APPENDIX H

Example Specifications for Glass Beads

Standard Specification for **Glass Beads Used in Traffic Paints**
AASHTO DESIGNATION: M 247-81 (1996)

1. SCOPE

1.1 This specification covers glass beads to be dropped or sprayed upon pavement markings so as to produce a reflectorized pavement marking.
1.2 Types:
1.2.1 *Type I*—shall be known as a standard gradation.
1.2.2 *Type 2*—shall be known as a uniform gradation.
1.3 *Flotation*—Either of the above gradation types may be obtained with flotation properties at the request of the purchaser.
1.4 *Moisture Resistance*—Either of the above types may be obtained with a moisture resistant coating if so specified by the purchaser.
1.5 The values stated in SI units are to be regarded as the standard.

NOTE 1—Since the flotation coating imparts moisture resistance to the beads the moisture resistance test may be waived by the purchaser if the beads are ordered with the flotation property.

TABLE 1 Gradation of the Glass Beads

Sieve Designation		Mass Percent Passing	
Standard mm	Alternate No.	Type I	Type II
0.850	20	100	—
0.600	30	75-95	100
0.425	40	—	90-100
0.300	50	15-35	50-75
0.180	80	—	0-5
0.150	100	0-5	—

2. GENERAL REQUIREMENTS

2.1 The beads shall be transparent, clean, colorless glass,smooth and spherecally shaped, free from milkiness, pits, or excessive air bubbles and conform to the following specific requirements.

3. SPECIFIC PROPERTIES

3.1 *Gradation*—The beads shall meet the gradation requirements for type as given in Table 1.
3.2 *Roundness*—The glass beads shall have a minimum of 70 percent true spheres.
3.3 *Crushing Resistance*—Retained 0.425-mm (No. 40) sieve 133 N (30lbs) minimum.
3.4 *Refractive Index*—The glass beads shall have a minimum refractive index of 1.50.
3.5 *Moisture Resistance-Flow Characteristics*—The beads shall not absorb moisture in storage. They shall remain free of clusters and lumps and shall flow freely from dispensing equipment.
3.6 *Floatation*—When tested in accordance with Section 4.5, a minimum of 90-percent beads shall float in xylene.

FIGURE H1 AASHTO specification for Type I and Type II glass beads. (*Source*: AASHTO M 247-81 2000.)

4. METHODS OF SAMPLING AND TESTING

4.1 The sampling shall be random in the following ratios—45 kg (100lbs) of sample (in full bags) per 4535 kg (10000lbs) shipped. Upon arrival material shall be reduced in a sample splitter to a size of approximately 1 kg.

4.2 The following requirements shall be tested with the following test methods.

Gradation —ASTM D 1214
Roundness— ASTM D 1155
Crushing —ASTM D 1213

4.3 The refractive index shall be tested by liquid immersion method (Becke Line Method or equal) at a temperature of 25 ± 5°C (77 ± 9°F).

4.4 Flow Characteristics —Beads will flow properly when tested in accordance with procedure 4.4.1 unless they are specified to be moisture resistant, in which case procedure 4.4.2 will be followed.

4.4.1 A 100-g sample of beads is placed in a Corning 3140 crystallizing dish, 100-mm diameter by 50-mm depth. Place the dish in a Corning 3080 Desiccator (or equivalent) 250-mm inside diameter by 330-mm overall height and 130-mm chamber depth, which shall be filled with a sulfuric acid-water solution having a specific gravity of 1.10 (approximately 94-percent humidity) to a point 25.4mm below the top of a size 5 Coors 60003 Desiccator Plate. The sample shall remain in the covered Desiccator at 25 ± 5°C for 4 hours. Remove the sample from the Desiccator and transfer the beads to a metal pan. The beads shall be essentially free of lumps and clusters and shall flow without stoppage when poured slowly through a standard glass funnel (Corning 6120). 127-mm diameter, 102-mm stem length, and 11-mm stem inside diameter (Note 1).

4.4.2 A 100-g sample of beads is placed in a 600-mL beaker and an equivalent volume of distilled water shall be added to the beaker. The beaker will then stand for 5 minutes, at the end of which time the water shall be carefully poured off and the beads transferred to a clean dry beaker and allowed to stand for 5 minutes. The beads will then be poured slowly into a standard glass funnel (Corning 6120), 127-mm diameter, 102-mm stem length and 11-mm stem inside diameter. The beads shall flow through the funnel stem without stoppage. Slight initial agitation to start the flow through the funnel at the beginning of the test is permissible.

4.5 *Flotation Test*—Determine the mass of approximately 1 g to the nearest 0.0005 g, evenly distribute beads into a clean standard 100-mm glass Petri dish previously weighed to the nearest 0.0005 g. The dish is vibrated slightly to attain as near as possible a monolayer of beads. Xylene, C.P. Grade, is introduced at one side of the dish at a rate of 10 to 15 mL per minute from a burette until 30mL has been added. The floating beads are then carefully drawn off by suction through a suitably constricted delivery tube connected to a receiving flask. Excess xylene is drawn off so that no remaining heads are lost and the dish dried in an oven at 110 ± 5°C. The dish is weighted and the percentage of floating beads calculated.

5. PACKAGING AND MARKING

5.1 Glass Beads shall be furnished in kg (lbs) lots as specified by the purchaser and packaged in moisture proofed bags. Containers are to be guaranteed to furnish dry and undamaged beads. Each package shall contain the following information: name, and address of manufacturer, shipping point, trademark or name, the wording "glass beads," the specifications number, number of kg (lbs), the lot or batch number, and the month and year of manufacture.

NOTE 2—The test operations should be performed immediately on removal of the beads from the Desiccator.

FIGURE H1 (*Continued.*)

718.19 Glass Beads. Conform to AASHTO M 247 for the type specified. Table 1, Gradation of Glass Beads in AASHTO M 247 is supplemented by Table 718-2. Treat glass beads with an adherence coating as recommended by manufacturer.

Table 718-2
Gradation of Glass Beads

Sieve Size	Percent by Mass Passing Designated Sieve (ASTM D 1214)		
	Grading Designation		
	Type 3	Type 4	Type 5
2.36 mm			100
2.0 mm		100	95 - 100
1.7 mm	100	95 - 100	80 - 95
1.4 mm	95 - 100	80 - 95	10 - 40
1.18 mm	80 - 95	10 - 40	0 - 5
1.0 mm	10 - 40	0 - 5	0 - 2
850 μm	0 - 5	0 - 2	
710 μm	0 - 2		

For type 3, 4, and 5 glass beads, also conform to the following:

(a) Treat beads with a reactive adherence coating as recommended by the manufacturer.

(b) Roundness, FLH T 520 — 70% min/sieve size

(c) Refractive index, AASHTO M 247 — 1.50 - 1.55

FIGURE H2 FHWA specification for Type 3, Type 4, and Type 5 glass beads. (*Source*: FHWA FP 96 1996.)

Specifications for Glass Beads Used for Luminous Traffic Lines

1. GLASS BEADS FOR LUMINOUS TRAFFIC LINES:

1.1 Glass beads for use in luminous traffic lines shall conform to the requirements of AASHTO M 247, Type I. In addition, the quantity of angular particles shall not exceed one percent by weight. The quantity of glass particles showing milkiness, scoring, or scratching shall not exceed two percent by weight. Glass beads shall not impart any noticeable daytime hue to the paint or thermoplastic markings.
Glass beads conforming to the following alternate gradation may be used provided that all other requirements of AASHTO M 247 and this Specification are met.

Sieve Designation	Percent Passing
16	99-100
20	75-95
30	55-85
50	10-35
100	0-5

2. PACKAGING AND MARKING

2.1 Glass Beads shall be furnished in kg (lbs.) lots as specified by the purchaser and packaged in moisture proofed bags. Containers are to be guaranteed to furnish dry and undamaged beads. Each package shall contain the following information: name, and address of manufacturer, shipping point, trademark or name, the wording "glass beads," the specifications number, number of kg (lbs.), the lot or batch number, and the month and year of manufacture.

FIGURE H3 Georgia Department of Transportation glass bead specification. (*Source*: Georgia DOT 2000.)

APPENDIX I

Example Specifications for Raised Pavement Markers

718.20 Raised Pavement Markers. Furnish prismatic retroreflector type markers consisting of a methyl methacrylate, polycarbonate, or suitably compounded acrylonitrile-butadiene-styrene (ABS) shell fitted with retroreflective lenses. Make the exterior surface of the shell smooth.

Use a retroreflector with a minimum coefficient of (retroreflected) luminous intensity conforming to Table 718-3.

Table 718-3
Minimum Coefficient of (Retroreflected) Luminous Intensity (R_I)
Millicandelas per lux

Observation Angle °	Entrance Angle °	White(1)	Yellow	Red
0.2	0	279	167	70
0.2	20	112	67	28

(1) Crystal, clear, or colorless are acceptable color designations.

Make the base of the marker flat, patterned, or textured and free from gloss or substances that may reduce its bond to the adhesive. The deviation from a flat surface shall not exceed 1 millimeter.

FIGURE I1 FHWA specification for raised pavement markers. (*Source*: FHWA FP 96 1996.)

Section 919—Raised Pavement Markers

919.1 General Description

This section includes the requirements for raised pavement marker materials for use in reflective, ceramic, and channel markers.

919.1.01 Related References

A. Standard Specifications

General Provisions 101 through 150.

B. Referenced Documents

ASTM C 424

ASTM C 373

ASTM D 2240

ASTM D 4280

Federal Method TT-T-141, Method 4252

919.2 Materials

A. Requirements

Do not use any marker materials until the laboratory approves it.

1. Use raised pavement marker sources as listed in QPL 76.
2. Use raised pavement markers of the type shown in the Plans or specified in the proposal. This Specification references markers as follows:

Type	Description
1	One-way, one-color, 4 x 2 in (100 mm x 50 mm), reflective
2	Two-way, one-color, 4 x 2 in (100 mm x 50 mm), reflective
3	Two-way, two color, 4 x 2 in (100 mm x 50 mm), reflective
4	Round white, yellow or black ceramic, non reflective
5	Oval white, yellow or black ceramic, non-reflective
6	Oval white or yellow ceramic, reflective
7	White or yellow ceramic jiggle bar, non-reflective
8	White or yellow ceramic jiggle bar, reflective
9	White or yellow channel, non-reflective
10	White or yellow channel, reflective
11	Two-way, one-color, 4 x 4 in (100 mm x 100 mm), reflective
12	One-way, one color, 4 x 4 in (100 mm x 100 mm), reflective
13	Two-way, two color, 4 x 4 in (100 mm x 100 mm), reflective
14	Two-way, one color, flexible reflective
15	One-way, one color, flexible reflective

3. Definitions
   a. Angle of Incidence: Formed by a ray from the light source to the marker, and the normal to the leading edge of the marker face.

b. Angle of Divergence: Formed by a ray from the light source to the marker and the return ray from the marker to the measuring receptor.

c. Specific Intensity: The mean candela of the reflected light at a given incidence and divergence angle for each lux at the reflector on a plane perpendicular to the incident light.

4. Sampling

The Department will select at random the required number of markers for initial tests for each shipment or lot, as follows:

Reflective Markers	Ceramic Markers	Channel Markers
50	25	5

5. Certification

Submit a certification to the Engineer from the manufacturer showing the physical properties of the markers and their conformance to this Specification.

6. Packaging

Pack shipments in containers that are acceptable to common carriers.

a. Pack the containers to ensure delivery in perfect condition.

b. Clearly mark each package of pavement markers with the size, color, type, and lot number.

c. You are liable to replace any damaged shipments.

7. Acceptance

The Department will give conditional approval to raised pavement markers evaluated by the National Transportation Product Evaluation Program (NTPEP), the Georgia Department of Transportation, or other Department-approved test facilities and place them on QPL 76.

All white raised pavement markers must meet the requirements of this Specification and the following field performance requirements.

a. Conditional QPL Placement: The Department may add markers on a conditional basis to QPL 76. These markers must maintain an average Coefficient of Retroreflected Luminous Intensity of 1.5 candles per footcandle (cd/fc)* after a one-year field evaluation period through at least one of the test facilities specified above.

b. Final Acceptance or Rejection: The Department will accept or reject markers based on the marker maintaining an average Coefficient of Retroreflected Luminous Intensity of 0.5 candles per footcandle (cd/fc)* after a two-year field evaluation period through at least one of the test facilities specified above.

NOTE: Measure the coefficient of retroreflected luminous intensity at the 0 degree incident angle and 0.2 degree divergence angle.

919.2.01 Reflective Pavement Markers

A. Requirements

Plastic reflective pavement markers are types 1, 2, 3, 11, 12, and 13 (rigid plastic reflective) and types 14 and 15 (flexible reflective).

1. Rigid Plastic Reflective Markers

a. Use prismatic markers made with a methyl methacrylate or acrylonitrile butadiene styrene, a high-impact plastic shell filled with a mixture of inert thermosetting compound and filler material.

1) Ensure that the exterior shell surface is smooth and contains one or two prismatic faces, molded to reflect incident light from a single direction or from opposite directions.

2) Ensure that the shell is one color or a combination of two colors that will be the same as reflective elements and shall match the size and shape in the Plans.

b. Use two basic sizes—a standard (a base of 4 x 4 in [100 mm x 100 mm]) or a low-profile (a base of 4 x 2 in [100 mm x 50 mm]).

1) Ensure that reflective raised pavement markers have one or two lens surfaces that meet the requirements of ASTM D 4280, designation H—a marker with a hard, abrasion-resistant lens surface.

2) Ensure the marker base is clean and has no gloss or substance that may reduce the adhesive's bond. The Department will reject the marker if it has a soft or resin-rich film on the base.

2. Flexible Reflective Markers (Type 14 and 15)

Use markers manufactured by extruding plastic into an "L" shape, with nominal dimensions of 4 in (100 mm) long x 2 in (50 mm) high (vertical face) x 1 in (25 mm) wide (base leg). Ensure that the markers have the following:

- A pressure-sensitive adhesive with a paper release liner to the bottom of the base leg.
- Strips of metallized acrylic reflective sheeting on either one or both sides of the vertical face.
- A clear plastic cover to protect the reflective strip. Ensure that the cover withstands a chip-seal operation and is easily removed after the operation.

3. Color

Use clear, yellow, or red raised reflective pavement markers, as required.

If the reflection is off-color, the Department will reject the markers.

4. Specific Intensity

Ensure that the specific intensity of each reflective surface, when tested at 0.2 degree angle of divergence, has at least these values:

Incidence Angle	Clear	Yellow	Red
0°	3.0	1.50	0.75
20°	1.2	0.60	0.30

Calculate the intensity as follows:

$$SI = (R_L \times D^2) \div I_L$$

Where:

SI = Specific Intensity

R_L = Reflected Light

I_L = Incident Light

D = Test Distance

B. Fabrication

General Provisions 101 through 150.

C. Acceptance

The Department will accept markers based on the results of the physical tests and on the manufacturer's certification showing the physical properties of the markers and their conformance to this Specification.

The Department will conduct the following tests:

- Specific Intensity
- Compressive Strength
- Impact
- Temperature Cycle
- Shore A Hardness (Type 14 and 15 only)

1. Specific Intensity

a. Place markers so the center of the reflecting face is 5 ft (1.5 m) from a uniformly bright light source. Use a source with an effective diameter of 0.21 in (5 mm).

If using a test distance other than 5 ft (1.5 m), modify the source and receptor in the same proportion as the test distance.

b. Use a photocell receptor 0.5 in (13 mm) wide. Shield it to eliminate stray light.

c. Place the center of the light source aperture 0.2 in (5 mm) from the center of the photocell.

d. Use the following table to determine if the markers pass the tests (except the strength test), unless otherwise specified.

Markers that Pass	Department Action
48 of 50	Accept the lot.
44 or less of 50	Reject whole lot; no retest allowed.
45-47 of 50	Contractor can request a retest on 100 markers. The Department will pass each marker through all tests except the strength test.
96 of 100 retested	Accept the whole shipment
95 or less of 100 retested	Reject the whole shipment

2. Compressive Strength

Test for compressive strength as follows:

Standard Raised Markers 4 x 4 in (100 x 100 mm)	Low-Profile Markers 4 x 2 in (100 x 50 mm)
1. Select three random markers for the test.	
2. Center the base of the marker over the open end of a hollow, vertically positioned metal cylinder (1 in (25 mm) high, internal diameter of 3 in (75 mm), wall thickness of 0.25 in (6 mm)).	2. Position the marker on its base at the center of a flat, steel plate that has a minimum thickness of 0.5 in (13 mm).
3. Apply a load to the top center of the marker with a 1 in (25 mm) diameter solid steel plug at a rate of	
0.2 in (5 mm) per minute.	0.03 in (0.75 mm) per minute.
4. The marker fails if it breaks or deforms at a load less than	
2,000 lbs (8.9 kN)	4,000 lbs (17.8 kN)
Or if the shell and the filler material significantly delaminate, regardless of the load required to break the marker.	
5.If any of the 3 samples fail, the Department will test 6 additional samples.	
6.If any of the 6 additional samples fail, the Department will reject the entire lot.	

3. Impact Test

a. Condition all prismatic reflective faces that meet the requirements of ASTM D 4280, designation H, before the impact test.

b. Choose at random 20 markers for each test.

c. Condition the markers in an oven at 130 °F (54° C) for one hour.

d. While at this temperature, drop a 0.42 lb (0.2 kg) dart fitted with a 0.25 in (6 mm) radius spherical head from 18 in (450 mm) above the reflective face.

e. Drop the dart perpendicularly onto the center of the reflective surface. The cracks in the impact area shall appear generally concentric.

f. The Department will reject the marker if more than two radial cracks longer than 0.25 in (6 mm) appear, or if radial cracks extend to the edge of the reflective face.

g. Use the following table to determine if the markers pass the tests.

Markers that Pass	Department Action
18 of 20	Accept the lot.
16 of 20	Reject the lot.
17 of 20	The Contractor may request a retest. The Department will test 20 additional lenses.

19 or less of 20 retested	Reject the lot.

4. Temperature Cycle
   a. Subject the same markers used for impact testing to 3 cycles of 140 °F (60 °C) for 4 hours followed by 20 °F (–7 °C) for 4 hours.
   b. The Department will reject the markers if they crack or delaminate after this test.
   c. Use the following table to determine if the markers pass the tests.

Markers That Pass	Department Action
18 of 20	Accept the lot.
16 of 20	Reject the lot.
17 of 20	The Contractor may request a retest. The Department will test 20 additional lenses.
19 or less of 20 retested	Reject the lot.

5. Hardness (Type 14 or 15 only)
   a. Select five random markers.
   b. Use ASTM D 2240 to determine the Shore A hardness.
   c. Measure the hardness. The Department will reject markers whose body and clear protective cover hardness is less than 80.

D. Materials Warranty

General Provisions 101 through 150.

919.2.02 Ceramic Pavement Markers

A. Requirements

Ceramic pavement markers are types 4, 5, 6, 7, and 8.

1. Use ceramic pavement markers made from a heat-fired, white, vitreous, ceramic base and a heat fired, opaque, glazed surface to produce the properties required in these Specifications.
   a. Do not place glaze on the marker bottom where it connects to the road surface.
   b. Thoroughly and evenly mature the markers. Ensure that they have no defects that affect appearance and serviceability.
   c. Use reflective ceramic markers that meet the specific intensity of each reflective surface according to Subsection 919.2.01.A.4.
   d. Ensure that the mean thickness of the glazed surface is at least 0.005 in (0.13 mm) when measured at least 0.25 in (6 mm) from the edge of the marker.
   e. Ensure that the water absorption of the ceramic markers does not exceed 2 percent of the original dry weight when tested according to ASTM C 373.
   f. Ensure that the glazed surface does not craze, spoil, or peel when passed through one cycle of the Autoclave test at 250 psi (1724 kPa) (ASTM C 424).
2. Use the designated colors for the white and yellow markers.
   a. Ensure that the colors are uniform.
   b. Ensure that black matches Federal Color No. 595-27038.
   c. Determine the color by visually comparing each marker with calibrated standards having CIE Chromaticity Coordinate limits. Determine the limits with Federal methods of test TT-T-141, Method 4252, using a rectangle with the following corner points:

	1		2		3		4		(90MGO)
White	.290	.316	.310	.296	.330	.320	.310	.344	80 min.
Yellow	.435	.485	.445	.435	.544	.456	.516	.484	50 min.

B. Fabrication

General Provisions 101 through 150.

C. Acceptance

1. Use a random sample of five markers for each of the required tests in Subsection 919.2.01.C.3 to Subsection 919.2.01.C.4, and Subsection 919.2.01.C.5. Use the Compressive Strength Test in Subsection 919.2.02.C.3.
2. Use the following table to determine if the markers pass the tests.

Markers that Pass	Department Action
5 of 5	Accept the lot.
3 or less of 5	Reject the lot; no resample allowed.
4 of 5	The Contractor may request a retest. The Department will retest an additional 25 random markers in the test or tests where the original sample failed.
20 of 25 retested	Accept the lot.
19 or less of 25 retested	Reject the lot; no resample allowed.

3. Compressive Strength Test
   a. Center the markers with the base down over the open end of a vertically positioned hollow metal cylinder. Use a cylinder 1 in (25 mm) high with an internal diameter of 3 in (75 mm) and a wall thickness of 0.25 in (6 mm).
   b. Apply a load at 0.2 in (5 mm) per minute to the top of the markers through a 1 in (25 mm) diameter solid metal cylinder centered on the top of the markers.
   c. Apply the load until the marker breaks.
   d. The markers pass if the average compressive load of all five markers is at least 1,500 psi (6.7 kN). No individual marker shall be less than 1,200 psi (5.3 kN).

D. Materials Warranty

General Provisions 101 through 150.

919.2.03 Channel Pavement Markers

A. Requirements

Channel pavement markers are type 9 and 10 markers only.

1. Use channel pavement markers made of either a heat-fired, white, vitreous, ceramic base with a heat-fired, opaque, glazed surface, or a 9 gauge (3.9 mm) steel body with a heat-fired porcelain finish.
   a. Ensure both ceramic and steel channel markers have no defects that affect appearance and serviceability.
   b. Ensure that the mean thickness of the glazed surface of ceramic channel markers is at least 0.005 in (0.13 mm) when measured at least 0.25 in (6 mm) from the edge of the marker.
   c. Ensure that mean thickness of the porcelain finish on the steel channel markers is at least 0.030 in (0.76 mm).
   d. Ensure that the water absorption of the ceramic markers does not exceed 2.0 percent of the original dry weight when tested according to ASTM C 373.
   e. Ensure that the surface of the markers do not craze, spoil, or peel when passed through one cycle of the Autoclave test at 250 psi (1724 kPa) (ASTM C 424).
2. Use the designated colors for the white and yellow markers.
   a. Ensure that the colors are uniform.
   b. Determine the color by visually comparing them with calibrated standards having CIE Chromaticity Coordinate limits. Determine the limits with Federal methods of test TT-T-141, Method 4252, using a rectangle with the following corner points:

	1		2		3		4		(90MGO)
White	.290	.316	.310	.296	.330	.320	.310	.344	80 min.
Yellow	.435	.485	.445	.435	.544	.456	.516	.484	50 min.

B. Fabrication

General Provisions 101 through 150.

C. Acceptance

1. Ensure that Type 10 markers meet the specific intensity of each reflective surface according to Subsection 919.2.01.A.4
2. Use a random sample of five markers for each of the required tests in Subsection 919.2.01.C.2, Subsection 919.2.01.C.3, Subsection 919.2.01.C.4, and Subsection 919.2.01.C.5.
3. Select two of the five markers and subject them to all the required tests.
4. Use the following table to determine if the markers pass the tests.

Markers that Pass	Department Action
2 of 2	Accept the lot.
0 of 2	Reject the lot; no resample allowed.
1 of 2	Retest the three remaining markers.
3 of 3 retested	Accept the lot.
2 or less of 3 retested	Reject the lot; no resample allowed

D. Materials Warranty

General Provisions 101 through 150.

March 2000

PAVEMENT MARKERS

List No. 22

RECESSED PAVEMENT MARKERS

Manufacturer	Size	Marker Number	Adhesive Part No.
Ray-O-Lite		2004, 2004S Type B,C,D,G,H,K,X,Z,DR	EP-326 Epoxy
Avery Dennison (formerly Stimsonite)	for 4.5" slots	948	2202 Epoxy or AASHTO-M237, Type II
Avery Dennison (formerly Stimsonite)	Replacements for 4.0" slots	944SB	2201 Epoxy or AASHTO-M237, Type II

SNOW PLOWABLE RAISED PAVEMENT MARKERS

Manufacturer	Model No.	Reflector Number	Adhesive Part No.
Avery Dennison (formerly Stimsonite)	98	940	2203 Epoxy or AASHTO-M237 Type IV or Liquid Nails

Note: The Model 98 has been discontinued. The information about the approved reflector is provided for replacement of reflectors in existing units.
The Model 98 has been replaced by the following:

Avery Dennison (formerly Stimsonite)	101	944	2203 Epoxy or AASHTO M237 Type IV or Liquid Nails

The following reflector may be used as a replacement insert in the Model 101 casting

Ray-O-Lite		2004, 2004S Type B,C,D,G,H,K,X,Z,DR	Liquid Nails

RAISED PAVEMENT MARKERS

Manufacturer	Size	Marker Number	Adhesive Part No.
Avery Dennison (formerly Stimsonite)	4"X4"	911	2202 Epoxy or AASHTO-M237, Type II

FIGURE I2 Virginia Department of Transportation approved pavement marker products list. (*Source*: Virginia DOT 2000.)

APPENDIX J

Example Test Method for Quality Control Testing of Pavement Markings Used by the Virginia Department of Transportation

2-1-94

Virginia Test Method

For

Quality Control Testing of Pavement Markings

Designation: VTM-94

1. **Scope**

This method of test outlines five (5) procedures for quality control testing of pavement markings:

A) Checking for moisture in the pavement
B) Determination of the wet mil thickness of liquid markings
C) Determination of mil thickness for thermoplastic markings
D) Determination of application rate of glass beads applied by pressurized spray or drop-on methods
E) Visual Inspection

2. **Apparatus**

The apparatus required for each procedure is outlined in the appropriate section below.

3. **Procedures**

A) Checking for moisture in the pavement - There are two methods described in this section. Method 1 is to be used prior to application of markings. Method 2 is only to be used during thermoplastic application.

Method 1

a) Apparatus - 6" x 6" clear plastic square
Duct tape

b) Procedure - Select a location representative of the pavement surface where markings are to be applied. Secure all edges of the plastic to the pavement surface with the duct tape. The pavement surface must be visible through the plastic.

After a period of time, check for condensation of moisture on the plastic. The appropriate time between taping and inspecting the plastic will vary with ambient conditions; If

moisture is present it will be drawn out more quickly in a sunny location than in the shade. However, shady areas are more likely to contain moisture. Always choose a test location that represents the "worst case" scenario. Generally, a minimum of twenty (20) minutes is recommended.

The presence of moisture on the plastic indicates that there is moisture in the pavement surface.

Method 2

a) Apparatus - #15 Tar paper
Duct tape

b) Procedure - Select a location where markings are to be applied. Place the tar paper on the pavement surface. Secure the tar paper to the surface with the duct tape such that it will not be displaced when the thermoplastic is applied.

Apply the marking material to the tar paper. Wait approximately one (1) minute to allow any moisture in the pavement to condense onto the tar paper. Carefully remove the tar paper from the pavement. (Thermoplastic is applied from 400 to 475°F. Work gloves should be worn.)

Inspect the underside of the tar paper for condensation of moisture. Presence of moisture on the tar paper indicates that there is moisture in the pavement surface.

B) Determination of the wet mil thickness of liquid marking materials - This procedure is to be used to verify the thickness of all liquid pavement marking materials, except thermoplastic, immediately following application thereof.

a) Apparatus - calibrated wet mil gauge
* sample plate (sheet metal - 4 in. x 6 in., 20 to 40 mils thick)
piece of cloth

b) Procedure - Select a level location in the path of where the markings are to be applied. Place the plate on the pavement surface and secure it with the duct tape such that it will not be displaced when the marking is applied.

This test cannot be performed on a sample that contains glass beads. The glass bead gun must be turned off prior to application of the marking material to the sample plate.

Apply the marking material to the sample plate using the equipment being evaluated.

Thickness is specified in wet mils for all liquid markings except thermoplastic. Thus, all thickness measurements must be performed while the material is still wet.

Immediately after application, place the gauge into the material on the sample plate until the posts on the gauge are firmly in contact with the plate (see figure 1). The gauge is configured such that the probes indicate a thickness from a line drawn between the posts. The last probe with material on it indicates the thickness. Care must be taken not to press too hard as this may indent the sample plate and give a false reading.

Read the thickness from the gauge.

The gauge should be cleaned with a cloth immediately after taking the reading. Consistent cleaning will prevent build-up of dried material.

C) Determination of mil thickness for thermoplastic marking materials - This determination is made on the dried film. One of the two following methods is to be used depending on the quantity of voids in the substrate. The specified thickness is defined as the amount of material thickness above the surface of the roadway. Method 1 is to be used for dense graded substrates or when using an extrusion die applicator. Method 2 is to be used for any type of applicator when the substrate is open graded and a substantial amount of material lies below the effective plane of the pavement surface.

Method 1

a) Apparatus - Calipers accurate to 0.001 inch
* sample plate (sheet metal - 4 in. x 6 in., 20 to 40 mils thick)

b) Procedure - Measure and record the thickness of the sample plate. Select a location in the path of where the markings are to be applied. Place the plate on the pavement surface and secure it with the duct tape such that it will not be displaced when the marking is applied.

This test will not be accurate when performed on a sample that contains drop-on or pressure applied glass beads. The glass bead gun or dispenser must be turned off prior to application of the marking material to the sample plate.

Apply the marking material to the sample plate using the equipment being evaluated.

Thermoplastic is applied from 400 to 475°F. Wait until the sample cools sufficiently to be moved without flowing.

Carefully remove the sample plate from the pavement. Work gloves should be worn.

Using the calipers, measure the total thickness of the thermoplastic and the sample plate. Subtract the panel thickness from the total thickness to obtain the thickness of the applied material.

NOTES FOR B & C ABOVE:

1 - The samples obtained from the procedures B and C above should be inspected for even material thickness across the entire cross-section of the plate and even edges when viewed from above as detailed in (E) below.

2 - The methods of sampling outlined above may also be used to collect samples for visual inspection of glass bead distribution and embeddment as outlined in (E) below.

3 - The section of marking where the thickness samples were obtained does not contain glass beads. When it has thoroughly dried cooled or cured, a new marking with glass beads should be applied over the test marking.

* 1) Specified dimensions for length and width of sample plate are minimums. Larger sizes may be required for certain applications, ie. double yellow lines, or where operator skill dictates.

The specified thickness of the sample plate (20 to 40 mils) must be maintained: A thinner plate will deform while taking readings and produce false results. A plate thicker than that specified (ie. sign stock) will alter the distance between the gun and the pavement. This can also result in false readings.

Method 2

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Under Development

This method will require the use of a new device that will be used to measure the thickness of the marking by taking direct measurements on the surface of the roadway..

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D) Determination of application rate of glass beads applied by pressurized spray or drop-on methods - There are two methods for making this determination:

Method 1 may only be performed after verifying the speed at which the pavement marking equipment actually travels to achieve the proper wet mil thickness of the applied marking.

Use of Method 2 is not limited.

Development of Table 1

Calibration of the pavement marking equipment involves determining the appropriate pressure and speed required to achieve the appropriate wet mil thickness. Once this speed is established the pressure of the glass bead gun is adjusted to deliver the appropriate quantity of beads per gallon of material.

Table 1 is based on the following: A line that is four (4) inches wide at 15 wet mils that is 320 feet long takes one (1) gallon of material. Therefore, properly calibrated equipment will deliver the specified quantity of beads in the time it takes to travel 320 feet. Table 1 simply converts the speed in MPH to the time it takes to travel 320 feet. Since the specified quantity of beads (ie. 6 Lbs./gal. for paint) should be delivered in the time it takes to travel 320 feet, the values in the Table 1 apply to all bead guns set up to cover 4 inch lines for any specified application rate.

Method 1

a) Apparatus - Calibrated one (1) gallon bucket. (This bucket is graduated in one (1) pound increments beginning at six pounds. Graduations may be marks, indentions or drilled holes.

b) Procedure - Determine the time required to dispense the specified quantity of beads from Table 1.

Position the bucket under the bead gun such that all beads dispensed will be caught in the bucket.

Turn on the bead gun for the time increment from Table 1 (The pressure must be at the same setting that is used while applying markings.)

Compare the level of beads in the bucket with the appropriate graduation.

If there is a difference of ½ inch or greater between the level of the beads and the mark, adjustments must be made to the equipment to close this gap.

Table 1	
Vehicle Speed (MPH)	**Time to Dispense Specified Quantity of Glass Beads (seconds)**
4	54.5
5	43.6
6	36.4
7	31.2
8	27.3
9	24.2
10	21.8
11	19.8
12	18.2
13	16.8
14	15.6
15	14.5
16	13.6
17	12.8
18	12.1

Method 2

This method utilizes Table 2. This table converts the various specification quantities per gallon to units of pounds per linear foot for a four inch line.

a) Apparatus - Canvas Sample Bag
String
Scales or balance accurate to ±0.01 lb.

b) Procedure - Mark a distance on the roadway between 50 and 350 feet.

Weigh the sample bag and record.

Tie the sample bag onto the bead gun. Operate the equipment in the same manner as if markings were being applied except that

the paint gun should be turned off while collecting the bead sample.

Weigh the sample bag and beads.

Subtract the weight of the sample bag from the weight of the sample bag and beads.

Referring to Table 2, calculate the minimum weight of beads for the distance traveled. The actual weight collected must equal or exceed this value.

Table 2

Glass Bead Application Rate per Linear Foot For a Four Inch Line

Specified Application Rate (Lbs / Gallon)	Glass Beads per Linear Ft. (Lbs / L.F.)
6	0.0188
8	0.025
10	0.03125
25	0.0781
Spec. = 7 lbs./100 Sq.Ft. Equivalent = 7 lbs./300 L.F. (for Thermoplastic)	0.0233

Example

Given: Thermoplastic markings are being applied. A 4.12 lb. sample is collected over a distance of 175 feet.

Calculate the beads required:

Table 2 yields 0.0233 lbs./L.F. for thermoplastic.

175 x 0.0233 = 4.08 lbs. (minimum)

Since the amount collected exceed 4.08 lbs., this is a passing test.

E) Visual Inspection - Knowing material quantities does not assure that everything was distributed correctly. This procedure provides guidelines for the visual inspection of pavement markings. Markings which do not meet the criteria stated below fail this procedure and should be rejected.

Visual inspections are made with regard to one of two (2) items: the marking itself or the glass beads.

1) The Marking

a) The location of markings should be compared with the plans and/or the Manual of Uniform Traffic Control Devices (MUTCD). Markings that do not conform to these requirements are unacceptable.

b) Markings must be of the specified width.

c) Markings must be checked for even thickness. This may be done by either inspecting the samples taken for thickness measurements or viewing the marking directly on the pavement. With either method, look for uneven thicknesses in the cross-section of the marking.

2) The Glass Beads - Visual inspection of glass bead application are either with regard to distribution or embeddment

Distribution

a) Beads should cover the entire marking.

b) Beads should be evenly distributed across the entire marking.

c) All beads should either be embedded into or onto the marking with little or no loss onto the adjacent pavement.

Embeddment

a) Visual inspections with regard to the embeddment of beads into the marking material should be made directly on the pavement surface. The specifications for bead embeddment are general. It is not feasible to obtain exact percentages of buried vs. non-buried beads.

Generally, a marking that fails the visual inspection for bead embeddment exhibits one of the following conditions:

1) Most or all the beads are buried in the marking material.

2) Beads are insufficiently buried (most or all beads are on the surface of the marking).

3) "Pulsed" beads - This is caused by rapid fluctuations in the delivery of the beads to the gun.

4) Most or all beads are on one side of the marking.

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