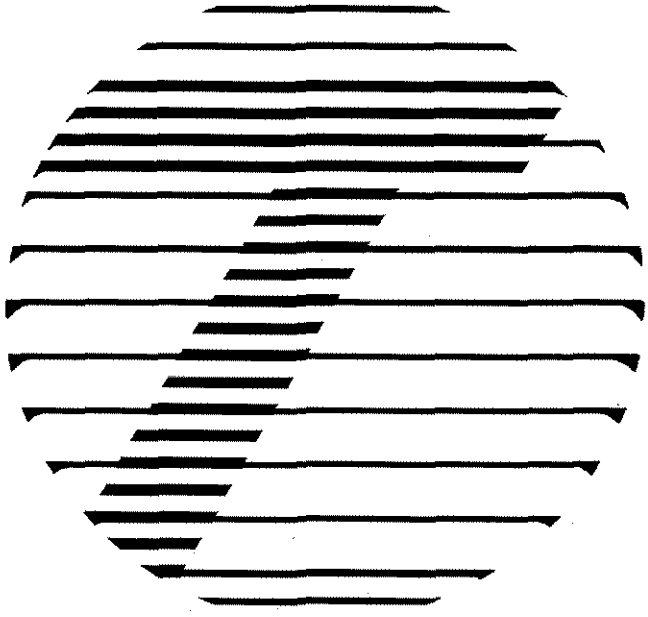
PAVEMENT MARKING MATERIAL GUIDELINES



NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU

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I. INTRODUCTION

The Department uses various types of pavement marking materials which are applied either by Regional maintenance forces or by contractors on capital construction projects. The purpose of these markings includes delineation for center lines, lane lines, and edge lines; hatch lines such as are used in medians and gore areas; and special markings (intersection markings) such as stop lines, crosswalks, arrows, words, and symbols. Pavement marking materials fall into three general categories: 1) nondurable markings, including standard reflectorized traffic paints; 2) durable markings, including epoxies, polyesters, thermoplastics, and preformed tape markings; and 3) raised snowplowable pavement markers (RSPMs). One of the Department's goals is to provide effective pavement marking on a year-round basis through effective and appropriate use of these materials.

An effective pavement marking is one that provides adequate daytime and nighttime visibility over its expected service life. For traffic paints and durable markings, effective daytime visibility is achieved when the pavement markings visually appear to be performing as originally installed in terms of color and design. Effective nighttime visibility requires that a significant portion of the light from a vehicle's headlamps is reflected back to the driver. This characteristic is called retroreflectivity. To achieve adequate retroreflectivity, reflective spheres must be present in sufficient quantities in paints and durable markings. In the case of raised snowplowable pavement markers, retroreflectivity is provided to selected portions of the highway geometry by using reflective lenses mounted in metal housings which are affixed to the pavement.

Factors which control the performance of pavement markings include traffic density, weather, material durability, surface compatibility, and proper application. Once a material is selected for an application and proper surface preparation is performed, the quality of the application must be monitored on a continual basis through proper inspection techniques. This document provides an overview of the characteristics of pavement marking materials currently used by the Department, and discusses inspection techniques to assure their proper application. It is to be expected that regional experience with these pavement markings will vary as the materials, application equipment, surface preparation, application conditions, and pavement environment vary.

II. PAVEMENT MARKING MATERIAL CATEGORIES

A. NONDURABLE PAVEMENT MARKINGS

Standard Reflectorized Pavement Marking Paints

Standard reflectorized pavement marking paint (traffic paint) is a versatile longline pavement marking material which is not considered a 'durable' marking. It is recommended for use on roadways with low traffic volume (less than 5000 AADT).

Traffic paint may also be applied on a newly constructed roadway with a traffic volume greater than 5000 AADT if epoxy or polyester markings cannot be applied before nightfall, or before the end of the working day. Epoxy or polyester may then be applied directly over the traffic paint (maximum one layer) during the same construction season or during the following construction season.

Table 1 – Traffic Paint Application Summary

Specification	**Standard Specification Section 640**
Recommended Use	**Longline**
Recommended Traffic Volume	**<5000 AADT[1]**
Cost per Meter (100mm width) **- 0.38 mm (wet film thickness) [2]** **- 0.51 mm (wet film thickness)** **- 0.75 mm (wet film thickness)**	 **$0.18 to $0.53** **Insufficient data** **Insufficient data**
Service Life [3] (Yrs)	**0.5 to 1.0**
Application Conditions	**Air ≥10°C and rising** **Pavement ≥10°C and rising**
Recommended Thickness **- all existing and new pcc** **- new acc** **- open graded or paver placed**	 **0.38 mm** **0.51 mm** **0.75 mm**
No-Track Time (Minutes)	**3**
Reflective Spheres	**0.75 kg/ℓ**

1. **Other applications are appropriate as indicated above. Designers should refer to the Regional list of highways that qualify for durable pavement markings.**
2. **Unlike durable markings, traffic paint thicknesses diminish significantly as solvent evaporates.**
3. **May be reduced for some applications, refer to Appendix C.**

Material Requirements. Traffic paint must comply with Federal and State air quality regulations for the emission of volatile organic compounds (VOCs). For this reason, solvent-based traffic paints are seldom used: NYSDOT predominantly uses waterborne traffic paint. The newest and most durable type of waterborne traffic paint is one that uses a fast-dry acrylic resin emulsion. This paint contains a 100% acrylic resin emulsion, prime and extender pigments, additives, and water as the solvent/emulsion agent. The paint is normally supplied in drums but it may be supplied in smaller containers (pails) for use with portable paint applicators. The inside of paint containers must be painted or lined to avoid gelling or coagulation of the paint. (Coagulation can also occur if the traffic paint freezes.)

Section 640 - Reflectorized Pavement Marking Paints are accepted based on the manufacturer's name and the brand name of the material appearing on the Department's Approved List.

Cost and Service Life. The cost of traffic paint installed on capital construction projects varies widely due to the difference in the quantities used. Based on a 100 mm width, the cost ranges from $0.18 to $0.53 per meter. The service life of traffic paint is 6 to12 months depending on traffic volume, geographic location, and weather conditions at the time of application. The service life of waterborne traffic paint may be less when the application or curing temperatures are less than 10°C. This characteristic of traffic paint is of special concern late in the season when temperatures for curing will be lower following its application.

Pavement Compatibility. Traffic paint is compatible with new and aged conventional asphalt and concrete pavements. It is also compatible with many other specialty types of asphalt and concrete pavements. Appendix A includes descriptions of the different types of specialty pavements, and Appendix C indicates the compatibility of traffic paint with various surfaces.

Pavement Marking Compatibility. Traffic paint may be applied over itself or over any other type of pavement marking. However, traffic paint debonds more quickly when it is applied over durable markings (i.e. epoxy, polyester, thermoplastic, or preformed tape). *Traffic paint should not normally be applied over durable markings (longline or special markings) that are expected to be restriped with another durable marking, because the traffic paint will cause the overlying durable marking to debond.*

Surface Preparation. Loose debris and foreign contaminants should be removed prior to striping, and the pavement should be dry. Removal of pavement markings or curing compounds is not necessary. Refer to Appendix D for information on handling and waste disposal.

Application and Inspection. Traffic paint may be applied using mobile or portable application equipment, and it may be applied with either atomizing or airless striping equipment. "Wetted" parts (parts in contact with the paint) in the striping equipment must be either stainless steel, painted metal, or teflon. Waterborne paint in contact with other

types of materials may cause the paint to gel or coagulate. The wet film thickness of traffic paint should be either 0.38 mm for existing pavement surfaces and new concrete surfaces, or 0.51 mm for new asphalt pavement surfaces. For open graded or paver placed surface treatments, a wet film thickness of 0.75 mm may be required. The wet film thickness of traffic paint may be checked using the inspection procedures outlined in Appendix E. Reflective glass spheres are immediately applied to the wet paint at the rate of 0.75 kg/ℓ of paint. (See Appendix F and Appendix G.)

The ambient and pavement surface temperatures at the time of application should be a minimum 10°C and rising. Fast-dry, acrylic waterborne paint will chemically form a more durable marking when applied at warmer temperatures. A waterborne paint applied at 21°C will be more durable than a waterborne paint applied at 10°C. Fast-dry, acrylic waterborne traffic paint may be applied at ambient temperatures or heated as high as 60°C. (Refer to the manufacturer's instructions.) The main purpose of heating the material is to lower the viscosity for proper spraying. *Fast-dry acrylic waterborne paints must never be heated above 65 °C because the paint will coagulate in the painting equipment.*

The drying time of waterborne traffic paint depends on weather conditions (temperature, humidity, and wind) at the time of application. The water in these paints does not evaporate as quickly as solvents such as toluene. Ideal weather conditions for optimum drying of waterborne paint are high temperature, low humidity, and high wind velocity. Excessive paint thickness can increase the drying time. The typical no-track time under ideal conditions is 3 minutes. Coning and/or lane closures are not normally necessary but may be required if the paint is not drying properly.

Waterborne paints require time to form a durable film that will resist "washout" from a rainstorm. *Waterborne traffic paint should not be applied if rain is expected within 4 hours after paint application.*

B. DURABLE PAVEMENT MARKINGS

Three types of pavement markings used by NewYork State are considered 'durable' pavement markings, suitable for longline delineation: epoxy, polyester, and thermoplastic. For reasons of surface compatibility and use limitations, epoxy is the preferred material for longline (and also hatch line) pavement markings. Preformed tape pavement markings are also durable, and are the preferred materials for intersections; however, seasonal limitations or performance characteristics sometimes results in epoxy markings being used for intersections. Designers should refer to the Regional list of highways that qualify for durable striping when selecting pavement markings.

1. Epoxy Reflectorized Pavement Markings

Epoxy is a durable pavement marking which is the primary longline material used for Regional striping contracts. In addition to being used for center lines, lane lines, and edge lines, epoxy should be used for hatch lines such as in medians and gore areas.

Table 2 – Epoxy Application Summary

Specifications	**Standard Specifications 685 and 727-03 Special Specification 18685.07/.08M (Wet-night Visibility Spheres)**
Recommended Use	**Longline, Intersections[1], Hatch**
Recommended Traffic Volume	**All**
Cost per Meter (100mm width) [2] - 0.38 mm - 0.51 mm	** $0.26 to $0.33 Insufficient data**
Service Life (Yrs) [3] - acc - pcc	** 2 to 3 1.5 to 2**
Application Conditions	**Air and Pavement ≥ 10°C and rising (not damp)**
Thickness - all existing and new pcc - new acc	** 0.38 mm 0.51 mm**
No-Track Time (Minutes)	**30(regular dry @ 25° C) 60(slow dry @ 25° C)**
Reflective Spheres	**2.4 kg/ℓ or 1.2 kg/ℓ Type I plus 1.2 kg/ℓ Type II**

1. **For frictional considerations at intersections, use standard size (or Type II) reflective spheres only, minimize width of transverse boundary lines (300 mm, max), and avoid placing ladder bars in the wheelpaths.**
2. **Upstate, without wet-night visibility spheres. Where/when contracts, add 30%.**
3. **May be reduced for some applications, refer to Appendix C.**

Material Requirements. Epoxy is a two-component (Part A base and Part B hardener), 100% solids material. Part A contains epoxy resin and "prime" (high quality) pigment. The mix ratio is 2:1 by volume, Part A to Part B, respectively. Epoxy may be either a regular-dry or a slow-dry formulation.

Epoxy pavement marking material that arrives at the project site must be packaged in its original container with proper labeling that shows the manufacturer's name and the brand name of the epoxy as it appears on the Approved List. Each component is supplied by the

epoxy manufacturer in drums or tote (storage) tanks. Quality assurance testing is performed on each lot of material, therefore, the shipping containers must have red and green metal seals signifying that the epoxy has been sampled, laboratory tested, and accepted by the Department.

Section 685 - Epoxy Reflectorized Pavement Markings (with standard size reflective glass spheres) is the primary construction specification. *Specification 727-03 White and Yellow Epoxy Reflectorized Pavement Markings* controls the materials requirements for these products. Epoxy with standard size reflective glass spheres provides good long-term dry-night reflectivity but provides only fair wet-night reflectivity due to the size of the spheres and the thickness of the epoxy. *Special Specification 18685.07/.08 M - Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres)*, which requires a combination of standard size and larger size reflective glass spheres, can provide better wet-night reflectivity. The larger reflective glass spheres used in this specification, however, are more susceptible to snowplow damage, therefore, current policy states that only Regions 8, 10, and 11 may use the larger, wet-night visibility spheres.

Epoxy pavement markings should be placed at a thickness of 0.38 mm on existing pavements and new concrete pavements, but on new asphalt pavements the required thickness is 0.51 mm.

Epoxy with standard size reflective glass spheres (Section 685) may be used as intersection markings where cool weather installation is expected or where performance problems with preformed tape makes epoxy a more suitable choice. *Epoxy with wet-night visibility spheres should not be used for intersection markings.* If epoxy is used for high-visibility, ladder bar crosswalks, the standard crosswalk design should be modified so that the epoxy ladder bars are only 0.3 m wide and are not placed in the wheelpaths (typically about 1.0 m wide). Appendix H shows a standard and a modified high-visibility, ladder bar crosswalk design.

Cost and Service Life. In general, when epoxy with standard size reflective glass spheres is used in large quantities in Regional striping contracts, the bid prices range from $0.26 to $0.33 per meter. The expected service lives are 2 to 3 years on conventional asphalt and 1½ to 2 years on concrete. Using the slow-dry type of epoxy may extend the service life of epoxy on concrete pavement, but the no-track times are much longer than the regular-dry formulation.

Pavement Compatibility. Epoxy is compatible with new and aged conventional asphalt and concrete pavements. It is also compatible with many other asphalt and concrete specialty pavements developed in recent years. Appendix A includes descriptions of the different types of specialty pavements and Appendix C shows when epoxy is recommended.

Pavement Marking Compatibility. Epoxy is compatible with existing epoxy markings, provided that the existing epoxy is at least one construction season old. Epoxy that is less than one construction season old which requires restriping must have a substantial amount of the reflective glass spheres in the existing surface removed to successfully bond the new epoxy marking. Epoxy is compatible when applied over thermoplastic. It is also compatible

if applied over traffic paint, provided that the epoxy is applied over a single layer of traffic paint that is applied directly to the pavement. Epoxy is not compatible with polyester pavement markings or with preformed tape. The epoxy will lose its bond to these surfaces prematurely. (Refer to Appendix C.)

Surface Preparation. *Section 635 - Cleaning and Preparation of Pavement Surfaces For Pavement Markings* should be used to remove epoxy or thermoplastic pavement markings that have a poor or marginal bond to the pavement, curing compound from concrete pavement, preformed tape and polyester pavement markings, and multiple layers of traffic paint. Prior to restriping existing epoxy with new epoxy, the adhesion of existing epoxy on concrete pavement should be evaluated by attempting to remove the epoxy with a knife blade. The bond of aged thermoplastic (8 to 10 years old) to the pavement surface also should be evaluated prior to restriping with new epoxy.

When multiple layers of epoxy (2 or more) exist, it may be necessary to remove all existing layers of epoxy before restriping if experience shows that the epoxy or the reflective glass spheres are failing prematurely.

For the repair of newly placed (same season) defective epoxy markings, *Section 685 - Epoxy Reflectorized Pavement Markings* requires that a substantial amount of the reflective glass spheres be removed from the defective epoxy marking before restriping. Also, if the defective epoxy marking is uncured, the entire thickness of uncured epoxy must be removed prior to restriping with epoxy. Loose debris and foreign contaminants should be removed. Refer to Appendix D for information on handling and waste disposal.

Application and Inspection. Epoxy longline pavement markings are applied using mobile striping equipment that has manual (hand) spraying capability for hatch lines and special (intersection) markings. An air blast gun should be mounted on the striping equipment in front of the epoxy spray guns to remove loose debris simultaneously with the epoxy striping. Ambient and pavement surface temperature requirements are a minimum 10°C and rising. Epoxy should not be applied to damp or wet pavement surfaces.

Application of epoxy pavement markings is by airless spray. Positive displacement pumps (proportioning pumps) produce high pressure (typically 10 to14 MPa) for proper spraying and for proper mixing of the two components. The three cylinders of each proportioning pump provide the 2:1 mix ratio. The Part A and Part B components are combined in a manifold or "Y block" and then mixed in a static mixing tube just prior to spraying onto the pavement. After spraying has ceased, a solvent is used to purge the mixed epoxy. Recently, the "impingement" method has been developed for the application of epoxy. One of its advantages is that it greatly reduces or eliminates the need to use solvent to purge the spraying system of mixed epoxy. The impingement method does not use a static mixing tube. Instead, the two epoxy components are forced together in a mixing chamber at high pressures (typically 18 to 20 MPa). After spraying ceases, the mixing chamber is mechanically cleaned through the use of a purge rod.

Each of the epoxy components is heated according to the manufacturer's recommendations (normally 25°C to 65°C). Overheating of the components may result in heat polymerization

(hardening). Heat is primarily used to reduce the viscosity for proper spraying and for proper mixing (blending) of the Part A and Part B components. It also helps to reduce no-track time.

The allowable variation of the 2:1 epoxy mix ratio is small. The mix ratio is monitored by gages that show the pressure in each of the three cylinders of the proportioning pump. The three pressures should be reasonably equal but may vary slightly due to the difference in viscosity of the two components.

Applying the specified thickness is critical to the long-term performance of epoxy. An epoxy marking that is not applied at the proper thickness will wear or abrade away quicker than expected, and will experience premature loss of the reflective glass spheres due to improper embedment. The thickness of epoxy can be randomly checked by taping a metal plate to the pavement and measuring the wet film thickness (without glass spheres) with a wet film thickness gage. The best method of verifying the epoxy thickness is by calculating the daily "yield." This can be done by measuring the total amount (liters) of epoxy (Part A and Part B), the total lineal meters of epoxy striping, and the average width of the epoxy lines. The yield should be measured and calculated each time the striping truck is loaded with new material. The thickness or yield of epoxy markings may be determined by using the inspection procedures outlined in Appendix E.

Reflective glass spheres are applied immediately onto the liquid epoxy at relatively high coverage rates for long-term reflectivity and to reduce tracking by car tires. Section 685 requires that the reflective glass spheres be applied at the minimum coverage rate of 2.4 kg/ℓ of epoxy. This quantity of reflective glass spheres will completely cover the surface of the epoxy marking (sandpaper appearance) and leave a small excess on the top surface of the epoxy. *Special Specification 18685.07/.08* requires a minimum coverage rate of 1.2 kg/ℓ for Type I (large size) and 1.2 kg/ℓ for Type II (standard size) reflective glass spheres. Due to the larger size of the Type I spheres, the amount of marking surface area covered by this "double-drop" method will be less than with the "single drop" method which is used when only standard spheres are applied.

Field no-track time, as defined in the specification, at 25 °C is 30 minutes for regular-dry and 60 minutes for slow-dry epoxy. The epoxy may cure more slowly in cooler weather. *Coning and/or lane closures are required to prevent tracking by vehicles and damage to the epoxy markings.*

The epoxy markings should be checked for proper curing (hardness) shortly after their application and just prior to their final acceptance. If the application equipment is not functioning properly, the epoxy could be applied at an improper mix ratio or it could be applied without the components being thoroughly blended. An improper mix ratio or inadequate blending will produce uncured, generally discolored (black or brown) epoxy. Uncured, discolored epoxy may appear in a cyclic pattern (regularly spaced intervals) or as longitudinal streaking. A cyclic pattern may indicate that the proportioning pumps require rebuilding or replacement. Longitudinal streaks of discolored epoxy may indicate that the static mixing tube requires cleaning or replacement. Areas of discolored (uncured) epoxy

can spread to adjacent areas over time (weeks or months depending on the severity of the improper mix ratio.)

Proper curing of the epoxy markings should first be checked approximately one hour after application. One or more random areas, approximately 30 m long, should be checked with a knife blade for differences in hardness. Significant differences in hardness along the 30 m section, especially those that occur in a cyclical pattern, could indicate an improperly applied epoxy marking. The hardness of the epoxy markings also should be checked with a knife blade 24 hours after application. Epoxy manufacturers formulate their products using different raw materials, therefore, the degree of cure after 24 hours may vary from one manufacturer to another. In general, after 24 hours the epoxy markings should be cured to the point that it is difficult to penetrate the epoxy with a knife blade. The epoxy should not be flexible (soft) or be capable of being easily removed from the pavement. Severe mix ratio problems may also be visually evident (black or brown discolored areas) at the time of this inspection. If discolored or uncured areas are found, the Engineer should immediately notify the Contractor to repair the application equipment.

Prior to final acceptance, the epoxy markings should be visually inspected during the daytime for black or brown colored, defective (uncured) areas. The specification requires the Contractor to repair defective epoxy markings. A nighttime drive-through survey should also be conducted to evaluate the retroreflectivity.

2. Polyester Reflectorized Pavement Markings

Polyester is a durable longline pavement marking material which is another option (after epoxy) for use on Regional striping contracts. Polyester has usage limitations (application and pavement compatibility) that are not associated with epoxy pavement markings. Based upon formal research conducted in New York State, polyester was recommended for use on low traffic volume (<5000 AADT) highways. Originally, it was intended as a supplemental pavement marking for State maintenance striping crews which traveled long distances to apply traffic paint in outlying areas of their Region. Since its initial use, polyester has been installed by two Regions on higher traffic volume highways that were previously striped with epoxy pavement markings; however, data on the performance of these applications is limited. Polyester application equipment does not have the manual spray capability for applying hatch lines or special markings (intersection markings).

Table 3 – Polyester Application Summary

Specification	Special Specification 91685.07 M
Recommended Use	Longline
Recommended Traffic Volume	<5000 AADT[1]
Cost per Meter (100mm width) - 0.38mm	 $0.23
Service Life [2] (Yrs) - acc - pcc	 2.0 NR
Application Conditions	Air ≥10°C and rising Pavement ≥10°C and rising (not damp)
Recommended Thickness - acc	 0.38 mm to 0.51 mm
No-Track Time (Minutes)	30 @ 25° C
Reflective Spheres	2.4 kg/ℓ

1. Other applications may be appropriate as indicated above.
2. May be reduced for some applications, refer to Appendix C.

Material Requirements. Polyester is a two-component (Part A base and Part B hardener), approximately 100% solids material. The Part A base contains polyester resin, styrene and/or methyl methacrylate, plus pigments or fillers. Part B hardener is a catalyst (commonly methyl ethyl ketone peroxide). Other types of catalysts are available, some of which are fire resistant. The mix ratio of polyester is 50:1 by volume, Part A to Part B, respectively.

Special Specification 91685.07 M - Polyester Reflectorized Pavement Markings is the primary specification. Approved suppliers of polyester are listed within the specification. Current specifications require a polyester material that has a field drying time of approximately 30 minutes, therefore, a conventional (regular-dry) formulation must be supplied. *Fast-dry polyesters are not allowed.*

Quality assurance testing (sampling at the manufacturer's facility and lab testing of each lot) is not performed for polyester. The material is accepted at the job site based upon the proper labeling on the shipping containers.

Cost and Service Life. In general, when polyester is used in large quantities in Regional striping contracts, the bid price is approximately $0.23 per meter. The expected service life of polyester on conventional asphalt pavement is 2 years.

Pavement Compatibility. Polyester is compatible with new and aged conventional asphalt mixes with some limitations. For new asphalt pavement, traffic paint is typically applied as the initial pavement marking and then polyester is either applied later in the year or during the following construction season through a Regional striping contract. *If polyester is applied to new asphalt pavement during the same construction season, the polyester generally should not be applied until the asphalt pavement is at least 30 days old.*

Polyester is not generally recommended for use on concrete pavement. Most other States adhere to this practice. Polyester is compatible with many other specialty types of asphalt pavements that have been recently developed. Appendix A includes descriptions of the different types of specialty pavements, and Appendix C indicates the compatibility of polyester with various pavement surfaces.

Pavement Marking Compatibility. Polyester is compatible with existing polyester pavement markings, provided that the existing polyester is at least one construction season old. Polyester that is less than one construction season old, that requires restriping, should have a substantial amount of the reflective glass spheres in the existing surface removed by grinding to successfully bond the new polyester marking material.

Polyester is compatible with existing traffic paint. Although no formal research has been conducted, it is recommended that polyester only be applied over a single layer of traffic paint that is applied directly to the pavement.

Field testing has demonstrated that polyester is not compatible over existing epoxy pavement marking material.

Due to the lack of actual field experience, it is not recommended that polyester be applied over thermoplastic or over preformed tape.

Surface Preparation. *Section 635 - Cleaning and Preparation of Pavement Surfaces For Pavement Markings* should be used to remove: polyester pavement markings that exhibit a poor or marginal bond to the pavement; epoxy, thermoplastic, and preformed tape; and multiple layers of traffic paint. Loose debris and foreign contaminants should be removed. Refer to Appendix D for information on handling and waste disposal.

Application and Inspection. Polyester longline pavement markings are applied using mobile striping equipment that does not have manual (hand) spraying capability for hatch lines or special markings (intersection markings). An air blast gun should be mounted on the striping equipment in front of the spray guns to remove loose debris immediately prior to striping. The conventional dry formulation is normally applied by the air atomization method. Catalyzation is achieved by the "external" method through which the Part A base and the Part B hardener components are sprayed toward each other, intersecting at the point of application.

Polyester is applied at a 0.38 mm to 0.51 mm wet film thickness (without glass beads). Reflective glass spheres are immediately applied to the wet polyester film at the minimum rate of 2.4 kg/ℓ of polyester to provide long-term reflectivity and to reduce tracking by car tires. The inspection procedures outlined in Appendix E can be used with polyester to check for the proper thickness. Ambient and pavement surface temperature requirements for polyester application are a minimum 10°C and rising. Polyester should not be applied to damp or wet pavement surfaces. The polyester material may be applied without the use of heat. If heat is used, Part A can be heated to 38°C to improve viscosity and no-track time: *it should not be heated over 49 °C.* Part B hardener is not normally heated.

Field no-track time at 25°C is approximately 30 minutes. The no-track time can be shortened somewhat by adjusting the quantity of hardener. *Coning and/or lane closures are required to prevent tracking by vehicles and damage to the polyester markings.*

3. Thermoplastic Reflectorized Pavement Markings

Thermoplastic is occasionally used as an alternative to epoxy on new asphalt pavement for longline pavement markings and for hatch lines in medians or gore areas. It is possible to apply thermoplastic with portable equipment for special markings (i.e. intersection markings).

Thermoplastic has some usage limitations that are not associated with epoxy pavement markings. Thermoplastic is more susceptible to snowplow damage due to its specified thickness. It is more sensitive to adverse weather conditions (temperature and moisture) at the time of installation, and it cannot be restriped with thermoplastic. Thermoplastic does not adhere well to concrete pavement. For these reasons, epoxy is preferred over thermoplastic for longline and hatch line pavement markings. Preformed tape is the preferred material for intersection markings.

Table 4 – Thermoplastic Application Summary

Specifications	**Standard Specifications 687 and 727-01**
Recommended Use[1]	**Longline, Hatch**
Recommended Traffic Volume	**All**
Cost per Meter (100mm width)	**Relatively High and Variable**
Service Life [2] (Yrs) **- acc** **- pcc**	 **3 to 5** **NR**
Application Conditions	**Air ≥9.5°C and rising** **Pavement≥12.5°C and rising** **(not damp)**
Thickness **- acc**	 **3.2 - 4.8 mm**
No-Track Time (Minutes)	**10 @ 21° C**
Reflective Spheres[3]	**0.25 kg /m²**

1. **Intersection application possible with portable equipment.**
2. **Refer to Appendix C.**
3. **Surface application in molten state.**

Material Requirements. Thermoplastic is formulated as either a hydrocarbon resin or a modified alkyd resin material, and also includes prime and extender pigments, fillers, and reflective glass spheres which are premixed into the thermoplastic composition. It is commonly supplied in granular form packaged in bags but it can also be supplied in block form packaged in boxes. Either form is heated to a high temperature (232°C to 246°C) in a melting kettle. This type of thermoplastic is designed to be extruded, not sprayed onto the pavement.

Section 687 - Thermoplastic Reflectorized Pavement Markings is the primary construction specification. *Specification 727-01 White and Yellow Thermoplastic Reflectorized Pavement Markings* controls the materials requirements for these products. Each lot of thermoplastic pavement marking material is sampled and tested by the Department. The Manual of Uniform Record Keeping (MURK) Part 2A, the Materials Inspection Manual explains the evidence of acceptability for thermoplastic material.

Primers or adhesives used with thermoplastic are excluded from Federal and State air quality regulations.

Cost and Service Life. Due to the lack of sufficient quantities of data, comparative costs for thermoplastic cannot be provided. Its expected service life is 3 to 5 years.

Pavement Compatibility. Thermoplastic is compatible with new and aged conventional asphalt mixes. Thermoplastic is not recommended for use on concrete pavement or for most specialty types of pavements. Appendix A includes descriptions of the different specialty types of pavements and Appendix C shows when thermoplastic may be recommended.

Pavement Marking Compatibility. New thermoplastic is not recommended to be applied over existing thermoplastic. The profile or height of the two layers will make it susceptible to snowplow damage and the new thermoplastic will not bond properly to the existing layer of thermoplastic.

Thermoplastic is not recommended to be applied over any other type of pavement marking material. Thermoplastic forms a mechanical bond with the underlying pavement surface, therefore, it must penetrate into the pavement voids.

Surface Preparation. *Section 635 - Cleaning and Preparation of Pavement Surfaces For Pavement Markings*, should be used to remove all types of pavement markings. Loose debris and foreign contaminants should be removed. Refer to Appendix D for information on handling and waste disposal.

Application and Inspection. This type of thermoplastic is applied onto the pavement surface by the extrusion method. The best method of extrusion application is by using a mobile applicator which is better equipped to apply a good quality marking. The specification requires that contract quantities of 20 000 m (or more) of longline thermoplastic be applied using a mobile applicator. Contract quantities less than 20 000 m may be applied with portable application equipment.

Thermoplastic forms a mechanical bond to the pavement, therefore, weather conditions and material temperature at the time of application are critical to its performance. Asphalt paving is often done late in the construction season (October and November), therefore, thermoplastic installations under these circumstances must be closely monitored. The ambient temperature must be 9.5 °C and rising and the pavement surface temperature must be 12.5 °C. The pavement surface must be clean and dry. Blistering in the thermoplastic may indicate the presence of excessive moisture in the pavement. Windy conditions may cause the thermoplastic to cool more quickly, especially if the extrusion device is not properly shrouded. Thermoplastic markings applied under poor weather conditions may delaminate from the pavement during the first winter season.

Thermoplastic is heated in a melting kettle for several hours prior to its use. The molten material must be constantly agitated to thoroughly blend all of the components and to prevent overheating or "hot spots." Heating the material above 246 °C will degrade the resin and/or plasticizers. Overheating can become evident if white thermoplastic turns to a dull white or creamy color, or yellow thermoplastic turns to a brown or greenish color. Overheating can cause the thermoplastic to become brittle, lose its bond to the pavement, or crush to a powder. Manufacturers recommend not heating the material longer than 6 hours

at 204.5°C or no longer than 4 hours at 232°C. Manufacturers also recommend heating granular type thermoplastic *no more than 3 times*, and heating block thermoplastic *no more than 2 times* (ie. since block thermoplastic has already been heated once in the formation of the block from its material components.)

Primers for thermoplastic are only required if the pavement is more than one construction season old. The primer should be one that is recommended by the thermoplastic manufacturer and it should be applied in accordance with the manufacturer's written instructions.

The minimum material temperature for proper application of thermoplastic is 204.5°C at the point of deposition. Thermoplastic extrusion devices are normally jacketed with a heated oil medium and are shrouded to protect the thermoplastic from cooling too quickly. The extrusion shoe must be equipped with a temperature measuring device to show the temperature of the thermoplastic mixture (not the oil) at the point of deposition. The design of the extrusion device along with the speed of the applicating equipment, control the width and thickness (3.2 mm to 4.8 mm).

Reflective glass spheres are immediately dropped onto the molten thermoplastic at the rate of 0.25 kg/m^2 of thermoplastic surface to provide initial reflectivity. As the thermoplastic wears, the premixed glass spheres become exposed to provide long-term reflectivity.

Thermoplastic reaches a no-track time at 21°C in approximately 10 minutes. Coning and/or lane closures may be necessary to prevent tracking by vehicles and damage to the pavement marking. Detailed application and inspection guidelines for thermoplastic are contained in MURK Part 1B, the Construction Inspection Manual.

4. Preformed Reflectorized Pavement Markings

Preformed tape is primarily recommended for special markings (intersection markings) such as stop lines, crosswalks, arrows, words, symbols, and lane lines located at intersections. Preformed tape has better durability (abrasion resistance) compared to other types of durable pavement marking materials. It may be used for small placements of longline pavement markings when it is not feasible or cost effective to stripe with mobile application equipment.

If preformed tape is used for high-visibility, ladder bar crosswalks, the standard crosswalk design should be modified so that the preformed tape ladder bars are only 0.3 m wide and are not placed in the wheelpaths (typically about 1.0 m wide). Appendix H shows a standard and a modified high-visibility, ladder bar crosswalk design.

Preformed tape can tear or delaminate when it is used in areas of severe or sharp turning movements, therefore, its use in these types of areas should be limited. Epoxy may be a better alternative.

Table 5 – Preformed Tape Application Summary

Specifications	**Standard Specifications 688 and 727-04**
Recommended Use[1]	**Intersections** [3]
Recommended Traffic Volume	**All**
Cost per Meter (100mm width)	**Most Expensive**
Service Life (Yrs)	**3**
Application Conditions [2]	**Air ≥15.5°C** **Pavement≥21°C** **(not damp)**
Traffic Exposure (Minutes)	**10 @ 21° C for primer/adhesive**

1. **Small quantities of longline are allowable.**
2. **Seasonal Limitations also apply.**
3. **For frictional considerations at intersections, minimize width of transverse boundary lines (300 mm, max), and do not place ladder bars in the wheelpath. (See Appendix H.)**

Material Requirements. Preformed tape is a factory fabricated pavement marking material that is preformed into the proper thickness, width, and shape. Preformed tape is composed of a mixture of plastics or polymers, resins, pigments, and either glass and/or ceramic spheres for reflectivity. The bottom of the tape is precoated with a pressure sensitive adhesive.

Section 688 - Preformed Reflectorized Pavement Markings is the primary construction specification. *Specification 727-04 White and Yellow Preformed Reflectorized Pavement Markings* controls the materials requirements for these products.

Longline preformed tape is supplied in rolls of various widths and lengths. Preformed tape for special markings (i.e., intersections) may be supplied as precut symbols and legends, or in wide rolls for cutting out symbols and legends. The top surface of the preformed tape may be either flat (smooth) or profiled (patterned). Patterned surface preformed tapes are designed to provide better long-term dry-night reflectivity, and also better wet-night reflectivity compared to flat surface preformed tapes.

All preformed tapes have good initial reflectivity due to the reflective glass or reflective ceramic spheres that are present on the surface of the tape. Most of the smooth or flat surface preformed tape products lose a high percentage of that initial reflectivity during the early life of the product. Reflective spheres are included within the composition of the tape but those spheres do not typically become exposed due to the tape's high durability. When preformed tape is used in areas with overhead lighting, for example intersections, reflectivity is less critical.

A newer type of preformed tape with an embossed (profiled, raised pattern) surface has improved, longer-term reflective properties. However, the price of this preformed tape material does not make it cost-effective for large quantities of longline striping when compared to epoxy or polyester pavement markings.

Primers or adhesives used with preformed tape are excluded from Federal and State air quality regulations.

Preformed tapes are accepted at the project site based upon the appearance of the manufacturer's name and the brand name of the material on the Approved List.

Cost and Service Life. No cost data is provided since preformed tape is not used as a longline pavement marking. One of the reasons that it is not recommended as a longline pavement marking is its high material cost compared to other types of durable markings. The expected service life of preformed tape is a minimum 3 years on conventional asphalt and concrete.

Pavement Compatibility. Preformed tape is compatible with new and aged conventional asphalt and concrete, and some specialty types of pavements. Appendix A includes descriptions of the different specialty types of pavements and Appendix C shows when preformed tape may be recommended.

Pavement Marking Compatibility. Preformed tape is not recommended for installation over any type of pavement marking, including existing preformed tape. The bond of preformed tape is partially dependent upon the tape conforming to the surface texture of the pavement. Therefore, the bond of preformed tape may not be as good when it is placed over a smooth preformed tape surface. Placing new preformed tape over existing preformed tape also makes the pavement marking more susceptible to snowplow damage due to the increased height.

Surface Preparation. Loose debris and foreign contaminants should be removed. *Section 635 - Cleaning and Preparation of Pavement Surfaces for Pavement Markings* should be used to remove all types of pavement markings (including existing preformed tape) and curing compound on concrete pavement. Refer to Appendix D for information on handling and waste disposal.

Application and Inspection. Preformed tape may be installed onto the pavement surface (overlaid) as long as the temperature and seasonal limitations shown in the specifications are met. The ambient temperature should be a minimum 15.5 °C and the pavement temperature should be a minimum 21 °C. Seasonal limitations for placement are included in the specification because the preformed tape requires warm weather after its installation to be flexible and conform to the pavement surface as vehicle tires pass over it. A primer or adhesive is generally recommended by the manufacturer for use with preformed tape, especially for intersection markings. Preformed tape should not be installed until the primer has dried according to the manufacturer's recommendations. Primer or adhesive normally takes 10 minutes to dry at 21 °C.

Preformed tape is applied by hand, however, longline tape may be applied with a portable applicator. Following its application to the pavement, proper tamping or rolling according to the manufacturer's recommendations (minimum 90 kg load tamper cart or vehicle car tire) is important. Preformed tape may also be installed and rolled into the pavement (inlaid) during asphalt paving operations after finish rolling is complete. The specification requires that the pavement surface temperature be between 37.5 °C and 76.5 °C.

Most manufacturers require that the preformed tape not be installed if rainfall has occurred 24 hours prior to the tape application. The preformed tape manufacturer may recommend a moisture test to verify that the pavement is sufficiently dry. This test consists of placing a piece of plastic on the pavement, sealing the edges with tape, and waiting for a certain time period to check for moisture. Traffic may be allowed on preformed tape immediately after its installation.

The specification includes a 180-day performance period in which the Engineer does a final performance inspection to determine if any significant areas of preformed tape have failed and require repair.

C. SNOWPLOWABLE PAVEMENT MARKERS

Raised Reflectorized Snowplowable Pavement Markers

Raised reflectorized snowplowable pavement markers (RSPMs) consist of a snowplow-resistant housing with a retroreflector which can be used to supplement longline pavement markings and improve nighttime wet-weather delineation. They can reduce accident frequency by improving delineation in areas where encroachment, run-off-the-road, head-on, or sideswipe accidents occur.

The use of RSPMs should be limited to short sections of highway (maximum 0.8 km) where accidents can be reduced by improving wet-night delineation. Several large studies indicate that overuse of RSPMs may have a counterproductive effect on accident rates. Also, excessive use of RSPMs will result in unnecessary added maintenance costs to replace plow blades and truck components.

Table 6 – RSPM Application Summary

Specifications	**Special Specifications 18685.0310 M, .0311 M, .0312 M, .0313 M, and .0314 M Raised Reflectorized Snowplowable Pavement Markers** **Special Specifications 18685.0315 M, .0316 M, .0317 M, .0318 M, and .0319 M Replacement Retroreflector for Existing Raised Reflectorized Snowplowable Pavement Markers**
Recommended Use[1]	**Improvement of delineation where encroachment, run-off-the-road, head-on, or side-swipe accidents occur.**
Recommended Traffic Volume	**All**
Cost per Unit	**$30**
Service Life[2] **(Yrs)** **- housing** **- reflector**	 **Life of Pavement** **3 - 4**
Application Conditions	**Air and Pavement≥10°C (not damp)**
Set Time[3] **(Minutes)**	**10 @ 21° C**

1. **Overuse may be counterproductive.**
2. **Studies show 10 to 15% total snowplow damage per season.**
3. **Epoxy adhesive.**

Material Requirements. An RSPM housing is typically a heat treated, ductile iron casting containing a one-way or two-way retroreflector. The pavement is cut and a two-component epoxy adhesive is used to fasten the housing to asphalt or concrete pavement. A one component adhesive is used to bond replacement retroreflectors to existing housings.

Engineering Instruction 93-37 - Raised Reflectorized Snow Plowable Pavement Markers and *Engineering Instruction 99-23 - Raised Reflectorized Snow Plowable Pavement Markers* issued the policy, design criteria, installation guidelines, and other issues related to installing RSPMs. (*Special Specifications 18685.0310 M* through *18685.0319 M* were issued by *EI 99-023*.) RSPMs and replacement retroreflectors are accepted at the project site based upon their appearance on the Approved List, and the manufacturer's certification that the materials meet the specification requirements.

The epoxy adhesive for the housing and the adhesive for replacement retroreflectors are accepted at the project site based upon the manufacturer's certification that the materials meet the specification requirements.

Cost and Service Life. The installed cost of raised RSPMs is approximately $30 per unit when installed in large quantities. Housing life is normally equal to the life of the pavement unless snowplows damage housings which were improperly installed.

The installed cost of replacement retroreflectors is $7 per unit when installed in large quantities. Retroreflectors may require replacement at 3 to 4 year cycles due to lens damage or loss of reflectivity.

Pavement Compatibility. The epoxy adhesive used to adhere the housing to the pavement is compatible with asphalt and concrete. RSPMs should be removed from the pavement prior to any pavement rehabilitation, reconstruction, or resurfacing.

Surface Preparation. The pavement should be cut according to the manufacturer's recommended dimensions (width, length, and depth). Loose debris must be removed from the pavement cut and the pavement cut must be dry prior to dispensing the epoxy adhesive.

Application and Inspection. Improper installation of RSPMs will result in damage to the housing, the retroreflector lens, or the equipment on snowplows. In some instances, improper installation has resulted in the entire housing becoming dislodged from the pavement. The initial pavement cuts should be checked for the proper depth of cut by placing a casting in the hole prior to installing the epoxy adhesive. The sides or tabs of the housing should rest on the pavement surface and the leading edges of the housing should be slightly below the pavement surface. It is also important to check for proper depth of cut throughout the day.

After the pavement is cut according to the manufacturer's written instructions, the pavement cut should be cleaned and it should be free of loose debris prior to installing the epoxy adhesive. If water is used during cutting, the pavement cut should be surface-dry before the epoxy adhesive is installed. The ambient and pavement surface temperatures for the installation of RSPMs are a minimum of 10°C and rising. The surface temperature of the housing should be a minimum 10°C, and the temperature of the epoxy adhesive should be a minimum 10°C.

If necessary, the epoxy adhesive may be heated according to the epoxy manufacturer's written instructions to facilitate mixing and dispensing. Normally, the epoxy is automatically proportioned and mixed just prior to dispensing into the pavement cut. The pavement cut should be filled with epoxy to about 10 mm from the top of the pavement surface. The housing is immediately placed into the epoxy adhesive. *Extreme care should be taken to ensure that the sides or tabs on each side of the housing are resting on the pavement surface.* Epoxy adhesive should not cover any portion of the retroreflector lens. The installed RSPMs should be protected from traffic until the epoxy adhesive has hardened to a condition that will not allow movement of the housing.

The replacement of retroreflectors in existing housings should be performed when the ambient temperature and the housing temperature are a minimum 10°C, and the housing is dry. The existing retroreflector is removed and the underlying housing surface is cleaned in accordance with the specification. The protective liner or release paper, if present, is removed from the laminated elastomeric pad on the bottom of the new retroreflector. If recommended by the manufacturer, an approximate 10 mm diameter bead of adhesive is applied to the center of the pad or the housing. The retroreflector is installed in the housing and a minimum load of 45 kg is applied to the top of the retroreflector.

APPENDICES

APPENDIX A

DEFINITIONS

AADT - Average Annual Daily Traffic. A measure of traffic volume.

Acrylic Resin - The binder component in fast-dry waterborne traffic paint which binds the pigment, additives, and reflective glass spheres together, and also bonds the paint to the pavement surface.

Adherence Coating - Reflective glass spheres are sometimes treated with a coating (usually silane) to improve the bond of the spheres to the pavement marking. Reflective glass spheres treated with a silane adherence coating should not be used with fast-dry acrylic resin waterborne traffic paint, because the adherence coating allows the spheres to become overly embedded in the paint, resulting in poor initial reflectivity. Different types of adherence coatings are manufactured for compatibility with the specific type of binder (resin) used in the pavement marking material.

Approved List - A list of pretested and approved pavement marking materials maintained by the Materials Bureau. The Approved List is available on line at www.dot.state.ny.us.

Coagulation - A thickening of traffic paint which prevents its proper application.

Dual-Purpose Coating - Reflective glass spheres are sometimes treated with a coating to provide both moisture resistance and adherence properties.

Durable Pavement Marking - A pavement marking such as epoxy, polyester, or thermoplastic which, when properly applied, will perform adequately for two years or more.

Engineer or Engineer-in-Charge - The Engineer representing the Department of Transportation, having direct supervision over the execution of a contract.

Epoxy Pavement Marking - A two component, durable pavement marking system composed of an epoxy resin base plus a prime pigment (Part A), and a hardener (Part B).

Eradication - The removal of existing pavement markings.

Extrusion - The method of applying thermoplastic pavement marking materials to a pavement surface by forcing the heated thermoplastic mixture through a die.

Gelling - See Coagulation.

Hardener or Catalyst - A component of a liquid pavement marking that when combined at the proper mix ratio with a base or resin component causes cross-linking and film formation.

Ice Retardant Hot Mix Asphalt - A bituminous mix which includes encapsulated calcium chloride granules.

Longline Pavement Marking - Longitudinal pavement marking lines used to indicate the boundary of lanes, and the permissibility for (or prohibition against) entering an adjacent lane or area. The Department's Pavement Marking Policy defines longline pavement markings as: center lines, lane lines, edge lines, and hatch lines.

MEKP - *Methyl ethyl ketone peroxide. A hardener commonly used in polyester pavement markings* which fosters the polymerization process.

Microsurfacing - A mixture of polymer-modified asphalt emulsion, aggregate, mineral filler, and water.

Mix Ratio - The proportion of separately packaged components of a multicomponent material by which the components are to be combined and mixed before application.

Moisture Resistant Coating - Reflective glass spheres are sometimes treated with a coating (silicone) which prevents clumping of the beads due to high humidity and allows the beads to flow freely from the glass bead dispenser on the pavement marking equipment.

MURK - Manual for Uniform Record Keeping which sets up uniform project record procedures.

MUTCD - *Manual of Uniform Traffic Control Devices.*

No-Track Time - A condition where no visual deposition of a pavement marking material to the pavement surface is observed when viewed from a distance of 15 m, after a passenger car tire has passed over the line.

Paver Placed Surface Treatment - A warm, polymer-modified asphalt emulsion coat that is followed by a thin hot mix asphalt wearing course.

Pigment - Components of pavement marking materials which impart color, pavement hiding power, and UV stability characteristics.

Polyester Pavement Marking - A two component, durable pavement marking system composed of polyester resin, a styrene solvent, pigment, and a catalyst (usually MEKP).

Preformed Tape Pavement Marking - A solid, pre-made marking material which is used for legends, stop bars, symbols and transverse markings, and which is bonded to the pavement with pressure sensitive adhesives.

Quick-Set Slurry - A mixture of asphalt emulsion, aggregate, mineral filler and water.

Reflective Beads or Reflective Spheres - Round spheres, usually glass but sometimes ceramic, that when properly embedded in pavement marking materials produce retroreflectivity.

Region - One of the eleven geographical subdivisions of the State of New York represented by the New York State Department of Transportation.

Resin - The chemical component of spray-applied or extruded pavement markings which binds the pigment, additives, and reflective spheres together, and also, bonds the marking to the highway surface.

Retroreflectivity - The ability of a marking material to reflect light back to a light source.

Single Course Surface Treatment (Chip Seal) - A thin overlay consisting of the application of an asphalt emulsion followed by the application of a single layer of crushed stone aggregate.

Solvents - Chemicals added to traffic markings in their liquid phase to make them easier to handle and apply. When solvents evaporate sufficiently, the marking becomes a track-free solid.

Special Markings - The Department's Pavement Marking Policy defines special markings as: stop lines, crosswalks, arrows, words, symbols, and lane lines at intersections.

State - The State of New York, represented by the New York State Department of Transportation.

Thermoplastic Pavement Marking - A solid plastic material mixture at normal temperatures which is heated, agitated, and applied to the pavement surface by an extrusion process. Upon cooling, a solid, durable marking which is thermally bonded to the pavement surface.

Ultra-Thin Whitetopping - a thin pcc overlay with an accelerated set time.

VOCs - Volatile Organic Compounds. These are chemicals (including solvents) which readily evaporate at normal temperatures and which contribute to ground level ozone formation which is considered a health hazard. Many solvents are regulated (limited) by the Clean Air Act Amendment (CAAA) of 1990. Acetone and some chlorinated solvents have been exempted by the CAAA from VOC rules.

Wet-night Visibility Spheres - Large size beads or spheres that are applied to, or manufactured into a pavement marking material to improve night retroreflectivity during light to moderate rainstorms.

Yield - A measure of the coverage rate of a spray-applied or extruded pavement marking material, usually expressed in meters per liter (m/ℓ) or meters per kilogram (m/kg) for a given average line width and thickness.

APPENDIX B

CONVERSION INFORMATION

Metric to English Conversion

Multiply	By	To Obtain
kilometers (km)	3280.8	feet (ft)
kilometers (km)	0.6214	miles (mi)
kilograms (kg)	2.2046	pounds (lb)
liters (ℓ)	0.264	gallons (gal)
liters (ℓ)	33.81	fluid ounce (oz)
meters (m)	3.2808	feet (ft)
megapascals (MPa)	145.038	pounds/square inch (psi)
millimeters (mm)	39.37	thousands of an inch (mils)
millimeters (mm)	0.03937	inches (in)
square meters (m^2)	10.76	square feet (ft^2)

English Metric to Conversion

Multiply	By	To Obtain
feet (ft)	0.3048	meters (m)
fluid ounce (oz)	0.02957	liters (ℓ)
gallons (gal)	3.785	liters (ℓ)
inches (in)	25.4	millimeters (mm)
miles (mi)	1.6093	kilometers (km)
pounds (lb)	0.4536	kilograms (kg)
pounds/square inch (psi)	0.006895	megapascals (MPa)
square feet (ft^2)	0.0929	square meters (m^2)
thousands of an inch (mils)	0.0254	millimeters (mm)

Equivalencies:

1.0 km = 1000 m ($= 10^{3}$ m)

1.0 m = 1000 mm ($= 10^{0}$ m)

1.0 mm = 1000 μm ($= 10^{-3}$ m)

1.0 $\ell = 10^{-3}$ m^3

1.0 $\ell = 10^{6}$ mm^3

1.0 metric ton = 1000.0 kg

C° = 5/9(F° - 32°)

F° = (9/5)C° + 32°

APPENDIX C

PAVEMENT MARKING COMPATIBILITY CHART

EXISTING SURFACE / NEW MARKING	Traffic Paint	Epoxy New (< 1 season)	Epoxy Old (> 1 season)	Poly-ester New (< 1 season)	Poly-ester Old (> 1 season)	Thermo-plastic New or Old	Pre-formed Tape	New AC	Old AC	Chip Seal	Micro-Surf. AC or Quick-Set Slurry	Open Graded AC or Paver Placed Surf. Treat-ment AC	Ice Retar-dant AC	New or Old PC	White Top PC
Traffic Paint	√	√4, 9	√4, 9	√4, 9	√4, 9	√4, 9	√4, 9	√12	√	√	√7	√6	√11	√	√
Epoxy	√10	√3	√	NR	NR	√	NR	√12	√	NR	√5	√6	√11	√8	√8
Polyester	√10	NR	NR	√3	√	NR	NR	√2	√	NR	√2	√2, 6	√2, 11	NR	NR
Thermoplastic	NR	NR	NR	NR	NR	NR	NR	√	√	NR	NR	NE	√11	NR	NR
Preformed Tape	NR	NR	NR	NR	NR	NR	NR	√	√	NR	NR	NR	√11	√8	√8

NOTES:

1. √ = Compatible. NR = Not Recommended. NE = No field experience.
2. Pavement must be 30 days old.
3. Remove glass spheres by grinding or blast cleaning; remove uncured epoxy entirely.
4. May debond more quickly than over traffic paint or standard pavement.
5. Wait 7-14 calendar days for moisture to evaporate from pavement.
6. May require application thickness of 0.75 mm.
7. Wait for water to evaporate from pavement before applying same day striping.
8. If present, remove curing compound per Section 635.
9. Not recommended if the existing durable will be restriped with a new durable at a later date.
10. May only be applied over a single layer of traffic paint which is applied directly on the pavement.
11. Compatibility dependent upon the cleanliness (free of oil and sand) and dryness of the pavement (free of water).
12. Use 0.51 mm thickness pay item.

APPENDIX D

HANDLING AND WASTE DISPOSAL

Yellow-colored pavement markings have traditionally contained lead chromate as the prime yellow pigment due to its good performance and relatively low cost. The Department is investigating the feasibility of replacing lead chromate pigment in yellow pavement markings with alternative types of pigments, and currently has several field trials in place. Organic yellow pigments are available that do not contain lead or chromium, however, they are generally more expensive and have demonstrated long-term performance problems. Many states which have switched to organic yellow pavement markings have reported that the yellow color fades from ultraviolet exposure resulting in poor daytime color, and that the yellow pavement markings look whitish under nighttime illumination.

The lead content of yellow pavement markings used by the Department varies and is approximately: 2.2% by weight in yellow waterborne pavement marking paints and 10% by weight in dried yellow epoxy markings. (Percentages similar to epoxy are expected for yellow thermoplastic and yellow polyester markings.) While many manufacturers of preformed tape have replaced lead chromate with another type of yellow pigment which contains no lead, there is a possibility of lead presence in the waste from some of these materials at levels similar to epoxy. Awareness training and practices, including good hygiene, are required when working with lead-containing pavement markings.

If surface preparation standards require the removal of existing markings, the removed markings, including the pavement material and road debris containing the removed markings, require disposal as industrial* solid waste, typically at a municipal landfill facility. This pavement marking waste should be collected by typical construction methods, such as, sweeping and/or vacuuming of the debris. A permitted waste transporter is required for transport of over 227 kg (500 pounds) of waste within a single load to a disposal facility.

*Past testing by NYSDOT of yellow waste debris indicated that although lead and chromium were present, concentrations of these elements did <u>not</u> meet the regulatory limit for classification as a hazardous waste, and would therefore be considered as a non-hazardous industrial waste.

APPENDIX E

PAVEMENT MARKING INSPECTION

I. Pavement Marking Thickness (wet film thickness without reflective glass spheres):

The average installed thickness of a pavement marking line is calculated by determining the quantity (liters) of liquid material, and the length and width of the applied marking. These measurements are inserted into the formula shown below.

Thickness Formula for Epoxy, Polyester, or Traffic Paint:

$$\text{Thickness (mm)} = \frac{(10^3) \times \text{Quantity (liters)}}{\text{Length (meters)} \times \text{Width (millimeters)}}$$

NOTE: This thickness formula is designed to account for the actual line width which is applied in the field. A line that is specified to be 100 mm wide may actually be applied wider (110 mm or 115 mm wide). Coverage rates for standard line widths and thicknesses are shown below. Thickness of pavement marking is wet film thickness before application of reflective spheres. No provision is made for overspray/waste.

The quantity (liters) of liquid material used is determined by taking measurements in the material storage tank on the striping equipment. After the Contractor fills the storage tank, a measurement is taken from the top of the liquid material in the tank to a reference point at the top of the tank (d_1). When the Contractor stops striping and before the tank is refilled, another measurement is taken using the same procedure described above (d_2). The truck should be on a fairly level surface when taking depth measurements, and two measurements should be taken (each on opposite sides of the tank lid opening) to determine an average depth measurement.

The difference between the two depth measurements ($d_2 - d_1$) is then multiplied times a "tank factor" (ℓ/mm) to determine the quantity of material used. Some striping equipment manufacturers supply the Contractor with "tank factors," or with tank charts or tank graphs which show the quantity of material versus the tank depth. If the Contractor cannot supply this information, a "tank factor" may be obtained by filling an empty tank and measuring the unfilled depth each time a known quantity of striping material is loaded into the tank. The "known" quantity of striping material supplied in the shipping container should be verified (measured) prior to loading it into the tank.

For two-component epoxy, the quantity used in the thickness formula will be the sum of Part A (white or yellow) and Part B (hardener).

II. Pavement Marking Coverage Rates:

1. Epoxy, Polyester, or Traffic Paint:

   a. 0.38 mm (380 μm) thickness*, 100 mm width = 26.3 m/ℓ coverage rate

   b. 0.38 mm (380 μm) thickness*, 150 mm width = 17.5 m/ℓ coverage rate

   c. 0.51 mm (510 μm) thickness*, 100 mm width = 19.6 m/ℓ coverage rate

   d. 0.51 mm (510 μm) thickness*, 150 mm width = 13.1 m/ℓ coverage rate

   *Thickness of pavement marking before application of reflective spheres (wet film thickness in the case of traffic paint.)

   Conversion Factor

   1.0 liter of a 100 percent solids by volume material will cover 39.3 square meters at a 0.0254 mm (25.4 μm) thickness.

2. Thermoplastic:

   At 100 mm wide and 3.2 mm thick, thermoplastic will yield an average of 1524.6 m per metric ton (i.e., 1000 kg). At 3.2 mm thick, thermoplastic will yield an average of 152.5 square meters per metric ton.

APPENDIX F

REFLECTIVE GLASS SPHERES FOR PAVEMENT MARKINGS

Specification 727-03 (For Section 685 Epoxy)
Special Specification 18685.07/.08 M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres)
Special Specification 91685.07 M Polyester Reflectorized Pavement Markings
Specification 727-01 (For Section 687 Thermoplastic)
Specification 727-05 (For Section 640 Traffic Paint)

Currently, two types (gradation or size) of reflective glass spheres (or glass beads) are used with pavement markings: standard size and large size. All of the specifications listed above use standard size with the exception of *Special Specification 18685.07/.08 M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres*), which uses both standard size and large size reflective glass spheres.

Special Specification 18685.07/.08 M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres) is currently recommended in Regions 8, 10, and 11 with epoxy longline markings. This specification uses Type I (large size) gradation glass spheres and Type II (standard size) gradation glass spheres. During light to moderate rainstorms, large size glass spheres protrude above the film of water covering the pavement marking to provide improved wet-night reflectivity compared to standard size glass spheres. The long-term performance of Type I large size glass spheres is dependent upon their ability to resist "shaving" by snowplows and their ability to resist "popouts" from traffic wear.

Large size glass spheres have been field tested in epoxy pavement markings in several upstate Regions of New York State. Most of the field tests showed that the large size glass spheres were prone to failure from shaving by snowplows and sphere loss after one year. Only one field test (Region 1) showed that wet-night visibility spheres performed satisfactorily for two years. *Item 18685.07/.08M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres)* should not be used with epoxy intersection markings due to reported problems with friction, especially when the pavement markings are wet.

Material Requirements. The majority of reflective glass spheres are manufactured from recycled glass. The glass cullet is crushed, heated in a furnace, and then allowed to cool to form spheres. The glass spheres are graded to size and then treated with a coating prior to packaging (bags or boxes). The specifications require that a certain type of coating (moisture resistant, adherence, or dual-purpose) be applied to the glass spheres.

Standard size reflective glass spheres for *Specification 727-03* (Section 685 Epoxy), Special Specification 91685.07 M (Polyester), and *Specification 727-01* (Section 687 Thermoplastic) are accepted at the project site based upon manufacturer's certification. Standard size reflective glass spheres for *Specification 727-05* (Section 640 Traffic Paint) are accepted at the project site based upon the supplier's name on the Approved List. Type I (large size) and Type II (standard size) reflective glass spheres for *Special Specification18685.07/.08 M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres)* are accepted at the project site based upon the appearance of the manufacturer's name and brand name of the glass sphere on the Approved List.

The epoxy specification (*18685.07/.08 M)* for wet-night visibility spheres requires the use of an equal amount of large size (Type I) glass spheres and standard size (Type II) glass spheres. This "dual-drop" method has been shown to be more effective than using large gradation glass spheres alone ("single drop"). Large gradation glass spheres are designed to provide better wet-night reflectivity compared to standard gradation glass spheres. The sieve sizes for the large size glass spheres ranges from 2.00 mm to 850 μm. The sieve sizes for the standard size glass spheres ranges from 850 μm to 180 μm.

Some manufacturers supply wet-night visibility spheres which are designed for use with traffic paint. The gradation or size of these wet-night visibility spheres for traffic paint is slightly smaller than the Type I (large size) glass spheres used with epoxy. Wet-night visibility spheres are not recommended for use with traffic paint due to the added expense of the large spheres, and the paint's short service life. Also, the traffic paint may not properly retain the larger sized glass spheres due to the specified application thickness of the markings. The dry film thickness (cured) of traffic paint is approximately 0.13 mm less than the dry film thickness of epoxy due to the fact that the paint contains solvents which evaporate and the epoxy does not.

Reflective spheres for pavement markings are not always glass. One manufacturer has recently developed ceramic reflective spheres for pavement markings. The ceramic reflective spheres are used in some of the manufacturer's preformed tape products, and have been recently used in an experimental liquid durable pavement marking material.

Cost and Service Life. In Region 8, the cost of *Special Specification18685.07/.08 M Epoxy Reflectorized Pavement Markings (Wet-night Visibility Spheres)* is $0.38 per meter while the cost of *Section 685 Epoxy Reflectorized Pavement Markings* (standard size glass spheres) is $0.30 per meter. Therefore, the wet-night visibility spheres cost approximately $0.08 per meter more than standard size glass spheres. The service life of reflective glass spheres is dependent upon their size (large or standard), the service life of the pavement marking material, traffic volumes, and the geographic area of use.

Large gradation spheres are more susceptible to shaving damage from snowplows, and popouts (sphere or bead loss) as compared to standard size glass spheres.

Pavement Marking Compatibility. Reflective glass spheres are treated with a coating to prevent clumping of the spheres and/or to improve adherence of the sphere to the pavement marking. The reflective glass spheres may be treated with either a moisture resistant coating (such as silicone) which allows the spheres to flow freely from the glass sphere dispenser on the pavement marking equipment, an adherence coating (such as silane) to improve the bond of the spheres to the pavement marking, or a "dual-purpose" coating to provide moisture resistance and adherence properties. Different types of adherence coatings are manufactured for compatibility with the specific type of binder (resin) used in the pavement marking.

Reflective glass spheres treated with a silane adherence coating should not be used with fast-dry acrylic resin waterborne traffic paint. The adherence coating allows the sphere to become overly embedded, resulting in poor initial reflectivity.

APPENDIX G

PAVEMENT MARKING RETROREFLECTIVITY

A pavement marking is a system which consists of a pigmented, binder material and reflective spheres. The pigmented, binder material provides daytime visibility while the entire system provides nighttime visibility or retroreflectivity. The effectiveness of nighttime visibility is largely dependent upon the proper application of reflective spheres (beads), however, application of the pigmented, binder material at the specified thickness is also critical.

Optimum retroreflectivity is achieved by applying the reflective spheres at the minimum specified coverage rate. In addition, the spheres must be embedded into the pavement marking at a depth of 50% to 60% of the sphere diameter. If the reflective spheres are not properly embedded, the level of retroreflectivity will be reduced because the light from the vehicle headlamps will not be satisfactorily reflected back to the driver's eyes. In addition, the spheres will be easily dislodged by vehicle tires and by snowplowing operations. Liquid-type pavement markings that are applied in the field must be installed at the proper thickness to achieve proper sphere embedment. For these reasons, it's important to inspect the application of the Contractor's striping work for both pavement marking thickness and for reflective sphere coverage rate. Inspection for pavement marking thickness is discussed in Appendix E. Inspection of reflective sphere application is discussed below.

1. Inspection of Reflective Sphere Application

a. Equipment Calibration - The reflective sphere dispensing equipment can be calibrated after the wet film thickness (without reflective spheres) of the pavement marking material is satisfactory. The volume of reflective spheres can be measured using a stopwatch, a large container to collect the spheres, and a clear, transparent 1000 mℓ plastic container with 50 mℓ graduation marks.

Chart A and **Chart B** show the required reflective sphere volumes (mℓ) for a 0.38 mm thick pavement marking at 100 mm width and at 150 mm width, respectively. **Chart C** and **Chart D** show the required reflective sphere volumes for a 0.51 mm thick pavement marking at 100 mm width and at 150 mm width, respectively. For each chart, the normal speed of the striping truck and the specified reflective sphere coverage rate are used to determine the required volume (mℓ) of reflective spheres. The truck speed used from the chart should be the speed at which the wet film thickness of the pavement marking was satisfactory.

Chart A - Reflective Sphere Equipment Calibration

Equivalent Volume in Milliliters Per 10 Seconds For a
0.38 mm Wet Film Thickness, 100 mm Wide Line

Truck Speed (mph)	Reflective Sphere Application Rate (kg/ℓ)									
	0.72	0.96	1.20	1.44	1.68	1.92	2.16	2.40	2.64	2.88
10	800	1080	1340	1600	1880	2160	2400	2680	2930	3200
9	720	960	1200	1440	1680	1920	2160	2400	2560	2880
8	640	850	1070	1280	1500	1700	1920	2140	2350	2560
7	560	750	940	1120	1300	1500	1680	1880	2040	2220
6	480	640	800	960	1120	1280	1440	1600	1760	1920
5	400	530	660	800	930	1060	1200	1320	1460	1600
4	320	430	530	640	740	840	960	1060	1160	1280
3	240	320	400	480	560	640	720	800	880	960
2	160	210	260	320	370	420	480	520	580	640

Chart B - Reflective Sphere Equipment Calibration

Equivalent Volume in Milliliters Per 10 Seconds For a
0.38 mm Wet Film Thickness, 150 mm Wide Line

Truck Speed (mph)	Reflective Sphere Application Rate (kg/ℓ)									
	0.72	0.96	1.20	1.44	1.68	1.92	2.16	2.40	2.64	2.88
10	1200	1620	2010	2400	2820	3240	3600	4020	4400	4800
9	1080	1440	1800	2160	2520	2880	3240	3600	3840	4320
8	960	1280	1610	1920	2250	2550	2880	3210	3530	3840
7	840	1130	1410	1680	1950	2250	2520	2820	3060	3330
6	720	960	1200	1440	1680	1920	2160	2400	2640	2880
5	600	800	990	1200	1400	1590	1800	1980	2190	2400
4	480	650	800	960	1110	1260	1440	1590	1740	1920
3	360	480	600	720	840	960	1080	1200	1320	1440
2	240	320	390	480	560	630	720	780	870	960

Chart C - Reflective Sphere Equipment Calibration

Equivalent Volume in Milliliters Per 10 Seconds For a
0.51 mm Wet Film Thickness, 100 mm Wide Line

Truck Speed (mph)	Reflective Sphere Application Rate (kg/ℓ)									
	0.72	0.96	1.20	1.44	1.68	1.92	2.16	2.40	2.64	2.88
10	1070	1440	1780	2140	2500	2880	3200	3580	3920	4270
9	960	1280	1600	1920	2240	2560	2880	3200	3420	3840
8	860	1140	1430	1720	2000	2280	2560	2860	3140	3420
7	750	1000	1250	1500	1730	2000	2240	2500	2720	2960
6	640	850	1070	1280	1500	1700	1920	2140	2350	2560
5	440	700	880	1080	1240	1400	1600	1760	1950	2130
4	430	580	710	860	990	1160	1280	1420	1550	1700
3	320	430	530	640	750	860	960	1060	1180	1280
2	220	280	350	430	500	560	640	700	780	850

Chart D - Reflective Sphere Equipment Calibration

Equivalent Volume in Milliliters Per 10 Seconds For a
0.51 mm Wet Film Thickness, 150 mm Wide Line

Truck Speed (mph)	Reflective Sphere Application Rate (kg/ℓ)									
	0.72	0.96	1.20	1.44	1.68	1.92	2.16	2.40	2.64	2.88
10	1610	2160	2670	3210	3750	4320	4800	5370	5880	6410
9	1440	1920	2400	2880	3360	3840	4320	4800	5130	5760
8	1290	1710	2150	2580	3000	3420	3840	4290	4710	5130
7	1130	1500	1880	2250	2600	3000	3360	3750	4080	4440
6	960	1280	1610	1920	2250	2550	2880	3210	3530	3840
5	660	1050	1320	1620	1860	2100	2400	2640	2930	3200
4	650	870	1070	1290	1490	1740	1920	2130	2330	2550
3	480	650	800	960	1130	1290	1440	1590	1770	1920
2	330	420	530	650	750	840	960	1050	1170	1280

The calibration procedure is performed with the striping equipment in a stationary position, and with the liquid pavement marking spray guns turned off. A large container is placed under the glass sphere dispenser(s). The dispensing equipment is turned on and shut off after 10 seconds. The collected sample is poured into the 1000 ml graduated plastic container, leveled off, and measured to determine the actual volume.

If the volume of the collected sample is higher or lower than specified, the pressure in the reflective sphere tank can be adjusted. If the volume remains consistently low after several attempts to increase the tank pressure, the Contractor may need to add additional dispensers, or install a different type of dispensing equipment that will allow a larger flow of reflective spheres. If equipment for the calibration test is not readily available, contact the reflective sphere manufacturer, Regional Construction or Materials, or the Main Office Materials Bureau.

b. Visual Standard - During the course of the pavement marking installation, the application of reflective spheres can be inspected by visually comparing the installed lines to a "standard". The "standard" can be established by applying the pavement marking system to a metal plate (min. 100 mm x 300 mm) after calibration of the pavement marking wet film thickness and reflective sphere coverage rate. The truck must be traveling at the same speed that was used during the pavement marking system calibrations. Reflective spheres should be uniformly applied over the entire surface area of the "standard".

c. Calculation of Reflective Sphere Coverage Rate - The amount of reflective spheres used in relation to the amount of pavement marking material can be calculated by recording the weight of reflective spheres used for a given volume (liters) or a given length (meters) of striping. The total weight of reflective spheres can be divided by the total liters of striping material applied (see Appendix E, storage tank measurement), or the weight can be divided by the total meters of measured striping material.

2. Evaluation of Retroreflectivity

Calibration of striping equipment will not ensure that a durable, and highly retroreflective pavement marking is being applied at all times. Pavement marking spray tips can become clogged or worn, reflective spheres can become clogged in the dispensing equipment system, or the spheres can be blown to one side of the pavement marking by strong winds.

One way to detect retroreflectivity is to view the pavement marking on a clear, sunny day. The observer stands a short distance away from the pavement marking facing away from the sun. The pavement marking is viewed at an angle with the shadow of the observer's head falling near the pavement marking. When the observer is viewing the pavement marking at the appropriate angle, the light from the sun is directed back to the observer's eye. While this method can be useful to determine if a pavement marking has any retroreflectivity and if the reflective spheres are being uniformly applied to the pavement marking, *this is not an accurate method for inspecting or approving pavement marking work.*

An acceptable method to evaluate pavement marking retroreflectivity is to conduct a visual nighttime, drive-through survey. The vehicle headlamps should be on low beam illumination

since this represents the majority of nighttime driving conditions, and the pavement markings should be dry and clean. The overall night visibility can be rated using rankings of "1" for "Poor", "3" for "Fair", and "5" for "Good". Numerical ratings are convenient for calculating and reporting the overall night visibility of numerous roadway locations. Nighttime visibility surveys are subjective, therefore, ratings can vary between different inspectors.

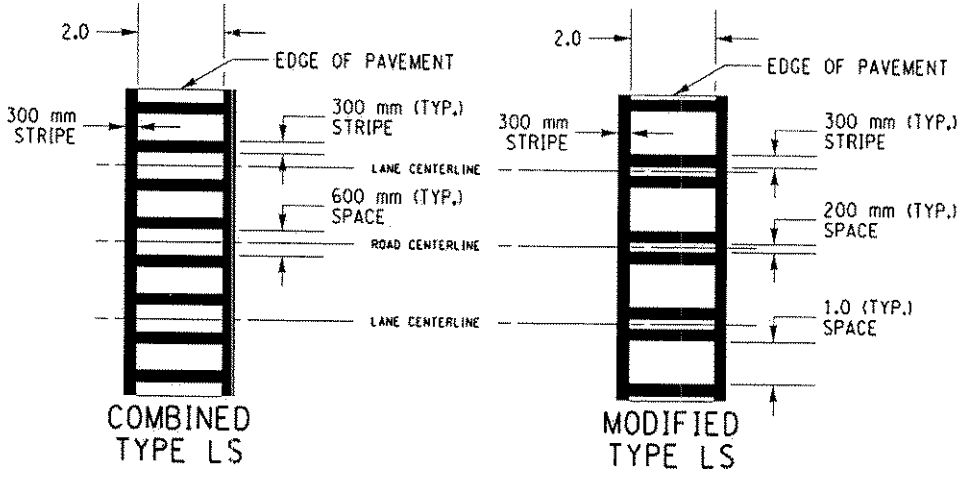
The best method for checking pavement marking retroreflectivity is by using a retroreflectometer designed specifically for horizontally applied pavement markings that contain reflective spheres. Newly designed, 30 meter viewing geometry retroreflectometers (portable and mobile) are now available and are commonly used or specified by many agencies. The design of these instruments simulate what a driver sees at night when viewing a pavement marking from a distance of 30 meters. The instruments measure retroreflectivity in units of millicandelas/square meter/lux ($mcd/m^2/lx$). An advantage of retroreflectometers is they may be used during the daytime (normal work hours), but they can be also used at night.

Numerous readings must be taken at various random locations when using a hand-held retroreflectometer. ASTM D 6359 Minimum Retroreflectance of Newly Applied Pavement Markings Using Portable Hand-Operated Instruments contains a statistical sampling procedure for taking "test point" readings at "checkpoint areas" within various length "zones of measurement". Mobile type, 30 meter geometry retroreflectometers take continuous readings while traveling at speeds up to 90 km/hr.

The Federal Highway Administration is in the process of determining minimum "maintenance" levels of retroreflectivity that will apply to all agencies' pavement markings. These minimum standards would be incorporated into the Federal Manual of Uniform Traffic Control Devices. A 30 meter geometry retroreflectometer would be one acceptable means to evaluate retroreflectivity. Nighttime visual surveys may be an acceptable alternative method. Although opinions vary, we expect that the minimum values ($mcd/m^2/lx$) that would be issued for a highway posted at a 90 km/hr speed limit and greater would probably be about 100 for white and 80 for yellow pavement markings.

APPENDIX H

LADDER BAR CROSSWALK DESIGNS



APPENDIX I

PAVEMENT MARKING APPLICATION CHART

APPLICATION FACTORS / NEW MARKING	USES	AADT	COST[1] PER METER @100mm ($)	LIFE[2] (Yrs)	TEMP	THICKNESS[3] (mm)	NO-TRACK TIME (Minutes)	REFLECTIVE SPHERES
Traffic Paint	Longline	<5000	0.18 to 0.53	0. 5 to 1.0	Air and Pvt≥10°C and rising	0.38 (existing and new pcc) 0.51(new acc) 0.75(og or pp)	3	0.75 kg/ℓ
Epoxy	Longline Intersections Hatch	All	0.26 to 0.33	2-3 (acc) 1.5-2 (pcc)	Air and Pvt≥10°C and rising (not damp)	0.38(existing and new pcc) 0.51(new acc) 0.75(og or pp)	30 (reg @ 25°C) 60 (slow @25°C)	2.4 kg/ℓ or 1.2 kg/ℓ Type I plus 1.2 kg/ℓ Type II
Polyester	Longline	<5000	0.23	2 (acc) NR pcc	Air and Pvt≥10°C and rising (not damp)	0.38 to 0.51(acc)	30 (@ 25°C)	2.4 kg/ℓ
Thermoplastic	Longline Hatch	All	High	3-5 (acc) NR pcc	Air≥9.5°C Pvt≥12.5°C and rising (not damp)	3.2 - 4.8(acc)	10 (@ 21°C)	0.25 kg/m²
Preformed Tape	Intersections	All	High	3	Air≥15.5°C Pvt≥21°C (not damp)	--	10 (@ 21°C) for primer/adhesive	–

NOTES: 1. Upstate, without wet-night visibility spheres. Where/when contracts, add 30%. 2. Factors are for recommended uses and pavement/substrate condition. (See Appendix C.) 3. Og = open graded. Pp= paver placed.