a soft cloth wet with a 70 % ethanol solution. Visually examine the specimens for damage resulting from fungus growth. If no pitting or textured surface is found, the sample will be reported to have passed.

S2. Reboundable Sheeting Requirements

NOTE S2.1—Not all types of sheeting are available in reboundable form.

S2.1 *Performance Requirements:*

S2.1.1 *Impact Resistance*—Retroreflective sheeting shall show no cracking or delamination outside of the actual area of impact when subjected to the impact test in accordance with S2.2.1.

S2.1.2 *Flexibility Requirements*—The sheeting shall be sufficiently flexible to show no cracking when tested in accordance with S2.2.2.

S2.1.3 *Adhesion*—When tested in accordance with S2.2.3, the adhesive backing of the retroreflective sheeting shall produce a bond to support a 1¾-lb (0.79-kg) weight for adhesive classes 1, 2, and 3 or a 1-lb (0.45-kg) weight for adhesive class 4 for 5 min, without the bond peeling for a distance of more than 1 in. (25.4 mm).

S2.1.4 *Outdoor Weathering*—The retroreflective sheeting shall be weather resistant and show no appreciable cracking, scaling, pitting, blistering, edge lifting, or curling, or more than 1/32-in. (0.8-mm) shrinkage or expansion after outdoor exposures specified in 7.6. The outdoor exposure time and minimum coefficient of retroreflection (R_A) after exposure is specified in Table S2.1. Retroreflectivity measurements after outdoor weathering will be made only at 0.2° observation and −4 and +30° entrance angles.

S2.2 *Test Method:*

S2.2.1 *Impact Resistance*—Retroreflective sheeting, applied to a 3 by 5 by 0.040-in. (76 by 127 by 1.016-mm) 6061-T6 aluminum test panel as specified in 7.2 and test conditioned as

TABLE S2.1 Minimum Coefficient of Retroreflection (R_A) and Required Outdoor Exposure Times

Type	Months	Minimum Coefficient of Retroreflection (R_A)
I	12	65 % of Table 5
II	12	65 % of Table 7
III	12	80 % of Table 8
IV	12	80 % of Table 9
V	12	80 % of Table 11
VI	6	50 % of Table 13
VII	12	80 % of Table 1
VIII	12	80 % of Table 2
IX	12	80 % of Table 3
X	12	80 % of Table 4

specified in 7.1, shall be subjected to the impact of a 4-lb (1.82-kg) weight, with a ⅝-in. (15.8-mm) diameter rounded tip, dropped from the height necessary to generate an impact of 100 in.-lb (11.3 N-m).

S2.2.2 *Flexibility*—The sheeting shall be bent, in 1 s, around a ⅛-in. (3.2-mm) mandrel with adhesive contacting the mandrel. For ease of testing, spread talcum powder on the adhesive to prevent sticking to the mandrel. The test specimen shall be 2¾ by 11 in. (70 by 279 mm). The test temperature shall be 32°F (0°C).

S2.2.3 *Adhesion*—Apply the sheeting to a test panel, 0.040-in. (1.016-mm) minimum thickness, prepared as specified in 7.2. Bond 4 in. of a 1 by 6-in. (25.4 by 152-mm) specimen to a test panel. Condition (see 7.1) and then attach the weight to the free end and allow it to hang free at an angle of 90° to the panel surface for 5 min, without the bond peeling for more than 1 in. (25.4 mm).

S2.2.4 *Outdoor Weathering*—Test two panels in each location in accordance with Table 16. After panels have been exposed for the number of months listed in S2.1.4, wash and condition them in accordance with 7.6.2, then test for coefficient of retroreflection. Report the average of the coefficient of retroreflection measured at each geometry on the two panels from each exposure location.

S3. Artificial Accelerated Weathering

S3.1 *Scope*—This supplementary test may be used for provisional qualification of sheeting before the results from outdoor weathering are available. When they become available, the results from outdoor weathering take precedence over the results from laboratory-accelerated weathering tests.

S3.2 *Test Requirements*—Expose four replicate specimens for the times required in Table S3.1. The minimum length and width for test specimens is 2.75 in. (70 mm). Do not remove panels from the device during a water spray cycle. Make sure they are dry before removing them from the device. After exposure, wash and condition them in accordance with 7.6.2, then measure retroreflectance at 0.2° observation and at –4° and +30° entrance angles. The average retroreflectance of the four replicate specimens shall be at or above the minimum requirements described in Table S3.1. After exposure, the test specimens shall show no appreciable cracking, scaling, pitting, blistering, edge lifting, or curling or more than 1/32-in. (0.8-mm) shrinkage or expansion. The specimens shall also conform to the requirements of Table 17, and of Table 6, Table 10, Table 12, or Table 14, when tested in accordance with 7.4 and 7.7.

TABLE S3.1 Exposure Times and Photometric Requirements for Artificial Accelerated Weathering

Type	Hours	Minimum Coefficient of Retroreflection (R_A)
I	1000	50 % of Table 5
II	2200[A]	65 % of Table 7
III	2200[A]	80 % of Table 8
IV	2200[A]	80 % of Table 9
V	2200	80 % of Table 11
VI	250	50 % of Table 13
VII	2200[A]	80 % of Table 1
VIII	2200[A]	80 % of Table 2
IX	2200[A]	80 % of Table 3
X	2220[A]	80 % of Table 4

[A] When sheeting is specified for construction work zone applications, the laboratory-accelerated weathering time shall be 500 h.

S3.3 *Test Conditions*—Conduct exposures in a filtered open flame carbon-arc exposure device in accordance with the requirements of Practices G 151 and G 152. The spectral power distribution of the filtered open flame carbon-arc shall be in accordance with the requirements in Practice G 152 for carbon-arc with daylight filters. Use the following exposure cycle:

Continuous light with equilibrium black panel temperature controlled to 63 ± 3°C (145 ± 9°F). Once every 2 h (120 min), spray water on specimens for 18 min.
In devices capable of controlling chamber humidity, maintain relative humidity at a 50 ± 5 % equilibrium during the light-only interval.

APPENDIXES

(Nonmandatory Information)

X1. Related Information

X1.1 Other Specifications

X1.1.1 American Association of State Highway and Transportation Officials. AASHTO designation M 268-03[4].

E 1247 Practice for Detecting Fluorescence in Object-Color Specimens by Spectrophotometry

[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

X2. Correction Factors for Conversion from Illuminant C to Illuminant D65

X2.1 Table X2.1lists the correction factors to change measurements made using illuminant C to approximate measurements made using illuminant D65.

TABLE X2.1 Correction Factors for Conversion from Illuminant C to Illuminant D65

NOTE—As an example, a blue sample which measured (x, y, Y) = (0.150, 0.150, 5.0) using Illuminant C would be converted to (0.149, 0.158, 5.0) to provide the result using Illuminant D65.

Color	x	y	Y
White	+0.003	+0.014	0.00
Yellow	+0.001	+0.002	0.00
Orange	+0.001	+0.001	0.00
Green	+0.000	+0.019	0.00
Red	+0.000	+0.001	0.00
Blue	–0.001	+0.008	0.00
Brown	+0.000	0.000	0.00