TECHNICAL SPECIFICATIONS
FOR
PAINTED PAVEMENT MARKING

1. Description

This work shall consist of furnishing and installing a multiple component, retroreflective traffic marking system in accordance with this provision and in reasonably close conformity to the lines, dimensions, patterns, locations, and details shown on the plans or established by the Engineer. This specification describes the system which consists of an acrylic, high build, fast drying, white and yellow waterborne traffic marking paint; bonded core elements; and glass beads that can be used on bituminous and Portland cement concrete pavements. The waterborne traffic marking paint shall be applied by spray method onto asphalt cement concrete and Portland cement concrete surfaces and immediately followed by the application of bonded core reflective elements and glass beads. Upon drying, the resulting traffic marking shall be adherently reflectorized and capable of resisting deformation by traffic. This work will be accomplished after all paving has been completed. All work shall be in accordance with the version of the Manual on Uniform Traffic Control Devices for Streets and Highways, that is in effect on the date of advertisement for this contract. Temporary pavement marking will not be paid for under this item.

2. Materials

a. General- The markings shall be comprised of a durable, low VOC, fast drying, white and yellow waterborne traffic paint with an acrylic polymer emulsion and with reflective media adhered to the paint. The reflective media shall consist of glass beads as well as bonded core reflective elements.

b. Composition

i. Waterborne Traffic Marking Paint- The finished paint shall be formulated and manufactured from first-grade materials and shall be a fast drying, water based, acrylic resin type paint capable of withstanding air and roadway temperatures without bleeding, staining, discoloring, or deforming.

1. Condition in the Container - The paint, as received, shall show no evidence of; biological growth, corrosion of the container, livering or hard settling. The paint shall be returned to a smooth and homogeneous consistency, which is free from; gel structures, persistent foam or air bubbles, using only hand mixing.

2. Shelf life - When stored in a three-quarters filled can for a period of thirty days, the paint shall be in a homogeneous state with no skinning, curdling, hard settling or caking that cannot be readily remixed.

3. Degree of Settling, minimum, ASTM D869

White	Yellow
7	7

A 500 ml (1 pint) paint can is filled with a well-mixed sample. The can is capped and allowed to set undisturbed at 23±2°C and 50±5% relative humidity for 14 days. The settling is then determined as specified in ASTM D869. The 1-quart laboratory samples of each batch, as received, shall also pass this test.

4. Nonvolatile Content, Weight %, ASTM D2369

White	Yellow
77	76
±2.0	±2.0

5. Pigment Content, Weight %, ASTM D3723

White	Yellow
60	58
±2.0	±2.0

6. % Nonvolatile in Vehicle (%NVV), Weight %, minimum

White	Yellow
42	42

Calculated as; $\%\ NVV = \frac{\%\ \text{Nonvolatile Content} - \%\ \text{Pigment}}{100 - \%\ \text{Pigment}} \times 100$

7. Density, g/ml at 25°C, ASTM D1475

White	Yellow
1.68± 0.04 (14.0 lbs/gallon)	1.63± 0.04 (13.6 lbs/gallon)

8. Consistency, K.U. at 25±1°C, ASTM D562A

White	Yellow
80-95	80-95

9. Fineness of Dispersion, Hegman, minimum, ASTM D1210

White	Yellow
3.0	3.0

10. Dry to No Pick-Up Time, without beads, minutes, maximum, ASTM D1640

White	Yellow
10	10

11. Dry Through, at 90% Relative Humidity, minutes, maximum, ASTM D1640

White	Yellow
120	120

A 15 mil wet film of the candidate paint placed immediately in a humidity chamber maintained at 72.5°F±2.5°F and 90%±3%

relative humidity shall have a "dry-through" time less than, equal to, or up to 15 minutes longer than the specifier's laboratory reference paint when run at or close to the same time. Alternatively, 120 minutes maximum dry through can be used. The dry through time must be tested in accordance with ASTM D1640, except that the pressure exerted will be the minimum needed to maintain contact between the thumb and film.

12. Volatile Organic Compounds (VOC), grams per liter of paint, excluding water, maximum

White	Yellow
150	150

Use ASTM D3960 or other approved method in effect at the time of paint manufacture to determine the VOC level and water content of the paint.

13. Flashpoint, °C, minimum, ASTM D93 Method A

White	Yellow
60	60

14. Flexibility, ASTM D522 Method B

White	Yellow
Pass	Pass

Use 100x150 mm tin-plated steel panels 250μm thick. Prepare the panel by lightly buffing one side with Grade 0 (medium-fine) steel wool, followed by cleaning with toluene and drying. Draw down the paint on the buffed side of the panel to a wet film thickness of 130μm. Air dry the panels for 24 hours at standard conditions, then bake for 5 hours at 105±2°C and finally condition the panel for 30 minutes at standard conditions. Bend the panel 180° over a 13 mm mandrel in 1 second, then examine under a magnification of 10 diameters. The paint film shall not; crack, chip, or flake when the panel is bent around the mandrel.

15. Appearance

White	Yellow
Pass	Pass

Draw down a 330μm thick wet film of the paint on a glass plate and allow to dry for 24 hours at standard conditions. The paint shall produce a film, which is smooth, uniform, and free from; grit, undispersed particles, craters, pinholes and cracking.

16. Dry Opacity, minimum

White	Yellow
0.93	0.87

On a black-white Leneta chart, Form 2C-Opacity, draw down a uniform 130μm (±5μm) thick wet film of paint covering both the

black and white portions of the chart. Measure the wet film thickness with an appropriate gauge. Dry for 24 hours at standard conditions. Use a BYK-Gardner "Color-Guide" Spectrophotometer to measure the opacity according to the manufacturer's instructions. Calibrate the spectrophotometer according to the manufacturer's instructions using; 2° Observer/Illuminant "C" measurement conditions, and the (Y, x, y) color system.

17. Yellowness Index, maximum

White	Yellow
8	-

Draw down a 330μm thick wet film of the white paint on two-75x150 mm chromate treated aluminum panels (i.e.: Q Panel Co., type AL). Dry for 24 hours at standard conditions. Save one panel for the Accelerated Weathering test (section 2.b.1.t). Using a BYK-Gardner "Color-Guide" Spectrophotometer, follow the manufacturer's instructions, and measure the Yellowness Index of the white paint film using the ASTM E313 mode.

18. Daylight Luminous Reflectance

White	Yellow
≥87	47-60

Using the draw down panels prepared in the Dry Opacity test, measure the reflectance of the white and yellow paint films using the BYK-Gardner "Color-Guide" Spectrophotometer. Follow the manufacturer's instructions to obtain the Reflectance or "Y" value.

19. Yellow Color

Draw down the yellow paint on two chromate treated aluminum panels as described in the Yellowness Index test. One panel should be used for the Accelerated Weathering test. Retain the other yellow panel as a control and for the Reflectance test. The yellow color shall match Federal Standard 595b, color #33538.

20. Accelerated Weathering Test, Ultraviolet Light and Condensate Exposure, 300 hours total, ASTM; G154 and G151

Prepare samples of the white and yellow paints as described in the Yellowness Index and Yellow Color tests. Alternately expose the samples to; eight hours of UV exposure at 60°C, followed by four hours condensate exposure at 50°C in a QUV Accelerated Weathering Tester. Type UVA-340 bulbs are used at an irradiance level of 0.77 watts per square meter per nm at 340 nm, as measured at the sample surface during the UV cycle. After 300 hours total exposure the paint samples shall meet the requirements below.

White – Yellowness Index after weathering, maximum, 12
Yellow – Must pass Yellow Color test after weathering

21. Scrub Resistance, cycles, minimum

White	Yellow
800	800

Follow the procedure in ASTM D2486. Prepare a panel using an appropriate bird doctor blade that will produce a uniform dry film thickness of paint between 80 and 100μm. Dry the panel for 7 days at standard conditions. The panel shall require more than 800 cycles to remove the paint film in one continuous line across the width of the shimmed area.

22. Lead, mg/kg in dried paint, maximum, ASTM D3335

White	Yellow
20	20

The white & yellow paints shall be free of lead, mercury, cadmium, hexavalent chromium and other toxic heavy metals as defined by the United States Environmental Protection Agency.

23. Chromium, mg/kg in dried paint, maximum, ASTM D3718

White	Yellow
5	5

24. Thick Application Cracking Resistance

White	Yellow
Pass	Pass

On a black-white Leneta chart, Form 2C-Opacity, draw down a stripe of the paint 75 mm wide and at least 150 mm long and having a 1530±130μm wet film thickness. Allow the paint to dry for 48 hrs. at standard conditions on a horizontal surface. After 48 hrs. the paint film shall not contain any cracks.

25. pH, minimum, ASTM E70

White	Yellow
9.9	9.9

ii. Acrylic Polymer Emulsion- The paint shall consist of a commercial high-build acrylic polymer emulsion.

iii. Reflective Media- The reflective media shall be made up of reflective bonded core elements and glass beads for drop-on application and shall conform to the following requirements:

1. Bonded Core Reflective Elements- The bonded core reflective elements shall contain either clear or yellow tinted microcrystalline ceramic beads bonded to the outer surface.

a. Index of Refraction- All microcrystalline ceramic beads bonded to reflective elements shall have a minimum index of refraction of 1.8 when tested using the liquid oil immersion method.

b. Testing Procedure for Refractive Index of beads by liquid immersion

Equipment Required:

- Microscope (minimum 100X magnification)
- Light Source- preferably sodium light or other monochromatic source, but not absolutely essential
- Refractive Index Liquids (available from R.P. Cargille Laboratories, Inc., Cedar Grove, NJ)
- Microscope Slide and Slide Cover
- Mortar and Pestle

Procedure:

- Using the mortar and pestle, crush a few representative beads and place a few of these crushed particles on a microscope slide.
- Place a drop of a refractive index liquid, with an index as close to that of the crushed particles as can be estimated, on the particles.
- Cover the slide with a microscope slide cover and view the crushed particles by transmitted light normal to the slight surface (illuminated from the bottom).
- Adjust the microscope mirror to allow a minimum light intensity for viewing. This is particularly important if sodium light is not used.
- Bring a relatively flat and transparent particle into focus.

Testing Criteria:

By slightly raising and lowering the objective (microscope tube), look for one or both of the following:

Becke Line- This light line will appear to move either into the particle or away from it. In general, if the objective is raised, the line will move toward the material of higher refractive index; if the objective is lowered, the line will move toward the material of lower index.

c. Variation in Particle Brightness- When raising the objective from a sharp focus, the particle will appear to get brighter or darker than the surrounding field. If it becomes brighter, the particles have a higher refractive index than the liquid. If it becomes darker, the glass has a lower refractive index than the liquid. In both cases, the opposite will be true if the objective is lowered. This test can be used to confirm that the beads are above or below a specified index. It can also be used to give an accurate determination of the index (+ or – 0.001). This is done by using several refractive index

liquids until a match or near match of indices occurs.

The index of the glass will equal that of the liquid when no Becke line and no variation in bead brightness are observed. The size and quality of the beads shall be such that the performance requirements for the retroreflective material shall be met.

d. Acid Resistance- A sample of microcrystalline ceramic reflective elements supplied by the manufacturer, shall show resistance to corrosion of their surface after exposure to a 1% solution (by weight) of sulfuric acid. The 1% acid solution shall be made by adding 5.7cc of concentrated acid into 1000cc of distilled water. CAUTION: Always add the concentrated acid into the water, not the reverse. Place 10g of the beads into a 100ml beaker and cover with 30-40 ml of the 1% sulfuric acid solution. Cover the beaker to prevent evaporation and allow the sample to be exposed for 24 hours under these conditions. Then decant the acid solution and rinse the sample with fresh DI water followed by drying the sample in a 150°F (66°C) oven for approximately 15 minutes or until the sample is dry. Microscopic examination (20X) shall show not more than 15% of the beads having the formation of a very distinct opaque white (corroded) layer on their entire surface to be classified as passing the acid resistance test.

2. Glass Beads- The required glass beads shall have an index of refraction of 1.5 when tested by the immersion method at 25°C (77°F). The glass beads shall be surface treated for optimal performance with waterborne traffic marking paint. The glass beads shall have a minimum of 70% Rounds as measured according to ASTM D1155. The surface of the glass beads shall be free of pits and scratches. The glass beads retained on the #40 U.S. Mesh Sieve (425 microns) shall have minimum crush strength of 30 pounds in accordance with ASTM D1213. The glass beads shall conform to either of the following gradation specifications:

P40 or equivalent

U.S. Standard Sieve Number	Size in Microns	% Passing By Weight
20	850	90 - 97
30	600	50 - 75
40	425	15 - 45
50	300	0 - 15
80	180	0 - 5

AASHTO M247 Type 1 or equivalent

U.S. Standard Sieve Number	Size in Microns	% Passing By Weight
20	850	100
30	600	75 - 95
40	425	-
50	300	15 - 35
80	180	-
100	150	0 - 5

c. Characteristics of Finished Traffic Marking- Because of normal variances in road surfaces, application processes, and measurement, the properties of markings made from the materials specified herein will vary from one installation to the next. When the materials are applied according to these specifications, they shall be capable of forming markings with the following reproducibility of properties:

i. Skid Resistance- The average initial skid resistance shall be 45 BPN or greater when tested according to ASTM E303.

ii. Retro-Reflectance- The initial retro-reflectance averaged over many installations shall be at least the values in the following table:

Retroreflectivity (mcd(ft^{-2})(fc^{-1})) {metric equivalent mcd(m^{-2})(lux^{-1})}

	White	Yellow
Dry	350	275
Wet recovery (ASTM 2177)	350	275
Wet continuous (ASTM 2176)	100	75

The initial retroreflectance of a single installation shall be the average value determined according to the measurement and sampling procedures outlined in ASTM D6359, using a 30-meter (98.4 feet) retroreflectometer. The 30-meter retroreflectometer shall measure the coefficient of retroreflected luminance, R_L, at an observation angle of 1.05 degrees and an entrance angle of 88.76 degrees. R_L shall be expressed in units of millicandelas per square foot per foot-candle [mcd(ft^{-2})(fc^{-1})]. The metric equivalent shall be expressed in units of millicandelas per square meter per lux [mcd(m^{-2})(lux^{-1})].

Initial performance of pavement markings shall be measured within 7 days after application.

iii. On-the-road Track-Free Time- When installed at 77°F and at a wet film thickness of 25±2 mils, the markings shall reach a no-track condition in less than 5 minutes. Track-free shall be considered as the condition where no visual deposition of the traffic paint marking to the pavement surface is observed when

viewed from a distance of 50 feet, after a free-rolling traveling vehicle's tires have passed over the line. The track-free time shall not increase substantially with decreasing temperature.

iv. Color after Application- The color of the applied white and yellow stripes and markings (with beads) shall conform to the daytime and nighttime color requirements in ASTM D6628.

3. Equipment & Construction Requirements

The Contractor shall furnish equipment and apply the materials according to the following specifications:

a. Equipment- The equipment shall be capable of producing markings that meet the specifications contained herein using the materials specified in Section 2 Materials.

i. The equipment shall be a mobile, truck mounted and self-contained pavement marking machine.

ii. The equipment shall be designed to maintain a uniform rate of speed at increasing or decreasing road grades.

iii. The equipment shall be capable of air blasting the pavement, spraying the traffic marking paint, and immediately dropping the reflective elements and glass beads in a single pass at speeds up to 8 mph.

iv. If using equipment containing a heat exchanger it shall be capable of heating and maintaining the heated temperature of the liquid not exceeding 100°F in the heat exchanger and 100°F at the spray nozzle to enable proper spraying of the traffic marking paint.

v. At any time throughout the duration of the project, the Contractor shall provide free access to his application equipment by the Engineer, his authorized representative, or a materials representative.

b. Construction Requirements

i. Moisture- The markings shall only be applied during conditions of dry weather and when the pavement surface is dry and free of moisture.

ii. Air Temperature and Humidity- The markings shall only be applied when road and air temperatures are above 50°F under humidity conditions of 85% or less.

iii. Surface Preparation- Marking operations shall not begin until applicable surface preparation work is completed and approved by the Engineer.

1. Prior to applying the markings, the contractor shall remove any remaining existing markings showing obvious signs of degradation and/or lack of adhesion.

2. Prior to applying the markings, the contractor shall remove all curing compounds on new Portland cement concrete surfaces.

3. Prior to applying the markings, the contractor shall remove all dirt, sand, dust, oil, grease and any other contaminants from the road surface.

iv. Dimensions- The reflectorized pavement markings shall be placed only on

properly prepared surfaces and at the widths and patterns as designated on the contract plans. The markings shall be applied in accordance with the Manual on Uniform Traffic Control Devices and in accordance with the Engineer's plans.

v. Other Restrictions- The Engineer and/or contractor shall determine further restrictions and requirements of weather and pavement conditions necessary to meet all other application specifications and produce markings that perform to the satisfaction of the Engineer. If the pavement surface contains heavy tines or very large aggregate used in open grade friction course or stone matrix asphalt mixes it may require additional surface preparation prior to application of liquid traffic marking system.

vi. Liquid Thickness- The liquid paint shall be applied at 25 mil ±2 mil wet film thickness.

vii. Reflective Media Application- The specified reflective media shall be dropped at rates to achieve the following coating weights:

Units	Glass Beads	Composite Reflective Elements
Pounds per 4-inch linear foot	0.026 lbs/4 -inch lf	0.011 lbs/4-inch lf
Grams per 4-inch linear foot	12 grams per 4-inch lf	5 grams per 4-inch lf
Pounds per gallon- 25 mils, 190 theoretical feet per gallon (4" line width)	5.3 lbs/gal	2.1 lbs/gal

viii. Overspray- The contractor shall ensure the traffic paint does not exhibit excessive overspray.

ix. Adhesion- The contactor shall ensure that the traffic paint is well adhered to the road surface, and that the beads and elements are well adhered to the binder.

x. Marking Performance- The typical average initial retroreflectance of the markings shall be those in the table that follows:

Condition	White	Yellow
Dry	350	275
Wet recover (ASTM 2177)	350	275
Wet continuous (ASTM 2176)	100	75

The average initial retroreflectance shall be determined according to the measurement and sampling procedures outlined in ASTM D6359, using a 30-meter retroreflectometer. The 30-meter retroreflectometer shall measure the coefficient of retroreflected luminance, R_L, at an observation angle of 1.05 degrees and an entrance angle of 88.76 degrees. R_L shall be expressed in units of millicandelas per square foot per foot-candle [$(mcd(ft^{-2})(fc^{-1})$]. The metric

equivalent shall be expressed in units of millicandelas per square meter per lux [$mcd(m^{-2})(lux^{-1})$].

Initial performance of pavement markings shall be measured within 7 days after application.

4. Inspection and Testing

During the application of the traffic paint, the Engineer may request the following tests to verify application to the parameters required in this specification.

a. Liquid thickness- During the appropriate locations along the alignment of the project site, the Engineer may obtain a sample of the wet traffic paint applied onto a test panel of aluminum for the purposes of checking for proper wet traffic paint film thickness. The traffic paint shall be applied without reflective elements or glass beads. Upon drying of the liquid material, the dry thickness shall be verified by the Engineer to meet the requirements of Section "Construction Requirements- Liquid Thickness" in this specification. The contractor shall provide to the Engineer the application speed of the equipment during the time of the sample.

b. Reflective Media- When required by the Engineer, the Contractor shall demonstrate to the Engineer the proper calibration of reflective elements and glass beads compared with the manufacturer's requirement. The calibration shall be conducted with a graduated cylinder or other similar device. Reflective elements or glass beads shall be collected from the reflective element and glass bead guns for a timed period. The volume of the reflective elements and glass beads collected shall be measured and compared with the manufacturer's requirements.

c. Application Panel- The Contractor shall provide to the Engineer at least one dry sample coated on aluminum, with typical dried liquid paint and reflective media applied onto the surface. This sample will serve as a record of the project application conditions and settings.

Method of Measurement

d. Painted Pavement Marking (Line) - The mileage of line complete in place and accepted, shall be measured along the center of each line. Where double solid barrier lines are used, each solid barrier line will be measured separately for payment. Where broken lane lines are used, only the marked line will be measured for payment. For quantities of Pavement Marking (Line) less than one mile, the accepted method of measurement shall be linear feet.

e. Painted Pavement Marking (Crosswalk Striping) and Pavement Marking (Stop Bar) - The length of each striping complete in place and accepted will be measured in linear feet to the nearest foot along the center line of each pavement marking.

f. Painted Pavement Marking (Channelization Striping) - The area of channelization striping including the boundary lines complete in place and accepted shall be measured and computed in square yards to the nearest square yard.

g. Painted Pavement Marking (Designs) - Designs or lettering will be measured for payment by the unit (each) complete in place or as stipulated in the Contract and on the Plans.

5. Basis of Payment

a. The Contractor shall be required to establish and locate all non-passing zones as well as provide the layout of all pavement markings for approval of the Engineer prior to placement of markings.

b. Retroreflective markings will be paid for at the contract unit price, which shall be full compensation for cleaning and preparing the pavement surface, for furnishing and placing all materials, and for all materials, labor, equipment and incidentals necessary to complete the work.

c. Payment will be made under the following bid items as set forth in the Bid Schedule:

Pay Item	Unit
Painted Pavement Marking (Line)	Lin. Mi.
Painted Pavement Marking (Line)	Lin. Ft.
Painted Pavement Marking (Cross-walk Striping)	Lin. Ft.
Painted Pavement Marking (Stop Line)	Lin. Ft.
Painted Pavement Marking (Channelization Striping)	Sq. Yd.
Painted Pavement Marking (Designs)	Ea.

d. When materials are found to be non-conforming under Sections 2(a) and 2(b), the material supplier shall provide replacement materials at no cost.

e. When markings are found to be non-conforming under Section 2(c), the contractor shall bear full responsibility for all repair work and associated costs, including purchase of replacement materials.

f. When the fault of non-conformance with the specification is indeterminate or in dispute, the materials supplier shall provide replacement materials and the contractor shall repair the markings, both at no cost to the Engineer and/or Agency.