



Standard Specification for Retroreflective Sheeting for Traffic Control¹

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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

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:

- B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate²
- B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]²
- B 449 Practice for Chromate Treatments on Aluminum³
- D 523 Test Method for Specular Gloss⁴
- E 284 Terminology of Appearance⁴
- E 308 Practice for Computing the Colors of Objects by Using the CIE System⁴
- E 808 Practice for Describing Retroreflection⁴
- E 810 Test Method for Coefficient of Retroreflection or Retroreflective Sheeting⁴
- E 991 Practice for Color Measurement of Fluorescent Specimens⁴
- E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation⁴
- E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus (Filter) Colorimetry⁴

E 1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry⁴

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials⁵

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials⁵

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests⁵

G 152 Practice for Operating Open-Flame Carbon-Arc Light Apparatus for Exposure of Nonmetallic Materials⁵

G 153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials⁵

2.2 Federal Specifications:

FP-92 Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects⁶

L-S-300C Federal Specification for Sheeting and Tape, Reflective: Non Exposed Lens⁷

2.3 AASHTO Specification:

M 268-84 I⁸

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 six types and five classes of retroreflective sheeting. Typical examples of materials and applications are provided for descriptive information only and are not intended to be limitations or recommendations.

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 Materials.

Current edition approved Jan. 10, 2000. Published April 2000. Originally published as D 4956 – 89. Last previous edition D 4956 – 99.

² *Annual Book of ASTM Standards*, Vol 02.02.

³ *Annual Book of ASTM Standards*, Vol 02.05.

⁴ *Annual Book of ASTM Standards*, Vol 06.01.

⁵ *Annual Book of ASTM Standards*, Vol 14.02.

⁶ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

⁷ Available from General Services Administration, 470 East L'Enfant Plaza S.W., Suite 8100, Washington, DC 20407.

⁸ Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol St., N.W., Washington, DC 20001.

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

4.2 Retroreflective sheeting shall be classified as follows:

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 engineering grade” and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

4.2.3 *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.

4.3 *Backing Classes*— The backing required for retroreflective sheeting Types I through V 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 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), and
- 5.1.7 Supplementary information, if required by the purchaser.

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),

5.1.7.3 Reboundable sheeting requirements (see Supplementary Requirement S2), and

5.1.8 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 1; Outdoor Weathering—24 months, see 6.4; Reflectance or Daytime Luminance—Table 2; Other requirements: When the colors orange, yellow, or white are specified for construction work zone applications, the outdoor weathering will be 12 months.

6.1.2 *Type II*—Minimum Coefficient of Retroreflection—Table 3; Outdoor Weathering—36 months, see 6.4; Reflectance or Daytime Luminance—Table 2; Other requirements: When the colors orange, yellow, or white are specified for construction work zone application, the outdoor weathering will be 12 months.

6.1.3 *Type III*—Minimum Coefficient of Retroreflection—Table 4; Outdoor Weathering—36 months, see 6.4; Reflectance

TABLE 1 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

^AMinimum Coefficient of Retroreflection (R_A) $\text{cd}/\text{ft}^2(\text{cd}\cdot\text{lx}^{-1}\cdot\text{m}^{-2})$.

TABLE 2 Luminance Factor (Y%) (Daytime Luminance)^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

^AFor Sheeting Types I, II, III and VI.

TABLE 3 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

^AMinimum Coefficient of Retroreflection (R_A) $cd/ft^2(cd-lx^{-1} \cdot m^{-2})$.

TABLE 4 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

^AMinimum Coefficient of Retroreflection (R_A) $cd/ft^2(cd-lx^{-1} \cdot m^{-2})$.

^BValues for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 6 Luminance Factor (Y%) (Daytime Luminance)^A

Color	Minimum	Maximum
White	50	...
Yellow	30	45
Orange	15	30
Green	6.0	15
Red	4.0	15
Blue	3.0	8.0
Brown	1.0	6.0

^A(Typically Non-Metalized Microprismatic Material) For Sheeting Type IV.

TABLE 7 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

^AMinimum Coefficient of Retroreflection (R_A) $cd/ft^2(cd-lx^{-1} \cdot m^{-2})$.

^BValues for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

TABLE 8 Luminance Factor (Y%) (Daytime Luminance)^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.

TABLE 9 Type VI Sheeting^A

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue
0.1° ^B	-4°	400	280	100	72	80	40
0.1° ^B	+30°	110	77	26	20	22	11
0.2°	-4°	250	170	70	30	35	20
0.2°	+30°	95	64	26	11	13	7.6
0.5°	-4°	200	136	56	24	28	18
0.5°	+30°	60	40	17	7.2	8.4	4.8

^AMinimum Coefficient of Retroreflection (R_A) $cd/ft^2(cd-lx^{-1} \cdot m^{-2})$.

^BValues for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

or Daytime Luminance—Table 2; Other Requirements: When the colors orange, yellow, or white are specified for construction work zone applications, the outdoor weathering will be 12 months.

6.1.4 *Type IV*—Minimum Coefficient of Retroreflection—Table 5; Outdoor Weathering—36 months, see 6.4; Reflectance or Daytime Luminance—Table 6; Other Requirements: When the colors orange, yellow, or white are specified for construction work zone applications, the outdoor weathering will be 12 months.

6.1.5 *Type V*—Minimum Coefficient of Retroreflection—Table 7; Outdoor Weathering—36 months, see 6.4; Reflectance or Daytime Luminance—Table 8; Other requirements: When the colors orange, yellow, or white are specified for construction work zone applications, the outdoor weathering will be 12 months.

6.1.6 *Type VI*—Minimum Coefficient of Retroreflection—Table 9; Outdoor Weathering—6 months, see 6.4; Reflectance

TABLE 5 Type IV Sheeting^A

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.1° ^B	-4°	400	270	160	56	56	32	12
0.1° ^B	+30°	120	75	48	13	13	7	3.0
0.2°	-4°	250	170	100	35	35	20	7.0
0.2°	+30°	80	54	34	9	9	5.0	2.0
0.5°	-4°	135	100	64	17	17	10	4.0
0.5°	+30°	55	37	22	6.5	6.5	3.5	1.4

^AMinimum Coefficient of Retroreflection (R_A) $cd/ft^2(cd-lx^{-1} \cdot m^{-2})$.

^BValues for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

or Daytime Luminance—Table 2.

6.2 *Coefficient of Retroreflection*—The coefficient of retroreflection shall meet or exceed the minimum requirements of Table 1, Tables 3-5, Table 7 and Table 9 as specified in 7.3.

6.3 *Daytime Color*—The color of the sheeting shall conform to requirements of Table 10 and one of the following Table 2, Table 6, or Table 8 when tested in accordance with 7.4. Daytime and nighttime color shall have substantially the same hue.

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

TABLE 10 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

^AThe four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 Standard Colorimetric System measured with CIE Standard Illuminant D65.

^BThe saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colors.

coefficient of retroreflection (R_A) after weathering is specified in Table 11.

NOTE 1—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 10 and one of the following: Table 2, Table 6, or Table 8 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 as specified in 7.12.

TABLE 11 Outdoor Weathering Photometric Requirements for All Climates

Type	Months ^A	Minimum Coefficient of Retroreflection, R_A
I	24 ^B	50 % of Table 1
II	36 ^B	65 % of Table 3
III	36 ^B	80 % of Table 4
IV	36 ^B	80 % of Table 5
V	36 ^B	80 % of Table 7
VI	6	50 % of Table 9

^ATesting at shorter intervals may be done to gather additional information.

^BWhen the colors orange, yellow, or white are specified for construction work zone applications, the outdoor weathering time will be 12 months.

7. Test Methods

7.1 *Test Conditions*—Unless otherwise specified herein, 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 herein, 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. 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 mm by 200 mm). Prepare the aluminum in accordance with Practice 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 *Color*—Test for Daytime Color:

7.4.1 Determine the chromaticity and luminance factor Y (%) in accordance with Test Methods E 308, E 1347, and E 1349 and Practices E 991 and E 1164.

7.4.2 For rotationally non-symmetrical materials, make a series of eight measurements. After each of these measurements, rotate the specimen 45° in the same direction about the axis, normal to the specimen surface and average the data. Make additional measurements until such further measurements do not result in a change in the Y value in excess of 1 % of the average to that point.

7.4.3 Instruments (spectrophotometers, colorimeters) used to measure daytime color should have 45/0 or 0/45 illumination and viewing geometry. The illumination angle should not vary from 45° by more than $\pm 10^\circ$ and the viewing angle should not vary from 0° by more than $\pm 15^\circ$, for the 45/0 condition. For the 0/45 condition, the requirements for illumination are interchanged.

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 11. Conduct exposures in locations with the climate types shown in Table 12. 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

TABLE 12 Climate Types for Use in Outdoor Exposures of Retroreflective Sheatings

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 (optional, but recommended)	28 to 34	10 to 17	Phoenix, AZ

Climate mutually agreed upon between the purchaser and the seller^C

^AClimate classification is in accordance with the Koppen reformed classification system.

^BOutdoor exposure results from Miami, FL and Phoenix, AZ are recognized internationally as benchmarks for evaluating durability of many different types of material and products.

^COutdoor 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.

rest rack. Fig. 1 is a diagram showing the arrangement of the clamping bars and the test specimen.

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 (1 % by weight in water, maximum concentration) of a mild detergent. 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 angle. Report the average of the coefficient of retroreflection measured at each geometry on the two panels from each exposure location.

NOTE 2—The HCl solution is used to remove water spots. If the proper water purity (0.2 ppm silica maximum) is used, the colloidal silica deposits that cannot be removed with HCL should be eliminated.

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 one 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 min 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 1/8-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 2 3/4 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 5/8-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°.

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

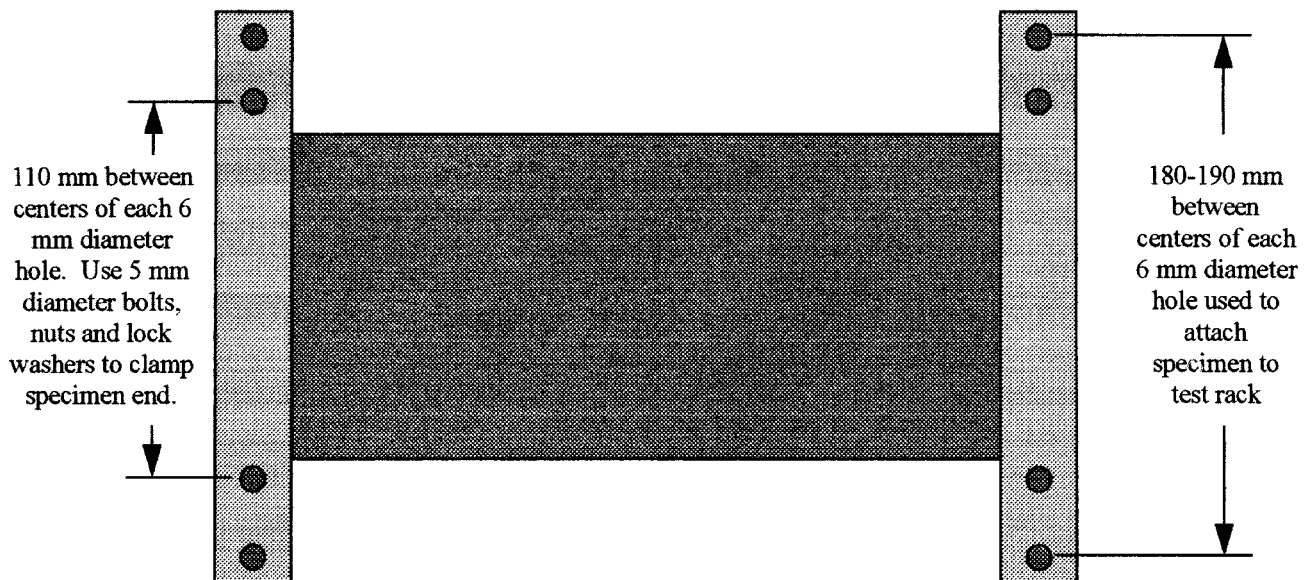


FIG. 1 Diagram Showing Clamping Bars Used for Attaching Type VI Sheeting Specimens to Test Rack for Outdoor Exposure

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 specifica-

tion 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 herein, all adhesively bonded and unbonded test samples and specimens shall be conditioned 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.

S1.2.2 *Panel Preparations*—Unless otherwise specified herein, 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, sheets in 0.020 in. (0.508 mm) thickness. The aluminum shall be prepared in accordance with Practice 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 6275.⁹ 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 7.4 to 50°F (−14 to 10°C). Subcultures incubated between 82.4 to 86°F (20 to 30°C) 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 ₂ H ₂ PO ₄	1.0 g
MgSO ₄ ·7H ₂ O	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

⁹ 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.

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.

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

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 ½₃₂-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 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 one 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 inch by 11 inch (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. minimum thickness (1.016 mm), 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 12. 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 70 mm (2.75 in.). 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 ½₃₂-in. (0.8-mm) shrinkage or expansion. The specimens shall also conform to the requirements of Table 10 and one of the following: Table 2, Table 6, or Table 8 when tested in accordance with 7.4, and 7.7.

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

Type	Months	Minimum Coefficient of Retroreflection (<i>R_A</i>)
I	12	65 % of Table 1
II	12	65 % of Table 3
III	12	80 % of Table 4
IV	12	80 % of Table 5
V	12	80 % of Table 7
VI	6	50 % of Table 9

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

Type	Hours	Minimum Coefficient of Retroreflection (<i>R_A</i>)
I	1 000	50 % of Table 1
II	2 200 ^A	65 % of Table 3
III	2 200 ^A	80 % of Table 4
IV	2 200 ^A	80 % of Table 5
V	2 200	80 % of Table 7
VI	250	50 % of Table 9

^AWhen the colors orange, yellow, or white are specified for construction work zone applications, the laboratory-accelerated weathering time will be 500 h.

S3.3 *Test Conditions*—Conduct exposures in a filtered open flame carbon-arc exposure device conforming to the requirements of Practices G 151 and G 152. The spectral power distribution of the filtered open flame carbon-arc shall conform to 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 $63 \pm 3^\circ\text{C}$ ($145 \pm 9^\circ\text{F}$). 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 $50 \pm 5\%$ equilibrium during the light-only interval.

APPENDIXES

(Nonmandatory Information)

X1. Related Information

X1.1 Federal Specifications

X1.1.1 FP85 Standard Specifications for Construction of Roads and Bridges on Federal Highways Projects.

X1.1.2 L-S-300C Federal Specification Sheeting and Tape, Reflective: Non Exposed Lens.

X1.2 Other Specifications

X1.2.1 American Association of State Highway and Transportation Officials. AASHTO designation M268-84 I.

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

X2.1 Table X2.1 lists 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

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).