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## ACKNOWLEDGEMENTS

The development of this training program is the product of combined efforts and vast resources of many individuals, groups and organizations.

Special appreciation goes to the following individuals for the production of this manual and all training materials:

Debra Casper	Mike McDonald
Carol Fisher	Sam Miller, Jr.
Wayne Fleming	Patricia Murray
John Geisel	James Pappas
Tom Hicks	Wendell Richards
Woody Hood	Gil Rushton
Warren Kelly	Ben Schiappa
Bruce Kenney	Ralph Smith, Jr.
Ramzi Khuri	James Swisher
Dave Kuniega	Ted Whitmore
Fred Lees	Richard Wray
Fred Lovett	Sharon Zanetti

Our gratitude is extended to the companies listed below for their permission to use their printed materials, slides, videos, and technical information.

3M Company  
Cataphote, Inc.  
Epoplex  
Flint Trading, Inc.  
Potters Industries  
Sherwin Williams  
Stimsonite Trelleborg  
Industry

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### BIBLIOGRAPHY

The Pavement Marking course is only available as an online course. This manual is designed to accompany the online course and generally follows the course. The manual's chapters are in the same order as the course modules and contain the same information although not in the specific order or formatting as the modules. You may use the manual as an "open book" resource when taking the examination. Exams must be completed by November 30, 2021. For questions concerning the exam contact CCWA at 804-523-2290.

**Test:** Open Book – 50 multiple choice

**Proficiency:** Open Book – 25 multiple choice - given with exam (Both tests taken at the same time/sitting)

**Grading:** Score 70% or better to pass

**Exam Results:** Certifications can be found on VDOTU. Non-VDOT personnel can find their results at the following website: <https://virtualcampus.vdot.virginia.gov/external> . Create a new account if you have never taken a VDOT certification course. If you do not know your login and password, DO NOT create a new account email [VDOTUniversity@vdot.virginia.gov](mailto:VDOTUniversity@vdot.virginia.gov) or call (804)328-3158 for login information and any questions.

**To be certified:** Students must pass the written exam by November 30, 2021.



### APPLICATION FOR VDOT MATERIALS TECHNICIAN CERTIFICATION

This is to affirm that \_\_\_\_\_ (Technician’s Name), hereinafter “Technician”, desires to be certified by VDOT as a **Pavement Marking Technician**. By making this Application, Technician acknowledges and agrees that Certification carries inherent rights and responsibilities. The rights include being exclusively sanctioned, along with others so certified by VDOT, to perform sampling, testing, and reporting of test results for quality acceptance, quality control and assurance programs. The responsibilities include performing and reporting tests with the accuracy and precision expected of the Technician in accordance with the required test procedures.

By signing this Application, Technician agrees to strive to maintain compliance with all rules, regulations, specifications, industry standards, procedures and policies, applicable to any work performed under the Certification. A violation of the above as determined by the VDOT Technician Certification Review Board may result in a suspension or revocation of the rights and responsibilities conferred on the Technician. Revocation or suspension of one Certification may be considered a revocation or suspension of all Certifications held by the Technician. Further, any suspension or revocation of Technician’s Certification in any other jurisdiction may result in the VDOT Technician Certification Review Board taking the same or other action, against Technician’s Certification in Virginia.

By signing below, Technician also affirms that he/she is aware that both State and Federal laws may govern construction projects in Virginia, including Title 18, United States Code, Section 1020, that states, in pertinent part, that anyone making falsifications on Federal-aid projects, “Shall be fined not more than \$10,000 or imprisoned not more than five years, or both.”

I, \_\_\_\_\_ (Print Name), affirm that I have read and fully understand the foregoing “APPLICATION FOR VDOT TECHNICIAN CERTIFICATION,” and I agree to be bound by these terms.

\_\_\_\_\_  
Technician’s Signature

\_\_\_\_\_  
Date

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# 1

## Standard Practices

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### Learning Outcomes:

- Know the functions and limitations of traffic markings
- Understand the general principles of markings

### Manual on Uniform Traffic Control Devices (MUTCD)

**Note:** The MUTCD can be downloaded from the FHWA website to supplement this manual: <http://mutcd.fhwa.dot.gov>

#### MUTCD SECTION 3A.01 FUNCTIONS AND LIMITATIONS

Support: Markings on highways have important functions in providing guidance and information for the road user. Major marking types include pavement and curb markings, object markers, delineators, colored pavements, barricades, channelizing devices and islands. In some cases, markings are used to supplement other traffic control devices such as signs, signals and other markings. In other instances, markings are used alone to effectively convey regulations, guidance, or warnings in ways not obtainable by the use of other devices.

Markings have limitations. Visibility of the markings can be limited by snow, debris, and water on or adjacent to the markings. Marking durability is affected by material characteristics, traffic volumes, weather, and location. However, under most highway conditions, markings provide important information while allowing minimal diversion of attention from the roadway.

Pavement markings can enhance roadway delineation with the addition of audible and tactile features such as bars, differential surface profiles, raised pavement markers, or other devices intended to alert the road user that a delineation on the roadway is being traversed.

The general functions of longitudinal lines are:

- A. A double line indicates maximum or special restrictions,
- B. A solid line discourages or prohibits crossing (depending on the specific application),
- C. A broken line indicates a permissive condition, and
- D. A dotted line provides guidance.

## **MUTCD SECTION 3A.02 STANDARDIZATION OF APPLICATION**

Standard: Each standard marking shall be used only to convey the meaning prescribed for that marking in this Manual. When used for applications not described herein, markings shall conform in all respects to the principles and standards set forth herein.

Guidance: Before any new highway, paved detour, or temporary route is opened to traffic, all necessary markings should be in place.

Standard: Markings that are no longer applicable for roadway conditions or restrictions and that might cause confusion for the road user shall be removed or obliterated to be unidentifiable as a marking as soon as practical. Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible. All markings on Interstate highways shall be retroreflective.

Option: Markings may be temporarily masked with tape until they can be removed or obliterated.

## **MUTCD SECTION 3A.03 MATERIALS**

Support: Pavement and curb markings are commonly placed by using paints or thermoplastics; however, other suitable marking materials, including raised pavement markers and colored pavements, are also used. Delineators, object markers, barricades, and channelizing devices are visibly placed in a vertical position similar to signs above the roadway.

Guidance: The materials used for markings should provide the specified color throughout their useful life.

Consideration should be given to selecting pavement marking materials that will minimize tripping or loss of traction for pedestrians and bicyclists.

Object markers and delineators should not present a vertical or horizontal clearance obstacle for pedestrians.

## **MUTCD SECTION 3A.04 COLORS**

Standard: Markings shall be yellow, white, red, or blue. The colors for markings shall conform to the standard highway colors. Black in conjunction with one of the above colors shall be a usable color.

When used, white markings for longitudinal lines shall delineate:

- A. The separation of traffic flows in the same direction.
- B. The right edge of the roadway.

When used, yellow markings for longitudinal lines shall delineate:

- A. The separation of traffic traveling in opposite directions.
- B. The left edge of the roadways of divided and one-way highways and ramps.
- C. The separation of two-way left turn lanes and reversible lanes from other lanes.

When used, red raised pavement markers shall delineate roadways that shall not be entered or used.

When used, blue markings shall supplement white markings for parking spaces for persons with disabilities. When used, blue raised pavement markers shall indicate locations of fire hydrants along a roadway.

Option: Black may be used in combination with the above colors where a light-colored pavement does not provide sufficient contrast with the markings.

Support: When used in combination with other colors, black is not considered a marking color, but only a contrast-enhancing system for the markings.

## **MUTCD SECTION 3A.05 WIDTHS AND PATTERNS OF LONGITUDINAL PAVEMENT MARKINGS**

Standard: The widths and patterns of longitudinal lines shall be as follows:

- A. A normal line is 100 to 150 mm (4 to 6 in) wide.
- B. A wide line is at least twice the width of a normal line. The width of the line indicates the degree of emphasis.
- C. A double line consists of two normal width parallel lines separated by a 4-6 inch space. D. A broken line consists of normal line segments separated by gaps.
- E. A dotted line shall consist of noticeably shorter line segments separated by shorter gaps than used for a broken line. The width of a dotted line shall be at least the same as the width of the line it extends.

Guidance: Broken lines should consist of 3 m (10 ft) line segments and 9 m (30 ft) gaps, or dimensions in a similar ratio of line segments to gaps as appropriate for traffic speeds and need for delineation.

Option: A dotted line for line extensions may consist of 0.6 m (2 ft) line segments and 0.6 m (2 ft) to 1.8 m (6 ft) gaps. A dotted line for lane drop/add markings may consist of 0.9 m (3 ft) line segments and 2.7 m (9 ft) gaps.

## **GENERAL PRINCIPLES - LONGITUDINAL PAVEMENT MARKINGS**

Longitudinal pavement markings shall conform to the following basic concepts:

- Yellow lines delineate the separation of opposing traffic flows or mark the left edge of the pavement on divided highways and one-way roads.
- White lines delineate the separation of traffic flows in the same direction or mark the right edge of the pavement.
- Broken lines are permissive.
- Solid lines are restrictive.
- The width of a line indicates the degree of emphasis.
- Double lines indicate maximum restrictions.
- Raised pavement markers serve as position guides, and may supplement other types of markings.

## **LONGITUDINAL LINES**

The following examples illustrate the application of the principles and standards set forth in the previous sections.

- A normal, broken, white line is used to delineate lanes where travel is permitted in the same direction on both sides of the line. Its most frequent application is as a lane line for a multi-lane roadway.
- A normal, broken yellow line is used to delineate the left edge of a travel path where travel on the other side of the line is in the opposite direction. A frequent application is as a centerline of a two-lane, two-way roadway where overtaking and passing is permitted.
- A normal, solid, white line is used to delineate the edge of a path where travel in the same direction is permitted on both sides of the line, but crossing the line is discouraged, but not prohibited. It is also used to mark the right edge of the pavement. Frequently, this is used as a lane delineation line when approaching an intersection. A wide solid white line is used for emphasis when crossing requires unusual care. Frequently, it is used to delineate left or right turn lanes.
- A double solid white line is used to delineate a travel path where travel in the same direction is permitted on both sides of the line, but crossing the line is prohibited. It is frequently used before obstructions guiding the driver to pass on either side of the obstruction.
- A double line consisting of a normal, broken, yellow line and a normal, solid, yellow line delineates a separation between travel paths in opposite directions permitting traffic that is adjacent to the broken line to pass “with care” and prohibiting traffic adjacent to the solid line from passing. This is a one direction, no-passing marking. It is used on two-way, two- and three-lane roadways to regulate passing. It is also used to delineate the edges of a lane where travel in either direction is permitted as a part of a left-turn maneuver.



To permit a left turn maneuver, the marking shall be placed with the solid lines on the outside and the dashed lines to the inside of the lane. Traffic adjacent to the solid line may only cross this marking during a left-turn maneuver.

- A double line consisting of two normal solid yellow lines delineates travel in opposite directions prohibiting passing in both directions. This is a two-direction, no-passing marking. Crossing this marking with care is permitted only when making a left turn. It is frequently used before an obstruction that must be passed on the right or to form a channelizing island separating traffic in opposite directions.
- A double, normal, broken yellow line delineates the edge of a lane where direction of travel periodically changes and the line serves as a centerline at some point. It is used for a reversible lane.
- A normal dotted line is used to delineate a line through an intersection or interchange area. It shall be the same color as the preceding line.
- A solid yellow line delineates the left edge of a travel path to restrict passing on the left or to delineate the left edge of each roadway of divided streets or highways, one-way roadways, and ramps in the same direction of travel.

## **TRANSVERSE MARKINGS**

Transverse markings, which include shoulder markings, word and symbol markings, stop lines, crosswalk lines, speed measurement markings and parking space markings shall be white. However, transverse median markings shall be yellow. Blue and red are permitted under certain circumstances.

Because pavement markings are viewed from a low angle, transverse lines shall be proportioned to give visibility equal to that of longitudinal lines. Pavement marking letters, numerals, and symbols shall adhere to the Standard Alphabets for Highway Signs and Pavement Markings, in the MUTCD.

## **Excerpt from VDOT Road & Bridge Specifications Section 105:**

### **105.12—Coordination of Plans, Standard Drawings, Specifications, Supplemental Specifications, Special Provisions, and Special Provision Copied Notes**

The plans, Standard Drawings, these Specifications, supplemental specifications, special provisions, special provision copied notes, and supplementary documents are parts of the Contract. These Contract documents are defined in Section 101 - Definitions. A requirement occurring in one shall be as binding as though occurring in all. They are intended to be complementary and to describe and provide for a complete work. In case of a discrepancy, the following order of priority will apply, with the highest governing item appearing first and the least governing item appearing last:

- (a) Special provision copied notes. The pay items and pay units listed in the proposal have the same status as special provision copied notes.
- (b) Special provisions
- (c) Plans
- (d) Supplemental Specifications.
- (e) Specifications
- (f) Standard Drawings. Calculated dimensions, unless obviously incorrect, will govern overscaled dimensions.

Sketches, drawings, general notes and other written information that are not included in special provisions or special provision copied notes used in No Plan and Minimum Plan Concept projects will have the same status as plans.

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## MUTCD – MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

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### Part 3 – Markings

#### Chapter 3B – Pavement and Curb Markings

Section 3B.01 Yellow Centerline Pavement Markings and Warrants

Figure 3B-1. Typical Two-Lane, Two-Way Marking Applications

Figure 3B-2. Typical Four-or-More Lane, Two-Way Marking Applications

Figure 3B-5. Method of Locating and Determining the Limits of No-Passing Zones at Curves

Section 3B.08 Extensions Through Intersections or Interchanges

Figure 3B-11. Typical Pavement Marking Applications

Section 3B.09 Lane Reduction Transition Markings

Figure 3B-12. Typical Lane Reduction Transition Markings

## Chapter 3B. Pavement and Curb Markings

### Section 3B.01 Yellow Centerline Pavement Markings and Warrants

Standard: Centerline pavement markings, when used, shall be the pavement markings used to delineate the separation of traffic lanes that have opposite directions of travel on a roadway and shall be yellow.

Option: Centerline pavement markings may be placed at a location that is not the geometric center of the roadway.

On roadways without continuous centerline pavement markings, short sections may be marked with centerline pavement markings to control the position of traffic at specific locations, such as around curves, over hills, on approaches to highway-railroad grade crossings, at highway- railroad grade crossings, and at bridges.

Standard: The centerline markings on two-lane, two-way roadways shall be one of the following as shown in Figure 3B-1:

- A. Two-direction passing zone markings consisting of a normal broken yellow line where crossing the centerline markings for passing with care is permitted for traffic traveling in either direction;
- B. One-direction no-passing zone markings consisting of a normal broken yellow line and a normal solid yellow line where crossing the centerline markings for passing with care is permitted for the traffic traveling adjacent to the broken line, but is prohibited for traffic traveling adjacent to the solid line; and
- C. Two-direction no-passing zone markings consisting of two normal solid yellow lines where crossing the centerline markings for passing is prohibited for traffic traveling in either direction.

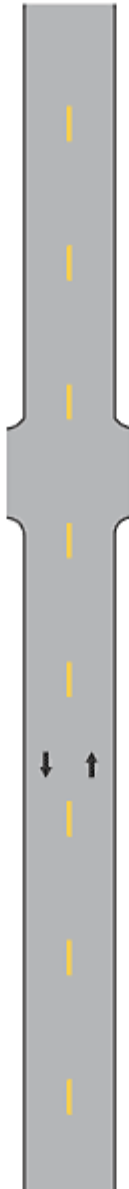
The centerline markings on undivided two-way roadways with four or more lanes for moving motor vehicle traffic always available shall be the two-direction no-passing zone markings consisting of two normal solid yellow lines as shown in Figure 3B-2.

### Section 3B.08 Extensions Through Intersections or Interchanges

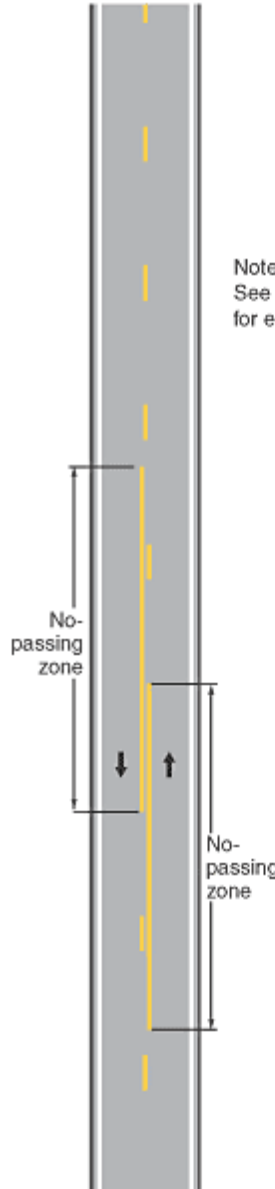
Standard: Pavement markings extended into or continued through an intersection or interchange area shall be the same color and at least the same width as the line markings they extend (see Figure 3B-11).

**Figure 3B-1. Examples of Two-Lane, Two-Way Marking Applications**

a - Typical two-lane, two-way marking with passing permitted in both directions



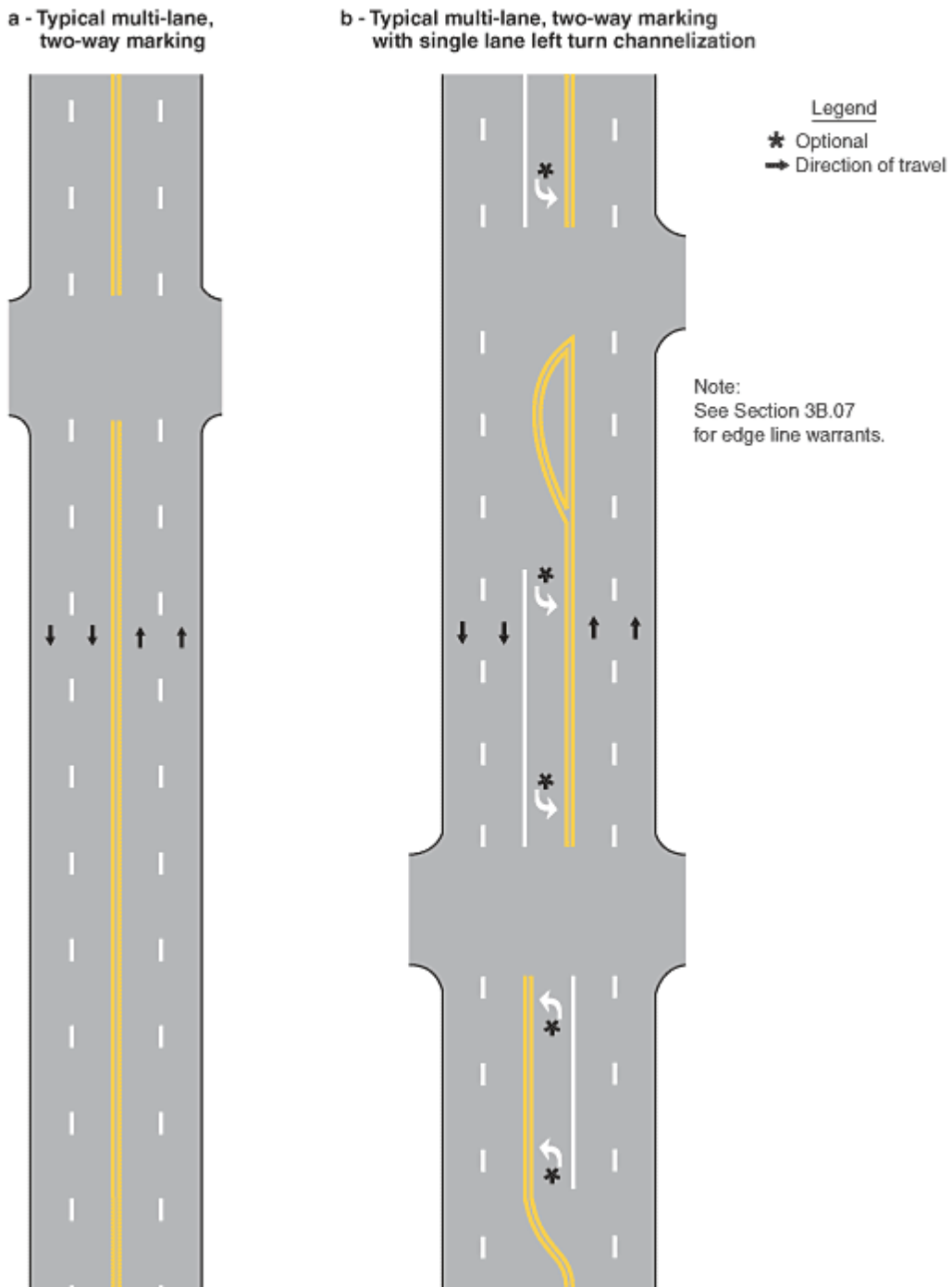
b - Typical two-lane, two-way marking with no passing zones



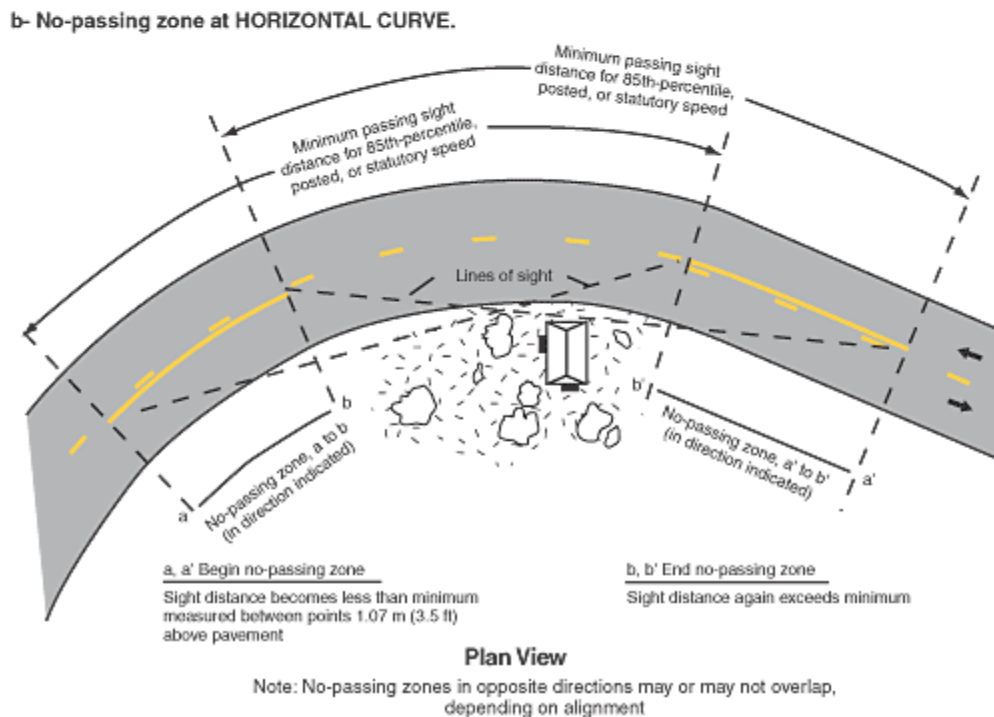
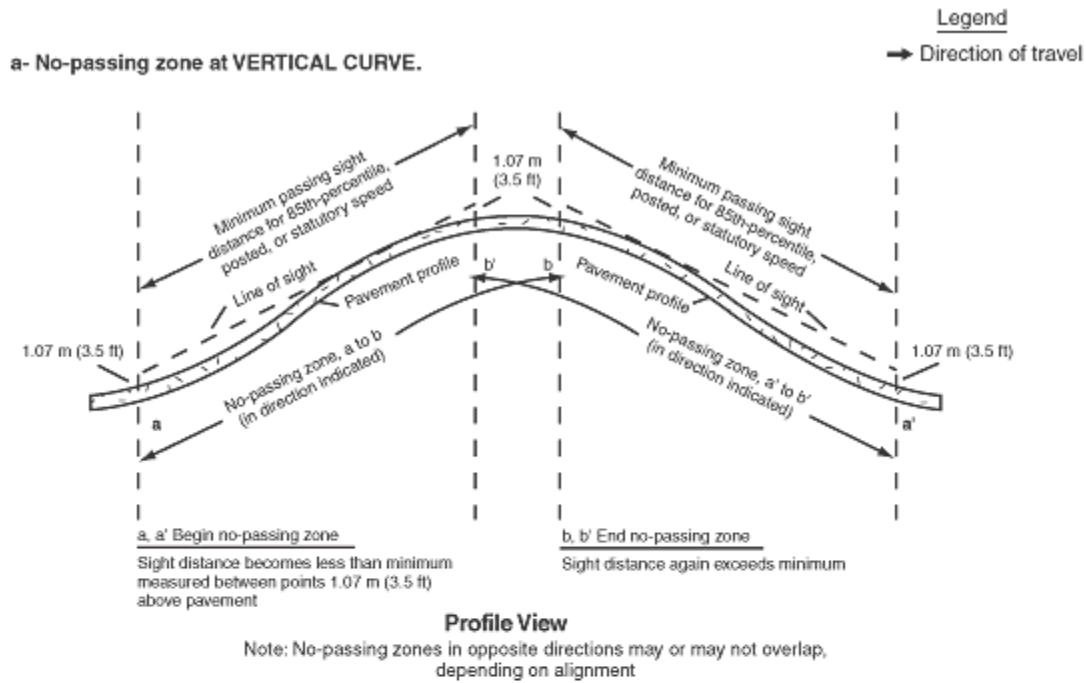
Legend  
→ Direction of travel

Note:  
See Section 3B.07  
for edge line warrants.

**Figure 3B-2. Examples of Four-or-More Lane, Two-Way Marking Applications**

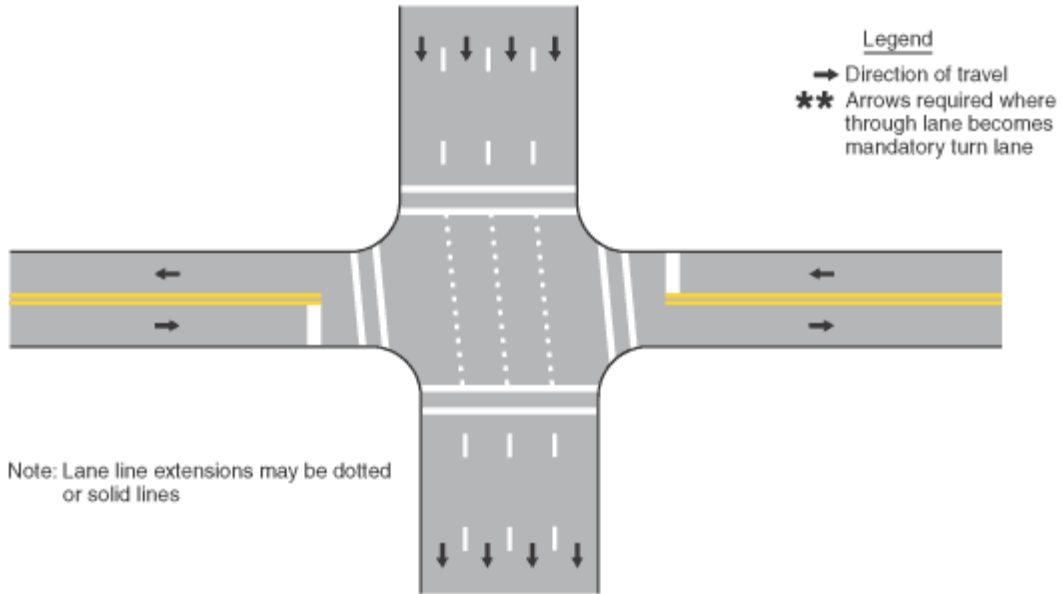


**Figure 3B-5. Method of Locating and Determining the Limits of No-Passing Zones at Curves**

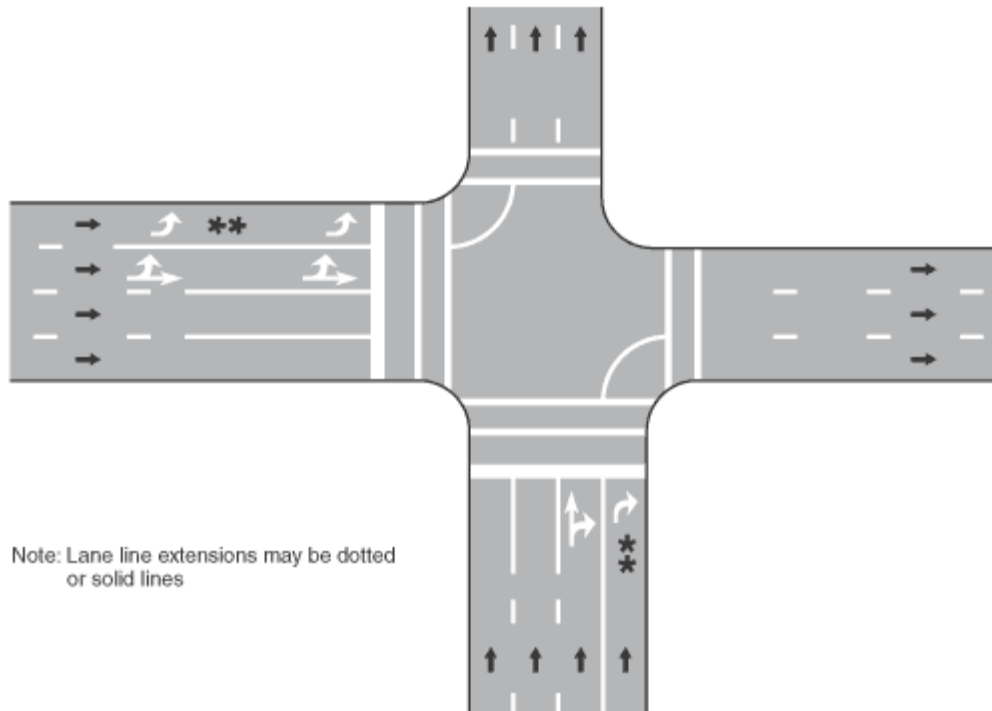


**Figure 3B-11. Examples of Extensions through Intersections (Sheet 1 of 2)**

**a - Typical pavement markings with offset lane lines continued through the intersection and optional crosswalk lines and stop lines**



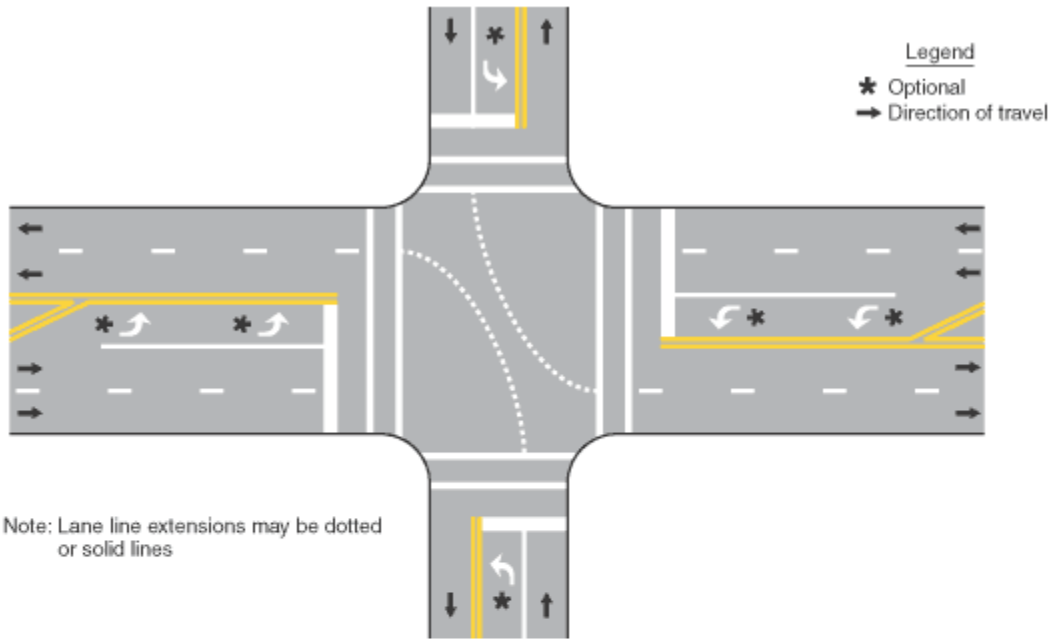
**b - Typical pavement markings with optional double-turn lane lines, lane-use turn arrows, crosswalk lines, and stop lines**



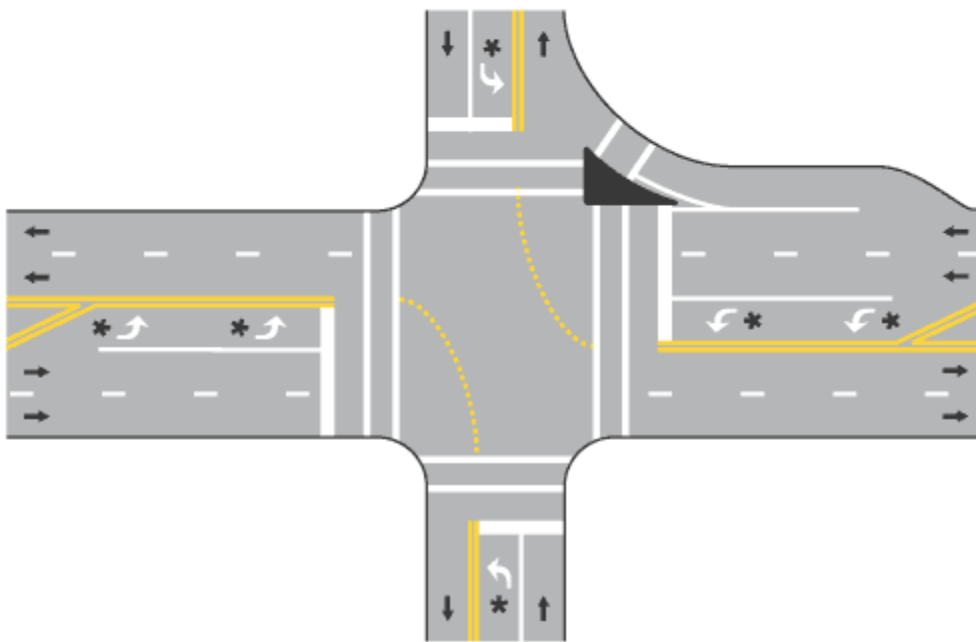


**Figure 3B-11. Examples of Extensions through Intersections (Sheet 2 of 2)**

c - Typical dotted line markings to extend longitudinal lane line markings



d - Typical dotted line markings to extend longitudinal centerline markings



**Option:** A normal line may be used to extend a wide line through an intersection.

**Guidance:** Where highway design or reduced visibility conditions make it desirable to provide control or to guide vehicles through an intersection or interchange, such as at offset, skewed, complex, or multilegged intersections, on curved roadways, or where multiple turn lanes are used, dotted line markings should be used to extend longitudinal line markings through an intersection or interchange area.

**Option:** Dotted edge line extensions may be placed through intersections or major driveways.

**Guidance:** Where greater restriction is required, solid lane lines or channelizing lines should be extended into or continued through intersections or major driveways. However, edge lines should not be extended into or continued through intersections or major driveways as solid lines

A single line of equal width to one of the lines of the double line should be used to extend a double line through an intersection.

To the extent possible, pavement marking extensions through intersections should be designed in a manner that minimizes potential confusion for drivers in adjacent or opposing lanes.

### **Section 3B.09 Lane Reduction Transition Markings**

**Standard:** Where pavement markings are used, lane reduction transition markings shall be used to guide traffic through transition areas where the number of through lanes is reduced, as shown in Figure 3B-12. On two-way roadways, no-passing zone markings shall be used to prohibit passing in the direction of the convergence, and shall continue through the transition area.

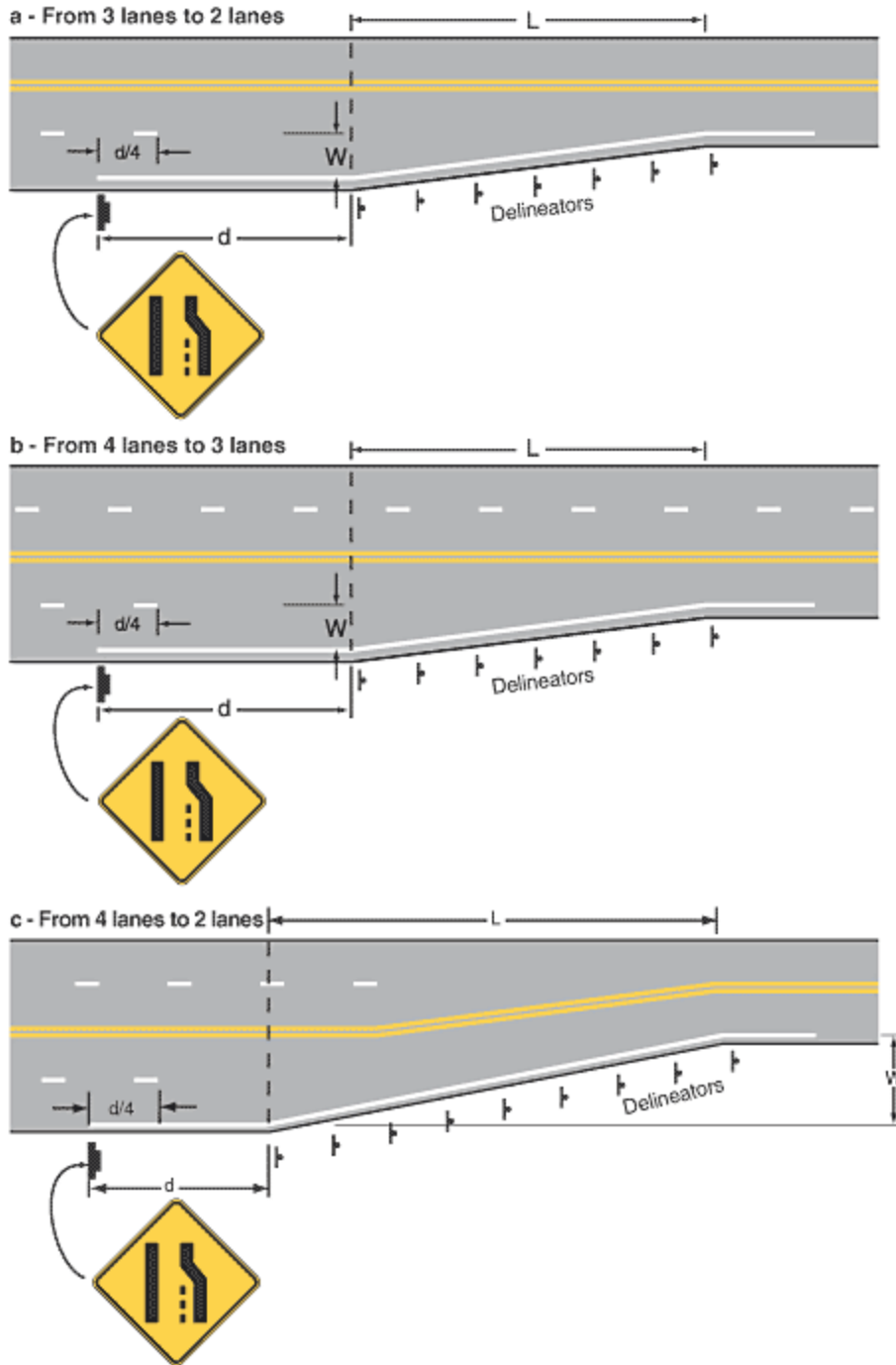
**Guidance:** For roadways having a posted or statutory speed limit of 70 km/h (45 mph) or greater, the transition taper length for a lane reduction should be computed by the formula  $L = 0.62 WS$  for speeds in km/h ( $L = WS$  for speeds in mph). For roadways where the posted or statutory speed limit is less than 70 km/h (45 mph), the formula  $L = WS^2/155$  for speeds in km/h ( $L = WS^2/60$  for speeds in mph) should be used to compute taper length. Under both formulas, L equals the taper length in meters (feet), W equals the width of the offset distance in meters (feet), and S equals the 85th-percentile speed or the posted or statutory speed limit, whichever is higher. Where observed speeds exceed posted or statutory speed limits, longer tapers should be used.

**Option:** On new construction, where no posted or statutory speed limit is established, the design speed may be used in the transition taper length formula.

**Guidance:** Lane line markings should be discontinued one-quarter of the distance between the Lane Ends sign (see Section 2C.33) and the point where the transition taper begins. Edge line markings should be installed from the location of the warning sign to beyond the beginning of the narrower roadway.

**Support:** Pavement markings at lane reduction transitions supplement the standard signs.

**Figure 3B-12. Examples of Lane Reduction Markings**



L = Length in meters (feet)  
 S = Posted, 85th-percentile, or statutory speed in km/h (mph)  
 W = Offset in meters (feet)  
 d = Advance warning distance (see Section 2C.05)  
 See Section 3D.04 for delineator spacing.

For speeds 70 km/h (45 mph) or more:  
 $L = 0.62 WS$  ( $L=WS$ )

For speeds less than 70 km/h (45 mph):  
 $L = \frac{WS^2}{155}$  ( $L = \frac{WS^2}{60}$ )

## References

See Appendix A for the following:

*VDOT Road & Bridge Specification Book*

Section 512.01 thru 512.02 (e)  
Maintaining Traffic

Section 704.01 thru 704.03 (a)  
Pavement Markings and Markers

## Chapter 1 Knowledge Check

1. The purpose of pavement markings is to communicate information about the traveled roadway so motorists can safely reach their destination.
  - a) True
  - b) False
2. Standard markings shall only be used to convey the meaning prescribed for them in the Manual on Uniform Traffic Control Devices (MUTCD).
  - a) True
  - b) False
3. In Virginia, the normal specified width of a longitudinal line is:
  - a) 3 inches
  - b) 4 – 6 inches
  - c) 8 inches
4. The standard for a broken line separating traffic in the same direction at the same speed limit is:
  - a) 8 ft. segments with 30 ft. gaps.
  - b) 40 ft. segments with 10 ft. gaps.
  - c) 10 ft. segments with 30 ft. gaps.
5. Solid yellow lines are used to delineate the separation of traffic flows in:
  - a) opposing directions.
  - b) the same direction.
6. The left edge of divided highways and one way roads is delineated by:
  - a) double yellow solid lines.
  - b) a broken white line.
  - c) a broken yellow line.
  - d) a single solid yellow line.
7. White lines are used to delineate the separation of traffic flows in:
  - a) opposing directions.
  - b) the same direction.
8. Broken lines are restrictive in nature.
  - a) True
  - b) False

- 
9. The right edge of divided highways and one way roads is delineated by:
- a) double solid yellow lines.
  - b) a broken white line.
  - c) a single solid white line.
  - d) a single solid yellow line.
9. Broken lines are restrictive in nature.
- a) True
  - b) False
10. Solid lines are restrictive in nature.
- a) True
  - b) False
11. A double line consists of two normal width lines separated by a 3 inch space.
- a) True
  - b) False
12. A pavement marking plan or sketch may not be required before a road is marked, but is strongly encouraged.
- a) True
  - b) False
13. A chalk line is the only approved way of pre-marking a road.
- a) True
  - b) False
14. Traffic control is not required when pre-marking on low volume roads.
- a) True
  - b) False
15. Which document takes precedence over all others?
- a) Road and Bridge Specifications
  - b) Plans
  - c) Special Provision Copied Notes
  - d) Special Provisions
16. In the Road and Bridge Specifications Book, which section specifies that the publication, "Quality Standards for Work Zone Traffic Control Devices" be used?
- a) Section 704
  - b) Section 235
  - c) Section 512
  - d) Section 246

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# 2

## Reflective Glass Beads

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### Learning Outcomes:

- ☑ Understand how glass beads perform.
- ☑ Ability to evaluate correct glass bead application for retroreflectivity.

### Background

Highway accidents and deaths began with the advent of the wheel. However, man has always been able to solve his problems. In fact, early highway safety methods were truly ingenious. Records show that in Rome, before Christ, recessed bricks or rocks were used in the center of the roads to keep chariots on their own side of the road. Also, over 350 years ago, light-colored rocks imbedded in the center of the roads in Mexico were used for the same purpose. Thus, markings have been used for many years to increase highway safety.

The first striping in the United States is credited to Edward Hines, a road commissioner in Wayne County, Michigan, back in the early 1900's. In 1921, a black stripe was painted by hand for one block of Madison, Wisconsin, because the Highway Commission concluded that the stripe kept traffic on the right side of the road. The obvious benefits of this centerline stripe were eventually recognized, and the idea spread.

In the early days, a substantial problem was how to get the stripe on the road. One of the first striping machines consisted of a wheelbarrow frame, a five-gallon tank, and a canvas-wrapped wheel with white paint in the tank channeled to drop onto the wheel. This allowed a man pushing the wheelbarrow to paint a white line down the center of the road. Using white paint improved the visibility of the line and helped channel traffic. However, at night the lines were hard to see and were found to wear rapidly.

The May 1924 issue of *Engineering News - Record* reported that the Ohio Highway Department placed white bricks in the center of a brick road at a cost of \$185 per lane mile. Brass cups or brass circles were also used in an attempt to find a material that was easy to see and would have better wearability. Radioactive ingredients were also mixed with traffic paint to try and get a better line.

This idea of using reflective beads became widely known in the late 1930's when the *Canadian Engineer* published a paper on "Luminous Marking for Highways." This article stated that "good visibility obtained and also the high abrasion resistance of the final product, made use of glass spheres advantageous."

In the early 1940's, during World War II, reflective beaded lines were used on highways to expedite traffic during blackouts. World War II was largely responsible for the widespread acceptance of beads to provide nighttime delineation due to the blackout condition imposed.

In 1942, *Engineering News - Record* wrote, "Paint surfaced with reflective beads has been found superior to any other type painted pavement marking. Five hundred miles of this type have been laid in Philadelphia and found to be very satisfactory. Although glass-beaded paint costs more, experience shows that it wears four to five times as long." In the early 1940's, it cost about three times as much to put down a beaded line as it did to put down a standard non-reflectorized pavement marking. Since that time, advances in technology in the reflectorized paint field have brought the price down significantly. However, even when reflectorized paint was first introduced, the greater durability of the paint line made the reflectorized paint more cost effective. Adding reflective beads made such an improvement in the traffic lines that a reflectorized line became the standard. Today, we use both reflectorized center and edge lines for greater safety. Figures 2.1 and 2.2 illustrate the difference between using pavement markings with and without reflective beads.



**Figure 2.1**  
**Pavement markings with reflective beads at night**



**Figure 2.2**  
**Pavement markings without reflective beads at night**



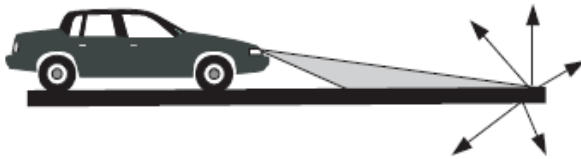
## How Glass Beads Work

### Retroreflectivity

Using beaded lines for nighttime reflectivity is now accepted worldwide. The advantages of using reflective beads are apparent when driving on a rural road at night. Added benefits of reflective beads are to protect marking material from tracking and to improve durability. However, during the day, a non-beaded paint line will appear richer and a more uniform color. However, this is misleading because the non-beaded paint line may not be visible at night.

If an engineer made the decision based only on the daylight evaluation, he/she would probably select the unbeaded line. If the same engineer evaluated these lines at night, he/she would undoubtedly select the beaded line.

Unbeaded paint lines will reflect light randomly in all directions. When round reflective beads are added, light is reflected directly to the source of the light. In industry, this is called retroreflectivity. The following illustrations demonstrate this.



**Figure 2.3**

**Roadway with unbeaded markings**



**Figure 2.4**

**Roadway with beaded markings**

In Figure 2.3 the light rays from an automobile's headlights illuminate a surface that does not retro-reflect. The light shining on the road, or a non-beaded line, is reflected in all directions. Only a very small amount is reflected directly back to the driver.

The beaded line illustrated in Figure 2.4 produces a much greater quantity of light reflecting directly back into the driver's eyes. Therefore, the driver sees the line better.

## Refractive Index of Glass

When light strikes a bead it is refracted and reflected. Refraction is the bending of the light. Refraction is observed when a pencil is dropped into a half filled glass of water; the pencil appears bent.

Reflective beads' ability to bend light is measured by its index of refraction, which is a ratio of the sine of the angle of incidence to that of the refraction.

The retroreflectivity of glass beads is better explained by examining the path of light as it enters a single bead in the paint (Figure 2.5). There are actually millions of tiny beads in each mile of beaded line that must perform this principle.

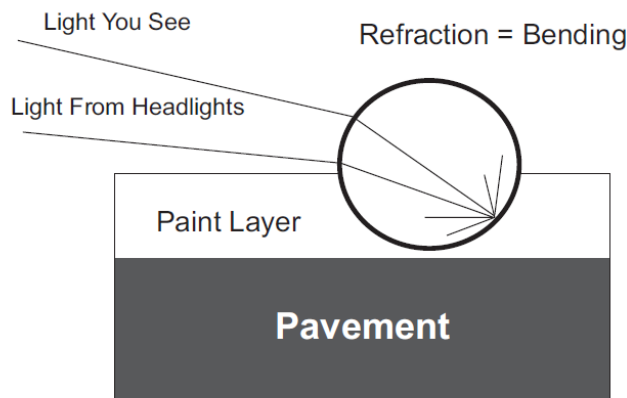


Figure 2.5

### How Beads Retroreflect Light

As the headlight beam enters the bead, it is bent or refracted downward. This beam then shines on the back surface of the bead, which is on top of the paint, thermoplastic, etc. It works a lot like a mirror. If the paint were not present, the light would continue through the bead and bounce in several directions. This is one reason for proper bead embedment depth (explained below). The light is bent (refracted) downward by the curved surface of the bead to a point below where the bead is embedded in the paint. Thus, when light is reflected off the paint at the back of the bead, a large portion of that light is reflected through the bead and refracted back toward your eyes.

The amount of refraction of light is characteristic of the glass itself and is known as the refractive index (R.I.) of the glass or bead. The refractive index of the glass is dependent upon the chemical and physical make-up of the glass material. Various types of beads have different indices of refraction and cause different amounts of light to be retroreflected.

Water has an index of refraction of 1.33, while the typical bead made with soda glass has a refractive index of 1.50. Beads used in the pavement marking industry are available in refractive indexes of 1.50, 1.65 and 1.90. The highest refractive material is 1.90 and is a very expensive bead to produce. Also, its durability is not as good as the soda glass type. Beads with a refractive index of 1.90 are generally called, "airport beads," since this type of bead is used to mark runways at airports.

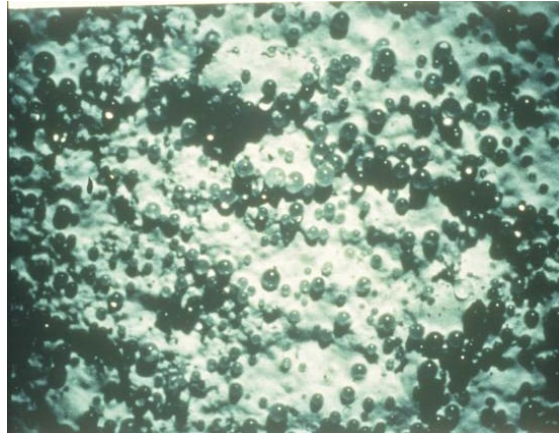
### **Glass Bead Embedment**

Retroreflectivity is dependent upon the embedment depth of the bead in the pavement marking material. Optimum embedment of reflective beads is 50-60% assuring optimum retroreflectivity. Embedment of less than 50% may affect the longevity of the beads. Increasing embedment beyond 60% significantly decreases the amount of light that can be directed back to the driver. A bead totally embedded in the binder is non-retroreflective because no light enters the bead. In summary, the amount of glass bead embedment will affect the retroreflectivity and the line durability. For optimum retroreflectivity and durability, a bead should be embedded at 50-60% of its diameter. Not all beads will be embedded 50-60%. Some beads will be completely buried and others will be embedded less than 50%.

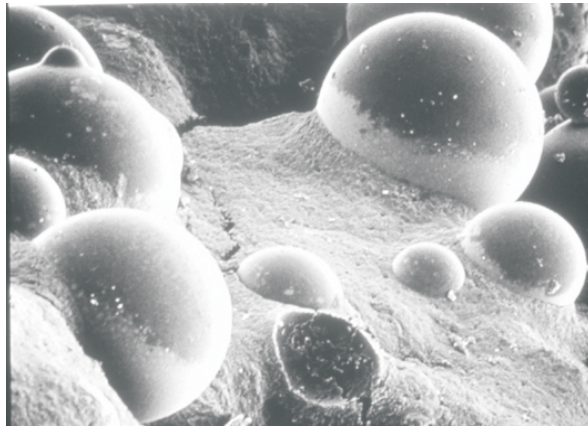
A new line will generally have 70% of all the beads completely buried in the paint or other marking material. The remaining 30% will be embedded in the surface and exposed to the headlights. Figure 2.6 shows beads that were sprayed too late behind the paint operation. The beads in this picture are insufficiently embedded. Figures 2.7a and 2.7b show beads embedded in a paint line that is too thin. Figure 2.8 illustrates proper bead embedment.



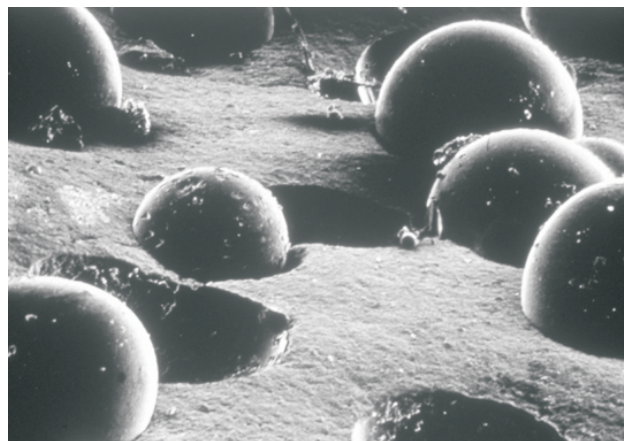
**Figure 2.6**  
**Improper bead embedment**



**Figure 2.7a**  
**Top view of reflective beads applied to a layer of paint that is too thin**

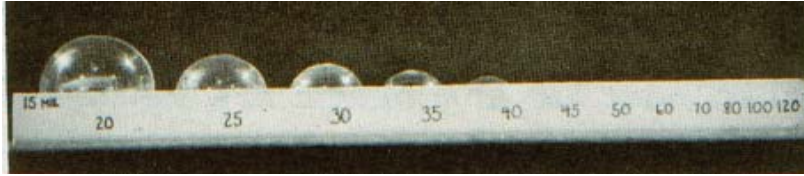


**Figure 2.7b**  
**Magnified view of reflective beads applied to a layer of paint that is too thin**



**Figure 2.8**  
**Magnified view of reflective beads at proper embedment depth**

Figure 2.9 illustrates the embedment of various sizes of beads in a 15 mil wet line. Figure 2.10 illustrates the embedment of the same beads after the line has dried to 8 mils. Notice the embedment depth of the 40-50 mesh beads in each line. These figures illustrate how 40-50 mesh beads end up at the proper embedment depth when applied to a 15 mil wet line that dries to 8 mils.



**Figure 2.9**  
**Beads in a 15 mil wet line**

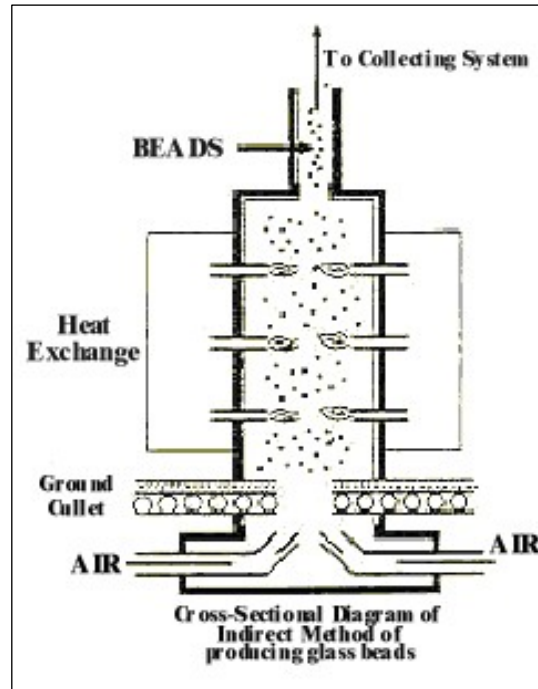


**Figure 2.10**  
**Beads in an 8 mil dry line**

## Manufacturing Methods

There are two basic manufacturing methods to make beads: the direct method and the indirect method. In the direct method, liquefied (molten) glass is sprayed and atomized into spheres similar to how water will form droplets when it is sprayed from the nozzle of a garden hose. As the molten glass is sprayed or forced out of the bead making tank, it is suspended as spherical droplets, which are cooled, collected, and then sifted through specifically - designed grading screens. This method, generally used for special formulations, can be used for 1.65 and 1.90 R.I. beads because their rheology will change from a molten state to a hardened bead.

The indirect method is the most commonly employed process for 1.50 R.I. In this method, a selected material (either new or reclaimed cullet) is pulverized into glass powder. This powder is then poured, sprayed, or sprinkled into a large three- to four- story furnace (Figure 2.11). The individual particles are blown through several flames until they soften and take the shape of spheres. These spherical droplets are cooled in the top half of the furnace and are then collected and sifted through specifically designed grading screens. Material from either method can be mixed to provide the necessary gradations to meet desired specification limits. After manufacturing, these highway beads are bagged and stocked for shipment.



**Figure 2.11**  
**Indirect method for manufacturing glass beads**

### **Bead Properties**

The size range or gradation and the roundness of the beads have a definite influence on the initial and long-term retroreflectivity of the pavement markings. Bead coatings will affect bead handling and adhesion to the pavement marking material. Numerous evaluations and years of experience have resulted in the selection of bead sizes for optimal performance under normal traffic conditions.

### **Size or Gradation**

The 20 to 80 mesh bead sizes are generally recommended based on the following assumptions:

- Striping equipment does not apply a uniform paint line because of uneven pavement and possible spray/atomization problems.
- The paint line is applied wet and thickness varies when dried.
- For optimum durability and visibility, a sphere should be embedded 50% to 60% of its diameter.
- The resulting reflectorized line will give the best possible retroreflectivity under all conditions.

Note: Figure 2.12 illustrates the typical sizes of glass beads



Typical Highway Gradation				Range For Larger Beads Depending On Binder			
	U.S Sieve	Microns	Inches		U.S Sieve	Microns	Inches
•	80	180	.0070	●	16	1180	.0469
●	50	300	.0117	●	14	1400	.0555
●	30	600	.0234	●	12	1700	.0661
●	20	850	.0334				

**Figure 2.12**  
Relative bead size comparison

**Roundness**

In order to be retroreflective, beads must be round. Only round beads can reflect light back toward the light source.

When standard beads are specified, they shall conform to AASHTO M247 or government agency specifications and must have a minimum percentage of round beads. Beads shall be smooth and spherically shaped.

While the manufacturing process generally produces round glass beads, a percentage of the beads are not round. Some glass beads take on an oval or “football” appearance. Also, some beads adhere to each other in the solidifying process.

**Bead Coatings**

Reflective beads can be effective without any coatings. However, in some humid areas it is difficult to apply the beads because they clump in the bead hopper or tank of the striping machines. To overcome this problem, a moisture- proof coating is applied to the beads allowing them to remain free flowing under all striping conditions. This coating alleviates problems during application, but was not designed to improve wet weather visibility. The moisture proof coating allows the beads to be stored, handled and applied without clumping. The proper coating will also enhance the adhesion between the bead surface and the pavement marking material. The coating that is generally used is a thermosetting silicone resin. Each manufacturer has their own system to make the beads flow without clumping. Some may use silicone oils or add inorganic particles such as china clay.

## Evaluation of Glass Beads

Before glass beads are approved, they must be tested to ensure they meet the specifications for refractive index, size, and roundness.

### Refractive Index Evaluation

To determine the refractive index (light bending phenomenon) of reflective beads, the beads are treated as a pigment. Most pigments are tested using the liquid immersion method at a temperature of 77 °F. To determine the refractive index of beads, refer to government agency specifications.

### Evaluation of Bead Size

To evaluate the bead size, the beads are hand sieved through standard sieves starting with the largest opening and progressing to the smallest opening sieve. The reflective beads are weighed on each sieve and the percent that passes through each sieve is calculated. Refer to Figure 2.13 for bead size guidelines.

SIEVE DESIGNATION U.S. Sieve Sizes	MASS PERCENT PASSING	
	Type I	Type II
20	100	-
30	75-95	100
40	-	90-100
50	12-35	50-75
80	-	0.5
100	0-5	-

**Figure 2.13**  
**Gradation of glass beads**

### Evaluation of Roundness

To evaluate roundness, the controlled vibration of a glass plate held at a fixed slope mechanically separates the reflective beads. The round reflective spheres will roll down the slope while the irregularly shaped particles vibrate to the top. After testing the complete sample, the percent of round beads is calculated by weighing the quantity of round beads that have rolled down the glass slope versus the quantity of irregular shaped beads that have vibrated up the glass slope.

Another method used to evaluate bead roundness is visual evaluation using magnification where beads are adhered to a transparent adhesive surface and viewed under magnification. This method is normally used to evaluate larger beads.



## **Application of Glass Beads**

The proper placement of beads and pavement marking material on a road surface is the most important step in obtaining a durable reflective line. During this process, all variables must be controlled. The following must be considered:

### **Liquid Pavement Markings**

Most highway marking material is applied on Hot Mix Asphalt (HMA) or Portland Cement Concrete (PCC). The major problem with these surfaces is obtaining a lasting bond between the binder and the substrate. This bond may be affected by dirt, substrate texture, the chemical or mechanical properties of the surface, concrete latency, curing compounds and road surface oils in new HMA pavement. The presence of residue, expansion joints, cracks and sealants can adversely affect the performance of the line.

### **Binders**

The resin in the marking material (paint, thermoplastic, etc.) is the “glue” adhering the beads to the road surface. The pigment/binder thickness is an important variable closely related to beads retainment and the quantity of beads used. The type and quantity of pigmentation and filler play an important role in the retroreflectivity of the beads as well as the daylight appearance of the line. After the best striping materials are selected, the three most important variables involved in the application of lines are the equipment, operator skill, and ambient conditions.

### **Equipment**

The application equipment must be in good condition and properly designed for the type of product it is to apply. The development and use of computer-aided delivery systems have helped provide adequate means to accurately control film thickness and bead application rates.

### **Operator Skill**

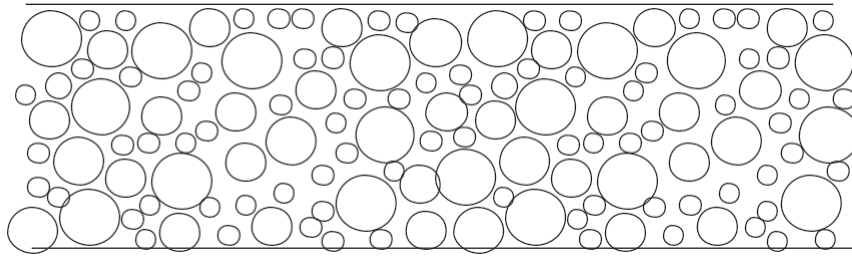
Operator skill is essential to achieve reasonable control over “liquid markings” and bead application. This applies to both the driver of the vehicle and the operator of the application controls.

### **Ambient Conditions**

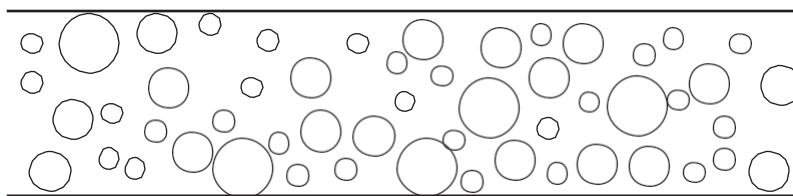
Pavement markings shall only be applied when the ambient conditions will give the best results. When striping must be done under more adverse conditions, the results may be affected.

## Evaluation of Glass Bead Application

The visual evaluation of a newly applied pavement marking line is an important part of the quality control process. Proper bead distribution and depth are critical to ensure a durable and retroreflective line. Since visual evaluation of glass bead application can be subjective, the following illustrations and descriptions are provided to demonstrate good and bad bead distribution. Figure 2.14 is a representation of a good stripe demonstrating uniform distribution of glass beads. This line will feel rough like sandpaper. Figure 2.15 shows a stripe with good distribution but not enough glass beads.

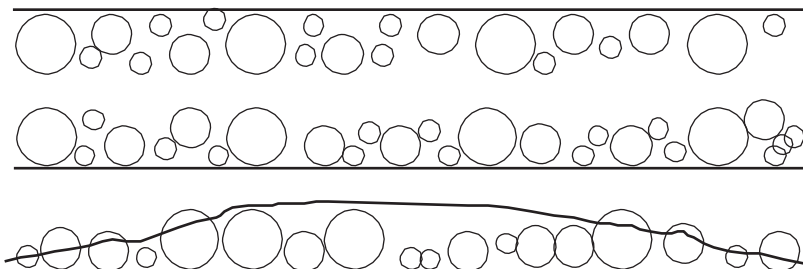


**Figure 2.14**  
**Representation of good bead distribution**



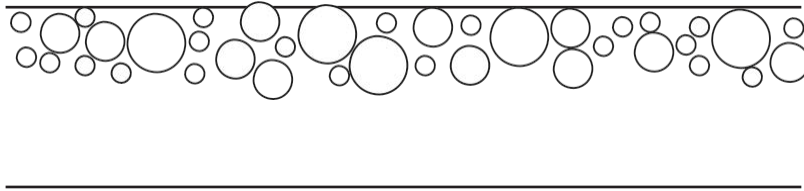
**Figure 2.15**  
**Too few beads**

Figure 2.16 shows striping material that is too thick in the center and too thin on the edges. The beads in the center of the stripe are covered with material and are non-reflective. The edges may be reflective but because of the thinner material film, not as durable. This may be due to improper atomizing pressure and/or improper material pressure and/or improper material viscosity.



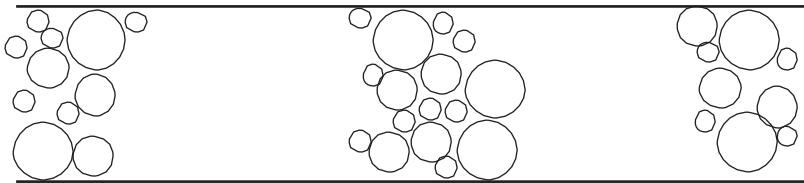
**Figure 2.16**  
**A contoured line**

Figure 2.17 illustrates poor distribution of beads. An improperly placed bead dispenser or possibly a windy day may result in the distribution of beads on only part of the stripe.



**Figure 2.17**  
Beads on only one portion of the line

Problems with inconsistent air pressure or pulsed air pressure may lead to pulsed or sporadic application of beads as illustrated in Figure 2.18.



**Figure 2.18**  
Line from a pulsating bead gun

## Evaluation of Retroreflectivity

While other aspects of appearance and durability are important to determine the useful life of pavement markings, those markings are only useful if they can be seen in all conditions, especially at nighttime. Retroreflectivity testing has improved the performance of pavement markings.

Retroreflectivity can be assessed either visually at night or by the use of retroreflectance meters such as the Mirolux-12, Ecolux, Gamma/ART Retrolux-1500, or the Delta LTL-2000. Currently in the United States, 15- and 30-meter geometry instruments, as well as mobile equipment technologies are used.

The color of the pavement marking may affect the results of the retroreflective instruments. For example, if a non-leaded yellow paint line begins to deteriorate from UV radiation (i.e.- get lighter in color) but has no bead loss from the initial application, the reflectometer values may increase.

In summary, **retroreflectivity** and **durability** are a function of the following parameters:

- The refractive index of the glass bead material
- Gradation or size of the glass beads
- Roundness of the beads
- The coating on the beads
- The embedment of the beads in the material
- The distribution of glass beads in the pavement material
- The number of exposed beads on the marking surface
- The relationship between the diameter of the beads and the striping material thickness

The first four items are controllable manufacturing items. These can be specified and tested for minimum requirements. The last four items are related to the application of materials. Even if the first four items are strictly adhered to, either a bad application of binder material or a bad application of beads will negate the quality of the ingredients and result in a non-durable and/or non-retroreflective pavement marking.

### **New Materials**

Advances in striping materials (i.e. higher solids, better reactive polymers, etc.) as well as advances in adherence type coatings on reflective beads allow larger reflective beads to be used. These larger reflective beads provide better wet night retroreflective performance. Standard reflective beads, as previously described, may have their retroreflectivity “turned off” by a thin film of water. The new larger reflective beads stick up above a water film and continue to retroreflect headlights during rain. However, the larger beads are more susceptible to snow plow damage. Figure 2.19 is a troubleshooting guide for bead application problems.

<b>REFLECTIVE BEAD APPLICATION TROUBLESHOOTING</b>			
<b>PROBLEM</b>	<b>CAUSE</b>	<b>EFFECT</b>	<b>REMEDY</b>
<b>Beads on one side</b>	<ul style="list-style-type: none"> <li>• Bead gun out of alignment</li> <li>• Clogged bead gun</li> </ul>	<ul style="list-style-type: none"> <li>• Poor night visibility</li> </ul>	<ul style="list-style-type: none"> <li>• Adjust alignment of gun cap</li> <li>• Rebuild gun</li> </ul>
<b>Excessive bead use</b>	<ul style="list-style-type: none"> <li>• Worn gun needle, seat and orifice</li> <li>• Excessive glass bead pressure</li> </ul>	<ul style="list-style-type: none"> <li>• Supply problems</li> </ul>	<ul style="list-style-type: none"> <li>• Rebuild gun</li> <li>• Decrease pressure</li> </ul>
<b>Beads in middle of line</b>	<ul style="list-style-type: none"> <li>• Bead tank pressure too low</li> <li>• Bead gun “off” and “on” control screw not adjusted</li> <li>• Bead gun cap out of alignment</li> </ul>	<ul style="list-style-type: none"> <li>• Poor night visibility</li> </ul>	<ul style="list-style-type: none"> <li>• Increase Pressure</li> <li>• Adjust control screw</li> <li>• Align cap deflector</li> <li>• Change to a smaller tip</li> </ul>
<b>All beads buried</b>	<ul style="list-style-type: none"> <li>• Bead gun too close to paint</li> <li>• Bead gun angle too shallow</li> <li>• Excessive paint millage</li> </ul>	<ul style="list-style-type: none"> <li>• Poor night visibility</li> </ul>	<ul style="list-style-type: none"> <li>• Re-align bead gun</li> <li>• Adjust angle of bead gun</li> <li>• Check wet millage thickness</li> </ul>
<b>All beads on top of line</b>	<ul style="list-style-type: none"> <li>• Bead gun too far from paint gun</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of durability</li> <li>• Initial very bright line</li> </ul>	<ul style="list-style-type: none"> <li>• Re-align bead gun</li> </ul>
<b>Pulsed bead application</b>	<ul style="list-style-type: none"> <li>• Bead tank pressure inadequate</li> </ul>	<ul style="list-style-type: none"> <li>• Violates standard</li> <li>• Loss of effectiveness</li> </ul>	<ul style="list-style-type: none"> <li>• Raise tank pressure</li> <li>• Rebuild applicator to increase pressure</li> </ul>
<b>Excessive amount of beads on road beside line</b>	<ul style="list-style-type: none"> <li>• Too much overlap of bead pattern on line pattern</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of reflectivity</li> </ul>	<ul style="list-style-type: none"> <li>• Move bead gun closer to roadway</li> </ul>

**Figure 2.19**  
**Reflective bead troubleshooting chart**

## References

See Appendix A for the following:

*VDOT Road & Bridge Specifications*

Section 234

Glass Beads for Reflectorizing Traffic Markings – This section references AASHTO M 247, Type 1 glass beads. The exception to this specification is that Virginia – DOT requires 80% of the beads to be round.

Section 704.03 (a) Procedures

(last paragraph)

See Appendix B for the following:

*VDOT Manual of Instructions*

Section 204.30 (a)

- (1) Sampling, Testing, and Approval
- (2) Acceptance (Requires Cert. I)

See Appendix C for the following:

*Virginia Test Methods*

VTM-94

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## Chapter 2 Knowledge Check

1. Reflective beads are used with pavement markings:
  - a) for skid resistance
  - b) to provide a filler for the paint
  - c) to enhance nighttime visibility
  - d) to produce a noticeable bump
  
2. The phenomenon where light is reflected directly back to the light source is called:
  - a) glow-in-the-dark
  - b) retroreflectivity
  - c) retro-fit
  - d) retro-illuminescence
  
3. For glass beads, the light bending phenomenon is known as:
  - a) the refractive index
  - b) the index card
  - c) index finger
  - d) the back-light ratio
  
4. The optimum embedment depth for reflective beads is
  - a) 20 to 40%
  - b) 50 to 60%
  - c) 30 to 40%
  - d) 80%
  
5. When inspecting pavement markings with regard to glass beads, which of the following criteria should be met?
  - a) Beads should be evenly distributed over the entire surface of the marking
  - b) 70 % of the beads should be buried, the remaining 30% shall be 50 to 60% embedded
  - c) Both a & b
  - d) None of the above

6. In order for glass beads to reflect light as intended, they must be:
- a) square
  - b) angular
  - c) buried
  - d) round
7. Proper bead distribution and depth are critical in ensuring a \_\_\_\_\_ line.
- a) durable and retroreflective
  - b) straight
  - c) properly colored
8. Correct glass bead application and embedment will result in the line feeling like:
- a) loose aggregate
  - b) smooth glass
  - c) sandpaper
  - d) all of the above



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# 3

## Traffic Paint

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### Learning Outcomes:

- Know the components of Traffic Paint
- Understand application methods

### Traffic Paint

Traffic paint is a thin layer of blended material. This chapter will describe waterborne traffic paint and solvent borne traffic paint. Reflective beads are added to the surface of the paint during application to produce nighttime retroreflectivity.

### Thickness

Paint should be applied at  $15 \pm 1$  mil.      1 mil = 0.001 inch      15 mil = 0.015 inch

### Components

Paint is mainly composed of finely ground pigments that are mixed into a resin or binder system. Then various ingredients and additives are incorporated for certain desired properties. A liquid (water or solvent) is added to the mixture to produce a material that is pliable by application equipment. All of the ingredients/components in traffic paint are added specifically for one or more of the following functions: aiding the manufacturing process, increasing storage time in containers, easing application, and increasing durability once the paint has been applied.

### Prime Pigments

Prime pigments are used to impart chemical properties such as UV stability, or physical properties such as color and hiding. Hiding is the ability of a paint to cover or block out the surface (substrate) beneath it. Titanium dioxide is typically used to make a white color. It is the primary pigment that gives traffic paint good hiding power.

Lead chromate was typically used to make a yellow color. However, due to health concerns with lead chromate pigments, organic pigments are now being used as a substitute for the lead chromate. Some types of pigments can be used interchangeably between solvent borne and waterborne traffic paint.

### **Extender Pigments**

Once the necessary amount of prime pigment is added for hiding, less expensive extender pigments or fillers are used to bring the pigment level up to the required point. Extender pigments not only reduce cost, they give paint consistency, durability, permeability, and scrubability. These properties are very important when considering the harsh environment and abuses that traffic paint must withstand. The main types of extenders are aluminum silicate (china clay), calcium carbonate, calcium sulfate, and magnesium silicate.

### **Resins or Binders**

The resin is the component that bonds the pigment and beads together. It also provides the adhesion to the road surface. The resin is the binder or glue in paint.

Waterborne paints typically use three types of resins. They are polyvinyl acetate latex, methylmethacrylate, or a one-hundred-percent acrylic resin. These materials are pre-reacted and put into solution using emulsifiers. These emulsions are materials that normally do not mix. Once the paint has been applied, it must allow the water to evaporate in order for the paint to “break” and adhere to the roadway. This settling is generally called coalescence. One-hundred-percent acrylics are used predominantly due to faster “no track” times and less heat needed during application.

Because of high humidity, waterborne paint will take longer to dry. Therefore, on low humidity days, waterborne paint will dry much faster. When there is less water in the air, the water can leave the film or evaporate much faster.

Solvent borne paints are typically linseed or soya oils and alkyd resins. These paints cure by solvent evaporation and the resin reacts with atmospheric oxygen to create a solid bond to the pigments, beads, and road surface. Some types of solvents used in these paints are naphtha, toluene, methanol, methylene chloride, and acetone. They are added to thin the paint out and make it easier to handle and spray.

Both waterborne and solvent borne paint resins have a critical value for the quantity of material that the resin can hold. This is called the critical-pvc pigment volume concentration. If this concentration is exceeded, the resin will not be able to bind the pigment and beads. This could also affect adhesion to the road surface.

### **Solvents**

With waterborne paint, the water is more of a diluent rather than a solvent. It holds the resin emulsion in solution with the other components until the paint has been applied. Fast-dry waterborne paints may contain ammonia and/or methanol. Ammonia and methanol are Volatile Organic Compounds (VOCs). These VOCs accelerate the curing process throughout evaporation.

In solvent borne paints, the evaporation rate is very important. Because of this, they need to be tailored to leave the film at the right time. When solvents evaporate too fast, the surface can skim over and trap the rest of the solvents within the film. Most solvent blends keep the film open while solvents escape. That is why, as a general rule, just any solvent will not work.

Heat can be considered as a solvent for both waterborne and solvent borne traffic paint because it can be used to make paint more fluid and aid in evaporation. Volatile Organic Compounds evaporate in the air. The Environmental Protection Agency (EPA) was mandated to establish VOC emission controls for “all field applied coatings.” The Clean Air Act Amendment (CAAA) of 1990 designated these controls as “architectural coatings.”

This category is very broad ranging from interior house paints to heavy-duty industrial maintenance coatings. Different VOC limits were established according to the intended use of the coatings. Traffic Marking Coating VOC limits were set at 1.25 lbs/gal. This is the result of the EPA’s effort to reduce ozone, which is a significant ground level health hazard. A few materials, acetone and some special chlorinated solvents, have been declared exempt from these regulations because they don’t increase ozone levels. From a 1990 nationwide baseline, the annual reduction of VOC emissions is 10,600 tons.

### **Additives**

Additives are included in paint to help prevent problems. One example is an anti-foam agent, which keeps paint from foaming during the high-speed mixing process. Other additives help prevent the paint from freezing, settling, or skimming in the drum. Additives usually only make up 0.1 to 5 percent of the paint. Some have a single function and others may have multiple functions. For example, ammonia acts as an accelerator for drying and keeps the pH level up in waterborne paint while being stored. It is important to maintain the pH level at 9.5 or higher to ensure the latex remains suspended in solution.

### **Reflective Beads**

A separate gun adds reflective beads to the wet paint at the time of application. Some agencies may also require the premixing of beads into the paint prior to application.

Reflective beads for painted markings are typically applied under pressure. This is necessary for the beads to achieve the proper embedment in the paint before its fast drying nature causes it to form a surface skin. The bead supply tank is pressurized to force the beads through the system to the bead gun.

Since the system is under pressure and is not loaded in a vacuum, moisture can condense inside the tank and cause clogging problems. For this reason, the manufacturer usually adds a moisture-proofing agent. Beads are typically applied at a minimum rate of 6 pounds of beads per gallon of paint.

Beads are generally shipped in 50-pound bags with 40 bags shrink-wrapped on a pallet. They may also be shipped in 2,000-pound boxes.

## Characteristics of Waterborne Paint

There are many disadvantages and advantages to using waterborne paints for pavement markings. One major disadvantage of waterborne paint is its sensitivity to temperature. Precautions must be taken to protect stored material from freezing and extreme heat. During application, latex paint is very sensitive to high humidity, which can drastically increase drying time. Conversely, low humidity creates a quicker drying time. Paint is also the least durable of all the markings and is not recommended for roadways with high traffic volumes.

Some advantages of waterborne paint are cost. It is the least expensive of all pavement markings. It can be applied at a faster rate than most other markings and under ideal conditions it can have a very fast dry time. Also, no solvents are needed for clean-up. Fast dry waterborne paint will achieve its best drying times under perfect ambient conditions: daytime, sunny, 70°F, low humidity and a breeze.

Some characteristics of waterborne paint are:

- Heat sensitivity
- Freezes easily
- Strong ammonia odor
- Humidity may affect drying times
- Can be flushed out with water and/or ammonia
- Generally not a hazardous waste for disposal - placarding not required (dependant on formulation)
- Reacts adversely to metals other than stainless steel
- Requires specially lined drums to prevent chemical reaction
- Can settle in the drum

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## Characteristics of Solvent Borne Paint

Some characteristics of solvent borne paint are:

- Humidity generally not an application problem
- Heat exchanger can be heated higher to assist in drying times
- Can film form at lower temperatures than waterborne
- Solvent blend critical to prevent skimming
- Requires placarding of vehicle
- Clean up flush material is hazardous waste
- Unused paint is hazardous waste for disposal purposes
- Can be very flammable
- Can easily settle in drum

Traffic paint is a one-component material that is generally shipped in 55-gallon drums with full open top lids. Traffic paint generally has a shelf life of one year. This information should appear on the shipping documents. Quality assurance tests may be performed to confirm that the original formulation is approved by the government agency and to verify the manufacturer's certification.

No paint forms a film well when applied at low temperatures.

## Application Considerations

Traffic paint is applied by conventional or airless spraying.

### Conventional

Conventional spraying uses air jets in the tip of the paint gun to break up, or atomize the paint. The tip then defines the shape of the spray to produce a properly applied line. The quantity of atomizing air needed to sufficiently break up the paint will depend to a large extent on the paints rheology, or flow characteristics.

The pressure needed to force the paint through the application system and out of the gun can vary from 60 to 140 psi, depending on the size of the plumbing and the type of spray gun used. This can be achieved using one of the following methods:

- In a pressure-pot system, the holding tank is pressurized to push the paint through the heat exchangers and lines to the gun for application.
- In a pumper system, the holding tank is not pressurized. A diaphragm pump is used to draw the paint from the tank and force it through the system and out to the gun.

### **Airless**

In an airless system, the paint is forced out through an orifice in the tip of the gun at a high pressure. The size of the hole determines how much paint is applied and the angle of the inner surfaces of the tip determines the width. Unlike the conventional system, there is no air mixed with the paint in the gun. The pressure created by the pump mechanism explosively forces the paint through the gun tip breaking the paint up into very small particles. The primary method for altering the width and thickness of the applied line is to change the tip. Chapter 11 shows a picture of a long liner truck.

## **Additional Factors to be Considered**

### **Material Temperature**

The manufacturer's Product Data Sheets specifies the material application temperature ranges. Fast-dry (ammoniated), waterborne paint only needs enough heat to allow a good flow of material through the application system (generally in the range of 90 °F to 120 °F at the gun tip).

It is very important not to overheat the solvent or waterborne traffic paint because they can ignite. Overheating fast dry, waterborne paint can also "drive off" the methanol and ammonia creating longer dry times. These two additives act as driers to keep the paint film open, helping the water escape.

### **Ambient Conditions**

Waterborne paint requires liquids to evaporate. This evaporation is dependent on the humidity (moisture in the air). Humid days will cause drying problems. Lower humidity and good air movement greatly improves waterborne materials drying. To achieve the optimal results, neither solvent nor waterborne traffic paint shall be applied below 50 °F (air temperature).

### **Pavement Surface Considerations**

The pavement shall be free of dirt, oil, grease, laitance, curing compounds, and moisture. On new HMA pavements, paint may dissolve road oils and cause a discoloration of the line. This line should be repainted as soon as it has dried in order to achieve the proper color.

### **Quality Assurance Field Testing**

Quality assurance field-testing shall be conducted in accordance with agency specifications

<b>Paint Application Troubleshooting</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
<b>Excessive Thickness (overall)</b>	<ul style="list-style-type: none"> <li>- Paint tank pressure too high.</li> <li>- Paint gun volume control (if present) open too wide.</li> <li>- Pump pressure too high.</li> <li>- Applicator speed too low.</li> </ul>	<ul style="list-style-type: none"> <li>- Buried beads- poor initial nighttime retroreflectivity.</li> <li>- Slow drying time-paint tracked by motorists.</li> <li>- Paint won't cure properly giving it a shortened life.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce tank pressure.</li> <li>- Adjust paint gun volume control.</li> <li>- Reduce pump pressure.</li> <li>- Increase speed.</li> </ul>
<b>Excessive Thickness (middle of line)</b>	<ul style="list-style-type: none"> <li>- Paint tank pressure too high.</li> <li>- Paint gun volume control (if present) open too wide.</li> <li>- Pump pressure too high.</li> <li>- Atomizing air pressure off or too low.</li> <li>- Material buildup in paint gun tip and/or shroud.</li> </ul>	<ul style="list-style-type: none"> <li>- Buried beads – poor initial nighttime retroreflectivity.</li> <li>- Slow drying time – paint tracked by motorists.</li> <li>- Paint won't cure properly – shortened life .</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce tank pressure.</li> <li>- Adjust paint gun volume control.</li> <li>- Reduce pump pressure.</li> <li>- Increase atomizing air pressure.</li> <li>- Clean paint tip and/or shroud.</li> </ul>
<b>Excessive Thickness (along one side)</b>	<ul style="list-style-type: none"> <li>- Material buildup in paint gun tip and/or shroud.</li> <li>- Clogged hole(s) in paint gun atomizing tip.</li> </ul>	<ul style="list-style-type: none"> <li>- Buried beads-poor initial nighttime retroreflectivity.</li> <li>- Slow drying time – paint tracked by motorists.</li> </ul>	<ul style="list-style-type: none"> <li>- Clean paint tip and/or shroud.</li> <li>- Clear clogged hole(s) in paint gun atomizing tip.</li> </ul>
<b>Insufficient Thickness</b>	<ul style="list-style-type: none"> <li>- Paint tank pressure too low.</li> <li>- Paint gun volume control (if present) not open enough.</li> <li>- Pump pressure too low.</li> <li>- Application speed too low.</li> <li>- Atomizing pressure too high.</li> <li>- Material buildup in paint gun tip and/ or shroud.</li> <li>- Material buildup in paint filter(s) and/or plumbing.</li> </ul>	<ul style="list-style-type: none"> <li>- Poor line quality and/or shortened life.</li> <li>- Beads won't adhere and/ or poor or no nighttime retroreflectivity.</li> </ul>	<ul style="list-style-type: none"> <li>- Increase tank pressure.</li> <li>- Adjust paint gun volume control.</li> <li>- Increase pump pressure.</li> <li>- Decrease speed.</li> <li>- Decrease atomizing air pressure.</li> <li>- Clean paint gun tip and/or shroud.</li> <li>- Clean paint filter(s) and/or plumbing.</li> </ul>

**Figure 3.1 - Paint Application Troubleshooting Guide**

<b>Paint Application Troubleshooting - continued</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
<b>Paint Line Not Drying</b>	<ul style="list-style-type: none"> <li>- Surface temperature too cold.</li> <li>- Material overheated.</li> <li>- High humidity.</li> <li>- Material past shelf life.</li> </ul>	<ul style="list-style-type: none"> <li>- Vehicle tracking markings.</li> <li>- Tracked marking no longer has required retroreflectivity.</li> </ul>	<ul style="list-style-type: none"> <li>- Cone markings.</li> <li>- Reduce material temperature.</li> <li>- Stop applying markings until environment improves.</li> <li>- Check surface temperature.</li> <li>- Check age of material.</li> </ul>
<b>Wide Paint Line</b>	<ul style="list-style-type: none"> <li>- Paint gun set too high.</li> <li>- Worn or damaged paint gun tip and/or shroud.</li> </ul>	<ul style="list-style-type: none"> <li>- Line does not meet standards.</li> <li>- Line has fuzzy edges.</li> </ul>	<ul style="list-style-type: none"> <li>- Lower gun.</li> <li>- Repair or replace tip and/or shroud.</li> </ul>
<b>Narrow Paint Line</b>	<ul style="list-style-type: none"> <li>- Paint gun too low.</li> <li>- Paint gun tip slot not at 90° angle to paint line.</li> <li>- Clogged paint gun tip and /or shroud.</li> <li>- Low air pressure in paint machine tire.</li> </ul>	<ul style="list-style-type: none"> <li>- Line does not meet standards.</li> <li>- Not as visible as a full – width line (day or night).</li> </ul>	<ul style="list-style-type: none"> <li>- Raise paint gun.</li> <li>- Reposition paint gun tip.</li> <li>- Clean paint gun tip and/or shroud.</li> <li>- Inflate tire.</li> </ul>
<b>Uneven Paint Line (spotty)</b>	<ul style="list-style-type: none"> <li>- Atomizing air pressure too low.</li> <li>- Paint tank pressure too low.</li> <li>- Old paint (viscosity too high).</li> <li>- Loose paint gun tip and/or shroud.</li> <li>- Insufficient heat.</li> <li>- No shroud.</li> </ul>	<ul style="list-style-type: none"> <li>- Poor appearance.</li> <li>- Line has fuzzy edges.</li> <li>- Slow drying time.</li> <li>- Paint won't flow smoothly.</li> </ul>	<ul style="list-style-type: none"> <li>- Increase atomizing air pressure.</li> <li>- Increase material tank pressure.</li> <li>- Rotate material stock.</li> <li>- Secure paint gun tip and/or shroud.</li> <li>- Increase heat (enough to get paint to flow evenly).</li> <li>- Install shroud.</li> </ul>

**Figure 3.1 Continued**



## References

See Appendix A for the following:

*VDOT Road & Bridge Specifications*

Section 704.01 thru 704.03 (a) 1.

704.01 thru 704.03 Description, Material Types, and Procedures

(a) Pavement Markings

1. Type A Markings

See Appendix B for the following:

*VDOT Manual of Instructions*

Section 204.30 (a) (1) and (2)

(1) Sampling, Testing, and Approval

(2) Acceptance (Requires Cert. I)

Approved List # 20

See Appendix C for the following:

*Virginia Test Methods*

VTM-94 Quality Control Testing of Pavement Markings

## Chapter 3 Knowledge Check

1. VDOT designated "Type A" traffic paint should dry "track-free within:
  - a) 5 minutes
  - b) 2 minutes
  - c) 60 seconds
  - d) 30 seconds
  
2. Reflective beads are normally:
  - a) added to the paint before it is applied to the roadway.
  - b) spray applied to the wet paint immediately following application of the marking material.
  - c) hand tossed into the marking.
  - d) applied after the marking has dried.
  
3. The minimum surface temperature at which Virginia designated Type A traffic paint may be applied is:
  - a) 30°F +
  - b) 45°F +
  - c) 50°F +
  - d) 60°F +
  
4. Before marking materials of any kind are applied, the surface of the roadway must be:
  - a) clean.
  - b) dry.
  - c) both a & b
  - d) none of the above
  
5. The specified application thickness for Virginia designated Type A traffic paint is:
  - a) 90 ±5 mils when set
  - b) 20 ±2 mil when wet
  - c) 15 ±1 mil when wet
  - d) 12 ±3 mil when wet
  
6. The minimum amount of glass beads to be applied to Type A paint is:
  - a) 6 pounds per gallon
  - b) 25 pounds per gallon
  - c) dependant on bead gradation
  - d) dependant on environmental conditions

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# 4

## Liquid Thermoplastic

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### Learning Outcomes:

- ☑ Be aware of the components and characteristics of liquid thermoplastic
- ☑ Understand the three basic application methods
- ☑ Know the steps for correct application

### Thermoplastic Material

Thermoplastic resin material has various uses, including being a durable pavement marking material. Thermoplastic is a blend of solid ingredients that become liquid when heated. It comes from the manufacturer intermixed with some reflective beads. When heated and properly agitated, the dry thermoplastic compound becomes a homogenized liquid. Reflective beads are intermixed and suspended in this liquid. Applied at the proper temperature, the thermoplastic melts into the upper surface of the Hot Mix Asphalt (HMA) pavement forming a thermal bond. When applying thermoplastic to Portland Cement Concrete (PCC), a primer/sealer from the thermoplastic manufacturer shall be used to ensure a proper bond to the surface.

Thermoplastic provides a visible, durable pavement marking because of its thickness and the use of intermixed and drop-on beads.

### Components

Thermoplastic resin marking is composed of pigment, reflective beads, filler, binder, and additives.

#### Pigment

Pigment is primarily used to impart color and to provide some chemical property, such as hiding or UV stability. Titanium dioxide is typically added to provide a white color and lead chromate or organic pigments are typically added to provide a yellow color. Because of environmental and health concerns, lead compounds in pavement marking material have been eliminated.

### **Reflective Beads**

Thermoplastic is manufactured with a certain percentage of beads intermixed with the unmelted material. Additional beads are added to the surface of the applied line at a rate of 7 pounds per 100 square feet (300 linear feet for 4 inch markings) of marking material.

### **Filler**

Fillers are pigments and are used to provide bulk. Once the necessary color and hiding has been obtained, fillers such as a mixture of calcium carbonate, sand, and other inert materials, are used to provide the needed volume adding durability, without the higher cost of the hiding pigments.

### **Binder**

The binder is generally either hydrocarbon or alkyd. Generally, thermoplastic takes its name from the type of resin present. The hydrocarbon resin is made from petroleum-derived resins. The alkyd type is made from a naturally occurring resin. Both types of material are thermoplastic, they melt when heat is applied. Heat is used to form the initial shape and is also used to reform the shape. The material does not change chemically, but physically, during heating and application.

### **Additives**

Additives like plasticizers are added to enhance rheological, or flow characteristics. Because the plasticizer can burn away, overheating and excessively reheating the thermoplastic can dramatically affect the quality of the line.

### **Solvent**

There are no solvents in the traditional sense. The heating process transforms the thermoplastic material from a solid into a liquid.

## **Material Characteristics**

Two types of thermoplastics, hydrocarbon and alkyd, that exhibit different properties are used in pavement marking applications.

### **Hydrocarbon**

- Relatively more heat stable than alkyd
- Exhibits predictable application properties
- Can break down under heavy oil drippings

**Alkyd**

- More resistant to deterioration from petroleum products
- Highly heat sensitive
- Requires great care during application
- May thicken if heated too long, causing it to become gummy and unstable, which will result in inconsistent markings

Manufacturers recommend that alkyd type material only be used if a new HMA surface will be marked in fewer than 10 days.

The manufacturer's application guidelines shall always be followed. Material formulations for extruded material are different than for spray material. The formulations are not generally interchangeable for each type of application. There are interchangeable formulations based on the method of application. It is important to verify that the proper and appropriate material is being used for the method of application.

Other factors that should be considered when using thermoplastics are packaging, shelf life, mixing materials, primers and priming, and material testing.

**Packaging**

Hydrocarbon and alkyd thermoplastic are available in either granular or block form. The granular material is usually packaged in 50-pound bags. All other product components have been physically mixed together, but not heated. Manufacturers recommend heating this material no more than 3 times before discarding. The bags may be heat degradable.

The standard package for block material is 50-pound boxes. Supplied in this form, the components have already been heated to mix them together. Since it's been heated once during production, manufacturers recommend heating this material no more than 2 additional times before discarding.

**Shelf Life**

Thermoplastics have a shelf life of one year when stored inside at a temperature less than 100°F. This must be considered when accepting the material for a project. Shipping documents are required to have the expiration or shelf life data printed on them.

**Mixing Materials**

Alkyd and hydrocarbon materials shall NOT be mixed. This applies to material in the melter equipment. If it is necessary to change from one type of material to the other, the melter shall be thoroughly cleaned first.

### **Primers and Priming**

Primers are used as a “bridge” between thermoplastic and a surface where thermoplastic will not readily adhere. In other words, the primer bonds to the surface, and the thermoplastic bonds to the primer.

Some government agency specifications require the use of primer on all hydraulic cement concrete roadways. Manufacturers of thermoplastic recommend using a primer on HMA surfaces that are more than two years old, oxidized, and/or have aggregate exposed.

Primer must be applied to ensure adequate coverage, and must be allowed to cure according to manufacturer’s instructions before applying thermoplastic. The primer must be from the same source as the thermoplastic material.

### **Application Methods**

There are three basic methods of applying liquid thermoplastic. These vary according to the type of device or gun that is used in applying the line to the roadway.

#### **Spray Gun**

This method of application is accepted in many states for all markings. It involves using a gun that is similar to that used in conventional paint application (i.e. the system is under pressure to deliver the material to the gun, and air is used to atomize the thermoplastic in the gun prior to its being forced out onto the roadway).

A major advantage of this method is that it is possible to go faster and cover rough surfaces with greater ease.

A major disadvantage of spraying is that going faster may result in heat loss of the material and may adversely affect the bond between the marking and the substrate. Also, the thickness of the applied line is more difficult to control than other application methods because it is directly affected by the speed of the applicator.

#### **Screed / Extrusion Shoe**

This method of application is typically used for legends, crosswalks, stop bars, etc. Thermoplastic material is forced through a die or shoe riding on the pavement surface. With gravity extrusion, the hot thermoplastic enters a trough or shoe that has a gate. The gate opening is set to produce the specified thickness as the material flows onto the pavement. Since the heat is maintained in the extrusion device, the bond remains consistent as long as the pavement surface is consistent. There are a number of extrusion devices that differ primarily in the inner workings of the shoe itself.

The major advantage of this method is that the material flows onto the pavement uniformly at the correct thickness. It’s easy to get a well-defined line on most surfaces, and greater thickness can be achieved than with the spray method.

A major disadvantage is that on uneven surfaces, the material will flow out from the sides of the shoe, since the sides are used to contain the material. Also, the speed of application is much slower than that of the spray method.

### **Ribbon Gun**

This method of application involves using a gun that rides just above the pavement surface. Material is forced through the system and into the gun, and from there it flows onto the pavement. This method is NOT accepted by all agencies.

A major advantage of this method is that it produces sharp edges and is easier to mark rough surfaces. However, a major disadvantage is that it may go on too fast, causing too much heat loss, resulting in a poor bond.

## **Application Considerations**

- **Bead distribution:** Reflective bead application should be uniform across the entire line. Check for proper volume, distribution, and embedment. Remember that material temperature and thickness can also affect bead embedment. The material guns must be synchronized with the bead guns to ensure that the entire surface area of the material is properly reflectorized.
- **Mixing:** Material should be agitated frequently.
- **Application temperature:** Changing ambient temperatures can affect application. Beware, wind chill may cool the gun. Raising the thermoplastic temperature to compensate for this may result in overheating that may char the material.
- **Material adhesion:** Thermal bonding is essential. After the material has cooled, the bond can be checked for adherence. Refer to the government agency or manufacturer specifications for this procedure.
- **Maximum heating time:** Total heating time must not exceed the material manufacturer's recommendations.
- **Maximum holding time:** Do not hold thermoplastic above 400°F for more than six hours.
- **Maximum temperature:** At no time shall the thermoplastic exceed 475°F. Care must be taken not to exceed the flash point indicated in the government agency or manufacturer specifications.
- **Maximum reheats:** Reheat granular thermoplastic a maximum three times, block two times. Color change indicates the material is overheated and beginning to scorch: white thermoplastic turns beige or creamy; yellow may become pale, or develop a brownish or greenish tint.
- **Cleaning:** Schedule the melter for cleaning if charred or burned particles remain on the screen during transfer. Completely flush the system when changing from alkyd to hydrocarbon or vice versa.

- Also, when changing from one color to another it is necessary to run several bags of the new color material through the entire system, and then discard. This will ensure that the newly applied marking is the proper color.
- **Operating tip:** Completely drain kettle before overnight shutdown whenever possible (this will aid in expediting the loading process for the next production day). Keep the kettle closed to protect from moisture and other contaminants.
- **Precautions:** Guard against temperature loss during transfer.
- **Safety tip:** Keep a cooler of ice water on the long-line or hand-line machine during application. In case of accidental contact with hot thermoplastic material, use the ice water to cool the affected area immediately. Follow the instructions on the Materials Safety Data Sheet or call a physician. **DO NOT ATTEMPT TO PULL THE HOT THERMOPLASTIC MATERIAL FROM THE AFFECTED AREA.**

## Material Testing

Quality Control/Quality Assurance (QC/QA) or acceptance testing will be as described in each government agency's materials testing specifications.

Derived quantities are based on 4-inch, 5-inch, and 6-inch wide lines using hydrocarbon material and will vary with material specific gravity, application methods, and pavement surface texture. Alkyd has approximately 2.5 percent less yield due to the specific gravity of the material.



The following chart contains a typical testing measure to determine thermal bonding and thickness. For additional accuracy, contact the thermoplastic manufacturer for their thermoplastic yields.

<b>APPROXIMATE THERMOPLASTIC YIELDS</b>						
	<b>For a 4-Inch Line</b>		<b>For a 5-Inch Line</b>		<b>For a 6-Inch Line</b>	
mils	lf/lb	lb/mile	lf/lb	lb/mile	Lf/lb	lb/mile
<b>SPRAY APPLICATION – DENSE GRADED SUBSTRATE</b>						
40	7.5	704	6.0	880	5.0	1,056
60	5.0	1,056	4.0	1,320	3.33	1,584
90	3.375	1,564	2.7	1,956	2.25	2,347
<b>SCREED/EXTRUSION – DENSE GRADED SUBSTRATE</b>						
60	4.5	1,173	3.6	1,467	3	1,760
90	3.125	1,690	2.5	2,112	2.08	2,534
125	2.25	2,347	1.8	2,933	1.5	3,520
<b>SCREED/EXTRUSION – OPEN GRADED SUBSTRATE</b>						
60	3.75	1,408	3.0	1,760	2.5	2,112
90	2.75	1,920	2.2	2,400	1.83	2,880
125	2.125	2,485	1.7	3,106	1.42	3,727

**Figure 4.1**  
**Approximate thermoplastic yields**

## **Inspection and Quality Control**

A vital component of quality assurance is inspection and quality control before, during, and after application. Regardless of the method of installation, there are some absolutes that must be followed.

These factors must be addressed to achieve good application:

- Type of material being used and thickness of application
- Temperature of material during application
- Ambient and surface conditions
- Reflective bead rate, pattern, and embedment

### **Type of Material**

The proper type of material (alkyd or hydrocarbon) must be used based on which application is being performed. Even if all the other factors are correct, they can never overcome the use of the wrong type of material. For example, hydrocarbon may not be the best choice when applying a stop bar at an intersection that has heavy truck traffic. The oil and gasoline drippings can break down the resin causing premature failure.

### **Material Temperature**

Temperature is very important in the proper mixing, melting, and bonding of thermoplastic. Temperature guidelines must be followed. Most manufacturers recommend 420°F as the ideal material temperature. If the material is too hot or has been heated too long, it will be scorched, which affects bonding, durability, and color. Material must also be agitated properly in the melting tank while being heated so that the intermixed reflective beads do not settle, thus altering the composition of the applied line. Also, thermoplastic that is too cold will cause application and durability problems. If thermoplastic is too cold, it will not melt into the roadway resulting in a poor bond. Thermoplastic that is too cold will also prevent the reflective beads from embedding deep enough, resulting in accelerated bead loss and lower retroreflectivity.

### **Ambient Conditions**

An air temperature of at least 50°F and rising is typically required. Windy conditions may affect ambient temperature and cause material displacement during application.

### **Pavement Surface Considerations**

Pavement surface temperature shall be at least 55°F and rising. The pavement surface must also be clean and dry. Keep in mind that surface conditions may change as the applicator goes from sunny to shady areas. When installed on porous surfaces, hot liquid thermoplastic fills voids, creating a good mechanical bond. Larger quantities of material may be required to yield the minimum thickness since the hot material sinks into the voids compounds and laitance must be removed. Primer sealer must be used on all concrete surfaces.

To ensure a good bond, the material should not be applied too quickly to avoid entrapping air. All grease, oil, dust, dirt, and debris must be removed prior to applying thermoplastic. In addition, on concrete surfaces, curing

### **Moisture**

If hot thermoplastic is applied over a moist surface, pits will appear in the line resulting in delamination. Thermoplastic shall not be applied if moisture is present on the road surface.

The following test may be conducted to determine if moisture is present. Method 1 or 2 can be used to test for moisture in pavement prior to installing thermoplastic; however, Method 2 is specific for thermoplastic.

Method 1: Tape an 6 inch by 6 inch sheet of thin plastic to the road surface, being careful to seal all the edges. After 20 minutes, examine the bottom of the sheet and the road surface. If moisture is present, do not apply thermoplastic. Wait from 30 minutes to an hour and repeat the test until there is no moisture on the road surface or on the underside of the plastic.

Method 2: Securely tape tar paper to the road surface. Apply marking material to the tar paper. After 1 minute, carefully remove tar paper from road surface wearing work gloves. Examine the underside of the tar paper. If moisture is present do not apply thermoplastic. Retest after sufficient drying time.

Figure 4.2 is a troubleshooting guide for thermoplastic application problem.

<b>Thermoplastic Application Troubleshooting</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
<b>Applied line appears rough on surface and edges.</b>	<ul style="list-style-type: none"> <li>- Material not cured</li> <li>- Material applied too cold.</li> </ul>	<ul style="list-style-type: none"> <li>- Loss of durability</li> <li>- Out of standards</li> </ul>	<ul style="list-style-type: none"> <li>- Raise material temperature.</li> <li>- Increase amount of material.</li> <li>- Decrease atomizing air pressure (if spray application).</li> </ul>
<b>Applied line is wavy with irregular edges.</b>	<ul style="list-style-type: none"> <li>- Material too hot.</li> <li>- Application pressure too high.</li> <li>- Extrusion gate too wide or material flowing past gate.</li> <li>- Road surface uneven.</li> </ul>	<ul style="list-style-type: none"> <li>- Poor reflectivity</li> <li>- Poor appearance</li> <li>- Poor durability</li> </ul>	<ul style="list-style-type: none"> <li>- Verify correct mat'l for type of application.</li> <li>- Lower pressure application.</li> <li>- Adjust application equipment/ lower application rate.</li> </ul>
<b>Line appears discolored, beige, or dingy (dull white).</b>	<ul style="list-style-type: none"> <li>- Material overheated or reheated too many times.</li> </ul>	<ul style="list-style-type: none"> <li>- Does not meet color standard.</li> <li>- Material is brittle - low durability.</li> </ul>	<ul style="list-style-type: none"> <li>- Adjust material temperature.</li> <li>- Discard material.</li> </ul>
<b>Line appears pitted.</b>	<ul style="list-style-type: none"> <li>- Trapped moisture</li> <li>- Material not cured</li> <li>- Trapped air</li> </ul>	<ul style="list-style-type: none"> <li>- Poor surface bond</li> <li>- low durability</li> </ul>	<ul style="list-style-type: none"> <li>- Stop operation until road dries.</li> <li>- Stop operation until primer cures.</li> <li>- Slow application to fill voids in open graded pavement.</li> </ul>
<b>Line appears lumpy</b>	<ul style="list-style-type: none"> <li>- Charred material</li> <li>- Unblended material</li> </ul>	<ul style="list-style-type: none"> <li>- Low durability</li> </ul>	<ul style="list-style-type: none"> <li>- If lumps appear burnt or dark in color, screen mat'l to remove lumps.</li> <li>- If lumps appear grainy or unmixed, hold material at 420°F until they dissolve.</li> </ul>
<b>Line appears stretched or pulled</b>	<ul style="list-style-type: none"> <li>- Material applied too cold.</li> <li>- Material applied too fast.</li> </ul>	<ul style="list-style-type: none"> <li>- Poor surface bond</li> <li>- low durability</li> </ul>	<ul style="list-style-type: none"> <li>- Raise temperature.</li> <li>- Lower speed of application.</li> </ul>

**Figure 4.2**  
**Thermoplastic Application Troubleshooting Guide**

<b>THERMOPLASTIC APPLICATION TROUBLESHOOTING - Continued</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
Line appears scarred or gapped	- Charred material - Dirt or debris on pavement surface.	- Poor surface bond - low durability	- If lumps appear burnt or dark in color, screen material to remove lumps. - Clean pavement surface.
Line appears uneven at beginning or end. Or line exhibits dribbles between skips.	- Applicator not adjusted properly	- Poor appearance	- Adjust applicator
Line marred by tire tracks	- Opened to traffic too soon.	- Poor reflectivity - Poor appearance	- Keep traffic off longer. - Add more beads.

<b>REFLECTIVE BEAD TROUBLESHOOTING</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
Line appears smooth, shiny, or glossy	- No reflective beads. - Insufficient reflective beads.	- No initial reflectivity	- Adjust or reposition bead gun - Need more beads
Line appears smooth or dimpled	- Beads have sunk too low	- No initial reflectivity	- Lower material temperature - Reposition bead gun - Increase bead application rate
Line appears glazed	- Beads are not embedded properly	- Early loss of initial reflectivity	- Raise material temperature. - Reposition bead gun.
Line appears cratered	- Beads have popped out	- Low initial reflectivity	- Raise material temperature - Reposition bead gun

**Figure 4.3**  
**Reflective Bead Troubleshooting Guide**

## References

See Appendix A for the following:

*VDOT Road & Bridge Specifications*

Section 704.01 thru 704.03 (a) 2. a.

704.01 thru 704.03 Description, Material Types, and Procedures

(a) Pavement Markings

2. Type B Markings

a. Thermoplastic (Class I)

See Appendix B for the following:

*Manual of Instructions*

Section 204.30 (a) (1) and (2)

(1) Sampling, Testing, and Approval

(2) Acceptance (Requires Cert. I) Both white and yellow material are tested however, yellow thermoplastic formulations have been pre-tested to assure acceptable nighttime color. Approved List # 43 (Yellow Thermoplastic Only)

See Appendix C for the following:

*Virginia Test Methods*

VTM-94 Quality Control Testing of Pavement Markings

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## Chapter 4 Knowledge Check

1. Liquid thermoplastic pavement marking material:
  - a) is a blend of solid materials that becomes liquid when heated.
  - b) is just like paint.
  - c) is not allowed for pavement markings.
  - d) sets-up when a catalyst is applied.
  
2. Markings constructed with liquid thermoplastic pavement marking materials are considered:
  - a) durable markings.
  - b) non-durable markings.
  - c) none of the above
  
3. Liquid thermoplastic comes from the manufacturer with reflective beads already intermixed.
  - a) True
  - b) False
  
4. Reflective beads have to be applied to liquid thermoplastic pavement markings.
  - a) True
  - b) False
  
5. Granular thermoplastic may be heated three (3) times.
  - a) True
  - b) False
  
6. Block thermoplastic may be heated three (3) times.
  - a) True
  - b) False

7. It is permissible to intermix alkyd and hydrocarbon thermoplastic materials in the same heating kettle.
  - a) True
  - b) False
  
8. Which of the following methods are acceptable for applying thermoplastic?
  - a) screed/extrusion shoe
  - b) ribbon gun
  - c) spray
  - d) all of the above
  
9. Virginia Road & Bridge Specifications requires the thickness of thermoplastic markings to be:
  - a)  $15 \pm 1$  mil when set
  - b)  $90 \pm 5$  mils when set
  - c)  $25 \pm 5$  mils when wet
  - d)  $1/8$  in when wet
  
10. Virginia specifies that glass beads be applied to the liquid thermoplastic immediately and uniformly across the entire line at the rate of:
  - a) 7 lb/100 ft<sup>2</sup>
  - b) 10 lb/gal
  - c) 6 lb/gal
  - d) 25 lb/gal



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# 5

## Preformed Thermoplastic

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### Learning Outcomes:

- ☑ Be aware of the components and characteristics of preformed thermoplastic
- ☑ Understand the application methods
- ☑ Know the steps for correct application
- ☑ Ability to perform inspection and quality control

### Preformed Thermoplastic

Preformed thermoplastic is a durable pavement marking system where thermoplastic symbols and legends are supplied in their final form and shape. Typically, the marking is supplied in large pieces, which are put together as a giant puzzle. Preformed thermoplastic pavement marking material combines the convenience of preformed markings with the performance qualities of hot applied thermoplastic. This heavy-duty intersection grade pavement marking material is ideal for high traffic areas where maximum wear and tear is present. Various brands are applied differently, so it is important to be familiar with the installation instructions for the type you are using. Always follow manufacturer instructions.

#### Type of Materials

There are two basic types of preformed thermoplastic markings. One requires preheating the road surface to a given temperature and the other does not.

### Components

Preformed thermoplastic markings are composed of pigments, reflective glass beads, fillers, binders and additives.

#### Pigments

Pigments are primarily used to impart color and to provide some chemical property, such as UV stability. Titanium dioxide is typically added to provide a white color. Lead chromate or organic pigment is typically added to provide a yellow color. Because of environmental and health concerns, the use of lead chromate compounds in pavement marking material is being eliminated.

### **Reflective Glass Beads**

Preformed thermoplastic is produced at the factory with a certain percentage of beads intermixed with the material. Additional beads are also added to the surface of the material when it is applied.

### **Fillers**

Fillers are typically a pigment and also provide bulk. Once the necessary color has been obtained, fillers such as a mixture of calcium carbonate, sand, and other inert materials are used to provide the volume of filler to give the necessary durability.

### **Binders (Resins)**

Binders are thermoplastic; they melt when heat is applied. The binder holds the pigments, reflective beads, and fillers together. Heat is used to form the initial shape. The material does not change chemically on heating and application.

### **Additives**

Additives such as plasticizers are added to control flow characteristics. Because the plasticizer can burn away, overheating and excessive reheating of preformed thermoplastic can affect the durability and overall quality of the marking.

### **Solvents**

Preformed thermoplastic pavement markings contain no solvents. It is the heating process that transforms the thermoplastic material from a solid into a liquid.

## **Material Characteristics**

Other factors that should be considered when using preformed thermoplastics are packaging, shelf life and primers/sealers.

### **Packaging**

Linear preformed thermoplastic is packaged in 3 to 4 foot long strips in sturdy cardboard boxes. Symbols are manufactured in pieces so they may be packaged and shipped easily.

### **Shelf Life**

Preformed thermoplastic has a shelf life of one year when stored inside at a temperature between 35°F and 95°F. Due to the heavy weight of the thermoplastic, no more than 25 packs shall be stacked on top of one another.

### **Primers/Sealers**

Primers/Sealers are used as a “bridge” between preformed thermoplastic and the surface where preformed thermoplastic will not readily adhere such as worn old HMA. Essentially, the primer bonds to the surface, and the thermoplastic bonds to the primer.

In order to prevent moisture from entering under the marking on PCC, it is important to seal the surface with a primer/sealer before the marking is installed. This will help prevent failures during freeze/thaw periods. Follow manufacturer recommended installation instructions to ensure that the correct type of primer/sealer is used.

## Application Methods

Preformed thermoplastic can be applied with a propane-fueled heat torch. When you arrive at the work location, review the temperature conditions, weather conditions, and pavement conditions to make sure that the preformed thermoplastic can be successfully applied based on manufacturer recommendations. If the situation does not comply with the manufacturer's recommendations, it is recommended that you wait until conditions improve before installing the preformed thermoplastic.

### Heat Torch

This method of application ensures that proper heat is applied to the preformed thermoplastic for a good bond to the road surface. The flame of the propane fueled heat torch should be moved in a fan shaped pattern to ensure even heating of the material. To obtain the best results, the torch should be moved in a slow even motion approximately 4 to 12 inches over the material. It is helpful to keep the wind at your back so the heat will be carried across the marking.

### Application on HMA

- 1) Thoroughly clean the application area. All loose particles (sand, dust, and other debris) must be removed. Utilize a power blower or compressed air if possible. Otherwise, sweep the entire area completely.



**Figure 5.1**  
**Cleaning pavement prior to application**

- 2) Ensure that no moisture is present prior to positioning the preformed thermoplastic material on the pavement surface. A heat torch may be used to remove moisture.
- 3) If required, preheat the surface to the temperature recommended by the manufacturer. Not all types of preformed thermoplastic require preheating.
- 4) Position the preformed thermoplastic on the pavement surface. Position all connecting parts of the marking on the road with the exposed beaded side up. Make sure the marking is properly placed and that there are no gaps between the segments of legends and symbols.



**Figure 5.2**  
**Placement of material**

- 5) Begin heating the material by moving the torch slowly and steadily over the material. Move the heat torch in a sweeping motion, approximately 2 feet wide over the marking at a height of 4 to 12 inches so that heat is evenly distributed across the marking, slowly melting the material. The preformed thermoplastic material must be heated throughout the process to achieve a bond with the pavement.



**Figure 5.3**  
**Arrow symbol being applied by heat torch.**

- 6) As you heat the preformed thermoplastic, monitor the visual signs or temperature requirements. It is important not to “overheat” the material otherwise the top coating of beads will sink into the preformed thermoplastic and be less retroreflective initially.

- 7) Inspect the freshly applied preformed thermoplastic marking to ensure that complete bonding has occurred over the entire area. After the preformed thermoplastic has cooled to near ambient temperature, try to lift an edge or cut an area in the interior of the material with a chisel where it appears to have been heated the least. Try to lift a portion of the material; if the material can be lifted without evidence of asphalt on the underside, insufficient heat has been applied. Simply reapply heat until adequate bonding has occurred. This is called an “adhesion test.”



**Figure 5.4**  
**Adhesion test being performed**

- 8) When performing the adhesion test on material applied on PCC roads, you should see a thin layer of the material adhering to the road surface. After performing the adhesion test, remember to reheat the tested area.
- 9) Additional reflective beads should be hand cast on top of the marking as preformed thermoplastic will cool and set rapidly within a few minutes of application. If desired, setting time can be accelerated with a spray of cool water or hand casting of additional reflective glass beads on top of the marking.

#### **Application on PCC or Old HMA**

- 1) Follow steps 1, 2 and 3 as stated above for application on HMA. Worn, polished concrete should be ground or milled so the surface becomes rough.
- 2) Lay out the marking pattern using chalk or crayon as required for guidance.
- 3) Apply primer/sealer to areas outlined in chalk or crayon. Allow the primer/sealer to dry until it will not transfer to the finger when touched. The more porous the surface, the more sealer is required. **Caution: Do not accelerate the drying process by using an open flame. The sealer may be flammable at this stage.**
- 4) It is important to apply primer/sealer to the entire area where the preformed thermoplastic will be applied.
- 5) Continue with steps 4 through 9 as stated above for application on HMA.

## Application Considerations

The pavement surface must be dry before applying preformed thermoplastic or primer/sealer. The pavement surface must also be free of dirt, dust, chemicals, and oily substances. Do not apply on top of any existing marking materials other than thermoplastic. However, first remove any loose thermoplastic and ensure that no moisture is present. If the old thermoplastic is oxidized (powdery surface), grind or heat it and scrape the top surface so fresh material is exposed. A primer/sealer may be required on PCC or old HMA. Make sure to follow manufacturer instructions. When applying preformed thermoplastic caution should be taken if loop detectors or other utilities are in the location.

Most preformed thermoplastic materials may be applied at air temperatures down to 35°F. However, surface temperature is critical and must conform to manufacturer recommendations. Protective clothing shall be worn during the installation of preformed thermoplastic pavement marking materials. The protective clothing shall consist of leather boots or work shoes, and long pants (note: synthetic fabrics should be avoided). General safety rules should be followed when using propane.

## Inspection and Quality Control

A vital component of quality assurance is inspection and quality control before, during, and after application. Regardless of the method of installation, there are some absolutes that must be followed.

The following factors must be addressed in order to achieve good application:

- Sufficient heating of the material during application
- Ambient and surface conditions
- Reflective bead embedment

Never leave the job site without performing the adhesion test (refer to Application on HMA Step 7, under Application Methods) to test the bond between the HMA and the material. Any deviation from manufacturer recommendations may result in application failures and shall be properly documented if unavoidable. Figure 5.5 is a troubleshooting guide for preformed thermoplastic application problems.

<b>PREFORMED THERMOPLASTIC APPLICATION PROBLEMS</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
Bonding/Adhesion	Surface not clean	Poor surface bond-low durability	Clean with blower to remove surface debris
Bonding/Adhesion	Moisture in road surface	Poor surface bond- low durability	Heat road to remove moisture
Bonding/Adhesion	Non-conforming existing marking (i.e. tape, paint, etc)	Poor surface bond- low durability	Remove or install before or behind old marking
Bonding/Adhesion	Deteriorating road surface	Poor surface bond- low durability	Resurface
Bonding/Adhesion	Too little heating	Poor surface bond- low durability	Visual signs/temperature should be observed
Bonding/Adhesion	Deicing chemicals on road surface	Poor surface bond- low durability	Power wash area or wait until after rain to install
Bonding/Adhesion	Dated material	Poor surface bond- low durability	Rotate stock/ 1 year shelf life
Bonding/Adhesion	Curing agents on Portland Concrete Cement	Poor surface bond- low durability	Blast or power wash
Bonding/Adhesion	Worn polished aggregates on road surface	Poor surface bond- low durability	Grind and blow clean
Bonding/Adhesion	Lack of sealer	Poor surface bond- low durability	Use sealer
Low or no retroreflectivity	Too little or too much heat	Glass beads not embedded enough or sunken into material	Look for visual signs when heating
Low or no retroreflectivity	No surface beads/ poor hand casting	Too few glass beads/ unevenly distributed	Use shaker to apply beads evenly
Low skid resistance	Too much heat	Glass beads buried in material	Look for visual signs
Low skid resistance	No surface beads/ poor hand casting	No beads to assist with skid resistance	Use shaker to apply beads evenly
Smearing and discoloration	Opened to traffic before marking has cooled down	Reduced visibility	Use glass beads or water to cool material down or wait until cool
Discoloration of newly installed marking	- Tracking from new HMA - Oil dripping or other chemical spills	Reduced visibility	Use additional reflective beads to protect the new marking
Gaps between pieces not melted together	- Too little heat - Shelf life exceeded - Pieces not touching before heating	Poor adhesion/ poor appearance	- Heat more - Rotate stock - Make sure pieces are touching before heating

**Figure 5.5**  
**Preformed Thermoplastic Application Problems**

## References

See Appendix A for the following:

*VDOT Road & Bridge Specifications*

Section 512.03 (n)

(n) Construction Pavement Message Markings

Section 704.01 thru 704.03 (a)

704.01 thru 704.03 Description, Material Types, and Procedures

(a) Pavement Markings (First paragraph after Table VII-1) Message Markings

For all other information see the **Manufacturers Material Safety Data Sheets (MSDS) and Application Instructions.**

Preformed Thermoplastics are currently being qualified through NTPEP test procedures. No specifications have been established in the VDOT Road & Bridge Book at this time.



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## Chapter 5 Knowledge Check

1. There is no need to add glass beads to newly applied preformed thermoplastic since they are intermixed with the material at the factory.
  - a) True
  - b) False
  
2. When stored inside at a temperature between 35°F and 95°F, preformed thermoplastic has a shelf life of :
  - a) 6 months
  - b) 3 months
  - c) 1 year
  - d) 18 months
  
3. Preformed thermoplastic is considered to be a:
  - a) durable pavement marking
  - b) non-durable pavement marking.
  
4. When preformed thermoplastic has been positioned on the pavement, it is necessary to heat only the edges of the material to achieve a good bond with the pavement.
  - a) True
  - b) False
  
5. When a small portion of freshly applied preformed thermoplastic has been chiseled up to inspect for bonding with the pavement, it should \_\_\_\_\_ on the underside.
  - a) be clean
  - b) have some asphalt stuck to it
  - c) look powdery

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# 6

## Epoxy Resin

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### Learning Outcomes:

- Know components and characteristics of Epoxy Resin
- Understand the application methods

### Epoxy Resin

Epoxy resin is a durable, two-component pavement marking material consisting of a pigmented resin base and a hardener. Before installation, both components are mixed at a ratio of 2 parts resin: 1 part hardener, and applied by a specialized epoxy application truck. These criteria are based on the manufacturer's specifications. This material is sprayed and combined with drop-on reflective beads to provide nighttime retroreflectivity.

### Components

#### Pigments

Epoxy resin pavement markings use pigments, similar to all other pavement marking materials. Pigments are ground and dispersed into the resin side of the system.

#### Mixture

The epoxy resin is mixed with the hardener creating a binder system that is sprayed to form a durable pavement marking. To realize all the advantages of an epoxy system, it is critical that the components are properly mixed. Each component is stored in separate tanks on the epoxy application truck and heated to temperatures in accordance with manufacturer recommendations. Proportioning pumps draw the material at a 2:1 ratio. The material is then mixed by a static mixing tube or impingement gun and sprayed onto the road surface.

#### Reflective Beads

Beads are uniformly applied across the entire width of the marking by a bead gun located immediately behind the epoxy spray gun. A double drop method is typically used for the application of the beads. Large and small beads are typically applied at a rate of 11 to 13 lbs/gal for each bead size for a total of 25 lbs/gal.

## Characteristics of Epoxy Resin

Epoxy striping material is classified as 100 percent solids, meaning the evaporation of solvents or water is not used to cure the material. Thus, without this evaporation process, a typical application rate of 20 mils wet yields 20 mils of dry material. Epoxy striping material is cured via a thermoset chemical reaction.

### Advantages

- Good wet-night visibility
- Can be applied at lower temperature
- Makes a mechanical bond with the road surface
- Good bead retention
- Low profile resists snowplow damage
- Epoxy does not contribute volatile organic compounds

### Disadvantages

- Slow cure (no-track time)
- Mix proportions are critical

## Method of Application

The mixed epoxy material is heated and sprayed onto the road surface. The equipment performing this operation is a specially designed epoxy truck that cannot be used to apply any other liquid binder material. Because of the composition of the material, environmental temperatures will increase or decrease the no-track times.

### Shelf Life

Epoxy material has a shelf life of one year. The manufacture date should be stated in the shipping documents.

### How to Mix the Material

The mix ratio for epoxy resin material is typically 2:1 (2 parts resin to 1 part hardener). It is very important that components are mixed thoroughly and at the correct ratio prior to being sprayed on the road surface. The mixing operation is a function of the epoxy installation truck. It shall be performed in accordance with manufacturer's recommendations.

### Temperature

Epoxy shall not be applied unless the surface and ambient temperatures are a minimum of 50°F and rising. Remember that no-track times increase as the temperature decreases and vice versa. Always check temperature minimums (air and surface) when applying epoxy.

### Pavement Surface Considerations

The road surface shall be free of curing compounds, laitance, oil, grease, salt, dust, or other debris. Epoxy materials shall not be applied if moisture is present on the road surface. Epoxy material must be applied according to the manufacturer's instructions. Epoxy materials can be applied over other epoxy materials. However, this shall only be done one time. Beyond that, removing the old material is required.

<b>EPOXY RESIN SPRAY APPLICATION TROUBLESHOOTING</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
<b>Heavy centers</b>	-Inadequate fluid delivery	-Tracking -Erratic wear patterns - "railroad tracks" initially	-Increase fluid pressure -Decrease tip size
<b>Light centers</b>	-Inadequate fluid delivery	-Tracking -Erratic wear patterns - "railroad tracks" initially	-Increase tip size - Replace tip
<b>Surging pattern</b>	-Pulsating fluid delivery	-Does not conform to standards. -Erratic wear patterns	-Reduce demand - Remove restrictions in supply system. - Check supply hose for leaks
<b>"Lop-sided" millage</b>	- Worn tip sides - Clogged tip	-Erratic wear patterns	- Replace tip - Clean tip
<b>Line too wide</b>	- Gun too high - Fan angle on tip too wide	-Does not meet standards	-Lower gun - Adjust tip size if necessary
<b>Line too narrow</b>	- Gun too low -Fan angle on tip too narrow	-Does not meet standards	- Raise gun - Adjust tip size if necessary
<b>Applied line too thin</b>	- Inadequate tip hole - Traveling too fast for tip size - Change in delivery pressure	-Does not meet standards -Poor durability	- Change tip size - Decrease speed of application - Verify pressure settings
<b>Applied line too thick</b>	- Tip size too large - Traveling too slow for tip size - Change in delivery pressure	- Too long a cure time - May cause shape problems - Poor retro-reflectivity to	- Change tip size - Increase speed of application - Verify pressure settings
<b>Too much hardener</b>	- Displacement pumps not properly synchronized.	- Dark or black lines -Takes too long to cure	- Adjust pumps
<b>Too little hardener</b>	- Displacement pumps not properly synchronized.	- Poor durability	- Adjust pumps

**Figure 6.1**  
**Epoxy Resin Spray Application Troubleshooting**

## References

See Appendix A for the following:

*VDOT Road & Bridge Specifications*

Section 246.01 thru 246.02 (a) (a)

Color Requirements

Section 246.02 (e) 1. and 2.

(e) Epoxy Resin Material (Type B, Class III)

1. Composition

2. Physical Requirements

Section 704.01 thru 704.03 (a) 2. c.

704.01 thru 704.03 Description, Material Types, and Procedures

(a) Pavement Markings

2. Type B Markings

c. Epoxy Resin (Application and Bead Application)

See Appendix B for the following:

*Manual of instructions*

Section 204.30 (a) (1) and (2)

(1) Sampling, Testing, and Approval

(2) Acceptance (Requires Cert. I)

See Appendix C for the following:

*Virginia Test Methods*

VTM-94 Quality Control Testing of Pavement Markings

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## Knowledge Check Chapter 6

1. Epoxy pavement marking material:
  - a) is a two component system.
  - b) has glass beads intermixed by the manufacturer.
  - c) uses a catalyst.
  - d) all of the above
  
2. Epoxy pavement marking material does not contain solvent.
  - a) True
  - b) False
  
3. For epoxy pavement markings, the ratio of resin to hardener is:
  - a) critical.
  - b) specified by the manufacturer.
  - c) 2 parts resin to 1 part hardener
  - d) all of the above
  
4. The Virginia specified thickness for epoxy pavement markings is:
  - a)  $15 \pm 2$  mils when wet
  - b)  $12 \pm 1$  mil when set
  - c)  $20 \pm 1$  mil when wet
  - d)  $90 \pm 5$  mils when wet
  
5. The equipment used to apply epoxy resin pavement markings cannot be used to apply any other liquid binder material.
  - a) True
  - b) False
  
6. The minimum surface temperature for applying epoxy markings in Virginia is:
  - a) 30°F+
  - b) 35°F +
  - c) 50°F+
  - d) 60°F +
  
7. Glass beads should be applied to the surface of epoxy resin at the rate of:
  - a) 6 pounds per gallon
  - b) 25 pounds per gallon
  - c) depends on epoxy temperature
  - d) depends on surface temperature

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# 7

## Polyurea Resin

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### Learning Outcomes:

- Know components and characteristics of Polyurea Resin
- Understand the application methods

### Polyurea Resin

Polyurea marking material is a durable, two component pavement marking. Polyurea materials cure by reacting amine terminated resins with an isocyanate component which forms a urea linkage. Polyurea materials can cure to a hard film within one to two minutes and continue to fully cure after application therefore; formulations are adjusted for reaction (cure) times for the desired performance properties.

### Components

#### Pigments

Polyurea pavement markings use pigments similar to all other pavement marking materials. Pigments are ground into the resin portion to achieve the desired color, contrast ratio and durability.

#### Mixing

Polyurea pavement markings must be completely mixed using two parts Component A (amine) to one part of Component B (isocyanate) when applied. It is very important this ratio is consistent throughout the application. Each component is stored in separate pressurized tanks on the application equipment and is heated to the correct temperatures in accordance with the manufacturer's recommendations. Proportioning pumps draw the material in a 2:1 ratio to an airless static mixing tube or impingement mixing gun and sprayed applied to the road surface.

### **Reflective Beads and/or Optics**

Reflective beads or optics are uniformly applied to the entire width of the marking by a bead gun located immediately behind the polyurea spray gun. A double drop method is typically used for applying large and small glass beads or a combination of glass beads with other optic materials.

Prior to the application of polyurea markings, the contractor and the inspector must verify the specifications or contract documents to ensure the application meets requirements.

Beads are uniformly applied across the entire width of the marking by a bead gun located immediately behind the epoxy spray gun. A double drop method is typically used for the application of the beads. Large and small beads are typically applied at a rate of 11 to 13 lbs/gal for each bead size for a total of 25 lbs/gal.

### **Characteristics of Polyurea**

Polyurea marking material is classified as a 100 percent solids material, meaning the evaporation of solvents or water does not take place. With no evaporation process during cure, the two components react with each other to form a dry cured marking. Polyurea is typically applied at a 20 +/- 1 mil wet film thickness and will yield a 20 mil dry film thickness after curing.

#### **Advantages**

- Good Abrasion resistance
- Can be applied in a wide range of temperatures
- Makes a mechanical bond with road surfaces
- Fast cure times are achieved
- More tolerant to moisture than other markings

#### **Disadvantages**

- Mix proportions are critical
- Incomplete mixing will increase porosity and result in poor adhesion

### **Method of Application**

Polyurea is applied using a specially designed truck that is capable of applying two parts of the Part A component by volume to one part of Part B component by volume. Separate tanks containing Parts A and B materials are under pressure to assist the proportioning pumps in drawing the correct ratio of materials through the plumbing system for heating, mixing and spraying. Glass beads and/or optics are also stored in separate tanks under pressure. Prior to application, all equipment, spray guns and bead guns shall be calibrated to ensure the specified amounts of material components as well as glass beads and/or optics are supplied at the correct ratios for the specified application.

It is very important to verify the manufacturer's installation instructions for material pressures required, for material components, for glass beads and/or optics applied as well as truck speed prior to and during the application of polyurea markings.

### **Shelf Life**

Polyurea materials have a shelf life of 24 months in their original unopened containers. Shipping documents and containers shall have identification numbers or batch dates for confirmation of when products were manufactured. Materials shall be stored in accordance with the manufacturer's instructions. It is very important to verify the manufacturer's requirements for shelf life and storage conditions have been met prior to loading operations.

### **Temperature**

Polyurea markings can be applied in a wide range of ambient temperatures. However, the marking contractor and the inspector must verify not only ambient conditions, but also the material and surface temperatures. With pigmented resinous materials and cold temperatures, the viscosity will increase (become thicker) and in warm or hot conditions the materials will have a decreased (or thinner) viscosity. All temperature requirements shall be in accordance with the manufacturers Product Data Sheet (PDS). Polyurea marking material can be applied at an ambient temperature of 35°F.

It is very important to verify the manufacturer's requirements for material, surface and ambient conditions are in accordance with the manufacturers Product Data Sheet (PDS) prior to and through out the application of polyurea markings.

### **Pavement Surface Considerations**

Road surfaces shall be free of curing compounds, oil, grease, salt, dirt, debris, moisture and other debris that may reduce the adhesion or durability of the applied marking. Polyurea markings may be applied directly after hot mix asphalt (HMA) paving operations providing the mat has cooled sufficiently to hold the marking equipment without deforming the road surface.

It is very important for the contractor and inspector to verify surface conditions in accordance with the manufacturers Product Data Sheet (PDS) prior to and through out the application of polyurea markings.

### **Cure Time**

There are several stages of cure when considering paint and coatings. The typical field measurement for drying or curing of pavement markings is called "No-Track-Time." Polyurea markings will typically reach a no-track condition in approximately two minutes where other manufacturers may formulate their products to reach a no-track condition in seven to ten minutes. This time may vary depending upon air, surface and material temperatures.

It is very important for the contractor and inspector to verify no-track-times achieved given the temperatures encountered. No-track-time shall be in accordance with the manufacturers Product Data Sheet (PDS) prior to and through out the application of polyurea markings.

**Quality Control of Application and Documentation**

All verified information from Manufacturer’s Product Data Sheets (PDS), material documentation, work completed and quality control measurements taken shall be reported to the Department using an approved Pavement Marking Daily Log and Quality Control Report, Form C-85. Polyurea, binder and glass beads are approved as a system per VDOT’s Approved List of materials.

Polyurea Spray Application Troubleshooting			
Conventional Application			
Problem	Cause	Effect	Remedy
Heavy centers	<ul style="list-style-type: none"> <li>- Material tank pressure too</li> <li>- Inadequate fluid delivery</li> <li>- Fluid or gun tip clogged</li> <li>- Material too cold</li> </ul>	<ul style="list-style-type: none"> <li>- Tracking</li> <li>- Erratic wear patterns</li> <li>- "Railroad Tracks" initially</li> </ul>	<ul style="list-style-type: none"> <li>-Verify delivery pressure</li> <li>- Decrease tip size</li> <li>- Clean fluid line and gun tip</li> <li>-Verify material temp.</li> </ul>
Light centers	<ul style="list-style-type: none"> <li>- Inadequate fluid delivery</li> <li>- Fluid or gun tip clogged</li> <li>- Material too cold</li> </ul>	<ul style="list-style-type: none"> <li>- Erratic wear patterns</li> <li>- Poor durability</li> <li>- No durability</li> </ul>	<ul style="list-style-type: none"> <li>Verify delivery pressure</li> <li>-Increase tip size</li> <li>-Clean fluid line and gun tip</li> <li>-Verify material temp.</li> </ul>
Surging patterns	<ul style="list-style-type: none"> <li>- Pulsating material delivery</li> <li>- Proportioning pump or compressor malfunction</li> </ul>	<ul style="list-style-type: none"> <li>- Erratic application</li> <li>- Non conformance to Spec.</li> </ul>	<ul style="list-style-type: none"> <li>-Verify consistent delivery pressure</li> <li>-Check for supply line for leaks</li> <li>-Clean supply line and gun tip</li> </ul>
Uneven millage across width	<ul style="list-style-type: none"> <li>- Gun not aligned</li> <li>- Worn gun tip</li> <li>- Clogged gun tip</li> </ul>	<ul style="list-style-type: none"> <li>- Erratic wear pattern</li> <li>- Poor durability</li> <li>- Non conformance to Spec.</li> </ul>	<ul style="list-style-type: none"> <li>-Verify gun alignment</li> <li>-Clean gun tip</li> <li>-Replace gun tip</li> </ul>
Line too wide	<ul style="list-style-type: none"> <li>- Gun too high</li> <li>- Gun tip fan pattern too wide</li> </ul>	<ul style="list-style-type: none"> <li>- Non conformance to Spec.</li> </ul>	<ul style="list-style-type: none"> <li>-Lower gun</li> <li>-Verify gun tip orifice</li> </ul>
Applied line too thin	<ul style="list-style-type: none"> <li>- Incorrect tip size</li> <li>- Appl. speed too fast</li> <li>- Change in delivery pressure</li> <li>- Material too hot</li> </ul>	<ul style="list-style-type: none"> <li>- Poor Durability</li> <li>-Non conformance to Spec.</li> </ul>	<ul style="list-style-type: none"> <li>Change gun tip</li> <li>-Decrease appl. speed</li> <li>-Verify delivery pressure</li> <li>-Verify material temp.</li> </ul>
Applied line too thick	<ul style="list-style-type: none"> <li>- Incorrect gun tip</li> <li>- Appl. speed too slow</li> <li>- Change in delivery pressure</li> <li>- Material too cold</li> </ul>	<ul style="list-style-type: none"> <li>-Longer cure times</li> <li>-Over embedment of glass and/or optics</li> </ul>	<ul style="list-style-type: none"> <li>- Verify gun tip orifice</li> <li>-Increase appl. speed</li> <li>-Verify delivery pressure</li> <li>-Verify material temp.</li> </ul>
Line not curing	<ul style="list-style-type: none"> <li>-Insufficient proportion of hardener to resin</li> <li>-Air, surface or material too cold</li> </ul>	<ul style="list-style-type: none"> <li>-Extended time in lane</li> <li>-Markings being tracked</li> <li>-Eradicate and replace</li> </ul>	<ul style="list-style-type: none"> <li>Verify delivery pressure of both components</li> <li>-Verify air, surface and ambient conditions</li> </ul>

## Chapter 7 Knowledge Check

1. What is one advantage for using Polyurea pavement marking material?
  - a) Good abrasion resistance.
  - b) Is mixed with water to apply to road surface.
  - c) Is applied using a latex paint equipment.
  - d) Mix proportions are not critical.
  
2. Polyurea pavement marking material is normally applied at the following thickness:
  - a) 10 mils
  - b) 20 mils
  - c) 50 mils
  - d) 120 mils
  
3. Polyurea pavement marking material cure time is less than one minute.
  - a) True
  - b) False
  
4. What is the sheet called where manufacturer's product information is found for polyurea application requirements?
  - a) Manufacturer's Sheet Products (MSP)
  - b) Performance Product Sheet (PPS)
  - c) Product Data Sheet (PDS)
  - d) Data Product Materials (DPM)
  
5. Polyurea is typically applied at a 20 mil wet film thickness and will yield a 20 mil dry film thickness after curing.
  - a) True
  - b) False

## References

See Appendix A for the following:

*VDOT ROAD & BRIDGE SPECIFICATION BOOK*

To be added.

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# 8

## Preformed Tape

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### Learning Outcomes:

- Know the types of preformed tapes
- Understand the application methods

### Preformed Tapes

Preformed tapes come in rolls. The tape consists of pigments, resins, and reflective materials (glass beads or reflective elements) and comes ready to use with or without adhesives. Additional adhesive (primer) can be applied to the pavement to enhance the bond. This material can be used for lane lines, legends, symbols, and transverse markings.

### Components

Tapes are similar to other markings: pigments are used to produce color, and suitable resins are used to provide the necessary wear characteristics.

#### Resins

Pre-reacted resins hold the beads and pigments in place. For this reason, the tape is ready for installation upon delivery. Additionally, there may be an adhesive backing on the bottom side of the resin for adhesion to the roadway surface.

#### Reflective Materials

The manufacturer has already added reflective materials to the resin. Additional reflective materials are not added in the field.

#### Primers/Glues

Tapes, depending upon the type, may use primer and/or adhesives in addition to those already applied by the manufacturer. These various compounds are used to promote adhesion to the roadway surface.

Generally, tape that has been properly stored (sheltered at room temperature) will be usable for a period of one year. In addition to the normal requirements for accepting materials on the project, the manufacturer's expiration date must also be clearly shown. Certification letters for the tape, and for all related sealers and primers must be provided.

## Types of Preformed Tapes

Tapes fall into one of two categories: permanent and removable.

### Permanent Tapes

Permanent pavement marking tapes are either flat or patterned. These tapes may require the use of a primer/sealer (unless otherwise recommended by the manufacturer). The cost of the sealer is usually included in the price of the tape. When applied properly, this material resists movement under traffic. A primer/sealer shall be applied to the roadway prior to the application of this material. Permanent tapes are generally used for longitudinal edge lines, skip lines, stop lines, crosswalks, legends, and symbols.

Patterned tape is textured, and is sometimes referred to as “profile tape.” Patterned tape used for longitudinal edge lines or skip lines on HMA is usually in-laid.

### Removable Tapes

Removable tapes can be removed (pulled from the pavement surface) without using heat, solvents, or mechanical eradication. Generally, these tapes should be removed within 6 months of installation and should not leave any permanent residue on the road surface. The use of primers or additional glue may or may not be required. Although these tapes are similar in appearance to permanent tape, they may have an additional fiber mesh bonded in the resin. This mesh provides the necessary tensile strength allowing the tape to be pulled up from the roadway without breaking or tearing.

Blackout or black tape is another type of removable tape that is used to temporarily (no more than 120 days) cover existing marking on an HMA road. Black tape, however, does not contain any reflective material. For example, if a permanent lane needs to be temporarily moved during construction and then reestablished at a later time, the black tape could be applied over the existing lines to hide them and new lines applied with another removable tape. When construction is complete, the original lanes can be reestablished by removing the black tape and the other temporary tapes. Black tape shall not be used on PCC roads.

## Application Methods

Flat and patterned tapes are normally installed by using a roller applicator. This is a walk-behind push cart that holds and applies one or two rolls of tape. The applied tape is then pressed onto the road surface using a walk-behind tamper cart. Weights are stacked on this cart to provide the necessary force to press the tape to the road. The tape manufacturers specify the required weight needed for each type of tape. This roller applicator and tamper procedure helps ensure that the tape is applied straight, especially in long line applications. If the manufacturer requires additional primers or glues, they can either be rolled or sprayed onto the tape and/or road surface.

- When patterned tape is in-laid, no primer is used. It is in-laid with the last pass of the paving roller; the temperature of HMA is critical.

All tape manufacturers provide installation guides to address concrete and asphalt surface conditions.

## Pavement Surface Considerations

The minimum application temperature is determined by manufacturer recommendations. Ensure good adhesion by making sure that the surface is clean, dry and free of contaminants. The VTM-94 moisture test should be performed prior to installing PM Tape.

<b>PREFORMED TAPE APPLICATION TROUBLESHOOTING</b>			
<b>Problem</b>	<b>Cause</b>	<b>Effect</b>	<b>Remedy</b>
<b>Material rolls up or shifts</b>	-Not bonded prior to traffic - Tape crossing traffic - No primer adhesive	-Loss of effectiveness	-Replace material with proper tamping, adhesive and primer.
<b>Poor Material adherence</b>	-Moisture in pavement -Dirty surface -No primer -Expired shelf life	-Errant delineation  -Loss of Material -No delineation	-Replace material applying properly

**Figure 8.1**  
**Preformed tape troubleshooting chart**

Since the material is preformed, the only actions that are necessary are being sure that the material is the correct material specified, is placed properly, and is applied properly. FOLLOW MANUFACTURER RECOMMENDATIONS.

## References

See Appendix A for the following:

*VDOT ROAD & BRIDGE SPECIFICATION BOOK*

Section 512.03 (i)

- (i) Construction Pavement Marking  
(Types D and E)

Section 704.01 thru 704.03 (a) 2. d.

704.01 thru 704.03 Description, Material Types, and Procedures

- (a) Pavement Markings
  - 2. Type B Markings
    - b. Plastic Backed Preformed Tape (Installation Requirements)

See Appendix B for the following:

*MANUAL OF INSTRUCTIONS*

Section 204.30 (a) (1) and (2)

- (1) Sampling, Testing, and Approval
- (2) Acceptance (Requires Cert. II)  
Approved List # 17

Follow Manufacturers installation instructions.

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## Knowledge Check Chapter 8

1. Preformed tapes do not contain pigments.
  - a) True
  - b) False
  
2. Preformed pavement marking tapes can be used for:
  - a) permanent applications.
  - b) temporary construction zone markings.
  - c) both a & b
  
3. When patterned tape is inlaid, no primer is used.
  - a) Never use a primer
  - b) Use a primer when the temperature is below 80 °F.
  - c) Follow the manufacturer's installation instructions.
  
4. Glass beads are applied to pavement marking tapes:
  - a) 6 lb per 105 ft
  - b) 7 lb per 360 ft
  - c) by the manufacturer
  
5. The minimum surface temperature at which pavement marking tapes may be applied is:
  - a) 40°F +
  - b) 50°F +
  - c) 60°F +
  - d) as recommended by the manufacturer
  
6. Virginia specifications allow pavement marking tapes to be tamped with vehicle tires.
  - a) True
  - b) False

7. Virginia Road & Bridge specifications state that the contractor is responsible for supplying a copy of the manufacturer's installation recommendations to the project inspector.
- a) True
  - b) False
8. Virginia designated Type E tape is:
- a) red
  - b) yellow
  - c) black
  - d) white

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# 9

## Pavement Markers

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### Learning Outcomes:

- Know the types of pavement markers
- Understand the application methods

### Pavement Markers

Pavement markers are pre-manufactured, reflectorized devices that provide positive in-roadway delineation at night, especially during inclement weather and in areas where roadway alignment variations dictate guidance that cannot be achieved by pavement markings and roadside delineation alone. The Manual on Uniform Traffic Control Devices (MUTCD) allows the use of pavement markers as a supplement to traditional longitudinal markings. Pavement markers cannot be used as a replacement for standard linestriping.

### Types of Pavement Markers

Pavement markers are composed of a base material that is designed to resist impacts from traffic and to provide an adherent surface securing the marker to the roadway. Some agencies use a series of hard, non-reflectorized raised markers to form a line where overhead lighting is available. Other agencies require that all pavement markers be reflectorized. The retroreflective surface can either be reflective sheeting or a prismatic reflector. The outer cover of the prismatic area can be either plastic or glass.

The most common types of pavement markers are raised, temporary, recessed snow plowable, and plastic inlaid markers.

### Raised Temporary Markers

Raised temporary markers are normally used with construction zone markings. They are commonly referred to as “temporary markers” or “RPMs”. Specifications often require the use of temporary pavement markers in transition areas of work zones that will encroach upon the traveled roadway for a period of more than two days, and in other areas as required by the engineer.

These markers are glued to the roadway with a bitumen or epoxy adhesive. Most markers of this type consist of a plastic body with a reflective surface. They must be inspected on a routine basis and placed as necessary when they become damaged or removed by traffic.

### Temporary Overlay Markers (TOMs)

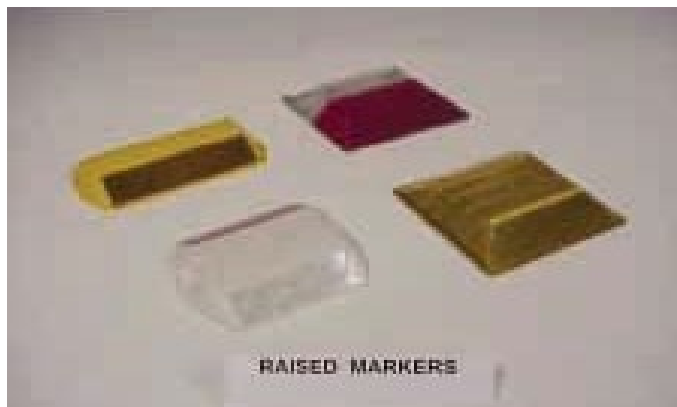
This is a flexible temporary marker used per the specification up to 14 days on asphalt overlays. See figure 9.1



**Figure 9.1**  
**Temporary Overlay Marker**

### Peel and Stick Marker

Another general type of temporary raised marker is the “peel and stick type”. These markers generally have a paper backing that is removed to expose a butyl/adhesive pad. The marker is then applied to the roadway and firmly pressed in place. Figure 9.2 shows a variety of raised temporary markers.



**Figure 9.2**  
**Raised temporary markers**

### Recessed, Snow Plowable Marker System

This marker system consists of a tapered slot that is cut into the roadway. A marker similar to the raised marker is affixed in the slot using epoxy or other approved adhesive. It is designed to allow the snowplow blade to slide over the slot without contacting the marker since it is just below the roadway surface.



Recessed snow plowable markers can only be used effectively where there is sufficient traffic speed (35+ mph) to “whip” out any water and/or dirt that may collect on or in front of the marker lenses. This type of marker has a plastic body with a reflective surface. Figure 9.3 shows several recessed, snow plowable pavement markers.



**Figure 9.3**  
**Recessed snow plowable markers**

### **Plastic Inlaid Markers (PIMs)**

This system consists of a reflective marker lens glued in a protective plastic holder. This plastic holder and lens is positioned and epoxied into the plunge cut in the middle of a 7-foot groove that is cut in the pavement surface. The system is designed so that a snowplow blade will ride over the groove and reflective lens, leaving the lens undamaged. The reflective lens can be replaced in the plastic holder using an approved adhesive.

While this system is very visible and long lasting, it needs to be installed and maintained correctly to ensure the plastic holder and lens stays in place in the road.



**Figure 9.4**  
**Plastic Inlaid Marker**

**Installation Procedure:**

1. **Determine the correct marker location**

- In pavement with no deficiencies
- Not on joints or cracks
- Away from lane striping

2. **Cut the groove**

The cutting equipment will need to be calibrated to cut the correct groove and plunge cut per the specifications with the following critical parts:

- Groove length and correctly tapered ends
- Groove depth – maximum ½” depth
- Center plunge cut depth – maximum 1” depth

Cut the 7-foot tapered groove and make the center plunge cut in the middle of the groove. The groove and center plunge cut will need to be cleaned out of any loose debris or dirt prior to adding the epoxy adhesive.

3. **Fill cut with epoxy**

- Partially fill the center plunge cut with the correctly mixed epoxy.

4. **Place the marker holder**

Place the marker holder and lens, and add additional epoxy until the epoxy is even with the top of the marker holder. Be sure that NO epoxy covers the reflective lens and that the marker holder does not float up out of the epoxy before the epoxy hardens.

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## References

See Appendix A for the following:

*VDOT Road & Bridge Specification Book*

Section 512.03 (k)

(k) Temporary Pavement Markers

Section 704.03 2. (c) 1. and 2. (c)

Pavement Markers

1. Plastic Inlaid Markers
2. Raised Pavement Markers

See Appendix B for the following:

*MANUAL OF INSTRUCTIONS*

Section 204.30 (a) (1) and (2)

(1) Sampling, Testing, and Approval

(2) Acceptance (Requires Cert. II)

Approved List # 22

Also, follow Manufacturers installation instructions.

## Knowledge Check Chapter 9

1. Pavement markers may be used in lieu of pavement markings.
  - a) True
  - b) False
  
2. The most common types of pavement markers are:
  - a) raised, temporary
  - b) plastic inlaid markers
  - c) recessed, snow plowable
  - d) all of the above
  
3. Raised temporary pavement markers are glued to the roadway with a bitumen or epoxy adhesive.
  - a) True
  - b) False
  
4. Raised temporary pavement markers are normally used with:
  - a) permanent markings
  - b) construction zone markings
  - c) a & b
  - d) none of the above
  
5. Plastic inlaid markers are installed using bitumen adhesive.
  - a) True
  - b) False



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# 10

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## Learning Outcomes:

- ☑ Understand the importance of quality and workmanship
- ☑ Be familiar with pre-installation considerations and responsibilities
- ☑ Know proper installation procedures
- ☑ Understand the Acceptance of Materials
- ☑ Comprehend the Inventory Tracking Program

## Quality and Workmanship

The successful installation of pavement markings depends upon a logical sequence of events that involves planning, installation, and acceptance. These steps are necessary to ensure that:

- All materials have been tested in accordance with the specifications. Quality Control/Quality Assurance (QC/QA) or acceptance testing shall be performed as set forth in each agency's material testing specifications.
- Proper markings are installed at the intended locations.
- The completed installation meets the criteria established in the specifications for quality and workmanship.
- The finished product is aesthetically pleasing and provides clear direction to motorists.

## Pre-installation Considerations

To ensure quality, there are some important steps that must be taken before the pavement marking material is installed.

The four primary objectives of project management that must be met before any markings are applied are Material Verification, Road Surface Considerations, Review of Pavement Marking Layout Details, and Pre-construction Discussion.

### **1) Material Verification**

To verify that the correct materials are supplied and used on the job, the contract material specifications must first be reviewed. Material test results and/or products must then be compared against specifications to ensure that they are correct. Project inspectors and contractors must be familiar with the application requirements for all the specified material through addendums or special provisions. All additions to the published specifications, as well as the effective date of the specifications and standards, are listed in the job proposal.

### **2) Road Surface Considerations**

The contractor will need to consider the road surface, the proper application and pavement marking adhesion. Road surfaces can be concrete, asphalt, chip seal or slurry seal. Follow the manufacturers' installation recommendations. Generally, for chip seal and slurry, a cure time from 1 -14 days is needed to allow the moisture to escape before pavement marking can be successfully applied.

### **3) Review of Pavement Marking Layout Details**

The layout of all markings shall be reviewed in detail. Additionally, all drawings and measurements shall be reviewed for accuracy. The layout is either included in the plans or referenced in the standard plans and drawings.

### **4) Pre-construction Discussion**

Agencies typically require that only materials approved by the engineer shall be used on the project. At the pre-construction meeting, the project engineer, inspector and contractor will review and discuss the acceptance procedures and specifications in general. The type of materials, methods of application, and other installation considerations should be discussed.

## **Pre-installation Responsibilities**

### **VDOT Responsibilities:**

- Review the MUTCD and established specifications to determine the correct location and type of pavement marking to be installed.
- Project Inspectors ensure:
  - That weather and surface conditions comply with specifications
  - Periodic monitoring is performed at the start of the day and every 3 hours thereafter.
  - Any unsatisfactory work is reported to the contractor immediately.
- Project personnel shall ensure that an approved source of materials has been furnished for the types of materials used.
- The project inspector shall ensure that weather and surface conditions comply with the specification requirements prior to allowing pavement marking operations to begin.
- The project personnel shall ensure that the pavement marking field layout (pre-marking) conforms to plans and MUTCD requirements.
- The project personnel shall ensure, through random inspection, that materials are applied in accordance with contract documents.



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## Contractor's Responsibilities:

- The contractor's QC Technician should ensure the Inventory Tracking Documents are on hand for all pavement marking materials used.
- Weather conditions should be monitored
- The plans, contract, specifications, and MUTCD shall be reviewed to determine the location and type of pavement markings to be installed. Also, review the plans and the contract to ensure that the type of material specified conforms to the contract documents.
- A copy of the manufacturer's installation recommendations must be obtained and supplied by the contractor for the type of materials used. Specific recommendations shall be followed in conjunction with the specifications.
- A copy of the Material Safety Data Sheet (MSDS) must be obtained, as required by Occupational Safety and Health Administration (OSHA) for each type of material to be used or work is not to proceed.
- The contractor must obtain and complete all required documents from VDOT.
- The QC technician shall ensure that the pavement marking field layout (pre-marking) conforms to plans and MUTCD requirements.
- The QC technician shall ensure, through random inspection, that materials are applied in accordance with contract documents.
- Striping equipment shall be checked for proper calibration and obvious mechanical deficiencies. The contractor is required to demonstrate that all equipment is capable of performing the intended work prior to beginning actual application.

## Installation

Safety Considerations: Traffic control must be constantly monitored to minimize disruption and to ensure compliance with the VA Work Area Protection Manual (WAPM) and the MUTCD. Workers shall wear hard hats, safety vests and steel-toed shoes/boots.

The contractor shall measure the application thickness, color, and the bead application rate at the beginning of each workday and a minimum of every three hours thereafter, for paint, thermoplastic, and epoxy. State agency specifications designate required procedures. Once application of the pavement markings begins, the following items should be closely monitored:

- Material temperatures shall be randomly checked during application.
- In order to prevent tracking, the applied material must be cured sufficiently to ensure tracking does not occur.
- The temporary pavement markers should be installed according to the contract documents, specifications, and manufacturer recommendations.
- The contractor's quality control technician must constantly monitor the quality and workmanship of the material being applied. Line width, length, thickness, and color shall be checked frequently to ensure compliance with the contract documents, and a written report (quality control report) shall be submitted to the agency's inspector.

- Unacceptable work must be identified, reported to the contractor, and corrected prior to further application and final payment.
- Pay quantities for materials being applied shall be measured and documented after each operation or at the end of the day's operation.
- Payment for completed work shall be dependent on compliance to contract requirements and the quality of the work.

## Acceptance of Materials

### The Source of Materials Document:

The VDOT form C-25 is commonly called the "Source of Materials" document. A source of materials is required to be submitted by the contractor no later than seven (7) days prior to start of work so that testing, sampling and acceptance can be pre-assigned.

This document details to the Department where and from whom the contractor will obtain the material. Upon assignment of the method of acceptance or inspection, the document is returned to the project and Contractor. This is done so that untested material does not arrive on the job site and cause delays while the material is being sampled and tested. Sometimes it is necessary to assign "on the job sampling".

NOTE: The Source of Materials Document (C-25) can be submitted electronically via the VDOT website. Each district will process the Source of Materials document for each project specific to that district.

Section 106.01(b): The details of how pavement markings are to be accepted and the documentation necessary for the project records are detailed in the Materials Division Manual of Instructions. Also detailed is how a sample is to be taken and how much that sample can represent. An attempt is made to either sample or pre-approve at the source of supply to facilitate ease of acceptance.

Material is accepted by one of following methods:

- 1) Certification I - Batch tested
- 2) Certification II - Approved List and requires manufacturers certification letter
- 3) Special Product Evaluation List (SPEL)
- 4) Visual Acceptance

### Certification I

These are materials that are required to be tested as a batch or lot before use on a project. Each new batch or lot produced, must be tested and accepted before use. Examples of materials requiring Certification I are paint, thermoplastic, epoxy, polyester and glass beads.

The Certification I statement should read: We certify that our product (batch or lot number) \_\_\_\_\_ on invoice number \_\_\_\_\_ or shipping ticket number \_\_\_\_\_ has been sampled, tested, and approved by VDOT Materials Division as indicated by Laboratory Test Number, MS \_\_\_\_\_, or by an approved Quality Control Plan as indicated by its unique test number \_\_\_\_\_.

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Note: Some materials that require a Certification I may be included on an Approved List. (Refer to Certification II for an explanation of the Approved List or QPL). However, every batch or lot produced must still be tested and approved before use.

## **Certification II**

These are materials that are tested and approved for use far in advance of their need on a project. Once these materials are approved, they are placed on an Approved List (or Qualified Products List - QPL) in the Manual of Instructions.

Some materials (pavement marking tape, pavement markers) don't have to be tested before use on each project. The Contractor simply selects these materials from the Approved List and begins using them.

These materials should arrive on the project with the following Certification II statement: We certify that our product has been tested, approved, and placed on a qualified products list. We certify that our (batch or lot number) \_\_\_\_\_ on invoice number \_\_\_\_\_ is the same product that was tested and approved. Indicated on the shipping document will be the test number from the approved list.

## **Special Product Evaluation List (S.P.E.L.)**

Some selected materials may be used on projects under a trial basis. These materials are normally used alongside approved materials and are monitored for performance. The S.P.E.L. Committee oversees these trials and makes recommendations for possible future use.

## **Visual Acceptance**

The visual evaluation of pavement marking materials finished products on the road.

## **Materials Inventory Tracking Program**

State agencies (DOT's), cities and towns will specify their requirements for acceptance of pavement marking materials.

Section 704 of the Road and Bridge Specifications and the Manual of Instructions require the Contractor to use an approved inventory tracking system for all materials received from the Manufacturer.

The program consists of three (3) primary components:

- 1) The Source of Materials Document - The C-25 ( Discussed on page 10-4)
- 2) **Inventory Ledger** - The striping Contractor maintains a running inventory of all materials received and shipped. When the records associated with the inventory are examined, a given load or batch of material received by the striping Contractor can be tracked to all projects where it was used. Thus it is readily apparent when a given batch has been exhausted. Furthermore, shipments of all materials can be tracked over a period of time. (Refer to Page B-7 for Inventory Ledger)

3) **Contractors Daily Log and Quality Control Report (C-85)** - The Contractor's Certified Pavement Marking Technician shall fill out this report completely (in accordance with Section 704.03(a) of the Road & Bridge Specifications) by hand in ink on a daily basis or at the end of each operation to track materials used, quantities installed or eradicated, certification information, material test numbers (MS No.), work completed (with locations), and recorded Quality Control test results. C-85 forms submitted for project records shall not be modified to incorporate any other information such as contractor personnel, equipment used, etc. The following data must be included on the C-85 form:

1. General Information - Contractor's name, project number, date, start time, finish time weather conditions, air temperatures and surface temperatures.
2. Materials Documentation - Type of material, quantity, unit of measure, certification type, MS number and expiration date of material.
3. Work Completed - Type of material, contract item number, quantity, location installed, width and color of marking.
4. Quality Control Measurements - Type of material, quality control measurement used, location of test, time of test and inspector's initials.
5. Signatures and dates by both the contractor's certified Pavement Marking Technician and the Engineer (VDOT Inspector)

Note: If the C-85 is in an electronic format, it must be current and in a printable form in order to be available for the Pavement marking Technician and the VDOT representative's signature.

The Contractor's Certified Pavement marking Technician shall review this report with the Engineer (VDOT Inspector) on a daily basis. The Engineer (VDOT Inspector) shall sign the report after reviewing and confirming quantities. Pay quantities are confirmed from this report.

PAVEMENT MARKING CONTRACTOR'S DAILY LOG AND QUALITY CONTROL REPORT						
Contractor: <i>STRAPE KINGS INC.</i>			Date: <i>7/8/11</i>	Start Time: <i>8:15 AM</i>	Finish Time: <i>6:30 PM</i>	
Job/Project No: <i>0095-074-726, N501</i>				Sheet	<i>1</i>	of <i>1</i>
Weather: <i>PARTLY CLOUDY</i>						
Air Temp. (Start) <i>82°F</i>		Air Temp. (Finish) <i>96°F</i>		Surface Temp. (Start): <i>86°F</i>		
* MATERIALS DOCUMENTATION:						
Type of Material	Quantity	Units	Certification Letter (Type/Date)	MS Number	Exp. Date	
<i>TYPE F CLASS 1</i>	<i>39</i>	<i>GAL.</i>	<i>CERT. 1</i>	<i>21742</i>	<i>6/2012</i>	
<i>SNOW FLOWABLE MARKERS</i>	<i>78</i>	<i>EACH.</i>	<i>CERT. 11 LETTER DATED</i>	<i>5/21/11</i>		
WORK COMPLETED:						
Type of Marking	Contract Item No.	Quantity	Units	Location/Description	Width	Color
<i>ERADICATION</i>	<i>54105</i>	<i>875</i>	<i>L.F.</i>	<i>M.P. 34.7 TO 34.9</i>	<i>6 INCHES</i>	
<i>TYPE F CLASS 1</i>	<i>54554</i>	<i>6,300</i>	<i>L.F.</i>	<i>M.P. 38 TO 39.2</i>	<i>8 INCHES</i>	<i>WHITE</i>
<i>MARKERS</i>	<i>54217</i>	<i>625</i>	<i>EACH</i>	<i>M.P. 37.4 TO 47.4</i>	<i>4"</i>	<i>W/RED</i>
Quality Control Measurements:						
Material Type	Q.C. Measurement (Units)		Location	Time	Inspector (Initial)	
<i>MOISTURE TEST (PLASTIC)</i>	<i>PASS</i>		<i>M.P. 38</i>	<i>8:30 AM</i>	<i>W.L.S.</i>	
<i>TYPE F PAINT PLATE TEST</i>	<i>16 MILS</i>		<i>M.P. 38</i>	<i>8:45 AM</i>	<i>W.L.S.</i>	

\* Material shipped under this certification has been tested and approved by VDOT as indicated by laboratory test numbers listed hereon.

Contractor Q. C. Technician	<i>William L. Smith</i>	Date	<i>7/8/11</i>
VDOT Representative	<i>Robert T. Walker</i>	Date	<i>7/8/11</i>

Copy District Traffic Engineer

\*\*\* Pay Quantity to be based on actual field measurement verified by the Engineer.

<b>PAVEMENT MARKING CONTRACTOR'S DAILY LOG AND QUALITY CONTROL REPORT</b>						
Contractor:			Date:	Start Time:		Finish Time:
Job/Project No:				Sheet		of
Weather:						
Air Temp. (Start)		Air Temp. (Finish)		Surface Temp. (Start):		
* MATERIALS DOCUMENTATION:						
Type of Material	Quantity	Units	Certification Letter (Type/Date)	MS Number	Exp. Date	
WORK COMPLETED:						
Type of Marking	Contract Item No.	Quantity	Units	Location/Description	Width	Color
Quality Control Measurements:						
Material Type	Q.C. Measurement (Units)		Location	Time	Inspector (Initial)	
* Material shipped under this certification has been tested and approved by VDOT as indicated by laboratory test numbers listed hereon.						
Contractor Q. C. Technician				Date		



E22-LASGCCCF VIRGINIA DEPARTMENT OF TRANSPORTATION PAGE: 2  
 CONTRACT ID : CM10PM6P96327 STATE PROJ NUM:PM6P-059-F10,F101,M501  
 FEDERAL PROJ NUM:STP-PM06(321)  
 ORDER NO. G83 DATE 12/08/10  
 SCHEDULE OF ITEMS REVISED

LINE	ITEM	ITEM DESCRIPTION	APP QTY.	UNIT PRICE	BID AMOUNT
SPEC NUMBER			UNITS	DOLLARS CTS	DOLLARS CTS
COMMON ITEMS					
0030	16242	AGGR. BASE MATL. TY. I OR II NO. 21A OR 21B	2361.00		
	ATTD		TON	21 9100	51729 51
0020	16350	ASPHALT CONCRETE TY. SM-12.5A	19820.00		
	315		TON	65 0700	1289687 40
0030	16355	ASPHALT CONCRETE TY. SM-12.5D	11909.00		
	315		TON	65 0700	774918 63
0040	16516	FLEXIBLE PAVE. TIE-IN PLANING 0" - 2"	1074.00		
	515		SY	7 5000	8055 00
0050	24265	MAINTENANCE OF TRAFFIC *	1		
	511		LS	19149 0000	19149 00
0060	54032	TYPE B CLASS I PAVE. LINE MARKING 4"	225337.00		
	704		LF	0 4100	92388 17
0070	54042	TYPE B CLASS I PAVE. LINE MARKING 24"	182.00		
	704		LF	11 6000	2002 00
0080	54106	ERADICATION OF EXIST. NONLINEAR PAVE.MARKING	604.00		
	512		SF	8 0000	4832 00
0090	54217	SNOW FLOW. RAISED PAVE. MARKER ASPH.CONC	1452.00		
	704		EA	22 9000	31944 00
0100	54300	PAVEMENT MESSAGE MARK. ELONGATED ARROW SINGLE	11.00		
	704		EA	260 0000	2860 00
TOTAL ITEMS IN SECTION 0001					2277565 71
TOTAL BID					2277565 71

Schedule ID: PM-6P-10  
 District: Fredericksburg  
 Commonwealth of Virginia -- Department of Transportation  
 Asset Management Division  
 Plant Mix  
 Date: 2/18/2010

County Of: Essex Co.  
 Page 1 of 4  
 Essex Co.

Route:	17	Milepost From:	26.00	0.28 Miles North Of Route 724
Subdivision:	NBL	Milepost To:	27.70	South End Of Occupada Creek Bridge
Lane:	XIII			
Traf Grp:	XIII			

Notes:  
 Rideability Pay Factor is in effect for this item.

Item Code & Description	Detail	Len(m)	Wid(ft)	Dep(in)	Gal/SqYd	Lbs/SqYd	Quantity	UOM
16242 - AGGR.BASE MAT.TY.I OR II NO. 21A OR 21B	Shdr 2' L & 1' R	1.70	3.00	1.50			247	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	Shdr 8' R	1.70	8.00	1.50			658	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	Mainline	1.70	22.00			180.00	1,975	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	4 Xovers; 2 Corn; 4 TL						300	TON
16516 - Flexible Pavement Tie-In 0'-2"	Mill 150' Before Bridge	0.03	30.00	1.50			528	SY
54032 - TY.B C.L.I PAVE. LINE MARK. 4"	White						12,420	LF
54032 - TY.B C.L.I PAVE. LINE MARK. 4"	Yellow						8,976	LF
54217 - SNOOW FLOW/RAISED PAVE.MARK.ASPH.CONC	White						136	EA

Route:	17	Milepost From:	27.72	North End Of Occupada Creek Bridge
Subdivision:	NBL	Milepost To:	29.62	0.57 Miles North Of Route 637
Lane:	XIII			
Traf Grp:	XIII			

Notes:  
 Rideability Pay Factor is in effect for this item.

Item Code & Description	Detail	Len(m)	Wid(ft)	Dep(in)	Gal/SqYd	Lbs/SqYd	Quantity	UOM
16242 - AGGR.BASE MAT.TY.I OR II NO. 21A OR 21B	Shdr 2' L & 1' R	1.90	3.00	1.50			276	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	Mainline	1.90	23.00			180.00	2,307	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	6 Xovers; 1 Corn; 6 TL						414	TON
16355 - ASPHALT CONCRETE TY. SM-12.5D	Shdr 8' R	1.90	8.00	1.50			736	TON
16516 - Flexible Pavement Tie-In 0'-2"	Mill 150' After Bridge	0.03	31.00	1.50			546	SY
54032 - TY.B C.L.I PAVE. LINE MARK. 4"	Yellow						10,032	LF
54032 - TY.B C.L.I PAVE. LINE MARK. 4"	White						14,340	LF



ORDER NO.: G83  
 CONTRACT ID. NO.: CM010PM6P96327

**SUMMARY OF ESTIMATED QUANTITIES FOR PM-6P-10**

Summary of Estimated Quantities (Contract)					
Item	Unit	Quantity	Item	Unit	Quantity
AGR. BASE MATERIAL TYPE I OR II NO. 21A OR 21B	TON	2361	ASPHALT CONCRETE TY. SM-12.5A	TON	19,820
ASPHALT CONCRETE TY. SM-12.5D	TON	11,909	FLEXIBLE PAVEMENT PLANING TIE-IN 0'-2"	SY	1,074
TY. B CL I PAVE. LINE MARK 24"	LF	182	TY. B CL I PAVE. LINE MARK 4"	LF	225,337
SNOW PLOW RAISED MARKER ASPH. CONC.	EA	1,452	ERADICATION OF EXIST. NONLINEAR PAVE. MARKING	SF	604
MAINTENANCE OF TRAFFIC	LUMP SUM	1	PAVE. MESS MARK. ELONG. ARROW SIN	EA	11

STATE FORCES WORK  PARTICIPATING  NON-PARTICIPATING

These items and quantities provided for estimating purposes only.

## Chapter 10 Knowledge Check

1. VDOT requires that by the end of each workday, form C-85, "Contractor's Daily Log and Quality Control Report", must be signed by the Contractor and submitted to the:
  - a) Materials Division
  - b) Contractor's Certified Q.C. Technician
  - c) Engineer or VDOT Inspector
  - d) State Police
  
2. VDOT specifications state that before proceeding with work, surface temperature and weather conditions must be checked for compliance with the specifications by the:
  - a) Project Inspector
  - b) Contractor's Certified Q.C. Technician
  - c) Paint Truck Operator
  - d) Traffic Engineer
  
3. Layouts for pavement markings must be in conformance with:
  - a) Special Product Evaluation List.
  - b) The Manual on Uniform Traffic Control Devices(MUTCD).
  - c) Virginia Test Method Manual (VTM).
  - d) Materials Division Manual of Instructions.
  
4. VDOT requires that quality control tests be conducted in accordance with:
  - a) The 1994 Road and Bridge Standards.
  - b) The MUTCD.
  - c) The manufacturer's recommendations.
  - d) VTM-94.
  
5. What topics should be discussed at the pre-construction conference held prior to beginning pavement marking operations?
  - a) Specifications
  - b) Types of materials
  - c) Method of application
  - d) All of the above
  
6. A copy of the manufacturer's recommended installation instructions for pavement marking tape does not have to be supplied by the contractor.
  - a) True
  - b) False

- 
7. A Material Safety Data Sheet (MSDS) must be obtained by the contractor for each material required for a particular type of pavement marking.
    - a) True
    - b) False
  8. In Virginia, traffic control must be constantly monitored to minimize disruption and to ensure compliance with:
    - a) The Virginia Work Area Protection Manual
    - b) The Materials Division Manual of Instructions
    - c) The MUTCD
    - d) All of the above
    - e) a and c
  9. The Contractor is required to measure the application thickness and bead application rate:
    - a) Before completing the work
    - b) At the beginning of each workday and every three hours thereafter
    - c) Once
    - d) Twice daily
  10. Both the Contractor and the Inspector should constantly monitor the installation and quality of the material being placed.
    - a) True
    - b) False
  11. In addition to application rates and glass bead distribution, markings should be inspected with regard to:
    - a) Width
    - b) Length
    - c) Color
    - d) All of the above
  12. VDOT requires in order that corrective action be taken, the inspector should immediately report unacceptable work to:
    - a) The Manufacturer.
    - b) The Resident Engineer.
    - c) The Contractor.
    - d) None of the above

13. When should pay quantities be compared and confirmed by the contractor and inspector?
  - a) Before proceeding with the work
  - b) At the end of each operation or the end of each workday
  - c) Before the end of the project
  - d) Only at estimate time
  
14. Before beginning work, the Source of Materials C-25 document is required to insure that under normal conditions:
  - a) Only approved materials are used
  - b) Appropriate test coverage is obtained
  - c) Only tested material arrives at the project
  - d) All of the above
  
15. VDOT specifications require the Materials Inventory Tracking system to be maintained by the:
  - a) Contractor
  - b) Project Engineer
  - c) Materials Section
  - d) District Administrator
  
16. The Contractor's inventory is monitored by the:
  - a) Central Office Materials Quality Assurance Section
  - b) District Materials Engineer
  - c) Resident Engineer
  
17. Copies of materials certifications are to be retained by the Contractor as part of the Materials Inventory Tracking documentation.
  - a) True
  - b) False
  
18. When materials are delivered directly from the manufacturer to a VDOT project, the project inspector will contact:
  - a) The Traffic Engineer
  - b) Central Office Materials Quality Assurance Section
  - c) The Manufacturer
  - d) The Resident Engineer
  
19. Contractor's Daily Log and Quality Control Report (C-85) is required on Federal Projects only.
  - a) True
  - b) False

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# 11 Equipment

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## Learning Outcomes:

- ☑ Know the types of equipment
- ☑ Understand where and how the equipment is used
- ☑ Be responsible for Quality Control

## Basic Components

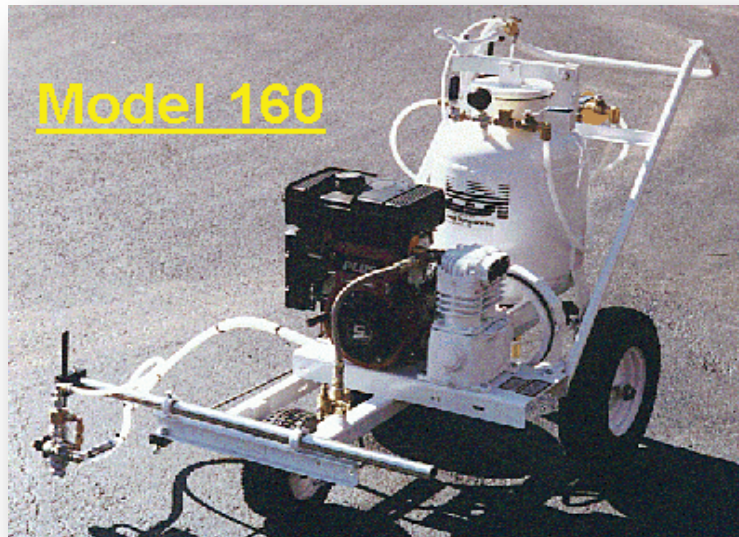
Pavement marking equipment comes in many shapes and sizes. All equipment manufacturers have their own configuration of basic components for a given application. A long-line paint truck manufactured by one company may look considerably different from the paint truck of a different manufacturer.

Although a specific machine is built to apply a specific type of material, all pavement marking equipment, except preformed tape applicators, will generally fall into one of the following categories: long-liners and hand-liners.

Long-liners are designed to produce long distance pavement markings. They are self-propelled and are equipped to carry relatively large quantities of material. Most are set up with more than one applicator or spray gun. Figure 11.1 shows a typical long liner. Hand-liners, which are much smaller than long-liners, are designed for operators to walk behind. They can only carry a limited quantity of material. The need for walk-behind applicators may be stated in the contract documents. Figure 11.2 illustrates a typical walk-behind applicator.



**Figure 11.1**  
Typical long-line application truck



**Figure 11.2**  
**A typical walk-behind applicator**

Long-liners vary somewhat from the specific systems they incorporate based on the type of pavement marking material they are designed to apply (paint, epoxy, thermoplastic, etc.). However, the following components can be found on all long-liners:

- Air compressor (airless applicators included)
- Material holding tank (with mechanical agitators)
- Reflective bead tank (pressurized)
- Cleaning system (cannot be in-line system)
- Material heating system (if necessary)
- Material applicators (spray guns, etc.)
- Reflective bead guns
- Control system (spray gun control, skip timer, etc.)
- Counter system (for measuring distance and/or material)
- Guidance aid (some means for the operator to line up with the road or with existing markings)

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## Pre-stripe Inspection

The following is the recommended procedure for the engineer prior to beginning work on the project:

- The engineer or designee will become familiar with the equipment by walking around it with the operator. They should discuss how the machine is set up and how it operates. During this discussion, the engineer or designee should be assured that everything is in working order. The preceding checklist may be used as a guide for this procedure.
- The contractor shall apply a sample marking for inspection. While this is taking place, the engineer or designee will ensure that the contractor is taking quality control test samples for thickness and width of material, and reflective bead application rate (according to government agency specifications). The results of the quality control tests shall be reviewed and discussed with the contractor.
- Before proceeding with the work, the engineer or designee will inspect the marking and test panels for quality, clean edges, even bead distribution, proper bead depth, required width, and general appearance. This is discussed in detail in the appropriate chapter in this manual.

If any problems or inconsistencies are discovered, DO NOT PROCEED WITH THE WORK!

## Quality Control

Clear communication and cooperation yields positive inspector/contractor interaction and helps ensure quality. This is essential regardless of the type of work. Discuss any problems with the contractor's certified quality control technician and stay informed of the adjustments the contractor makes to correct them. The following guidelines will ensure proper quality:

- Once the work is in progress, the engineer and contractor's quality control technician shall periodically stop, get out of the truck, and inspect the line.
- Continuous close attention to the appearance of the line is the best way to ensure quality work.
- Generally, inspection of the actual marking is the best tool for determining equipment problems.
- Proper width does not ensure even edges.
- Proper material thickness does not ensure adhesion.
- Proper bead application rate does not ensure either retention or proper embedment.
- To ensure quality, the pavement markings must be inspected closely.

Typically, the contractor's certified quality control technician is required to make the quality control checks according to the government agency's specifications. The purpose behind any quality control plan is to ensure quality. Whenever there are any doubts about the quality of the work, they **MUST** be investigated.

Deficiencies may or may not be due to equipment problems. When everything is working properly, pavement markings can be compared to an orchestra; all the components must work together. Material properties, weather conditions, and operator skill can all affect the quality of the final marking. Diagnosing the cause or combination of causes for a given problem can be very difficult. Engineers and inspectors who are knowledgeable about pavement marking equipment are better able to identify equipment problems.

As always, it is the responsibility of the contractor to solve the problem. However, this should never be misconstrued to lead the engineer away from helping to identify problems. In other words, although the engineer cannot tell the contractor how to fix a problem, knowledgeable engineers can and should be considered a valuable tool for the contractor, always keeping in mind that quality is the main goal.



## References

See Appendix A for the following:

*VDOT Road & Bridge Specification Book*  
Section 512

## Knowledge Check Chapter 11

1. A long-line paint truck manufactured by one company should look exactly the same as that of a different manufacturer.
  - a) True
  - b) False
  
2. Which item mentioned below is a component for a long-line truck?
  - a) cleaner system
  - b) reflective bead tank
  - c) counter system
  - d) all of the above
  
3. The inspector should be knowledgeable with the pavement marking equipment to help identify problems.
  - a) True
  - b) False
  
4. Clear communication and cooperation between the inspector and contractor helps ensure quality.
  - a) True
  - b) False
  
5. One must inspect pavement markings “close up” to ensure quality.
  - a) True
  - b) False

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# 12 Eradication

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## Learning Outcomes:

- ☑ Know and know the purpose of eradication
- ☑ Understand correct eradication procedures

## Definition/Purpose

Eradication describes the removal of existing pavement markings. Pavement markings are eradicated to change or modify the existing travel lanes and to prepare the road surface for new markings.

## Undesirable Effects

If pavement markings are not eradicated properly, several different markings may exist at the same time, as shown in Figure 12.1. Often, the scars left by some removal methods may appear like additional pavement markings (see Figure 12.2). This may create a hazardous condition for motorists.



Figure 12.1  
Roadway with confusing multiple lines



**Figure 12.2**  
**Scars from removed marking**

It was once common practice to cover the existing marking with either black paint or asphalt (Figure 12.3). Heavy traffic would often wear away this paint or asphalt and the unwanted marking would become visible again. From a safety perspective, this is not a practical solution except for extremely short durations (i.e. overnight).



**Figure 12.3**  
**Black paint wearing off of previous marking**

## Methods of Eradication

There is no method of eradication that is free from drawbacks. Whatever the method, it must effectively remove the marking to the specified degree, while at the same time doing the least damage to the pavement. Eradication methods must be submitted to VDOT for approval prior to beginning the work.

Methods that have typically been used are:

- Blasting (hydro, sand or shot)
- Grinding
- Combination of blasting and grinding
- Type E Black Tape            Note: Must be used on asphalt and not longer than 120 days

The effectiveness of the method is dependent on three things:

- The type and thickness of the marking being removed
- The type of pavement
- The skill of the operator

For example, thermoplastic markings cannot withstand abrasive blasting because the heat generated when the abrasives strike the marking melts the thermoplastic. Grinding is not acceptable on grooved or tined PCC because it will remove the texturing of the pavement surface. Most chemical strippers are hazardous materials with disposal problems. Heat can make HMA pavement slick. Depending on the amount of heat, safety problems may result. Hydro-jetting or hydro-blasting uses water and can cause slick pavements in the wintertime.

## Specifications

The contract will specify how eradicated residue is to be contained and disposed. OSHA safety requirements must be followed. Section 512 of the VDOT Road and Bridge Specifications requires that 90% of the markings to be eradicated if installation will be over other markings. If the markings are removed for lane shifts or transitions, 100% of the markings must be removed.

## Inspection

The eradicated lines are to be inspected for:

- Thoroughness of eradication
- Damage to the pavement surface

## References

See Appendix A for the following:

*VDOT Road & Bridge Specification Book*

Section 512.03 (j) Eradicating Pavement Markings

Section 704.03 2. (b) Eradication

Also, see specific requirements of application in Section 704 for each type of marking material over an existing marking.

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## Chapter 12 Knowledge Check

1. Failure to remove existing markings when there are shifts in the traffic pattern can:
  - a) be misleading.
  - b) be confusing.
  - c) create a hazardous condition.
  - d) all of the above
  
2. Which of the following methods is not acceptable for long term eradication?
  - a) grinding and blasting
  - b) black paint
  - c) Type E tape
  - d) both a and b
  - e) both b and c
  
3. All residue created when eradicating pavement markings must be:
  - a) swept into the ditch.
  - b) contained.
  - c) recycled.
  - d) burned.
  
4. Eradication methods, other than those specified, must be submitted to the project engineer for approval prior to beginning work.
  - a) True
  - b) False
  
5. Eradicated lines should be inspected for:
  - a) thoroughness of eradication.
  - b) minimum amount of damage to the pavement.
  - c) both a & b
  - d) none of the above

6. Virginia designated Type E black tape may only be used on hydraulic cement concrete roadways.
  - a) True
  - b) False
  
7. One of the criteria in Virginia for using Type E black tape in lieu of eradication is that the traffic pattern will shift back to the original pattern within:
  - a) 90 days.
  - b) 1 month.
  - c) 120 days.
  - d) 6 months.



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# A

## Specifications

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### VDOT Road & Bridge Specifications (\*)

SECTION 106.01 Control of Materials .....	A-1
SECTION 234 Glass Beads for Reflectorizing Traffic Markings.....	A-2
SECTION 512 Maintenance of Traffic. ....	A-2
SECTION 704 Pavement Markings & Markers.....	A-6

\* Consult the current or applicable *VDOT Road and Bridge Specification Book* and Special Provisions for the most current specifications.

#### SECTION 106—CONTROL OF MATERIAL

##### 106.01 Source of Supply and Quality Requirements

The materials used throughout the work shall conform to the requirements of the contract. The Contractor shall regulate his supplies so that there will be a sufficient quantity of tested material on hand at all times to prevent any delay of work. Except as otherwise specified, materials, equipment, and components that are to be incorporated into the finished work shall be new. Within 30 days after notification of award of the contract, but not later than 7 days prior to the beginning of construction operations under the contract, the Contractor shall file a statement of the known origin, composition and manufacture of all materials to be used in the work, including optional or alternate items. Material requirements not previously reported shall be submitted at least 60 days prior to their use on the project, but not less than two weeks prior to delivery. The Contractor's statement shall be electronically submitted by use of Form C-25 and shall be identified by the complete project number, and all items or component materials shall be identified by the specific contract item number and the specification reference shown in the contract.

At the option of the Engineer, materials may be approved at the source of supply. If it is found during the life of the contract that previously approved sources of supply do not supply materials or equipment conforming to the requirements of the contract, do not furnish the valid test data required to document the quality of the material or equipment, or do not furnish documentation to validate quantities to document payment, the Contractor shall change the source of supply and furnish material or equipment from other approved sources. The Contractor shall notify the Department of this change, and provide the same identifying information noted in this section, at least 60 days prior to their use on the project, but less than two weeks prior to delivery.

## SECTION 234—GLASS BEADS FOR REFLECTORIZING TRAFFIC MARKINGS

### 234.01—DESCRIPTION.

This specification covers glass beads for application on liquid traffic marking materials so as to produce a reflective surface.

### 234.02—DETAIL REQUIREMENTS.

Beads shall be manufactured from glass of a composition designed to be highly resistant to traffic wear and weather. Glass beads shall be spherical in shape and shall conform to AASHTO M247 Type 1, except that at least 80 percent of the beads shall be round when tested in accordance with the requirements of ASTM D 1155 Procedure B. Beads shall be essentially free of sharp angular particles, milkiness and surface scoring or scratching.

## SECTION 512—MAINTAINING TRAFFIC

### 512.01—DESCRIPTION.

This work shall consist of maintaining and protecting traffic through areas of construction, maintaining public and private entrances and mailbox turnouts, constructing and obliterating detours, and protecting the traveling public within the limits of the project and over detours that are not a part of the state highway system in accordance with the contract documents.

### 512.02—MATERIALS.

- (a) **Materials** salvaged from the roadway shall be used in the maintenance of traffic insofar as possible. Material shall conform to the requirements of the applicable specifications.
- (b) **Signalization, barricades, channelizing devices, safety devices, and pavement markings** shall conform to the requirements of Division VII Traffic Control Devices of these specifications and the *Virginia Work Area Protection Manual* except where otherwise indicated. Retroreflective surfaces shall conform to the requirements of Sections 235, 247 and 702 as applicable.
- (c) **Temporary pavement markers** shall conform to the requirements of Section 235.
- (d) **Construction pavement markings** shall conform to the requirements of Section 246.

### PARTIAL SPEC. for 512.03

#### 512.03 Procedures

- (i) **Construction Pavement Markings:** Construction pavement markings shall be installed at locations shown on the plans and in the *Virginia Work Area Protection Manual*, and at other locations as directed by the Engineer. Construction pavement markings shall be selected from the Department's approved list of Construction Pavement Marking Materials. Construction pavement markings are classified as Types D, Classes I and II (removable tape), E (non-reflective black removable tape) and F, Classes I and II (temporary markings). Construction pavement markings shall be used as follows:
  - 1. **Type D construction pavement markings** shall be used on final roadway surfaces or in areas where traffic patterns are subject to change before pavement is resurfaced unless the surface temperature of the pavement is below the pavement marking manufacturer's recommended minimum application temperature. When the surface temperature of the pavement is below the manufacturer's minimum application temperature, a Type F construction pavement marking on the approved list under the same class as the specified Type D construction pavement marking may be used except on final surfaces.

The Contractor shall select a Type F product known to perform the best under those temperature conditions. When a Type F construction pavement marking is utilized in lieu of a Type D due to the surface temperature being below the manufacturer's minimum application temperature, the Contractor will be paid the price bid for Type D, which will include the Type F markings and any necessary eradication of existing pavement markings.

2. Type E construction pavement markings shall be used to cover existing markings in accordance with Section 512.03(j).
3. Type F construction pavement markings shall be used where the roadway is to be resurfaced prior to changes in the traffic pattern or where pavement is to be demolished and traffic patterns will not change before demolition.

Construction pavement markings shall be installed in accordance with the manufacturer's recommendations. Application thickness and bead application shall be in accordance with the manufacturer's recommendations except as follows. In the event the manufacturer's recommendation for material thickness and quantity of beads is less than utilized when the material was tested by the National Transportation Product Evaluation Program (NTPEP), the minimum values used during product installation shall conform to the NTPEP test values which are indicated on the approved list for the specific marking. The Contractor shall furnish a copy of the manufacturer's installation recommendations including the thickness, bead embedment and dispersment to the Engineer.

The Contractor shall maintain the construction pavement markings and shall correct any deficient markings by reapplying markings. Deficient construction pavement markings are considered to be any markings that do not provide adequate guidance to motorists due to inadequate retroreflectivity or color qualities, or due to problems with adherence to the pavement. The Engineer will make a visual nighttime inspection of all construction pavement markings to identify areas of markings that have inadequate retroreflectivity qualities.

Those markings that have inadequate retroreflectivity qualities as determined by the Engineer shall be replaced by the Contractor with the following exceptions:

- a. Reapplication of skip line construction pavement markings is not required unless the inadequate retroreflectivity qualities are for at least two consecutive skip lines.
- b. Reapplication of center, lane (except skip lines) or edge line construction pavement markings is not required unless the inadequate retroreflectivity qualities are for at least a continuous section of 70 feet.
- c. Reapplication of transverse markings is not required unless the inadequate retroreflectivity qualities are for at least a continuous section exceeding 3 feet.

### 512.03

In lieu of replacement of construction pavement markings based on visual observations by the Engineer, the Contractor may have retroreflectivity readings made. These measurements shall be taken within 48 hours after the Contractor has been notified of the deficient markings except additional time will be granted due to inclement weather that prevents the adequate measurement of the markings. The Contractor shall brush any form of debris from the line before performing the measurements. Measurements shall be taken in the presence of the Engineer using Contractor furnished equipment conforming to the requirements of ASTM E1710. The Contractor shall operate the equipment in accordance with the manufacturer's instructions and a copy of such instructions shall be provided to the Engineer.

The photometric quantity to be measured is coefficient of retroreflected luminance (R) which shall be expressed as millicandelas per square foot per foot-candle.

Measurements shall be accomplished at three random locations within each area of markings that have inadequate retroreflectivity qualities. When the length of the visually inadequate area is greater than one mile, measurements shall be accomplished at three locations per mile segment or portion thereof. Measurements for all lines shall be accomplished in the middle of the line horizontally. Measurements for skip lines shall be accomplished in the middle of its length. Measurements for transverse lines shall be taken outside of the wheel path locations. The Engineer will designate the locations along the line segments that the measurements shall be taken. The Contractor shall make a log of the measurements along with their locations and provide a copy to the Engineer. When the average of the three readings for an area is below 100 millicandelas per square foot per foot-candle, the Contractor shall reapply the markings as indicated above.

Construction pavement markings that have become unadhered to the pavement shall be reapplied by the Contractor with the following exceptions:

1. Reapplication of skip line construction pavement markings is not required unless the unadherence is for at least two consecutive skip lines.
2. Reapplication of center, lane (except skip lines) or edge line construction pavement markings is not required unless the unadherence is for at least a continuous section of 70 feet.
3. Reapplication of transverse markings is not required unless unadherence is for at least a continuous section exceeding 3 feet.

However, all construction pavement markings that have become unadhered to the roadway that may cause guidance problems for the motorists shall be removed by the Contractor.

Removable construction pavement markings shall also be replaced on tined concrete and high hit asphalt locations on time frames as recommended by the manufacturer of the marking to prevent the need for eradication. The Contractor shall furnish a copy of the manufacturer's recommendations to the Engineer.

Those construction pavement markings found in need of reapplication in accordance with the above requirements shall be reapplied by the Contractor at no additional cost to the Department with the following exceptions:

- a) Markings that have been under traffic for more than 90 days will be paid for at the contract unit price when needing reapplication unless the manufacturer's warranty coverage is still in effect.
- b) Markings damaged by the Department's snow removal or other maintenance and construction operations will be paid for at the contract unit price.

Construction pavement markings shall be replaced in accordance with the time requirements of Section 704.

Eradication for reapplication of Type F construction pavement markings is not required if allowed by the marking manufacturer provided the existing marking is well adhered and the total thickness of both the existing and reapplied marking combined will not exceed 40 mils. If not well adhered, 90 percent of the existing markings shall be removed prior to reinstallation of the markings. Temporary pavement markers shall be installed with construction pavement markings in accordance with (k) herein.

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- (j) **Eradicating Pavement Markings:** Markings that may conflict with desired traffic movement, as determined by the Engineer, shall be eradicated as soon as is practicable: either immediately prior to the shifting of traffic or immediately thereafter and prior to the conclusion of the workday during which the shift is made.

Eradication shall be performed by grinding, blasting, or a combination thereof. Grinding shall be limited to removal of material above the pavement surface except when removing thermoplastic and preformed tape markings, which may be removed by grinding alone. Blasting shall be used on both asphalt concrete and hydraulic cement concrete pavements to remove all other types of markings. Other methods may be submitted for approval by the Engineer. The Contractor shall ensure that the least amount of damage as possible occurs to the roadway surface when accomplishing the eradication.

When eradicating pavement markings, the Contractor shall ensure workers are protected in conformance to the requirements of *Occupational Safety and Health Administration's (OSHA)* standards as detailed in 29 CFR 1910 or 1926, whichever is the most stringent at the time. The Contractor shall collect the eradication residue during or immediately after the eradication operation, except dust shall be collected during the entire operation. Eradication residue from the removal of any pavement markings is considered to be a non-hazardous waste material and shall be disposed of in a properly permitted waste disposal facility in accordance with state and federal laws and regulations. Testing of the eradication residue for the eight RCRA metals will not be required.

When markings are removed for lane shifts/transitions, 100 percent of the marking shall be removed.

Non-reflective removable black construction pavement marking may be used to cover existing markings in lieu of eradication methods on asphalt concrete surfaces when its use will not be required for more than 120 days and when specified as a pay item. The Contractor shall use this material to cover markings as indicated in the plans or as directed by the Engineer. Non-reflective removable black construction pavement marking shall be applied in accordance with the manufacturer's recommendations.

- (k) **Temporary pavement markers** shall be installed with construction pavement markings, except non-reflective removable markings, in transition (lane drop) or lane shift areas of work zones which will encroach upon the traveled roadway for a period of more than three days and in other areas as required by the Engineer.

Temporary pavement markers shall be installed on twenty-foot centers in lane shift and transition areas. When temporary pavement markers are required in other areas, they shall be installed on forty-foot centers unless otherwise required by the Engineer. Temporary pavement markers shall be located between and in alignment with broken lines and beside solid line pavement markings. Where double line pavement markings separating traffic are installed, two-way markers shall be installed beside each line. The Contractor may install two one-way markers in lieu of each two-way marker at no additional cost to the Department.

Temporary pavement markers shall be installed with a hot applied bitumen adhesive except epoxy may be used on hydraulic cement concrete roadways and non-final surfaces of asphalt concrete roadways. Damage created in the pavement by removal of markers shall be repaired in kind by the Contractor at no additional cost to the Department.

Temporary pavement markers found in need of replacement shall be replaced by the Contractor at no additional cost to the Department except those markers damaged by the Department's snow removal operations or other maintenance and construction operations will be paid for at the contract unit price.

- (n) **Construction Pavement Message Markings:** Markings shall be installed at locations designated on the plans and as determined by the Engineer and shall consist of messages in accordance with the requirements of Section 704. Construction pavement message marking material including maintenance of the markings shall be in accordance with the requirements for construction pavement markings.

Retroreflective measurements shall be taken out of the wheel path locations and each separate entity of a pavement message marking shall be replaced when the average of the three readings for that entity is below 100 millicandelas per square foot per footcandle.

**Replacement and correction of ineffective work zone traffic control devices** shall be accomplished in accordance with the *American Traffic Safety Service Association's (ATSSA) Quality Standards For Work Zone Traffic Control Devices* publication with the following additions and exceptions:

1. Requirements herein for replacement and correction of construction pavement markings shall be used in lieu of the requirements contained in the section entitled Evaluation Guide Pavement Tape & Raised Pavement Markers.

## SECTION 704—PAVEMENT MARKINGS AND MARKERS

### 704.01—Description.

This work shall consist of establishing the location of pavement markings and installing pavement markings, pavement markers, and reflectorized material on specified pavements in accordance with these specifications, the *MUTCD* and as directed by the Engineer.

### 704.02—Materials.

The Contractor shall use an approved inventory tracking system for all materials received from the manufacturer. Shipment of materials from such inventory shall be accompanied by the following certification:

Material shipped under this certification has been tested and approved by VDOT as indicated by laboratory test numbers listed hereon.

- (a) **Pavement markings** shall conform to the requirements of Section 246.
- (b) **Glass beads** shall conform to the requirements of Section 234.
- (c) **Pavement markers** shall conform to the requirements of Section 235.

### 704.03—Procedures.

The Contractor shall have a certified Pavement Marking Technician present during pavement marking operations.

Pavement markings shall be installed on new roadways prior to opening the roadway to traffic. Pavement marking installation shall be completed within the time limits herein on roadways where the pavement markings have been removed or obscured and the roadway is open to traffic unless otherwise directed by the Engineer. Installation of Type B, Class VI pavement markings on asphalt roadways are not applicable to these requirements if they are inlaid with the last pass of the asphalt roller or directly after the asphalt roller utilizing a separate roller.



Installation of edge lines on roadways where the existing pavement markings have been removed or obscured are also required within these time limits unless otherwise indicated by the Engineer. Exceptions to the below time limits will be granted only for weather. Follow manufacturer's recommendations for the installation of epoxy resin.

Pavement marking installation on roads having traffic volumes of 10,000 ADT or more shall be completed within 24 hours after the end of the workday where the pavement markings were removed or obscured.

Pavement marking installation on roads having traffic volumes between 3,000 and 10,000 ADT shall be completed within 48 hours after the end of the workday where the pavement markings were removed or obscured.

Pavement marking installation on roads having traffic volumes of less than 3,000 ADT shall be completed within 72 hours after the end of the workday where the pavement markings were removed or obscured.

If the Contractor will not have pavement markings installed within the time limits set above, the Contractor shall install Type D construction pavement markings within the same time limits and maintain such until the final pavement markings can be installed. The cost of installing, maintaining and removing the Type D construction pavement markings shall be borne by the Contractor with no cost to the Department.

When establishing the location of pavement markings, the Contractor may mark the locations on the roadway by installing premarkings. Premarkings shall be accomplished using Type D (removable – any class) tape, chalk, or lumber crayons except special pavement markings such as stop lines, crosswalks, messages, hatching, etc. shall be accomplished using chalk or lumber crayons. All premarkings shall be of the same general color as the pavement markings being premarked. When tape is used as premarking, premarking shall consist of 4-inch x 4-inch maximum squares or 4-inch maximum diameter circles spaced at 100-foot minimum intervals in tangent sections and 50-foot minimum intervals in curved sections. At locations where the pavement marking will switch colors, e.g. gore marking, the ends of the markings may be premarked regardless of the spacing. When chalk or lumber crayon are used as premarking, the entire length of the pavement marking may be premarked. All premarkings shall be installed whereby its installation shall not affect the adhesion of the pavement markings. When Type D tape is used as the premarking and the lateral location of such premarkings to the final pavement markings exceeds 6 inches, the premarkings shall be removed at no cost to the Department.

### 704.03

- (a) **Pavement Markings:** Pavement markings shall be white or yellow markings as required by the *MUTCD* for the specific location or as specified by the Engineer and shall be installed in accordance with Table VII-1 unless otherwise recommended by the manufacturer and approved by the Engineer. The Contractor shall furnish a copy of the manufacturer's installation recommendations to the Engineer.

The Contractor shall perform quality control testing for application thickness and glass bead rate in accordance with VTM-94 at the beginning of each workday and every 3 hours thereafter. The Contractor shall be responsible for providing the apparatus indicated in VTM-94 that are needed to perform the quality control testing. Testing shall be performed in the presence of the Engineer.

The Contractor shall maintain a daily log (Form C-85) for both temporary and permanent pavement markings and markers. Entries in the log shall be made in ink, shall be legible, and the log shall be signed by the Contractor and delivered to the Engineer or designee by the end of each workday.

Pavement line markings shall consist of stop lines, crosswalks, and solid or skip lines used for, but not limited to, dividing lanes, marking edges, channelizing, outlining and marking safety zones around objects, and forming islands and parking lot stalls.

TABLE VII-1

## PAVEMENT MARKINGS

Type	Class	Name	Surface Temp. at Time of Application	Film Thickness (mils)	Pavement Surface	Application Limits
A	-	Traffic Paint	50 °F+	15 ± 1 when wet	AC HCC	May be applied directly after paving operations
B	I	Thermoplastic Alkyd	50 °F+	90 ± 5 when set	AC	May be applied directly after paving operations
	I	Thermoplastic Hydrocarbon	50 °F+	90 ± 5 when set	AC	Do not apply less than 30 days after paving operations
	II	Polyester resin	50 °F+	15 ± 1 when wet	HCC	Needs to be coned
	III	Epoxy resin	50 °F+	20 ± 1 when wet	AC HCC	Manufacturer's Recommendations
	IV	Plastic-backed preformed tape	Manufacturer's Recommendation	60 - 90	AC HCC	Manufacturer's Recommendations
	VI	Patterned preformed tape	Manufacturer's Recommendation	20 * 65**	AC HCC	Manufacturer's Recommendations
D	I & II	Removable tape	Manufacturer's*** Recommendation		AC HCC	Construction zone pavement marking
E	-	Removable black tape (non-reflective)	Manufacturer's *** Recommendation		AC	Construction zone pavement marking for covering existing markings
F	I & II	Temporary markings	Manufacturer's Recommendation*** (Film Thickness 40 mils max)		AC HCC	Construction zone Pavement marking

\* Thinnest portion of the tapes cross-section. This is the minimum required thickness.

\*\* Thickest portion of the tapes cross-section. This is the minimum required thickness.

\*\*\* In the event the manufacturer's recommendation for film thickness is less than utilized when the material was tested by the National Transportation Product Evaluation Program (NTPEP) or other Department approved test facility, the minimum values used during installation shall conform to the test values which are indicated on the approved list for the specific marking.



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**Section 704.03**

Crosswalks and stop lines shall be installed using Type B, Class I or IV markings. Solid lines or skip lines shall be installed using Type A or Type B markings as specified.

Pavement message markings shall be installed using Type B, Class I, IV or VI markings and shall include, but not be limited to, school zone markings, railroad crossing markings, disabled parking symbols, elongated arrows, word messages, etc. The word SCHOOL shall be formed with characters that are 10 feet in height where permitted by the normal roadway width. School zone markings shall extend transversely across both lanes of two-lane roadways and across two or more approach lanes of roadways of three or more lanes. Disabled parking symbols shall be 41 inches in height, 36 inches in width and shall use a 4-inch stroke width for the lines.

The Contractor shall protect the public from damage attributable to pavement marking operations. The Contractor shall be responsible for the complete preparation of the pavement surface, including, but not limited to, removing dust, dirt, loose particles, oily residues, curing compounds, concrete laitance, residues from eradication, and other foreign matter immediately prior to installing pavement markings. The pavement surface shall be dry at the time of installation when tested in accordance with VTM-94. The Contractor shall be responsible for providing the apparatus indicated in VTM-94 that are needed to perform the moisture test. Marking material shall not be applied within 24 hours following rain or other inclement weather.

Liquid markings shall be applied so as to prevent splattering and overspray and shall be protected from traffic until track free by the use of guarding or warning devices as necessary. If a vehicle crosses a marking and tracks it or if splattering or overspray occurs, the affected marking and resultant tracking shall be removed and new markings applied at the Contractor's expense.

Equipment shall also be thoroughly cleaned between changes in colors of materials. Pavement markings shall have clean and well-defined edges without running or deformation; shall be uniform, free of waviness; shall be straight on tangent alignment; and shall be on a true arc on curved alignment. The widths of pavement markings shall not deviate more than  $\frac{1}{4}$  inch on tangent nor more than  $\frac{1}{2}$  inch on curves from the required width. The length of the gap and the length of the individual stripes that form skip lines shall not deviate more than two inches. The length of the gap and individual skip line shall be of such uniformity throughout the entire length of each that a normal striping machine will be able to repeat the pattern and superimpose additional striping upon the existing marking.

Glass beads shall be applied at the rate specified herein and shall be evenly distributed over the entire surface of the marking. Beads shall be applied to the surface of liquid markings by a bead dispenser attached to the applicator that shall dispense beads simultaneously on and in the just-applied marking. The bead dispenser shall be equipped with a cut-off control synchronized with the cut off of the applied marking material so that the beads are applied totally to the completed line. Beads shall be applied while the liquid marking is still fluid. Approximately 70 percent of beads shall be buried in the marking, and the remaining 30 percent shall be 50-60 percent embedded in the surface. Beads installed on crosswalks and stop lines on roadways with curbs only (no gutter) may be hand applied for two feet at the end of each line next to the curb with 100 percent of the beads embedded 50-60 percent in the surface.

Markings found to be unacceptable shall be removed, and new markings applied at the Contractor's expense.

1. **Type A markings:** Paint may be applied to asphalt concrete and hydraulic cement concrete pavements. Paint shall not be applied over existing pavement markings of other materials unless the existing marking is 90 percent removed. Paint may be applied over existing paint markings.

Paint shall be applied with a line painting machine that is capable of hot spraying paint directly onto the pavement surface with a uniformity of feed through its nozzles for widths of 4 through 8 inches. The machine shall be capable of applying two pavement stripes, either solid or skip, at the same time when double line markings are required. Paint tanks on the equipment shall be equipped with a mechanical agitator and paint shall be thoroughly mixed and heated such that it will not track within 60 seconds after its application.

Non-truck mounted equipment shall be self-propelled and regulated to allow for calibration of the amount of material applied.

Glass beads shall be applied to the surface of the paint at the rate of 6 pounds per gallon of paint.

2. **Type B markings:**

Equipment shall be capable of providing mixing, heating and agitation of material. Material shall be uniformly heated throughout the system in accordance with the manufacturer's recommendations. Thermoplastic material shall be maintained in the heating kettle and applied to the road surface at a minimum temperature of 400 degrees F. Heating kettles shall be equipped with an automatic thermostatic control device. The Contractor shall furnish a properly calibrated infrared instrument for the purpose of measuring the actual temperature of molten thermoplastic material. Multi-component material shall be applied using internally injected guns for the mixing of catalyst and hardener.

**Non-truck mounted equipment for application of thermoplastic material shall be of the screed extrude type with a screw drive or shall be self propelled and regulated to allow for calibration of the amount of material applied. Non-truck mounted equipment for application of polyester and epoxy resin material shall be self propelled and regulated to allow for calibration of the amount of material applied.**

- a. **Thermoplastic (Class I)** material shall only be applied on asphalt concrete pavements and shall be applied by screed extrude, ribbon gun or spray equipment. Alkyd thermoplastic may be applied directly after the paving operations, however hydrocarbon thermoplastic shall not be applied less than 30 days after the paving operations.

Alkyd and hydrocarbon materials shall not be mixed together. Equipment shall be thoroughly cleaned before types of material are changed.

Thermoplastic shall not be applied over existing pavement markings of other materials unless the existing marking is 90 percent removed. Thermoplastic may be applied over existing thermoplastic markings. For concrete bridge decks that occur in asphalt roadways, Type B, Class VI tape shall be used.

Primer/adhesive shall be applied to asphalt concrete surfaces more than two years old and shall be from the same manufacturer as the thermoplastic.

Glass beads shall be applied to the surface of the marking at the rate of 7 pounds per 100 square feet.

- b. DELETED

- c. **Epoxy resin (Class III)** material shall only be applied to asphalt concrete pavement more than one day old and hydraulic cement concrete pavement. Epoxy resin shall not be applied over existing pavement markings unless the existing marking is 90 percent removed.

Glass beads shall be applied by the gravity method to the surface at the rate of 25 pounds per gallon of material.

- d. **Plastic-backed preformed tape** shall be installed in accordance with the manufacturer's recommendations and as denoted herein. Tape may be applied to asphalt concrete and hydraulic cement concrete pavements. Tape may be installed immediately following the final rolling of the new asphalt concrete surface. Tape shall not be applied over existing pavement markings of other materials unless the existing marking is 90 percent removed.

### Section 704.03

Primer/adhesive shall be used for all installations except when tape is applied immediately following the final rolling of the new asphalt concrete surface and shall be from the same manufacturer as the tape.

Tape for pavement line markings shall be applied by an application cart as recommended by the manufacturer. Tape shall be tamped into place with a tamper cart with the weight as recommended by the manufacturer. The use of a vehicle to ride over the markings for tamping will not be permitted.

(b) **Eradication:**

Eradication of pavement markings for restriping when required shall be in accordance with Section 512 except only 90 percent removal of the existing markings is required.

(c) **Pavement Markers:**

1. **Snow-plowable raised pavement markers** shall be installed by cutting two parallel grooves into the pavement at the depth and dimensions recommended by the manufacturer. Grooves shall be parallel to the adjacent pavement marking. Grooves shall be cut with saw blades having a diameter to match the curvature of the steel casting bottom and keels. Keel surfaces shall be free from scale, dirt, oil, grease, or any other contaminant that might reduce bonding.

Casting keels shall be bonded in the saw-cut grooves in the manner recommended by the manufacturer of the marker. The bonding material shall be from the Department's approved list or as recommended by the manufacturer of the marker. Noses of the casting shall be installed flush with the pavement surface. The installed height of the raised pavement marker shall be approximately 1/2 inch above the pavement surface. Ambient temperature at the time of installation of the snow-plowable raised pavement markers shall be at least 50 degrees F or higher.

The top of reflectors shall be mounted flush with the top of the casting.

2. **Raised pavement markers** shall be bonded to the pavement surface in accordance with the manufacturer's recommendations. Bonding material shall be from the Department's approved list or as recommended by the manufacturer of the marker except epoxy shall not be used on asphalt concrete pavements.

**704.04—Measurement and Payment.**

**Pavement line markings** will be measured and paid for at the contract unit price per linear foot. This price shall include the pavement marking material, surface preparation, quality control tests, daily log, guarding devices, primer/adhesive, and glass beads.

**Pavement message markings** will be measured and paid for at the contract unit price per each per location. This price shall include the pavement marking material, surface preparation, quality control tests, daily log, guarding devices, primer/adhesive, and glass beads.

**Pavement markers** will be measured and paid for at the contract unit price per each. This price shall include prismatic retroreflectors, pavement cutting, adhesive, and castings.

**Eradication of pavement markings** will be measured and paid for in accordance with Section 512.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Pavement line marking (Type and/or class and width)	Linear foot
Pavement message marking (Message)	Each Pavement
marker (Type, [ ]-way, and/or type pavement)	Each

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# B

## Acceptance/Inventory Tracking

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**Note: These lists are for training purposes only. Go to [www.VirginiaDOT.org](http://www.VirginiaDOT.org) for current lists.**

## **Excerpts From the VDOT Manual of Instructions**

### **Accepting Glass Beads on the Project**

Glass beads and other reflective optics are to appear as a separate entry on the Contractor's Daily Log and QC Report.

#### **Section 204.30 Reflective Materials**

(Secs. 231, 234, 235, 246, and 701) See Sec. 207 for acceptance of reflective materials on modified inspection procedures.

#### **(a) Pavement Markings**

##### **(1) Sampling, Testing and Approval**

Sampling of reflectorized pavement markings, including glass beads, in the field will not normally be necessary. This material is normally pre-sampled and pre-tested. Materials sampled at the point of manufacture should arrive at the job site or storage area with evidence of test as outlined below. If no such evidence is present, then representative samples need to be taken and shipped to the Central Office Laboratory, in accordance with Sec. 203, using Form TL-10, as outlined in Sec. 800.

##### **(a) Glass Beads**

Glass beads will be sampled at the point of manufacture by representatives of the State Materials Engineer and forwarded to the Central Materials Laboratory for testing and acceptance or accepted under an approved Quality Control Plan, namely the Virginia Glass Bead Acceptance Plan (VGBAP).

The Virginia Glass Bead Acceptance Plan (VGBAP) involves the sampling, testing, documentation and certification of glass beads by the manufacturer at the manufacturing site in combination with a VDOT monitoring effort. VDOT reserves the right to discontinue acceptance of glass beads in the event that verification test results indicate non-specification material is being provided or test procedures are not being followed.

Each batch of glass beads manufactured for use in Virginia must be sampled and tested. A batch is defined as no more than 132,000 pounds. From the batch, X number of units or bags of glass beads will be selected for testing, X being equal to the cube root of the number of units or bags in each batch. For example a batch of 132,000 lbs. contains 2640, 50 pound bags. The cube root of 2640 is 14. Therefore, 14 bags from a 132,000 lb. batch need to be selected. The 14 bags will be opened, split down using a 16:1 splitter and combined until a quart sample is obtained. This quart sample is further split in the laboratory until a 50 gram test sample is obtained and will be tested in accordance with the specified methods.

Glass bead testing equipment (Roundometer, Sieves, Balances, Scales, etc.) at the manufacturing facilities will be inspected by VDOT personnel or its representatives on an intermittent basis. A file of test reports representing this batch of glass beads must be maintained. A copy of the certified test reports must be provided to the VDOT Central Materials Division. Cooperation with VDOT and/or its representatives during periodic verification of certified test reports is required.

The manufacturer must perform the following responsibilities with the assistance of a VDOT approved commercial testing agency.

Quality Control Sampling by the manufacturer will be at the rate of one sample per batch of glass beads produced for use in Virginia.

The manufacturer is to test each batch of glass beads in accordance with ASTM D-1155 Procedure B for Roundness and ASTM D-1214 for Sieve Analysis. A moisture resistance test should also be performed.

Monitor samples will be taken to verify the manufacturer's testing procedures. The monitor sample will be taken at periodic intervals at the manufacturer's facility at the average rate of one per month. The sample taken for monitor acceptance will be a "split " sample, with the manufacturer testing a portion of the sample and VDOT's Central Materials Division testing the other portion.

Monitor samples will consist of one unit or bag of glass beads being randomly selected by VDOT personnel or its representative. This unit or bag will be split in the usual manner by the manufacturer's personnel in the presence of the VDOT's Inspector to obtain two (2) pint samples. One pint will be appropriately labeled and tested by the glass manufacturer, while the other will be tested by the VDOT Central Materials Division. VDOT will perform the tests in the same manner as the manufacturer.

The manufacturer is to maintain a file of certified test reports for all glass beads shipped to VDOT facilities as well as Contractors that perform work for VDOT. These reports are to be kept by the manufacturer for at least 12 months and are to be available for verification by VDOT personnel. (Refer to Page B-9 for example of Form C-85)

- 3) **Central Office Materials Quality Assurance Section** - The Materials Division monitors the striping Contractor's operation by reviewing the C-85. The QA Section also ensures that Manufacturer's certifications are maintained and that the current inventory records match the material on hand.

When materials are shipped directly from the manufacturer to the project, the inventory tracking program **will** apply. In these cases, the Project Inspector will contact the Central Office Materials Quality Assurance Section, who may audit the contractor's documentation of the materials. The Contractor will be responsible for maintaining all documentation as detailed above.

## Other Detailed Requirements

Pavement Markings are a safety item. In emergency situations, where approved by the engineer, pavement markings may be applied without the proper documentation. Section 204.30 of the Manual of Instructions provides for sampling, testing and documentation procedures when marking materials are to be sampled on the project. **Under the tracking program this should never happen. In all other cases the Contractor must present the appropriate documentation to the Inspector before proceeding with the work.**

This tracking ultimately leads to the manufacturer and test coverage. Certifications I & II are used to verify that the material used is that which was tested. It is **IMPOSSIBLE** to document usage after the fact. Contractors who do not have the necessary paper work prior to beginning work should not be allowed to proceed.

Laboratory.

The test reports shall contain the following information:

- Manufacturer's name and address
- Quantity represented
- Pallet numbers represented by the test Pallet numbers sampled for the test Unique Report Number
- Statement indicating that "the manufacturer certifies that these are the test results obtained on glass beads tested under the Virginia Glass Bead Acceptance Program." Test Results obtained on the sample of glass beads.

All shipping documents will contain sufficient information such that at any point, the glass bead pallet numbers may be "back tracked" to the original test results.

Shipping documents are to be provided to Contractors or VDOT for all shipments. (b)

### Traffic Paint

Traffic paint shall be sampled the same as "Paint", as outlined in Sec. 204.24.

### (c) Thermoplastic

Block type thermoplastic marking materials will require 1 block sampled and tested at the Central Office Chemistry Laboratory. Granular materials will be sampled by splitting to obtain a 1 quart sample for testing by the Chemistry Laboratory.

### (d) Preformed Tape

Approved List

### (e) Polyester Resin

Polyester shall be sampled the same as "Paint", as outlined in Sec. 204.24, except that the catalyst will not be sampled.



## (f) Epoxy Resin

Epoxy resin shall be sampled the same as "Paint", as outlined in Sec. 204.24, except that both components shall be sampled.

**(2) Acceptance**

- (a) After appropriate testing has been completed, the manufacturer of the material will attach a certification to their shipping documents similar to one of the following:

**Certification I**

We certify that our product (batch or lot number) on invoice number \_\_\_\_\_ or shipping ticket number \_\_\_\_\_ has been sampled, tested, and approved by VDOT Materials Division as indicated by Laboratory Test Number, MS \_\_\_\_, or by an approved Quality Control Plan as indicated by its unique test number \_\_\_\_.

**Certification II**

We certify that our product has been tested, approved, and is currently on a qualified products list. We certify that our (batch or lot number) on invoice number is the same product that was tested and approved. Indicated on the shipping document will be the test number from the approved list.

All related materials such as primers, sealers and adhesives for use with the markings shall be included on a shipping ticket covered by one of these certifications.

The individual pavement marking items will require certifications as indicated below:

## A. Construction Pavement Markings

Type D - Tape (removable)	Certification II
Type E - Tape (black, removable)	Certification II
Type F - Paint (temporary)	Certificaiton II
Glass Beads	Certification I

## B. Permanent Markings

Type A - Paint	Certification I
Type B	
Class I - Thermoplastic	Certification I
Class III - Epoxy	Certification I
Class IV - Tape (flat)	Certification II
Class VI - Tape (profiled)	Certification II
Glass Beads	Certification I

- (b) Materials shipped directly from the manufacturer for use on a specific project, and materials shipped to a central storage site for use on multiple projects shall be tracked by an inventory tracking program maintained by the Contractor.

The program shall be under the control of the Contractor who will keep a running inventory of all pavement marking materials shipped from that inventory, including all related materials such as primers, sealers and adhesives used in the application.

A Pavement Marking Materials Inventory Ledger form (see sample form Appendix B-10) shall be used to record all shipments to and from the Contractor's stock. A separate Pavement Marking Inventory Ledger shall be maintained for each type of material and for each manufacturer. All ledger entries shall be substantiated by manufacturer shipping documents which shall include the Certification I & II statements. Ledger entries for materials received into stock shall indicate quantity, units, date of receipt, manufacturer's lot or batch number, VDOT or other appropriate test numbers and balance on hand. When materials are taken from inventory for shipment to a project, ledger entries shall include quantity shipped, units, project number, date shipped, and balance on hand. All ledger entries shall be initialed by the Contractor and such initials certify that all entries are accurate and correct.

#### Contractor's Daily Log and Quality Control Report (C-85)

The Contractor's Daily Log and Quality Report is used to track the Contractor's pavement marking materials shipped and installed, quantities, certification information, sample test numbers (MS No's.), work completed (locations) and QC test results. The C-85 form shall have the statement, "Materials shipped under this certification have been tested and approved by VDOT as indicated by laboratory test numbers listed hereon." The C-85 form shall be reviewed and signed by the Contractor and the VDOT inspector on a daily basis.

Monitoring-The Materials Industrial Technician will perform periodic inspection at the pavement marking contractor's storage site and of project records to ensure that the records are being kept in compliance with the above. For those projects where the material is shipped directly to the project, the inspector shall contact the Materials Industrial Technician for monitoring the use of material. The Materials Industrial Technician shall be given free access to all files used in the tracking program and provided with copies of any documents from such files as may be requested. If the Materials Industrial Technician determines that material is untested or needs to be retested, samples shall be taken at the appropriate rate and forwarded to the Central Office Materials Laboratory. The Contractor shall not ship material in question until appropriate test coverage is obtained.

The Materials Industrial Technician will be responsible for obtaining a copy of each C-85 and making distribution to the receiving District Materials Engineer.

#### **(b) PAVEMENT MARKERS AND DELINEATORS**

Pavement markers and delineators will be accepted on approved list.

**Pavement Marking Materials Inventory Ledger**

**Contractor:** \_\_\_\_\_ **Address:** \_\_\_\_\_

**Material:** \_\_\_\_\_ **Manufacturer:** \_\_\_\_\_

Quantity Received	Unit (e.g./cubic yd)	Date Received	Batch No./Lot No.	MS No./List Assoc. No.	Applied on Project No.	Date Applied	Quantity Used	Balance In Stock	Contr. Initials

I certify the above material, quantities and information listed are correct and in accordance with The Virginia Dept. of Transportation, Materials Division, Manual of Instructions, Section 204.50(a)(2)(b).

Cc: Materials Div. Industrial Inspector  
District Materials Engineer

Contractor Representative

\_\_\_\_\_ (Signature)

Form C-85  
Rev. 3/07/07

<b>PAVEMENT MARKING CONTRACTOR'S DAILY LOG AND QUALITY CONTROL REPORT</b>						
Contractor:			Date:	Start Time:	Finish Time:	
Job/Project No:				Sheet	of	
Weather:						
Air Temp. (Start)		Air Temp. (Finish)		Surface Temp. (Start):		
* MATERIALS DOCUMENTATION:						
Type of Material	Quantity	Units	Certification Letter (Type/Date)	MS Number	Exp. Date	
WORK COMPLETED:						
Type of Marking	Contract Item No.	Quantity	Units	Location/Description	Width	Color
Quality Control Measurements:						
Material Type	Q.C. Measurement (Units)		Location	Time	Inspector (Initial)	
* Material shipped under this certification has been tested and approved by VDOT as indicated by laboratory test numbers listed hereon.						
<b>Contractor Q. C. Technician</b>				Date		
VDOT Representative				Date		
Copy	District Traffic Engineer District Materials Engineer		Pay Quantity to be based on actual field measurement verified by the Engineer.			

**(17) QUALIFIED PREFORMED TAPE LIST – (CHEMISTRY LAB)**

The following products have been prequalified, but the manufacturer must supply certification for each lot.

Manufacturer's instructions for installation shall be followed both as to method and temperature of application to pavement requirements. Primer/sealers may be required; the manufacturer's specific recommendations shall be followed, and the cost of the primer/sealer shall be included in the bid price or unit price. Although approved for use, not all products may be equal in all characteristics. Contractor needs to determine the best product for his intended use.

Type	Name	Manufacturer	Approval No.
<b>Type B</b>			
	<b>Class IV</b>		
	These tapes may be used for stop lines, crosswalks, messages and arrows only:		
	<b>White</b>		
	420	3M Manufacturing	STR-91-77
	Series 1000	Brite-Line Technologies	STR-96-137-PA
	ATM 300	Advance Traffic Markings	STR-98-TX-510
	<b>Yellow</b>		
	ATM 300	Advance Traffic Markings	STR-98-TX-511
	<b>Class VI</b>		
	These tapes may be used for edge lines, center and skip lines, messages and arrows only:		
	<b>White</b>		
	380I	3M Manufacturing	STR-96-160-PA
	380I ES (Extended Season)	3M Manufacturing	MS 13965
	380 WR	3M Manufacturing	MS 19276
	380 WR-ES (Ext.Season)	3M Manufacturing	MS 19276
	Stamark 860	3M Manufacturing	MS 11860
	380 I-5 Contrast Tape	3M Manufacturing	MS 11107
	For Center and Skip Line Only		
	<b>Yellow</b>		
	381I lead free	3M Manufacturing	STR-96-161-PA
	381I ES (Ext.Season)	3M Manufacturing	MS 13966
	381 WR	3M Manufacturing	MS 19277
	381 WR-ES (Ext.Season)	3M Manufacturing	MS 19277
	Stamark 861	3M Manufacturing	MS 11861
	381 I-5 Contrast Tape	3M Manufacturing	MS 11108
	For Center and Skip Line Only		

**QUALIFIED PREFORMED TAPE LIST**

The following products have been prequalified, but the manufacturer must supply certification for each lot.

**Type D Class I**

ATM 200 white	Advance Traffic Markings	STR-98-TX-507
ATM 200 yellow	Advance Traffic Markings	STR-98-TX-508
ATM 2000W white	Advance Traffic Markings	PMM-02-12-MS
ATM 2000Y yellow	Advance Traffic Markings	PMM-02-13-MS
Series 100 white	Brite-Line Technologies	STR-97-150-MN
Series 100 yellow	Brite-Line Technologies	STR-97-149-MN
RW-140 white	Trelleborg	PMM(2000PA)-187
RY-140 yellow	Trelleborg	PMM(2000PA)-188

**Type D Class II**

ATM 200 white	Advance Traffic Markings	STR-98-TX-507
Series 100 white	Brite-Line Technologies	STR-97-150-MN
ATM 2000W white	Advance Traffic Markings	PMM-02-12-MS
ATM 2000Y yellow	Advance Traffic Markings	PMM-02-13-MS

**Type D Class III**

Scotchlane 780 white	3M Manufacturing	MS-06-010 VDOT MS 18477
Scotchlane 781 yellow	3M Manufacturing	MS-06-011 VDOT MS 18478

**Type E**

Scotchlane Series A145	3M Manufacturing	STR-93-111
ATM 280 black	Advance Traffic Markings	STR-98-TX-509
Deltaline BTR	Brite-Line Technologies	STR-97-83-MN
RB-140 black	Trelleborg	PMM-01-UT-28

**(20) \*\*APPROVED WATER BORNE LEAD FREE TRAFFIC PAINT\*\* – (CHEMISTRY LAB)**

	<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b>White</b>			
	Sherwin Williams	BP14016	STR-97-41-AL
		BP14019	STR-97-44-AL
		BP15652	STR-98-PA-135
		BP15622	STR-98-PA-150
		BP17312	PMM(2000PA)-170
		BP17313	PMM(2000PA)-171
		BP17316	PMM(2000PA)-174
	<b>Ennis Paint (formerly LaFarge Road Markings and Centerline)</b>		
		CL -6000	STR-96-85-PA
		CL-6004	STR-96-68-PA
		CL-7018	STR-97-69-AL
		CL-8210	STR-98-PA-96
		CL-8214	STR-98-PA-100
		CL-8216	STR-98-PA-102
		CL-8218	STR-98-PA-104
		CL-8220	STR-98-PA-106
		CL-8222	STR-98-PA-108
	<b>Ennis Paint (formerly LaFarge Road Markings and Linear Dynamics)</b>		
		LD96-1002	STR-96-85-PA
		LD96-1008	STR-96-91-PA
		LD971001C	STR-97-138-AL
		LD981001	STR-98-PA-158
		LD981002	STR-98-PA-159
		LD981003	STR-98-PA-160
		LD981004	STR-98-PA-161
		LD981005	STR-98-PA-162
	<b>Ennis Paint (formerly LaFarge Road Markings)</b>		
		LRMOOWB-19	PMM(2000PA)-110
		LRMOOWB-20	PMM(2000PA)-111
		Douglas 303-98	STR-98-PA-214
		Ennis EP200W13	STR-98-PA-17
		Ennis EP200W14	STR-98-PA-18
		Ennis EP200W16	STR-98-PA-20
		EP415W03	PMM(2000PA)-61
		EP415W04	PMM(2000PA)-62

**(20) \*\*APPROVED WATER BORNE LEAD FREE TRAFFIC PAINT\*\* – (CHEMISTRY LAB)**

	<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b>Yellow</b>			
	<b>Sherwin Williams</b>	BP-14021 BP15611 BP15623 BP17314	STR-97-46-AL STR-98-PA-139 STR-98-PA-151 PMM(2000PA)-172
	<b>Ennis Paint (formerly LaFarge Road Markings and Linear Dynamics)</b>	LD961009 LD981009 LD981010	STR-96-92-PA STR-98-PA-165 STR-98-PA-166
	<b>Ennis Paint (formerly LaFarge Road Markings)</b>	LRMOOWB-31	PMM(2000PA)-122
	<b>Aexcel</b>	72Y-AO65	STR-96-148-PA
	<b>Ennis Paint</b>	Douglas 306-98 Douglas 307-98 Ennis EP200Y-15 Ennis EP200Y-18 EP415Y03 EP415Y04 EP415Y05 EP415Y06	STR-98-PA-217 STR-98-PA-218 STR-98-PA-26 STR-98-PA-29 PMM(2000PA)-66 PMM(2000PA)-67 PMM(2000PA)-68 PMM(2000PA)-69



**(22) PAVEMENT MARKERS – (CHEMISTRY LAB)****SNOW PLOWABLE RAISED PAVEMENT MARKERS**

<b>Manufacturer</b>	<b>Casting Model No</b>	<b>Reflector Description</b>	<b>Casting Adhesive</b>	<b>Reflector Adhesive</b>
Ennis Paint/Stimsonite	98 (note 1)	940 (note 2)	Lord Corp. Thermoset EP-87 or AASHTO-M237, Type IV Note 3, Note 4	Liquid Nails - 602
Ennis Paint/Stimsonite	101 MS 08185	944 Ray-O-Lite 2004 Ray-O-Lite 2004S 3M 190	Lord Corp. Thermoset EP-87 or AASHTO-M237, Type IV Note 3, Note 4	Liquid Nails – 602
Accent Stripe, Inc.	Northstar 41	Ray-O-Lite 2004 Ray-O-Lite 2004S 3M 190	Lumiline SMA or AASHTO- M237, Type IV Note 4	Liquid Nails – 602
Nightline	B-400	Ray-O-Lite 2004 Ray-O-Lite 2004S 3M 190	Poly-Carb or Epoplex MA 50 or Epoplex MA-52 AASHTO-M237, Type IV Note 4	Liquid Nails – 602
Hallen	H-1010 HP H-960 HP	Ray-O-Lite 2004 Ray-O-Lite 2004S 3M 190	Any casting adhesive that meets AASHTO-M237, Type IV Note 4	Liquid Nails – 602
Ray-O-Lite	Snow-Lite 100	Ray-O-Lite 2004 Ray-O-Lite 2004S 3M 190	Epoplex MA 50 Epoplex MA 52 Slocum Type M-397 Note 4	Liquid Nails – 602 Or BK0246-01 or

**NOTES:**

Note 1: The Model 98 has been discontinued. The 940 reflector can be used as a replacement in existing Model 98 castings. The Model 98 has been replaced with the approved castings listed below.

Note 2: All reflectors are approved for use in any casting in which they fit.

Note 3: Lord Corp. Thermostat EP-87 formerly Epoxy #2203.

Note 4: Any approved casting adhesive may be used with any casting provided they meet AASHTO M-237, Type IV specifications.

**EMPORARY PAVEMENT MARKERS**

<b>Manufacturer</b>	<b>Marker No.</b>	<b>Size</b>	<b>Adhesive</b>
Ennis Paint/Stimsonite	88	4" x 4"	2202 Bituminous or AASHTO-M237, Type II
Ennis Paint/Stimsonite	911	4" x 4"	2202 Bituminous or AASHTO-M237, Type II
Ennis Paint/Stimsonite	948	2" x 4"	2202 Bituminous or AASHTO-M237, Type II
Ray-O-Lite	"Standard" Types – B,D,DR 2004, 2004S	4" x 4"	Bitumen Adhesive
Ray-O-Lite	Types – B, C, D, DR, G, H, K, X, Z	2" x 4"	Bitumen Adhesive
Ray-O-Lite	Types – B, C, D, DR, G, H, K, X, Z	4" x 4"	Bitumen Adhesive
Ray-O-Lite	Model AA-ARC II Types – B, C, D, DR, G, H, K, X, Z	4" x 4"	Bitumen Adhesive
3M	290 (White) 291 (Yellow)	3.5" x 4" 3.5" x 4"	Bitumen Adhesive
Filtrona/Bunzl Extrusion-Tacoma, Inc	DAPCO RPM	4" x 4"	Bitumen Adhesive

**TRANSITORY PAVEMENT MARKER (TPM)-FOR 10-DAY MINIMUM USAGE**

Filtrona/Bunzel Extrusion-Tacoma, Inc.	TOM-W-1 TOM W-2 TOM Y-1 TOM Y-2	4" Length	Bitumen Adhesive
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**RECESSED PAVEMENT MARKERS**

<b>Manufacturer</b>	<b>Marker No.</b>	<b>Size</b>	<b>Adhesive</b>
Ray-O-Lite	2004, 2004S Types – B, C, D, DR, G, H, K, X, Z	For 4" wide slots/grooves	EP-326 Epoxy
Ennis Paint/Stimsonite	948	For 4.5" wide slots/grooves	2202 Bitumen or AASHTO-M237, Type II
Ennis Paint/Stimsonite	944SB	For 4" wide slots/grooves	2201 Epoxy or AASHTO-M237, Type II

**(43) \*\*Approved Yellow (Lead Free) Thermoplastic Products\*\*  
- (CHEMISTRY LAB)**

The following thermoplastic formulations have been evaluated and found to have satisfactory initial nighttime color. Note that, as part of materials acceptance, all production batches will be tested for comparison with the originally submitted samples.

**Ennis Paint (formerly Avery Dennison) (formerly Stimsonite)**

Product No. 884188 (formerly Y1D-5GX-VA-DCA) Product  
No. 884189 (formerly Y1D-5GX-VA-HRB) Product No.  
884186 (Y1D-5GX-VA-DCC)  
Product No. 884187 (Y1D-5GX-VA-HRC)

**Swarco**

Product No. Swarolux 98 STR-115  
Product No. Swarolux 98 STR-116  
Product No. VYALF001  
Product No. VYALF002

**Ennis Paint (formerly Cataphote)**

**Alkyd Extrude (Yellow L. F. Thermoplastic)**

Product No. 32101462  
Product No. 32101464  
Product No. 32101466  
Product No. 32101468  
Product No. 32101463

**Alkyd Spray (Yellow L. F. Thermoplastic)**

Product No. 32102462  
Product No. 32102464  
Product No. 32102466  
Product No. 32102468

**Ennis Paint (formerly LaFarge Road Marking and LDI )**

- Product No. E E VA AL F Y 99 1 (Made in Eastpoint, Ga.)
- Product No. P E VA AL F Y 99 1 (Made in Pennsdale, Pa.)
- Product No. E E VA AL F Y 99 2 (Made in Eastpoint, Ga.)
- Product No. P E VA AL F Y 99 2 (Made in Pennsdale, Pa.)
- Product No. E E VA AL F Y 99 3 (Made in Eastpoint, Ga.)
- Product No. P E VA AL F Y 99 3 (Made in Pennsdale, Pa.)
- Product No. EEVAAALFY998
- Product No. EEVAAALFY04
- Product No. EEVAAALFY06

**Crown Technology**

- Product No. Ecotherm 06-YAX-AACF
- 06-YAX-01CF
- 06-YAX-00CF

**Ennis Paint**

- Product No. Va-AK-SX-YNL-1

**S.Dobco**

- Product No. Y1X0605
- Y1S0605
- Y1X0615
- Y1X0625

**(48) \*\*APPROVED TYPE F CONSTRUCTION MARKINGS\*\* – (CHEMISTRY LAB)**

All waterborne paint markings shall be applied at a wet film thickness of 15±1 mil and a glass bead application rate of 6 pounds per gallon.

**WATERBORNE PAINT CLASS I**

<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b>White</b> Sherwin Williams	BP-14016	STR-97-41-AL
	BP-14019	STR-97-44-AL
	BP15652	STR-98-PA-135
	BP15622	STR-98-PA-150
	BP17312	PMM(2000PA)-170
	BP17313	PMM(2000PA)-171
	BP17316	PMM(2000PA)-174
<b>Ennis Paint</b> (formerly LaFarge Road Markings and Centerline)	CL-6000	STR-96-64-PA
	CL-6004	STR-96-68-PA
	CL-7018	STR-97-69-AL
	CL-8210	STR-98-PA-96
	CL-8214	STR-98-PA-100
	CL-8216	STR-98-PA-102
	CL-8218	STR-98-PA-104
	CL-8220	STR-98-PA-106
CL-8222	STR-98-PA-108	
<b>Ennis Paint</b> (formerly LaFarge Road Markings and Linear Dynamics)	LD96-1002	STR-96-85-PA
	LD96-1008	STR-96-91-PA
	LD971001C	STR-97-138-AL
	LD981001	STR-98-PA-158
	LD981002	STR-98-PA-159
	LD981003	STR-98-PA-160
	LD981004	STR-98-PA-161
LD981005	STR-98-PA-162	
<b>Ennis Paint</b> (formerly LaFarge Road Markings)	LRMOOWB-19	PMM(2000PA)-110
	LRMOOWB-20	PMM(2000PA)-111
Ennis Paint	Douglas 303-98	STR-98-PA-214
	Ennis EP200W13	STR-98-PA-17
	Ennis EP200W14	STR-98-PA-18
	Ennis EP200W16	STR-98-PA-20
	EP415W03	PMM(2000PA)-61
	EP415W04	PMM(2000PA)-62

**WATERBORNE PAINT CLASS I**

<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b><u>Yellow</u></b>		
<b>Sherwin Williams</b>	BP-14021	STR-97-46-AL
	BP15611	STR-98-PA-139
	BP15623	STR-98-PA-151
	BP17314	PMM(2000PA)-172
<b>Ennis Paint</b> (formerly Linear Dynamics) and LaFarge Road Markings	LD96-1009	STR-96-92-PA STR-98-
	LD981009	PA-165
	LD981010	STR-98-PA-166
<b>Ennis Paint</b>	LRMOOWB-31	PMM(2000PA)-122
<b>Aexcel</b>	72Y-AO65	STR-96-148-PA
<b>Ennis Paint</b>	Douglas 306-98	STR-98-PA-217
	Douglas 307-98	STR-98-PA-218
	Ennis EP200Y-15	STR-98-PA-26
	Ennis EP200Y-18	STR-98-PA-29
	EP415Y03	PMM(2000PA)-66
	EP415Y04	PMM(2000PA)-67
	EP415Y05	PMM(2000PA)-68
EP415Y06	PMM(2000PA)-69	

**WATERBORNE PAINT CLASS II**

<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b><u>White</u></b>		
<b>Sherwin Williams</b>	BP-14016	STR-97-41-AL
	BP-15652	STR-98-PA-135
	BP-15622	STR-98-PA-150
	BP-17312	PMM(2000PA)-170
	BP17313	PMM(2000PA)-171
<b>Ennis Paint(formerly Centerline and LaFarge Road Markings)</b>	CL-8214	STR-98-PA-100
	CL-8216	STR-98-PA-102
	CL-8218	STR-98-PA-104
	CL-8220	STR-98-PA-106
	CL-8222	STR-98-PA-108
<b>Ennis Paint(formerly Linear Dynamics and LaFarge Road Markings)</b>	LD981001	STR-98-PA-158
	LD981001	STR-98-PA-161
	LD981001	STR-98-PA-162

## WATERBORNE PAINT CLASS II

<b>Manufacturer</b>	<b>Product No.</b>	<b>NTPEP Submittal No.</b>
<b><u>White</u></b>		
Ennis Paint	Douglas 303-98	STR-98-PA-214
	Ennis EP200W13	STR-98-PA-17
	Ennis EP200W14	STR-98-PA-18
	Ennis EP200W16	STR-98-PA-20
	EP415W03	PMM(2000PA)-61
	EP415W04	PMM(2000PA)-62
<b><u>Yellow</u></b>		
Sherwin Williams	BP-14021	STR-97-46-AL
	BP-15623	STR-98-PA-151
	BP-17314	PMM(2000PA)-172
Ennis Paint formerly LaFarge Road Markings	LRMOOWB-31	PMM(2000PA)-122
Ennis Paint	Douglas 306-98	STR-98-PA-217
	Douglas 307-98	STR-98-PA-218
	EP415Y03	PMM(2000PA)-66
	EP415Y04	PMM(2000PA)-67
	EP415Y05	PMM(2000PA)-68
	EP415Y06	PMM(2000PA)-69

**(73) APPROVED WHITE AND YELLOW (LEAD FREE) PREFORMED THERMOPLASTIC**

<b>Manufacturer</b>	<b>Product Name</b>	<b>VDOT Approval</b>
<b>No. White</b>		
<b>Flint Trading</b> (336) 475-6600	PreMark	PMM (05)-PA-042
	Hot Tape	PMM (08)-PA-132
	Flame Tape	PMM (05)-PA-059
<b>Sherwin Williams</b> (706)846-2221	Smart Tape	PMM(05)-PA-017
Swarco	Preformed Thermoplastic White	PMM(08)-PA-224

**Yellow**

<b>Flint Trading</b> (336) 475-6600	PreMark	PMM(02)-PA-065
<b>Sherwin Williams</b> (706)846-2221	Smart Tape	PMM(05)-PA-018

**NOTE:**

The above materials shall be supplied at 125 mils in thickness.

Materials shall be installed in accordance with Manufacturer's installation instructions.

If material is applied to hydraulic cement concrete, the primer/sealer used shall be listed on the C-85 (Contractors Daily Log).

During application (when molten) the above materials shall be "flooded" with additional glass beads conforming to AASHTO M247 Type 1.



## List No. 74

**(74) APPROVED POLYUREA MARKINGS**

<b>Manufacturer</b>	<b>Color</b>	<b>Product No.</b>	<b>Retroreflective Optics*</b>	<b>NTPEP Submittal No.</b>
Epoplex Corp.	White	LS-90	M247 Type 1 (10lbs./Gal) Visibead (10lbs./Gal)	PMM -2002-PA-240
Epoplex Corp	White	GM-90	M247 Type 1 (6lbs./Gal) Visibead PlusII(6lbs./Gal)	PMM- 2006-MS-036
Ennis	White	HPS-5	M247 Type 1 (10lbs./Gal) M247 Type 4 (10lbs./Gal)	PMM-2008-PA-124
Ennis	Yellow	HPS-5	M247 Type 1 (Flood) M247 Type 4 (Flood)	PMM-2005-PA-050

NOTE: This same retroreflective optics materials (Type and quantity (lbs./Gal) used for the NTPEP tesing must be used with these products when installed on VDOT roads.

## List No. 75

**(75) APPROVED EPOXY MARKINGS**

<b>Manufacturer</b>	<b>Color</b>	<b>Product No.</b>	<b>NTPEP No.</b>
Ennis Traffic Safety Solutions	White	HPS-3	PMM -08-PA-180
Ennis Traffic Safety Solutions	Yellow	HPS-3	PMM -08-PA-121
Accent Stripe	White	Luminiline III	PMM-08-PA-110
Accent Stripe	Yellow	Luminiline III	PMM-08-PA-111
Poly Carb	White	Mark 55.3	PMM-08-PA-180
Poly Carb	Yellow	Mark 55.3	PMM-08-PA-181
Epoplex	White Yellow	LS-50	PMM-08-PA-190
Epoplex		LS-50	PMM-08-PA-191

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# VTM-94

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1. **Scope**

**Virginia Test Method - 94  
Quality Control Testing of Pavement Markings  
November 1, 2004**

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 film thickness of liquid markings
- C) Determination of film 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 of markings. Method 2 only to be used during thermoplastic application.

Method

1

- a) Apparatus
  - 6 x 6 inches 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 underside of 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.

- a) Apparatus
  - #15 Tar paper
  - Duct tape

## Method 2

- 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. If moisture is present, wait one hour and retest.

## B) Determination of the wet film 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 inch x 6 inch, 20 to 40 mils thick (0.5mm to 1.0mm) thick)
  - Piece of cloth
  - Duct tape
- 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, press the gauge firmly into the material on the sample plate until the posts on the gauge are firmly in contact with the plate. 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 film 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 .001 inch

\* Sample plate (sheet metal – 4 inch x 6 inch, 20 to 40 mils thick)

Duct Tape

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°. 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 &amp; 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).
- 2 - The methods of sampling outlined above may also be used to collect samples for visual inspection of glass bead distribution and embedment 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 thick, 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

\*\*\*\*\*

#### 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.

\*\*\*\*\*

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 film 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 film 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 lb/gal for paint) should be delivered in the time it takes to travel 320 feet , the values in 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 1/2 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**

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

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  $\pm 0.01$  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.

<b>Table 2</b>	
<b>Glass Bead Application Rate per Linear Foot for a Four Inch Line</b>	<b>Glass Bead Application Rate per Linear Foot for a Four Inch Line</b>
<b>Specified Application Rate (lbs/ Gallon)</b>	<b>Glass Beads per Linear Ft. (lbs. / L.F.)</b>
6	0.0188
8	0.025
10	0.03125
25	0.0781
Spec. = 7 lbs./100 ft. <sup>2</sup> 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 lb/L.F. for thermoplastic.

$$175 \times 0.0233 = 4.08 \text{ lb (minimum)}$$

Since the amount collected exceeds 4.08 lb, 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 thickness in the cross-section of the marking.

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## 2) The Glass Beads

Visual inspection of glass bead application are either with regard to distribution or embedment.

### 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 the marking with little or no loss onto the adjacent pavement.

### Embedment

- a) Visual inspections with regard to the embedment of beads into the marking material should be made directly on the pavement surface. The specifications for bead embedment 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 embedment 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

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# D

## Knowledge Check Answers

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### Chapter 1 Standard Practices Answers

1. The purpose of pavement markings is to communicate information about the traveled roadway so motorists can safely reach their destination.
  - a) True
2. Standard markings shall only be used to convey the meaning prescribed for them in the Manual on Uniform Traffic Control Devices (MUTCD).
  - a) True
3. In Virginia, the normal specified width of a longitudinal line is:
  - b) 4 – 6 inches
4. The standard for a broken line separating traffic in the same direction at the same speed limit is:
  - c) 10 ft. segments with 30 ft. gaps.
5. Solid yellow lines are used to delineate the separation of traffic flows in:
  - a) opposing directions.
6. The left edge of divided highways and one way roads is delineated by:
  - d) a single solid yellow line.
7. White lines are used to delineate the separation of traffic flows in:
  - b) the same direction.
8. Broken lines are restrictive in nature.
  - b) False

## Knowledge Check Answers

9. The right edge of divided highways and one way roads is delineated by:  
c) a single solid white line.
10. Solid lines are restrictive in nature.  
a) True
11. A double line consists of two normal width lines separated by a 3 inch space.  
b) False
12. A pavement marking plan or sketch may not be required before a road is marked, but is strongly encouraged.  
a) True
13. A chalk line is the only approved way of pre-marking a road.  
b) False
14. Traffic control is not required when pre-marking on low volume roads.  
b) False
15. Which document takes precedence over all others:  
c) Special Provision Copied Notes
16. In the Road and Bridge Specifications Book, which section specifies that the publication, "Quality Standards for Work Zone Traffic Control Devices" be used?  
c) Section 512

## Chapter 2 Reflective Glass Beads

### Answers

1. Reflective beads are used with pavement markings:
  - c) to enhance nighttime visibility
2. The phenomenon where light is reflected directly back to the light source is called:
  - b) retroreflectivity
3. For glass beads, the light bending phenomenon is known as:
  - a) the refractive index
4. The optimum embedment depth for reflective beads is
  - b) 50 to 60%
5. When inspecting pavement markings with regard to glass beads, which of the following criteria should be met?
  - c) Both a & b
6. In order for glass beads to reflect light as intended, they must be:
  - d) round
7. Proper bead distribution and depth are critical in ensuring a \_\_\_\_\_ line.
  - a) durable and retroreflective
8. Correct glass bead application and embedment will result in the line feeling like:
  - c) sandpaper

## Chapter 3 Traffic Paint Answers

1. VDOT designated "Type A" traffic paint should dry "track-free" within:  
c) 60 seconds
2. Reflective beads are normally:  
b) spray applied to the wet paint immediately following application of the marking material.
3. The minimum surface temperature at which Virginia designated Type A traffic paint may be applied is:  
c) 50 °F +
4. Before marking materials of any kind may be applied, the surface of the roadway must be:  
c) both a & b
5. The specified application thickness for Virginia designated Type A traffic paint is:  
c) 15 ±1 mil when wet
6. The minimum amount of glass beads applied to Type A paint is:  
a) 6 pounds per gallon



## Chapter 4 Liquid Thermoplastic Answers

1. Liquid thermoplastic pavement marking material:
  - a) is a blend of solid materials that becomes liquid when heated.
2. Markings constructed with liquid thermoplastic pavement marking materials are considered:
  - a) durable markings.
3. Liquid thermoplastic comes from the manufacturer with reflective beads already intermixed.
  - a) True
4. Reflective beads have to be applied to liquid thermoplastic pavement markings.
  - a) True
5. Granular thermoplastic may be heated three (3) times.
  - a) True
6. Block thermoplastic may be heated three (3) times.
  - b) False
7. It is permissible to intermix alkyd and hydrocarbon thermoplastic materials in the same heating kettle.
  - b) False
8. Which of the following methods are acceptable for applying thermoplastic?
  - d) all of the above
9. Virginia Road & Bridge Specifications requires the thickness of thermoplastic markings to be:
  - b)  $90 \pm 5$  mils when set
10. Virginia specifies that glass beads be applied to liquid thermoplastic immediately and uniformly across the entire line at the rate of:
  - a) 7 lb/100 ft<sup>2</sup>

## Chapter 5 Preformed Thermoplastic Answers

1. There is no need to add glass beads to newly applied preformed thermoplastic since they are intermixed with the material at the factory.  
c) False
2. When stored inside at a temperature between 35°F and 95°F, preformed thermoplastic has a shelf life of \_\_\_\_\_ .  
c) 1 year
3. Preformed thermoplastic is considered to be a:  
a) durable pavement marking
4. When preformed thermoplastic has been positioned on the pavement, it is necessary to heat only the edges of the material to achieve a good bond with the pavement.  
b) False
5. When a small portion of freshly applied preformed thermoplastic has been chiseled up to inspect for bonding with the pavement, it should \_\_\_\_\_ on the underside.  
b) have some asphalt stuck to it

## Chapter 6 Epoxy Resins

### Answers

1. Epoxy pavement marking material:
  - a) is a two component system.
2. Epoxy pavement marking material does not contain solvent.
  - a) True
3. For epoxy pavement markings, the ratio of resin to hardener is:
  - d) all of the above
4. The Virginia specified thickness for epoxy pavement markings is:
  - c)  $20 \pm 1$  mil when wet
5. The equipment used to apply epoxy resin pavement markings cannot be used to apply any other liquid binder material.
  - a) True
6. The minimum surface temperature for applying epoxy markings in Virginia is:
  - c)  $50^{\circ}\text{F} +$
7. Glass beads should be applied to the surface of epoxy resin at the rate of:
  - b) 25 pounds per gallon

## Chapter 7 Polyurea Answers

1. What is one advantage for using Polyurea pavement marking material?
  - a) Good abrasion resistance.
2. Polyurea pavement marking material is normally applied at the following thickness:
  - b) 20 mils
3. Polyurea pavement marking material cure time is less than one minute.
  - b) False
4. What is the sheet called where manufacturer's product information is found for polyurea application requirements?
  - c) Product Data Sheet (PDS)
5. Polyurea is typically applied at a 20 mil wet film thickness and will yield a 20 mil dry film thickness after curing.
  - a) True

## Chapter 8 Preformed Tape Answers

1. Preformed tapes do not contain pigments.  
b) False
2. Preformed pavement marking tapes can be used for:  
c) both a & b
3. When patterned tape is inlaid, no primer is used.  
c) Follow the manufacturer's installation instructions
4. Glass beads are applied to pavement marking tapes:  
c) by the manufacturer
5. The minimum surface temperature at which pavement marking tapes may be applied is:  
d) as recommended by the manufacturer
6. Virginia specifications allow pavement marking tapes to be tamped with vehicle tires.  
b) False
7. Virginia Road & Bridge specifications state that the contractor is responsible for supplying a copy of the manufacturer's installation recommendations to the project inspector.  
a) True
8. Virginia designated Type E tape is:  
c) black

## Chapter 9 Pavement Markers Answers

1. Pavement markers may be used in lieu of pavement markings. b)  
False
2. The most common types of pavement markers are:  
d) all of the above
3. Raised temporary pavement markers are glued to the roadway with a bitumen or epoxy adhesive.  
a) True
4. Raised temporary pavement markers are normally used with:  
b) construction zone markings.
5. Raised snow plowable marker castings are installed using bitumen adhesive.  
b) False

## Chapter 10 Installation & Quality Control Answers

1. VDOT requires that by the end of each workday, form C-85, "Contractor's Daily Log and Quality Control Report", shall be signed by the Contractor and delivered to the:
  - c) Engineer or VDOT Inspector
2. VDOT specs. state that before proceeding with work, surface temperature and weather conditions must be checked for compliance with the specifications by the:
  - b) contractor's certified Q.C. technician
3. Layouts for pavement markings must be in conformance with:
  - b) The Manual on Uniform Traffic Control Devices(MUTCD).
4. VDOT requires that quality control tests be conducted in accordance with:
  - d) VTM-94.
5. What topics should be discussed at the pre-construction conference held prior to beginning pavement marking operations?
  - d) all of the above
6. A copy of the manufacturer's recommended installation instructions for pavement marking tapes does not have to be supplied by the contractor.
  - b) False
7. A Material Safety Data Sheet (MSDS) must be obtained by the contractor for each material required for a particular type of pavement marking.
  - a) True
8. In Virginia, traffic control must be constantly monitored to minimize disruption and to ensure compliance with:
  - e) a and c
9. The contractor is required to measure the application thickness and bead application rate:
  - b) at the beginning of each workday and every three hours thereafter.
10. Both the contractor and the inspector should constantly monitor the installation and quality of the material being placed.
  - a) True

11. In addition to application rates and glass bead distribution, markings should be inspected with regard to:  
d) all of the above
12. VDOT requires in order that corrective action be taken, the inspector should immediately report unacceptable work to:  
c) the contractor.
13. When should pay quantities be compared and confirmed by the contractor and inspector?  
b) at the end of each operation or the end of each workday
14. Before beginning work, the Source of Materials Document is required to insure that:  
d) all of the above
15. VDOT specifications require the Materials Inventory Tracking system to be maintained by the:  
a) contractor
16. The contractor's inventory is monitored by the:  
a) Central Office Materials Quality Assurance Section
17. Copies of materials certifications are to be retained by the contractor as part of the Materials Inventory Tracking documentation.  
a) True
18. When materials are delivered directly from the manufacturer to a VDOT project, the project inspector will contact:  
b) Central Office Materials Quality Assurance Section
19. Contractor's Daily Log and Quality Control Report is required on Federal Projects only.  
b) False



## Chapter 11 Equipment Answers

1. A long-line paint truck manufactured by one company should look exactly the same as that of a different manufacturer.  
b) False
2. Which item mentioned below is a component for a long-line truck?  
d) all of the above
3. The inspector should be knowledgeable with the pavement marking equipment to help identify problems.  
a) True
4. Clear communication and cooperation between the inspector and contractor helps ensure quality.  
a) True
5. One must inspect pavement marking “close up” to ensure quality.  
a) True

## Chapter 12 Eradication Answers

1. Failure to remove existing markings when there are shifts in the traffic pattern can:  
d) all of the above
2. Which of the following methods is not acceptable for long term eradication?  
e) both b and c
3. All residue created when eradicating pavement markings must be:  
b) contained.
4. Eradication methods, other than those specified, must be submitted to the project engineer for approval prior to beginning work.  
a) True
5. Eradicated lines should be inspected for:  
c) both a & b
6. Virginia designated Type E black tape may only be used on hydraulic cement concrete roadways.  
b) False
7. One of the criteria in Virginia for using Type E black tape in lieu of eradication is that the traffic pattern will shift back to the original pattern within:  
c) 120 days.