



Designation: D 4956 – 07

## Standard Specification for Retroreflective Sheeting for Traffic Control<sup>1</sup>

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 approval. A superscript epsilon ( $\epsilon$ ) 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:*<sup>2</sup>

**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 811** Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions

**E 991** Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method

**E 1164** Practice for Obtaining Spectrometric 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 Colorimetry

**E 1349** Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional ( $45^\circ:0^\circ$  or  $0^\circ:45^\circ$ ) 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  $45^\circ$ :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

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<sup>2</sup> 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.

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 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:

**TABLE 1 Type VII Sheeting<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	-4°	1000	750	375	100	200	45	800	600	300
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	-4°	1000	750	375	100	150	60	30	800	600	300
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	-4°	660	500	250	66	130	30	530	400	200
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	-4°	800	600	300	80	120	40	24	640	480	240
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> Values for 0.1° observation angle are supplementary requirements that shall only apply when specified by the purchaser in the contract or order.

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 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.

**TABLE 5 Type I Sheeting<sup>A</sup>**

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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ ) cd/ft<sup>2</sup>(cd-lx<sup>-1</sup>·m<sup>-2</sup>).

**TABLE 6 Daytime Luminance Factor (Y %)<sup>A</sup>**

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

<sup>A</sup> For Sheeting Types I, II, III, and VI.

**TABLE 7 Type II Sheeting<sup>A</sup>**

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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ ) cd/ft<sup>2</sup>(cd-lx<sup>-1</sup>·m<sup>-2</sup>).

**TABLE 8 Type III Sheeting<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.1° <sup>B</sup>	-4°	300	200	120	54	54	24	14
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ ) cd/ft<sup>2</sup>(cd-lx<sup>-1</sup>·m<sup>-2</sup>).

<sup>B</sup> Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

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**.

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

**TABLE 9 Type IV Sheeting<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	−4°	500	380	200	70	90	42	25	400	300	150
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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 ( $Y$  %)<sup>A</sup>**

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

<sup>A</sup> (Typically Non-Metalized Microprismatic Material) For Sheeting Types IV, VII, VIII, IX, and X.

**TABLE 11 Type V Sheeting<sup>A</sup>**

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue
0.1° <sup>B</sup>	−4°	2000	1300	800	360	360	160
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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 ( $Y$  %)<sup>A</sup>**

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

<sup>A</sup> (Typically Metalized Microprismatic Delineator Material) For Sheeting Type V.

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, 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 1 3/4-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  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) and  $50 \pm 5\%$  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—

7.3.1 For lots, rolls, or sheets of retroreflective sheeting at least 1 yd long in new (unexposed) condition, take 3 samples in accordance with section 9.1. Determine the coefficients of retroreflection in accordance with Test Method E 810.

TABLE 13 Type VI Sheeting<sup>A</sup>

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
0.1° <sup>B</sup>	-4°	750	525	190	90	105	68	600	450	300
0.1° <sup>B</sup>	+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

<sup>A</sup> Minimum Coefficient of Retroreflection ( $R_A$ )  $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$ .

<sup>B</sup> 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 ( $Y\%$ )<sup>A</sup>

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

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

<sup>A</sup> Testing at shorter intervals may be done to gather additional information.

<sup>B</sup> When sheeting is specified for construction work zone applications, the outdoor weathering shall be 12 months.

7.3.1.1 To conform to this specification, the average of the 3 coefficients of retroreflection shall meet the minimum limits given in section 6.2 and none of the coefficients of retroreflection obtained on any of the samples shall be less than 80 % of the values required in section 6.2.

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.

7.4.2 There are three types of 45/0 (0/45) instruments: annular, circumferential, and uniplanar (see Fig. 1). Measure-

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

Climate Type <sup>A,B</sup>	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<sup>C</sup>

<sup>A</sup> Climate classification is in accordance with the Koppen reformed classification system.

<sup>B</sup> 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.

<sup>C</sup> 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.

ment 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)