OS-299 (11-13)

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DEPARTMENT OF TRANSPORTATION
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TRANSMITTAL LETTER

PUBLICATION:
Publication 648

DATE:
June 7, 2017

SUBJECT:

Publication 648 - PennDOT Pavement Marking Handbook

INFORMATION AND SPECIAL INSTRUCTIONS:

The attached publication provides information and instruction on the Department's Statewide Pavement Marking Program.

The following is a summary of the major changes that have been incorporated into this edition:

Lowered the minimum ADT for roads to be included in the paint program from 1,000 ADT to 500 ADT.

Added language in section 2.2.3 about the process for a District to follow when eliminating roads from the paint program that are not a numbered traffic route with an ADT greater than 500 and less than 1,000.

CANCEL AND DESTROY THE FOLLOWING:

Publication 648
October 6, 2009

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PennDOT Pavement Marking Handbook

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1. Manual on Uniform Traffic Control Devices (MUTCD)
2. PennDOT Publication 46-Traffic Engineering Manual
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4. PennDOT Publication 408-Highway Construction Specification
5. PennDOT Publication 111-Pavement Markings and Signing Standards
6. PennDOT Publication 213-Temporary Traffic Control Guidelines
7. PennDOT Publication 113-Highway Foreman Manual
8. PennDOT Publication 212-Offical Traffic Control Devices

1. INTRODUCTION

1.1 PURPOSE

The placement of pavement markings is an important highway safety and customer service activities rendered by the Department. Pavement markings communicate to the driver without requiring them to take their eyes off the roadway.

The Department adopted the Federal Highway Administration's (FHWA's) Manual on Uniform Traffic Control Devices (MUTCD) by reference when it adopted section 212.2 (67 Pa. Code section 212.2) on February 3, 2006 at 36 Pa.B. 537. The MUTCD is the national standard for all traffic control devices installed on any street or highway in the United States. This handbook will supersede the MUTCD when any portion of this handbook conflicts with the MUTCD.

The purpose of this Handbook is to provide Department employees that are directly involved with the day to day operation of the Truck-Mounted Paint Machine and the Small Paint Machine Programs information and instruction on the Department's Statewide Pavement Marking Program. This handbook also describes the organization and various functions necessary to develop uniformity of methods and practice in the placement of those pavement markings.

Current policies applicable to pavement markings have been incorporated into this manual. It is the responsibility of the Bureau of Maintenance and Operations (BOMO) to keep it current and up-to-date as future changes are issued.

2. ESTABLISHMENT OF PAVEMENT MARKING PROGRAMS

2.1 GENERAL

The ADE-Maintenance and/or ADE-Services are responsible for establishing two District-wide marking programs; one for the Truck-Mounted Paint Machine and the other for the Small Paint Machine.

There are many factors and variables which should be considered in developing the marking programs.

Life expectancies of pavement markings are affected by the amount of winter aggregates used, snow plowing, traffic volumes, locations of markings, materials formulations and other factors.

2.2 FACILITIES TO BE PAINTED

67 Pa. Code §212.5 details local authorities' responsibilities for installing pavement markings on state designed highways. The Department installs longitudinal pavement markings on highways and streets, which are on the State Highway System as follows:

2.2.1. First and Second Class Cities

A. All Interstate and Limited Access highways (only).

2.2.2. Third Class Cities and Boroughs

A. All Interstate and Limited Access highways.

B. All numbered traffic routes that are curbed or uncurbed, where parking is permitted, with a minimum pavement width of two, 10-foot traffic lanes plus an 8-foot parking area.

C. All numbered traffic routes with pavement widths of 16 feet or more that are structurally adequate and can safely accommodate Department paint machines.

D. Other selected highways.

2.2.3. Townships

A. All Interstate and Limited Access highways.

B. All three, four, five, six, and eight-lane divided and undivided highways.

C. Numbered traffic routes with pavement widths of 16 feet or greater that are structurally adequate and can safely accommodate Department paint machines.

D. Two-lane highways having an ADT of 500 or more and pavement widths of 16 feet or more that are structurally adequate and can safely accommodate Department paint machines.

E. Roads that are not numbered traffic routes having an ADT < 500 and pavement widths of 16 feet or more that are structurally adequate and can safely accommodate Department paint machines will be determined by each District.

F. Other selected highways.

Roads that are not a numbered traffic route with an ADT greater than 500 and less than 1,000 can be eliminated from the paint program if the District elects to do so. Consistent driver expectations, locations of schools, volume of truck or influx traffic, curves, grades and the number of days with fog are some of the factors that should be considered when making the determination of whether to eliminate a road from the paint program or not. Documentation with the factors considered in eliminating the road as well as any countermeasures installed in place of the markings such as additional signage or delineation shall be maintained by the District.

2.3 SCHEDULING AND PRIORITIES

2.3.1 General

During scheduling, priority should be given to the types of highways to be painted as well as maintenance and construction projects. Prior to the beginning of the painting season, the District Traffic Units in conjunction with the Maintenance Districts must review all interstate and expressway highways to determine if the existing pavement markings are expected to be adequate through the summer months. If the markings are not adequate or not expected to be adequate through the September Labor Day holiday, then those identified interstates/ expressways are to be painted first and completed by Memorial Day. The review and subsequent line painting for interstates and expressways is to be done for each route on a district-wide basis and not on a county-by-county basis.

2.3.2 Highway Priorities

The priority for painting highways is:

A. Roadways where the District has determined the pavement markings need to be replaced.

B. Interstates and other limited access highways.

C. Select US Routes, PA Routes and major arterials.

D. Three lane highways with Center Lane Left Turn Only and alternate passing zones.

E. Five lane highways with Center Lane Left Turn Only.

F. Two lane highways having an ADT of 500 or more and pavement widths of 16 feet or more that are structurally adequate and can safely accommodate Department paint machines.

G. Roads that are not numbered traffic routes having an ADT < 500 and pavement widths of 16 feet or more that are structurally adequate and can safely accommodate Department machines.

H. Other selected roadways.

2.3.3 Department Programs

Department programs affecting the paint program include, but are not limited to:

A. Resurfacing

B. Shoulder grading or oiling

C. Surface treatment

D. Crack sealing

E. Construction projects

F. Rumble Strips

Knowledge of the aforementioned programs and tentative completion dates should be considered in developing effective work plans.

2.3.4 Additional Guidelines

The District Paint Foreman should also consider the following:

A. Scheduling to eliminate or reduce “deadhead” time.

B. Developing a flexible schedule to enable the District to paint “special” locations. The Traffic Unit should continuously be aware of maintenance and construction completion dates.

C. Discuss the pavement marking schedule with the County Maintenance Manager one week prior to starting pavement marking operations.

D. Provide at least two days' notice to County Maintenance Managers prior to working out of the County Maintenance Building.

E. Communicate daily before the start of the shift with the County Maintenance Manager (CMM) and/or the Assistant County Maintenance Manager (ACMM).

F. The Foreman with anticipation of being off, even for one day, will appoint an Acting Foreman from the crew. The Foreman shall supply the Acting Foreman with a work schedule.

G. Check the weather forecasts.

H. Plan around busy traffic times.

I. Summer tourist areas.

J. Spring weather conditions

2.4 ANNUAL WORK PLAN

The Annual Work Plan should consist of separate listings, by County, of roadways to be painted by month during the painting season. The lists should include:

A. State Routes (SRs) with segments.

B. Road miles to be painted.

C. Types of pavement markings (lines, legends, arrows, etc.).

The work plan for the Truck-Mounted Paint Machine Program (see Chapter 7) should be prepared by the Traffic Unit and the paint foreman by April 1st and should include a list of highways that need to be painted. An auxiliary list of highways that would be painted if the normal work week were extended should also be developed. The auxiliary paint program should be approved by the ADE-Maintenance and/or ADE Services, District Traffic Engineer, and each County Maintenance Manager.

The work plan for the Small Paint Machine Program (see Chapter 11) should be prepared by the Traffic Unit by April 1st of each year and transmitted to the Assistant District Executive – Maintenance and/or Services for implementation. Department forces or ECMS or Service Purchase Contracts may be utilized to complete the program.

2.5 CONTRACT MARKINGS

All contract applied pavement markings shall be in accordance with current and approved Department Standards, Specifications, Regulations and Policies. The local union must sign off on the Annual Contract Paint Program.

3. PAVEMENT MARKING PERSONNEL AND ORGANIZATION

3.1 GENERAL

Pavement markings are a Traffic Engineering tool. The primary responsibility for the Pavement Marking Program has been assigned to the Assistant District Executive-Maintenance and/or Services. Secondary responsibility rests with the District Traffic Engineers and County Maintenance Managers.

3.2 TRAFFIC ENGINEERING AND OPERATIONS DIVISION

Central Office – Bureau of Maintenance and Operations Responsibilities

The Bureau of Maintenance and Operations (BOMO) is responsible for:

A. Establish pavement marking policies and guidelines

B. Develop standards, specifications, and regulations related to pavement marking

C. Develop annual contracts for the purchase of traffic paint and beads and pavement marking legends

D. Develop safety programs

E. Monitor the statewide use and inventory of traffic paint and beads

F. Perform quality assurance reviews of the pavement marking program.

G. Develop an Annual Report

3.3 ENGINEERING DISTRICT

3.3.1 Engineering District Responsibilities

The responsibility for the Pavement Marking Program in the District has been assigned to the Assistant District Executive-Maintenance and/or Services. The Assistant District Traffic Engineer (ADTE) – Operations, in addition to other duties, is responsible for coordinating the Pavement Marking Program which includes:

A. Preparation and supervision of schedules of operations.

B. Maintenance of paint inventory records.

C. Management of requisitions of required materials.

D. Assistance in budget preparation.

E. Conducting field studies to determine the projected life of traffic lines.

F. Develop an annual work plan that establishes the Truck-Mounted Paint Machine program for the coming painting season.

G. Conducting engineering and traffic studies to establish, remove or change passing or no-passing zones.

H. Establishing the annual Small Paint Machine program.

I. Evaluating the problems and results of the previous painting season.

J. Coordinating the annual winter refurbishing of the truck-mounted paint machines and ordering spare parts for the next painting season.

K. Review of pavement marking plans completed by consultant engineers or by the District to assure compliance with Department Standards and Regulations.

L. Reviews paint production to ensure timely completion of the Traffic Line Painting Program while monitoring production and application rates.

M. Establishes the RPM contract.

3.3.2 Paint Foreman

A. Responsible for the safety and mobility of all operations including traffic control measures. These traffic control measures also include sensitivity and consideration of motorists traveling behind or within the line painting convoy.

At all times, the foreman must evaluate the potential need to temporarily pull the paint convoy off the roadway to allow queued traffic behind or within the convoy to pass the line painting operation. The ultimate decision, on whether or not to pull off the roadway, is the responsibility of the foreman. Understanding that it is very difficult to spell out concise pull-off thresholds, the foreman must use sound judgment and common sense along with consideration of the following guidance factors to determine the most appropriate traffic control measure for the painting operation and motorists both, including potential temporary pull-offs.

1. Suitable pull-off / turn-around locations
    a. The availability of suitable pull-off locations or turnarounds is necessary to allow safe and easy exiting/re-entering of the highway with the paint equipment (wider areas are needed to maneuver and turn the equipment around).
2. Completion stage of the scheduled route/loop
    a. Is it safer and/or more effective to complete the scheduled route/loop, or to temporarily pull-off the roadway (taking into account both perspectives: paint operations and motorists)?
    b. Considerations include:
        - Availability of suitable pull-off/turn-around locations
        - The present stage of the scheduled painting operation (Ex: Are there 15 miles remaining (approx. 60 min.) vs. 1 mile (approx. 4 min.) before a planned route/loop is completed?).
3. Route locations and types
    a. Urban vs. rural areas. Obviously there are differences between urban vs. rural areas in regard to traffic volumes and potential line painting traffic queuing. These differences should be considered in the pre-planning phase so that potential safety and congestion issues are minimized on the scheduled routes/loops.
    b. Two -lane highways vs. multi-lane highways. The two-lane routes present more potential concerns for traffic safety/congestion issues as queuing occurs.
    c. Traffic queuing. The foreman, and his/her crew, will visually observe traffic volumes, and length of queue behind the paint convoy. As route location and conditions necessitate, the foreman may have to remove himself from the line paint convoy to evaluate queue lengths that go beyond the sight of the last paint convoy vehicle's operator.
    d. If the foreman determines queuing issues need attention, guidance factors 1 & 2 need considered before temporarily pulling-off.

    If painting operations are temporarily pulled-off the roadway, the foreman is responsible for overseeing the safety of doing so; exiting and re-entering all equipment in a safe manner at a safe location.

Alternate methods should be evaluated if unacceptable congestion is expected to persist (Ex: off-peak painting times, shorter scheduled routes or loops, etc.).

B. The Paint Foreman is also responsible for:

1. Monitoring storage, use and availability of supplies such as glass beads, paint, and repair parts. This includes taking glass bead and paint samples. These samples should be submitted to the Bureau of Project Delivery – Innovation and Support Services Division within one week of receipt.
2. Monitoring field crews, conformance to planned activities and initiation of corrective action.
3. Coordinating the District's Annual Traffic Line Painting Program with county maintenance programs and District construction projects to ensure timely repainting of resurfaced roadways and to prevent the covering of newly painted traffic lines. Assists in coordinating with the County Maintenance Manager for layout of patterns and transitions on resurfaced roadways.
4. Making work assignments to staff through crew payrolls; establishes and uses effective follow-up system to ensure critical actions and timelines are met and initiates corrective actions as needed; reviews work products for conformance to sound engineering principles and practices, specifications, standards and constructability.
5. Taking a lead role in maintaining a safe work environment for self, unit staff and visitors by using proper safety procedures and protective equipment; creates and encourages employee work area awareness and initiates proactive accident and injury avoidance measures; reports all personal injuring/accidents immediately, provides first-aid when appropriate, and ensures prompt medical treatment to limit risk of further injury.
6. Supervising of District Line Painting Crew and coordinating of annual pavement marking program. Monitors quality control of pavement marking activities. Planning functions include the preparation of work schedules, coordination with county and construction personnel, and assisting with the preparation of materials and parts orders and inventory control.
7. Being familiar with technical aspects of line painting equipment and able to diagnose mechanical problems and ensure the proper maintenance of both large and small paint machines.
8. Administering technical and non-technical training to paint crews and implements field policy and equipment changes.
9. Preparing and submitting field documentation including daily reports, expense accounts, payrolls and inventory transfers. Maintains daily production rates. Ensures adherence to Department pavement marking standards and quality control procedures. Monitors temperature and humidity conditions to determine when paint activities can be performed. Inspect markings for quality, adhesion and visibility. Performs field testing and adjustment of spray equipment. Obtains sample plates.
10. Demonstrating a working knowledge of applicable pavement marking standards, policies, regulations in accordance with Title 67, Chapter 212, MUTCD, Pub. 213, and Department directives. Must be knowledgeable in the application of durable pavement markings and can perform complex field layout of intersection markings, railroad crossing, etc. Must be able to interpret plans and specifications. Must be familiar with application, environmental policies and hauling regulations.
11. Ensuring that equipment assigned to paint crew is properly maintained in accordance with Department policies and regulations.

12. Training crew members, including new employees in pavement marking procedures and Department work place regulations and policies.
13. Installing, reviewing, inspecting and maintaining pavement markings and paint paddles. Review paint paddle locations during winter, spring, or rain days and have missing/damaged paddles replaced.
14. Operating safely including material handling procedures. Includes scheduling the use of a shadow vehicle when required.
15. Dealing with complaints in accordance with Department customer service initiatives and provides technical assistance to municipalities and outside agencies when requested. Must be able to interpret technical publications and evaluate new products and equipment.
16. Removing dead animals and debris from in front of the truck.

3.4 COUNTY MAINTENANCE DISTRICT

3.4.1 County Maintenance Manager

The County Maintenance Manager is responsible for the following when properly notified of needs (excluding emergencies):

A. Providing supplemental personnel and equipment for the Truck-Mounted Program.
B. Providing personnel and equipment to implement the Small Paint Machine Program, when performed by Department forces.
C. Providing personnel and equipment for requested layout and eradication crews.
D. Providing personnel to spot centerlines on routes that are paved or seal-coated by county.
E. Coordinate between Traffic Operations' agility line painting and municipalities to determine costs to ensure an equal return to the Department.
F. Provide personnel and equipment to properly unload and stock paint and glass beads.

3.4.2 Truck-Mounted Paint Machine Program

EQUIPMENT OPERATORS

On a normal truck-mounted paint machine operation there should be four equipment operators. When shadow vehicle(s) are required the operator(s), assigned from the appropriate county should be provided for the operation. Individuals with Equipment Operator B or other qualified classifications perform the functions of:

A. Paint Truck Driver
B. Operator – Right side paint controls
C. Operator – Left side paint controls
D. Supply Truck Driver
E. Shadow Vehicle Driver(s), when required

Each District should develop a Training Process/Program to ensure that operators are trained in all positions and periodically rotated in job assignments to assure efficient operation of all functions. In addition to operating the equipment, the operators shall be responsible for routine maintenance of the vehicles as well as paint equipment.

The paint truck driver is responsible for maintaining a uniform speed and aligning the truck to place the proper markings in the proper location on the road surface. The driver is also responsible for communicating any vital information that the paint control operators should be made aware of.

The right and left side paint control operators are responsible for the proper application of materials and for the proper interpretation of code markings on highways that indicate patterns to be painted. Paint patterns shall not be revised unless the foreman is instructed to do so by the Assistant District Traffic Engineer.

The supply truck driver is responsible to protect the newly painted lines from tracking by vehicles, observe the newly painted lines for line width, sharpness, uniformity and bead distribution, advising the foreman of any significant deviations; to keep the truck-mounted paint machine supplied with materials and to provide additional protection to the painting operation.

The shadow vehicle operator is responsible to protect the newly painted lines from tracking by vehicles and to provide protection for the painting convoy. Requirements for use of shadow vehicles are contained in Department Publication 213.

3.4.3 Small Paint Machine Program

When requested by the Assistant District Executive – Maintenance and/or Services, the Assistant District Traffic Engineer, or the County Maintenance Manager shall assign a sufficient number of properly trained personnel to assist in the deployment of the Small Paint Machine Program. The County Maintenance Manager is responsible for the quality and quantity of pavement markings, maintenance of equipment; correct reporting of work, maintenance and protection of traffic and assignment of personnel.

Markings that are under the minimum retroreflectivity number and/or if more than 20% of the marking is missing, the marking should be replaced.

3.4.4 Layout and Eradication

Layout personnel are responsible for designating new traffic line patterns; changes to previous pavement markings and placing centerline or lane line spots and pattern codes for badly worn traffic lines and/or resurfaced roads. These persons are assigned temporarily from the District Traffic Unit or the County Maintenance District.

Eradication personnel remove pavement markings from the pavement surfaces as requested by the District Traffic Unit.

4. PAVEMENT MARKING STANDARDS

4.1 STANDARDS

Each marking shall be used to convey the meaning prescribed for it in the Manual on Uniform Traffic Control Devices, Department Regulations, Standards, and this Handbook. Reference the Traffic Control Standards TC-8600 for description and placement of traffic lines.

4.2 TRAFFIC LINES

Pavement markings on highways and streets shall be four-inches wide (center lines and edge lines). However, six-inch lines shall be used for lane lines and eight-inch lines in gore areas on interstates and other four-lane highways. Spacing between double traffic lines shall be six inches.

Traffic lines are of two types, solid (continuous) or broken (segmented). Broken lines are of three designs. The normal broken or skip line is used for center or lane lines. The pattern shall consist of a 10-foot painted line and a 30-foot space. (The total cycle is 40 feet.)

A dotted line may be used to delineate the extension of a line through an intersection or interchange area. The pattern should consist of a 2-foot painted line and a 4-foot or 6-foot space. The dotted line is to be the same color and width as the line it extends.

Auxiliary lane lines or elephant tracks are the third type of segmented lines. This pattern is used in advance of lane drops and acceleration or deceleration lane situations on freeways and expressways. The markings consist of a 3-foot painted line and a 12-foot space. The elephant track is 8 inches wide.

4.3 APPLICATION AND MEANING OF TRAFFIC LINES

A. **A normal solid white line** is used as a right-side pavement edge marking. It is also used to delineate the edge of a travel path where travel in the same direction is permitted on both sides of the line, but crossing the line is discouraged. A frequent application is in advance of an intersection, which has two or more approach lanes.

B. **A double solid white line or a wide white line** (at least twice the width of a normal 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 restricted. It is used as a channelizing line in advance of obstructions, which may be passed on either side, but not encroached upon. It can also be used in one-way tunnels where traffic is not to cross the centerline.

C. **A double line** consisting of two normal solid yellow lines delineates the separation between travel paths in opposite directions when overtaking and passing is restricted in both directions. This is a two-direction no-passing marking. It is frequently used as a channelizing line in advance of an obstruction, which must be passed on the right and to form a channelizing island separating traffic in opposite directions.

D. **A single solid yellow edge line** delineates the left edge of a travel path to indicate a restriction against passing to the left or delineates the left edge of each roadway of divided streets or highways, one-way roadways and ramps in the direction of travel.

E. **A normal broken white line** is used to delineate the edge of a travel lane where travel is permitted in the same direction on both sides of the line. Its most frequent application is as a lane of a multi-lane roadway.

F. **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 when overtaking and passing is permitted with care.

G. **A double normal broken yellow line** delineates the edges of a lane in which the direction of travel is changed from time to time in such a way that the line serves as the center line of the roadway during some period. Its use is for a reversible lane, but only with proper signing and markings.

H. **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 where overtaking and passing are permitted with care for traffic adjacent to the broken line. This is a one-direction no passing marking and is used on two-way, two-lane roadways to regulate passing. It is also used to delineate the edges of a mandatory two-way left turn lane in which travel in either direction is permitted to use the lane, but only as part of a left turn maneuver. In the latter application, the markings are to be placed with the solid lines on the outside and the broken lines to the inside of the center turn lane. Traffic adjacent to the solid lines may cross this marking with care only as a part of a left turn maneuver.

4.4 TYPES OF MARKINGS APPLIED

A. The types of pavement markings normally applied by the Department include:
   1. Center lines
   2. Lane lines
   3. Edge lines
   4. Dotted lines
   5. Auxiliary lane lines (elephant tracks)
   6. Directional markings (arrows, legends)
   7. Railroad crossings
   8. Hatching
   9. S.P.A.R.E. Lines (State Police Aerial Reconnaissance Enforcement)
   10. Slow curve pavement markings (SCPM)

B. The types of pavement markings normally not applied by the Department include:
   1. Pedestrian crosswalks
   2. School crosswalks
   3. School and other warning legends
   4. Stop bars
   5. Parking stalls
   6. Curbs
   7. VASCAR lines
   8. Legends included as part of an approved traffic signal permit.

Under certain circumstances, the Department at its discretion may agree to install pavement markings that are typically a municipal responsibility. These arrangements are made directly between the municipality and the local Engineering District.

4.5 CENTER LINES AND LANE LINES

When used, appropriate center and lane lines should be placed on the following highways in accordance with the standards outlined below:

A. One-Way highways or Streets.

1. These facilities should have all lane lines painted with a broken (segmented) white pattern. Where it is desirable to minimize lane changing, such as at an approach to a crosswalk, intersection, horizontal or vertical curves, the broken line should be converted to a solid white pattern.

B. Two-Way Highways or Streets.

1. The center line marking on two-lane, two-way highways 16 feet or more in width that can safely accommodate Department paint machines should be either:
   a. A normal broken yellow line.
   b. A double line consisting of a normal broken yellow line and a normal solid yellow line.
   c. A double line consisting of two normal solid yellow lines.
2. On the approach to an intersection where the centerline is offset to provide a left turn lane, a double solid yellow line is necessary for the length of the offset and the appropriate transition length. A single solid white lane line is also required.
3. A two-lane highway with a truck-climbing lane should normally be painted as two lanes in one direction and one lane in the opposite direction.

C. Three Lane Roadways.

1. A double solid yellow centerline shall be used to separate opposing traffic on roadways where there are two lanes in one direction and one lane in the other direction.
2. Two double yellow centerlines shall be used to separate opposing traffic on roadways where there is one lane in each direction with the center lane reserved for two-way left turns. The double yellow center lines shall consist of yellow broken lines adjacent to the left turn lane and solid yellow lines adjacent to the through moving lanes.

D. Four or More Lanes Undivided.

1. The centerline on undivided highways where four or more lanes are always available should be a double solid yellow line.
2. A broken white line should be used to delineate the separation of traffic lanes in the same direction. Where crossing the lane line requires unusual care, the broken white lane line separating traffic flow in the same direction may be a solid white line.
3. On highways with more than four lanes, the following patterns may be used:
   a. An unbalanced lane flow on either side of the double solid yellow centerline.
   b. Center Lane Left Turn Only.
   c. Left Turn Lane Channelization in which the double solid yellow center line is offset on the approach to an intersection to allow two or more through lanes and one left turn lane.

E. Four or More Lanes Divided.

A broken white lane line shall be used to delineate the separation of traffic lanes in the same direction.

4.6 EDGE LINES

A. Edge lines on the right side of all roadways when used should be painted solid white. Edge lines on the left side of divided highways, including the interstate systems, should be painted solid yellow. Edge lines should normally be placed 4 inches from the edge of the pavement shoulder on the following highways:

1. Any numbered traffic route 20 feet wide or more

2. Two-lane 20 feet wide or more with an ADT of 500 or more.
3. Three-lane 36 feet wide or more.
4. Four-lane, undivided 48 feet wide or more.
5. Four-lane, divided two-lane directional roadway, 24 feet or more.
6. All highways more than four lanes.

B. Edge lines should not normally be placed on highways narrower than 20 feet.

C. White edge lines should not normally be placed on highways that have curbing. In some instances, white edge lines are painted where there is a wide shoulder and curbing or to designate a bike lane. This is to discourage traffic from using the shoulder or bike lane as a travel lane.

4.7 INTERCHANGE AREA LINES

All interchange area pavement markings shall conform to the PennDOT TC–8600.

4.8 SYMBOL ARROW PAVEMENT MARKINGS

The MUTCD requires symbol arrow pavement markings on exit ramps near crossroad terminals. In each lane of an exit ramp, one or more arrow pavement markings shall be placed near the crossroad terminal where studies indicate an existing or potential safety problem. The markings should be visible to a wrong-way driver.

On other highways, symbol arrow pavement markings may be placed to indicate permissive traffic movements. See PennDOT Standards TC-8600.

4.9 LINE THICKNESS

All painted center lines, lane lines, and legends should have a wet thickness of 15 mils and edge lines should have a wet thickness of 12 mils. Wet film gauge measurement should be taken of paint, on sample plates, in the field to set the paint guns. However, the crews are to use gallons per mile for proper application rates, as follows:

A. A 4-inch wide by 15 mils thick line has an application rate of 16.5 gallons per mile, a 6-inch wide by 15 mils thick line has an application rate of 24.75 gallons per mile and an 8-inch wide by 15 mils thick line has an application rate of 33.0 gallons per mile.

B. A 4-inch wide by 12 mils thick line has an application rate of 13.2 gallons per mile, a 6-inch wide by 12 mils thick line has an application rate of 19.8 gallon per mile and an 8-inch wide by 12 mils thick line has an application rate of 26.4 gallons per mile.

C. To determine gallons of waterborne paint for legends and symbols at 15 mil thickness, divide square feet of markings by 106.93.

5. PAVEMENT MARKING MATERIALS

5.1 INTRODUCTION

All of the pavement marking materials used on State highways must be in the Department's current listing of approved construction materials (Bulletin 15, Publication 35), or approved for use by Central Office.

5.2 MATERIALS

Refer to Publication 46, Section 3.2 for additional details. The following is a list of pavement marking materials, which are commonly used:

A. Waterborne Paint

B. Glass Beads – Recycled

C. Temporary Pavement Marking Tape

D. Cold Plastic Tape and Legends

E. Epoxy is a two-part, 100 percent solid material, which contains resins, and catalyst that is hot-spray applied after mixing.

F. Hot Thermoplastic is a synthetic resin material, which can be applied by screen, ribbon or spray methods.

G. Preformed Thermoplastic is a polymer thermoplastic material, which is fused in place by heat of a propane type torch.

H. Polyurea is a liquid pavement marking material consisting of a two-component, 100 percent solid, thermosetting material. Limited experience indicates that it is a durable pavement marking material that dries to no-track in 3 to 8 minutes at all temperatures down to about 40 degrees.

I. Polyester is a two-component material, which is applied separately to the surface.

J. Methyl Methacrylate – MMA is a two-part compound, which can be applied by extruded, spray or manual methods.

K. Wet Reflective Striping Tape

L. Snowplowable Reflective Pavement Markers

5.3 TRAFFIC PAINT

Waterborne Paint – There are many advantages and some disadvantages in utilizing 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.

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 cleanup. Fast dry waterborne paint will achieve its best drying times under perfect ambient conditions: daytime, sunny, 70 degrees 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
- Reacts adversely to metals other than stainless steel
- Requires specially lined containers to prevent chemical reaction
- Can settle in storage containers

5.4 GLASS BEADS – RECYCLED

All painted lane lines, edge lines, symbols, and legends shall have recycled glass beads applied as follows:

A. Type A beads at a rate of 7 pounds per gallon of paint.

5.5 DURABLE PAVEMENT MARKINGS

Labor intensive pavement markings such as legends, railroad crossings, symbol arrows, etc. should utilize longer life pavement marking materials as determined by the District. Department approved durable pavement marking materials should be used for longitudinal lines on high-volume roadways where traffic paint does not last a full year. Department approved durable pavement marking materials should also be used on short roadway sections where traffic paint does not last a full year, such as on curves and in intersections where turning traffic wears out the paint. Refer to the Traffic Engineering Manual (Pub. 46) Chapter 3 – Markings for details.

A. Cold plastic tape and legends is a preformed material, having pressure-sensitive adhesive on its back surface.

B. Epoxy is a two-part, 100 percent solid material, which contains resins, and catalyst that is hot-spray applied after mixing.

C. Hot thermoplastic is a synthetic resin material, which can be applied by screen, ribbon or spray methods.

D. Preformed thermoplastic is a polymer thermoplastic material, which is fused in place by heat of a propane type torch.

E. Polyester is a two-component material, which is applied separately to the surface.

F . Polyurea

G. Methyl Methacrylate – MMA is a two-part compound, which can be applied by extruded, spray or manual methods.

H. Wet reflective traffic tape

Triple drop glass beads can be used with durable pavement marking materials. Any durable pavement marking with triple drop and wet reflective tape should be installed in a recessed groove.

5.6 SNOWPLOWABLE REFLECTIVE PAVEMENT MARKERS

The primary purpose of pavement markers is to provide increased retroreflectivity during nighttime and/or adverse weather conditions.

The following represents guidelines used to determine if installed pavement markers should have the reflective elements replaced:

A. The average of the functional reflective surface areas remaining in an installation is less than 50% as estimated by the inspector.

B. The average visibility of the reflectors at night, in an installation, is less than 240 feet using low beam headlights. (Less than 3 RPM's are visible at a time on a tangent section of roadway.)

C. See PennDOT Traffic Control Standards TC-8602 for proper placement and description.

D. See Publication 46 for installation requirements.

6. MATERIALS PROCUREMENT, STORAGE, AND HANDLING

6.1 PROCUREMENT

Pavement marking materials are purchased from annual contracts obtained for the Department of Transportation by the Department of General Services. Copies of the contracts are furnished to each District. Each contract specifies minimum shipments, order dates and delivery dates. From time to time, special instructions for ordering materials may be issued.

Refer to the current contract language for paint order dates and supplier delivery timeframes.

Districts should attempt to keep the calendar year-end inventory of paint, to be used the next year, to between zero and one tote per county because of the need to store the paint inside to keep it from freezing.

6.2 STORAGE

Waterborne Paint: The shelf life of currently approved material is 12 months or as specified by the manufacturer. Waterborne traffic paints consist of an acrylic vehicle suspended in a water emulsion. Thus, the materials must be stored where they will not go through a freeze/thaw process. If the paint freezes and thaws, it may not be usable or recoverable and must be disposed of properly. Mixing may be required after 3 months of storage.

If waterborne paints go out of condition, they are not recoverable. When the paint looks like cottage cheese or has a granular texture, it is out of condition and must not be used. It will also skin over when exposed to air and the skin will not dissolve or mix into the paint.

Totes or drums containing environmentally sensitive material or material that could cause negative public perception (traffic paint is included in this category, although not necessarily hazardous nor are there any regulatory requirements for containment) should be stored in an area equipped with secondary containment. Secondary containment typically consists of dikes or curbs around a storage area capable of holding the volume of the largest container plus a reasonable allowance for precipitation. The base of the storage area shall be paved or otherwise lined with an impervious material. Storage areas containing floor drains, sewer drains or other outlets shall be properly protected to prevent discharging into system or surface or grounds waters. Winter storage areas must have secondary containment.

Summer storage area should consist of a structure with a roof and walls to protect paint from direct sunlight, have proper ventilation, an impervious floor, and preferably have secondary containment.

Winter storage areas must consist of a weather tight structure with an impervious floor, secondary containment, proper ventilation and heat to maintain the structure at 50 degrees F.

Paint totes may be stacked ONLY two high. Maximum storage per site should be determined by size of containment facility.

Signing identifying the products and material safety data sheets (MSDS) sheets must be posted at the storage area.

An ABC fire extinguisher must be within 50 feet of the facility.

A. Glass Beads: The beads, packed in moisture-proof cardboard boxes, must be stored in a cool, dry place to keep the beads and boxes from getting wet.

   Bead boxes may be stacked two high, but NO MORE than three high if stacked pyramid style.

B. Temporary Pavement Marking Tape and Durable Pavement Marking Materials: These materials should be stored in a cool, dry place and should be used within 12 months.

6.3 HANDLING

Waterborne paint is available in 275 gallon totes. These paints can be pumped from the 2" port valve or from the opening on the top of the tote. All port valves are to be fully operational and serviceable from the manufacturer. Paint may be pumped from the top of the tote but it is not preferred.

Waterborne paints skin over rapidly when exposed to air. Paint skins will not dissolve again and must be removed. This will affect short-term storage; when the paint machine is going to sit overnight or for several days, fill the tanks completely to minimize headspace in the tanks.

Paint machine operators must check for skins before starting out when the paint machine sits for an extended period.

6.3.1 Mixing

If paint is rotated and used fast enough, mechanical agitation may not be required. Paint totes, which sit for more than 3 months, must be checked and mixed before using.

6.3.2 Unacceptable Materials

All paints furnished must satisfy the requirements of the current test deck Specifications for Paint, Traffic, and Highway, White and Yellow for Use with Glass Spheres (glass beads) and the Department's traffic line paint contract. The paint should not show settling in a freshly opened container that cannot be easily redispersed with a paddle to a smooth homogeneous state. If material delivered to the Department is suspected of not meeting specification requirements, or of quality assurance or lot verification samples to not meet the criteria established in the contract provisions, the Department will conduct a follow-up evaluation. If the follow-up evaluation confirms the traffic paint does not meet the testing or specification criteria, the manufacturer will be required to replace the rejected paint in accordance with the current contract language. Paints that show any curdling, livering, caking, lumps, granules, thick skins, color separation or foreign matter should be rejected immediately and replaced by the manufacturer. See Appendix sheet A-18 for proper claim form.

6.3.3 Testing

The traffic line paint that is purchased from our annual contract has been applied and monitored on our test deck in accordance with our specifications and procedures. Based on the laboratory test portion of the evaluation, parameters are derived for the approved paints, which allow the lab to verify that the paint received in the Districts is the same as the approved material. Samples for testing are collected at the point of manufacture and may be collected in the field, as required.

A. In Plant: Paint is sampled from every production lot produced at the point of manufacture. (Each production lot consists of 2,000 to 10,000 gallons of paint.) This sample is submitted to the Materials and Testing Division for analysis. Testing, such as weight per gallon, percent total solids and viscosity provide verification of consistency between the production batch and the approval sample, as well as between each production batch.

B. In Field: Upon opening of totes verify that there is no evidence of thin paint, skinning, separation, etc. The presence of any of these conditions permits rejection of material.

C. Sampling is Required, Preferably upon Receipt: Waterborne Paint. Department Paint Sampling Method for Paint totes. Use the split sample 20-gallon method, draw off 10 gallons from the spigot and place back into tote, take 1 quart sample, draw off an additional 10 gallons from the spigot and place back in the tote, take a second quart sample: be sure to label #1 and #2. Seal can and properly label and identify. Any skins or other foreign matter should be sampled independently and in addition to the two-quart liquid sample. Samples should be submitted to Innovation and Support Division for analysis.

D. Sampling is Required, Preferably upon Receipt: Glass Beads. Use bead sample thief to take sample from all 4 corners and the center of the box, place in quart bottle, forward to lab. Refer to diagram in Appendix.

6.4 DISPOSAL OF CONTAINERS

Empty Bead Boxes: Proper disposition of empty containers must be ensured. Counties should consider recycling both cardboard boxes and wooden pallets.

Recycle Totes: Reseal totes and store properly, County Equipment Manager should contact the supplier when a minimum of 10 totes are accumulated for return to the manufacturer.

7. TRUCK-MOUNTED PAINT MACHINE OPERATION

7.1 INTRODUCTION

The function of the Truck-Mounted Paint Machine Program is to place longitudinal retroreflective traffic lines on state highways with machines equipped to place rapid dry paint.

7.2 ROADWAY OPERATION

The equipment listed below is recommended for the Truck-Mounted Paint Machine Program:

A. Paint machine with flashing arrow board or message board

B. Foreman's truck

C. Supply truck with flashing arrow board may have a tag along attenuator

D. Shadow vehicle with truck-mounted or tag along attenuator and flashing arrow board (as required on Interstates and/or other limited access highways)

While the sequence of vehicles listed above is normal, it is not mandatory. There are many occasions when exceptions to the order of travel may be necessary.

When painting on interstate highways and/or other limited access highways, a shadow vehicle is required as per Department policy. See Publication 213.

District may determine that additional protection may be necessary. Local State Police may be contacted for assistance in these instances.

7.3 SAFETY DEVICES

All safety devices shall be checked daily to assure that they are operational. These devices include all warning lights, flashers, flashing arrow boards, brake lights, fire extinguishers and signs.

Signs on the paint machines and supply trucks should have 8-inch black letters on orangeretroreflectorized backgrounds and be sized as indicated in the following table:

Paint Truck:

Front and rear	72" x 12"	Line Painting *
Rear	72" x 24"	Wet Paint When Flashing **

Supply Truck:

Rear	72" x 24"	Wet Paint When Flashing **
Rear	72" x 12"	Do Not Pass ***

* Bumper-Mounted on paint machine or lead vehicle, when used.

** White reflective legend may be incorporated directly on black flashing arrow board, if space is not available for sign.

*** Must be covered when not applicable.

In those cases where the design of the paint machine will not accommodate the sign sizes listed, adjustments in sign and letter sizes and placement may be made.

Message Boards on Paint Machines or Supply Trucks may contain the "Wet Paint" and "Do Not Pass" legend and appropriate legends to meet specific conditions.

Although the paint machines are considered oversize vehicles and need to be permitted annually, special provisions in the regulations indicate that because of other traffic warning devices and signs incorporated in the painting operation, oversize signs are not required.

7.4 EQUIPMENT

Galvanized steel and brass components should be eliminated from paint trucks due to the chemical composition of waterborne traffic paints. Stainless steel pipes and fittings are required.

7.4.1 Heating System

Achieving proper paint temperatures and maintaining that heat during long periods of painting without exposing the paint to dangerously high glycol temperatures is one of the toughest tasks facing the waterborne paint applicator. Improper heat is one of the most common causes of waterborne paint complaints. Inadequate paint temperatures cause poor spray patterns and longer dry times, while overheating the glycol to obtain adequate paint temperatures may result in gelled heat exchanger and paint hoses, which are extremely difficult to clean.

The paint temperature is sensed in the heat exchanger. This sensor controls the valve, which regulates the flow of glycol to the appropriate heat exchanger and heated hoses. When the maximum preset paint temperature is reached, the valve to the exchanger closes and a valve to the burner loop opens, thus maintaining an even glycol temperature. All paint hoses, pipes, manifolds, etc., from the exchangers to the guns must be jacketed with heated glycol. Insulation is not sufficient.

The burner is set to heat the glycol to proper temperature. This will prevent the paint from accidentally being overheated. Acrylic waterborne paints must be heated adequately in order to spray and dry properly.

Achieving and maintaining the paint temperatures requires the heating system to be working at maximum efficiency. Significant gains towards achieving this efficiency can be obtained by ensuring three things; 1) an adequately sized furnace, 2) larger-than-normal heat exchangers and 3) auxiliary circulation pumps to augment the flow of glycol.

7.4.2 Heat Exchangers

Waterborne paints react with the brass in a heat exchanger; therefore, paint machines utilize stainless steel heat exchangers. A heat transfer area of 64 square feet is typical for most paint machines. However, due to the higher specific heat of waterborne paints and the glycol temperature constraints, a larger exchanger of 85 to 100 square feet may be necessary. In order to minimize heat loss, the exchangers should also be mounted as close to the gun carriage as possible.

7.4.3 Furnace

The furnace for heat supply should be rated for at least 225,000 BTUs.

A. Operating Temperatures: Unless the manufacturer recommends otherwise, paint temperature of 110°F + 5°F at the guns is required for proper atomization and dry time of waterborne paint. The paint must not be allowed to rise above 130°F at any time. This requires a system to control both the maximum glycol temperature at 156-170°F in the heat exchanger and separate sensor controls to bypass the flow of glycol to the exchanger and jacketed paint lines when the paint temperature reaches 130°F. This system should be completely automatic. Manual systems or systems which monitor only paint or glycol temperature run a high risk of eventually resulting in a gelled heat exchanger or paint hoses. (Note: Gelled latex paint is extremely difficult to clean from a heat exchanger.) Systems, which control only glycol or paint temperature, will also be

unable to control the paint temperature in the narrow range required for consistent application. A major cause of dry time problems is heavy films or heavy centers which can often be traced to inadequate heat control. Viscosity is very dependent on material temperature, as is ease of spraying.

7.4.4 Pumps

All pumps in the system are stainless steel or aluminum diaphragm pumps with Teflon/Neoprene diaphragms. All wetted parts shall be impervious to waterborne paint's corrosiveness.

7.4.5 Compressor

An air compressor capable of supplying at least 250 CFM of air at 100 psi is recommended. Most of the air compressors are factory set to supply 80 to 100 psi. The higher surface tension of water requires more air for atomization. The pop-off setting may need to be raised to 125 psi. (Check with the compressor manufacturer for safety considerations first.) If the compressor setting cannot be raised it may be necessary to use a smaller fluid nozzle and reduce the speed of the truck.

7.4.6 Paint Guns

Follow proper aiming and cleaning procedures as recommended by the manufacturer.

7.5 MAINTENANCE

Traffic line painting equipment has advanced significantly. This is most evident in truck-mounted paint machines which incorporate complex air, hydraulic, electric and electronic systems to provide an efficient method of applying traffic line paint and reflective glass beads in the required widths and patterns. As with all complex machinery, a preventative maintenance program is required to assure efficient operation. Each paint machine has an Operator's Manual which should be available at all time in the field.

7.5.1 Standard Truck Chassis

The truck chassis shall have preventative maintenance performed in accordance with current Pennsylvania Department of Transportation policies as defined by the Fleet Management Division of the Bureau of Maintenance and Operations.

7.5.2 Specialized Painting Components

The paint crew should service the paint machine components under the direct supervision of the Paint Foreman. Service is broken down as follows:

A. When not in use, the paint machine should be kept in a facility which is totally enclosed to prevent moisture from affecting the complex electronics of the machine.

B. On a daily basis the following minimum maintenance shall be performed:

1. The paint gun tips and shrouds should be disassembled and cleaned. They must be adjusted for proper operation including uniformity of paint distribution, film thickness, line width and line spacing. The bead guns must be checked for proper bead distribution and a dispensing rate of 7 lbs. /gal.
2. The pump filler hose and piping should be cleaned or capped after completing loading of paint into the machine.
3. The coolant and oil levels of the complete unit including the compressor should be checked.
4. The carriages should periodically be cleaned to prevent excessive buildup of paint.
5. The overall machine should be cleaned when required to prevent hazardous

conditions arising from spilled paint, oil leakage, etc. In addition, the lights should be wiped clean to ensure adequate illumination.

6. The airline moisture separator should be checked at least once daily and more often in humid weather to ensure dry air. Where applicable, relief valves should be checked.

C. On a weekly basis, in preparation for weekend shutdown, the paint trucks should be filled.

D. On a monthly basis, the truck components should be scheduled for preventive maintenance.

E. The following should be performed on an “as required” basis: The paint tank lid, heat exchangers, filters, sediment screens, and lines should be cleaned.

F. The entire paint machine is to be disassembled, cleaned and refurbished each winter

7.6 SPARE PARTS

The Paint Foreman shall be responsible for identifying an adequate inventory of spare parts for the Truck-mounted paint machine(s) in the District by coordinating the purchasing of such spare parts with the District Equipment Manager. Special emphasis should be given to the low cost wearing parts requiring frequent replacement (consumable).

District Procurement personnel should consult the Consumable Policy to determine which parts need to be tracked in SAP inventory and which parts can be treated as consumable items. All parts should be charged to Program 813 regardless of whether they are classified as SAP inventory or consumable.

7.7 MODIFICATIONS TO EQUIPMENT

All significant modifications to paint equipment by the Districts shall be coordinated with BOMO and the Fleet Management Division.

8. APPLICATION OF WATERBORNE TRAFFIC PAINT

8.1 GENERAL

Waterborne traffic paints cure by a two-stage process. In the first stage, the water evaporates and the acrylic emulsion coalesces. This evaporation is dependent on temperature and humidity – low temperature and/or high humidity gives longer dry times. In the second stage, the acrylic polymer cross-links to provide a durable film. This reaction is dependent on temperature above 50°F and is the recommended minimum application temperature. Between 35°F and 50°F, the polymer will cross-link but the durability of the film will be severely reduced to 3 to 4 months instead of the usual 12 to 16 months.

Under conditions of 75°F, sunny and light wind, the fast dry material will dry to no-track in 90 seconds or less. If faster dry times are needed, reduce film thickness from 15 to 13 mils and increase bead rates to 8 to 10 pounds per gallon of paint applied. Do not increase material temperature above 130°F in an attempt to get faster dry times.

If materials must be applied below 50°F, line protection will be required since dry times will increase dramatically.

A. The general limits of the operating conditions for painting are a pavement temperature of 50°F or greater, relative humidity of less than 80%, wind speed of at least 1 to 2 mph and air temperature of 50°F or greater. Painting outside any of these limits is to be avoided, unless special precautions are taken.

B. Paint should be applied at a thickness of 15 mils wet, which is a rate of 16.5 gallons per mile for 4-inch lines and 24.75 gallons per mile for 6-inch lines. When paint is applied at thickness over 15 mils the dry times increase by a large degree. An increase of 2 to 4 mils in application can cause a 20% increase in water, which must be evaporated from the system and can result in an increase of 50 to 100% in the no-track times.

C. Fast-dry waterborne paints must be applied at 110°F + 5°F. Viscosity is very dependent on material temperature, as is ease of spraying. Excessive paint temperatures in the heat exchanger (above 130°F) could gel the paint in the exchanger lines, which would require a complete shutdown of the equipment.

D. Glass beads should be applied at 7 pounds per gallon of paint. For maximum retroreflectivity the truck speed should be 12 mph and the bead gun angle should be facing backward at a 20 degree angle.

E. The paints on our contract are fast-dry which means they reached a “no-track” condition in 90 seconds or less under ambient conditions on our test deck. Under low temperature and/or high humidity conditions, this time to dry will increase. Schedules should be adjusted to paint less vulnerable areas or lines when these conditions are present.

F. Waterborne traffic paints are sensitive to wet pavements and rain. Best results are obtained when pavements are dry (12 hours since measurable rain) and no rain occurs for 2 hours after application.

   1. Do not stripe on visibly wet pavements even though it has not rained recently.
   2 Lines need to cure completely before any rain. If it looks threatening, don’t chance it.
   3. If it does rain a significant amount, wait until the next day before trying to paint.

G. Early morning painting during the spring and late fall should be avoided since operating conditions are very marginal during these periods. Changes to the method of painting may be an option, e.g., doing only the edge line in the morning and the centerlines and the other edge line in the afternoon. Preheating the paint in the tanks by operating the heating system and recirculating the paint back into the tanks while traveling to the job site will reduce the impact

on the heating system during the actual painting operation. Storing the paint trucks inside during the evenings will also help maintain a warmer paint temperature.

The waterborne painting season should typically be April 15 to October 31.

8.2 INITIAL PREPARATIONS

Prior to leaving the base of operations, check each vehicle to verify all equipment is functioning properly. This includes arrow boards, flashing lights, radios and all line-painting functions.

A. Furnace, air compressor, air flow and paint guns.
B. Check calibration of bead guns for flow rate 7 lbs/gal.
C. Check air temperature and humidity.

8.3 AT LOCATION

The paint foreman should evaluate and record the air and pavement temperatures, humidity and pavement conditions at least three times a day and record them in the daily log. If not proper, he must then determine whether the conditions will permit a modified painting operation or requires moving to an alternate site. The following should be done initially and at two more times during the day.

A. Verify paint temperatures at the guns is acceptable when three guns are operating 90°F + 5°F.
B. Review line application, line width, bead distribution, bead embedment and dry times. (This should be done by the foreman throughout the day.)
C. Operators should check temperature and pressure readings on console throughout the day.

8.4 DOCUMENTATION

The foreman shall maintain a diary to document all data collected and any changes in conditions, which occur during the day that could affect quality of the paint line.

8.5 REMEDIAL MEASURES

The following measures provide recommended actions to alleviate certain identified problems, which may occur in the field.

A. Tracking
    1. Add more vehicles to paint convoy.
    2. Increase distance between first and last vehicle in convoy.
    3. Decrease line thickness from 15 mils to 13 mils (14 gal/mile) for centerline applications and from 12 mils to 10 mils (11 gal/mile) for edge line applications.
    4. Increase bead rate from 7 pounds per gallon to 8 to 10 pounds per gallon.
    5. Change hours of operation.
    6. Stop painting and move to a location where conditions are more favorable.
    7. Modify method of painting, e.g., edge line only in peak hours.
    8. Use cones or other devices to protect lines, particularly in high volume areas, commercial zones, locations with high volume turning movements or cross-traffic and

acceleration/deceleration lanes unless conditions exist where personnel cannot place or pickup cones safely.

9. Don’t paint.

B. Improper rate of beads or paint thickness.

1. Change vehicle speed
2. Check compressor pressures
3. Check paint temperatures
4. Reduce number of guns in operation

C. Improper line characteristics

1. Adjust gun height
2. Adjust air pressure
3. Check angle of guns

9. QUALITY ASSURANCE OF TRUCK-MOUNTED PAINT MACHINE PROGRAM

9.1 CENTRAL OFFICE

Data collected by Central Office is used to identify potential problems and

to inform the Districts of the quality of paint lines being applied. Quality Assurance (QA) reviews will collect data such as air and surface temperature, relative humidity, paint temperatures from paint guns, line width, bead dispensing rate, bead embedment and paint drying time based on the spacing of the vehicles in the line painting operation.

The latest QA form is maintained in the Bureau of Maintenance and Operations. QA forms are subject to revision as program emphasis is redirected to enhance the total program.

A. BOMO – Conduct QA's of each truck's operation and field application as time and resources permit.

B. BOMO – Conduct QA's of each truck, field application, administrative processes, and operations procedures as time and resources permit. Reviews paint plates.

9.2 DISTRICT

It is Department policy that a QA review of each paint machine shall be conducted by the Paint Foreman once a month and that sample plates from the review shall be submitted to Central Office. This procedure is required to ensure that at least once every 2 weeks, each paint machine is calibrated to paint quality traffic lines. BOMO reviews the sample plates and provides comments to the appropriate Assistant District Executive Maintenance, Assistant District Engineer-Services or District Traffic Engineer.

A. Assistant District Traffic Engineer or District Maintenance Manager – Monthly review of records with appropriate personnel and conducts field reviews of lines in two areas.

B. Foreman – Prepares daily log and conducts daily checks of line features, equipment operation and environmental conditions. Prepares report of problems. Obtain sample paint plates.

10. PERSONNEL HEALTH AND SAFETY

10.1 SAFETY EQUIPMENT

The use of an Air Purifying Respirator, full or half-face (N10SH/MSHA approved), with appropriate organic vapor cartridges may be used when filling or cleaning the paint tanks. Air purifying chemical cartridge/canister respirators do not supply oxygen and cannot be used in an oxygen-deficient atmosphere. Safety glasses/goggles are to be worn with all half-face respirators.

10.2 TRUCK-MOUNTED PAINT MACHINE AND SUPPLY TRUCK SAFETY REQUIREMENTS

The minimum equipment and warning devices are listed as follows:

A. At least one fire extinguisher on each vehicle with a UL rating of 10BC.

B. At least one First-aid kit on the Truck-Mounted Paint Machine.

C. Each crew shall carry a “spill kit” for liquid cleanup.

D. Warning devices for stopped vehicles:

These are equipment related issues which should be addressed during the assembly of the truck.

1. Three red emergency reflectors and two red flags, or three triangle reflectors. No flares or fuses are allowed to be carried on or in the trucks.

E. Tires:

1. Front – the minimum tread depth shall be 4/32 of an inch.
2. Others – the minimum tread depth shall be 2/32 of an inch.
3. No other visible defects as outlined in the Motor Carrier Regulations (bulges, tread separation, exposed fabric, cuts, etc.)

10.3 SHIPPING PAPERS

A shipping paper must be present in any vehicle which carries any amount of waterborne paint.

It is the responsibility of the Paint Foreman to ensure that the Operator’s Shipping Paper (See Appendix A, A-25) is prepared and carried by the drivers of the Truck-Mounted Paint Machine and the Paint Supply Truck.

The Operator’s Shipping Paper is filled out except for the total gallons you carry on the truck. If you carry any other hazardous materials fill in the sheet with those items.

10.4 DRIVER REQUIREMENTS

Any equipment operator who is assigned to drive the Truck-Mounted Paint Machine or the Paint Supply Truck must meet the following requirements:

A. Must be 21 years of age

B. Must read and speak English

C. Must have a valid Commercial Driver’s License with a tank endorsement for placarded vehicles.

10.5 DRIVER RECORDS

The District Safety and/or Training Coordinator is responsible for:

A. Making an annual review of a driver's record to determine if the driver meets minimum requirements.

B. Maintaining an annual list of traffic violations obtained from each driver.

C. Retaining the employment application of each driver.

D. Performing background checks on all violators of motor vehicle traffic laws and ordinances (other than for parking) and vehicular accidents.

10.6 ACCIDENTS/INCIDENT REPORTING

In addition to the Police Report, the driver must fill out the Department-required accident report form.

10.7 SPILL AND LEAK PROCEDURES

For minor spills or leaks (25 gal or less) follow the MSDS sheet, notify the county garage foreman and the District Traffic Unit.

When a spill occurs, the first step is to stop the spill or leak if this can be done safely. Turn off nozzles or close valves from the leaking container or system. Spills must be cleaned up immediately and reported to the appropriate District personnel. Follow the MSDS for hazard and safety information.

10.8 PENALTIES

For violation of any Federal HAZMAT Regulation pertaining to the routing, parking or other act in the actual operation of the vehicle, the driver of the vehicle shall be guilty of a misdemeanor. Also, any person who, as a shipper, carrier, cosigner or user of a hazardous material, shall knowingly or willfully violate Federal HAZMAT Regulations, shall be guilty of a misdemeanor. Penalties upon conviction of a misdemeanor shall be fines as listed below:

A. Driver

   1. First offense – a fine of not less than $100 nor more than $500 and/or 30 days in jail.
   2. Second offense – a fine of not less than $100 nor more than $500 and/or 60 days in jail.

B. Shipper, Carrier, Cosigner or User.

   1. First offense – a fine of not less than $500 nor more than $5,000 and/or 60 days in jail.
   2. Second offense – a fine of not less than $500 or more than $5,000 and/or 60 to 365 days in jail.

11. SMALL PAINT MACHINE PROGRAM

11.1 GENERAL

Pavement markings normally installed by the small paint machine crews include arrows at critical intersections and at exit and entrance ramps; legends such as “ONLY” or “STOP”, cross-hatching at exit gores; buffer zones at lane reductions and obstructions within the pavement; stop bars on critical approaches to intersections and off ramps; R/R crossing markings; speed measurement markings, and other items as required by the MUTCD or PUC. Reference TC-8600 for proper dimensions, layout and placement of horizontal markings.

11.2 RESPONSIBILITIES

The continuance of the small paint machine program at the reduced level requires that the responsibilities of the District Traffic Unit and Maintenance Unit be defined.

1. The District Traffic Unit should identify and inventory all pavement markings in the District and classify them as:
2. Painted by the municipality as per Publication 212. Markings to be maintained by municipalities include school crosswalks, crosswalks, stop bars, markings shown on traffic signal permits, and other small paint machine markings.
3. Essential markings to be maintained by the Department. Essential pavement markings include those markings required by MUTCD or PUC mandates or those deemed necessary for safety or traffic flow by an engineering analysis. Markings required by MUTCD include:
    a. Railroad crossing approaches (refer to TC-8600). At minor crossings or in urban areas, these markings may be omitted if an engineering study indicates that other installed devices provide suitable control.
    b. Wrong way control at highway ramp terminals (refer to TC-8600).
    c. Approaches to fixed obstructions within a paved roadway (refer to TC-8600).
    d. Preferential lane markings (refer to TC-8600).
    e. SPARE markings on freeways.
4. Non-essential markings. Non-essential pavement markings are defined as those markings which are either not required by the MUTCD or are not deemed necessary as a result of an engineering analysis for identified safety or traffic flow deficiencies. Examples include cross-hatching at exit gores having no apparent visibility or safety deficiency, stop bars at intersection approaches having adequate visibility and no record of motorists running stop signs, and R/R markings at railroad crossings on non-traffic route urban streets where stopping sight distance is adequate and other traffic control devices provide suitable control.
5. The District Traffic Units shall establish an annual listing of those sites which require repainting in the upcoming painting season. This list is to be provided to the Assistant District Executive – Maintenance and/or Services by May 1st of each year and entered into a Computerized Management System.

C. The Maintenance Unit has been assigned the responsibility to maintain essential pavement markings in a satisfactory condition. Contract and/or appropriate County maintenance personnel can accomplish the work. Material utilized can be either a durable marking material or traffic paint. It is important when using traffic paint that the small paint machines be used to apply pavement cross-hatching, legends or arrows, rather than hand application (no rollers or brushes). This will help ensure that the proper film thickness will be achieved, thereby increasing the durability and life expectancy of the marking.

Pavement marking legends or arrows which have been defined as essential should be incorporated into any surface overlay project using inlaid cold plastic or other marking material which has proven to be durable and maintenance-free.

D. District Traffic Units should identify their small paint machine program sites where each of the following are counted as separate sites:
    1. Each ramp and/or gore area.
    2. Each leg of an intersection.
    3. Each side of a railroad crossing.
    4. Each lane for a direction of a SPARE area.
    5. Each pair of left arrows for center lane left only.
    6. Each handicapped symbol.

11.3 EQUIPMENT REQUIREMENTS

The equipment normally required for the Small Paint Machine Program is:

A. Small Paint Machine
B. Trailer
C. Foreman's Truck
D. Additional equipment required by Publication 213 for traffic control

11.4 EQUIPMENT MAINTENANCE

At the start of the day's operations, the engine oil level and safety valve on the paint tank should be checked. At the end of the workday, the paint system should be thoroughly cleaned and the glass beads removed from the dispenser hoppers, if equipped. Other than this, little maintenance is required except periodic tune-up, lubrication and emergency repairs. Major overhauls should be performed during the non-painting season.

12. TRAFFIC CONTROL REQUIREMENTS

All traffic control devices and traffic control methods used during the pavement marking operation shall be in conformance with the Department's Work Zone Traffic Control Regulations Publication 212, Publication 213 and the MUTCD.

13. COMPUTERIZED MANAGEMENT SYSTEM

13.1 GENERAL

The Department has developed a Traffic Line Painting Program, using SAP. A ZIPY Payroll is to be used by the Districts to input daily paint production for the Truck-Mounted Paint Machine Program and the sites and production for the Small Paint Machine Program. In order to produce monthly statewide reports, the Districts should have all data entered in SAP according to the District procedures and policies.

13.2 ASSEMBLY NUMBERS

Please see Pub 113, Highway Foreman Manual.

APPENDIX A

GUIDELINES FOR THE SAFE CLEANING OF TRUCK MOUNTED PAINT TANKS

PennDOT's traffic line paint is formulated to bond with the pavement, suspend and hold glass beads, be track-free in two minutes or less, meet specified color requirements, and last through the winter.

These customer driven qualities of our paint make the cleaning of our truck mounted paint tanks arduous and labor intensive. To make sure that this demanding task is performed safely, the following guidelines are to be followed by the paint crews when cleaning the paint tanks on their paint trucks:

1. Clean tanks in a well ventilated area. Utilize exhaust fans, windows, and doors to keep a fresh supply of air in the cleaning area.
2. Circulate and flush the paint truck with water, preferably with hot water to dilute and dislodge the remaining paint.
3. Remove the tank lid assembly and set aside for separate cleaning.
4. Remove and properly dispose of any remaining large chunks of paint.
5. Pressure wash the paint tanks with heated water, if at all possible; removing as much paint as possible from all inside surfaces of the paint tank.
6. Finally, to clean all the hard to reach areas, a paint scrapper or putty knife can be used to scrape off the remaining paint.

   Required Personal Protective Equipment (PPE)

   • Jump suit

   • Gloves

   • Boots, rubber

   • Safety glasses with shields

   • Respirator

The Buddy System should be used so that employees can be monitored while cleaning the tanks. Limit duration of cleaning to two hours per employee.

Safety Reminder: When filling paint tanks with waterborne paint, do not breathe in the paint fumes. Monitor the paint level by opening the manhole plug and observing the flow of paint from a safe angle.

Waste Water Disposal: Do not discharge residual cleaning water directly into any water treatment plant without an agreement with the plant operator. Any other paint waste will need to be containerized and sent out with all other residual waste in accordance with the County's established waste pickup agreement.

OPERATIONAL EVALUATION

TRUCK-MOUNTED PAINT MACHINES

LOCATION: District_____ County _____ S.R. _____

DATE OF REVIEW:_____ TIME: _____ A.M./P.M.

WEATHER CONDITIONS:

Air Temperature _____ Pavement Temperature _____

% Relative Humidity _____ Wind: ____ None ____ Light ____ Moderate ____ Strong ____

REVIEWER: _____ Telephone: _____

EQUIPMENT:

1. Truck No.: _____ Foreman: _____
2. Are all gauges, counters, speedometers, etc. on the truck, which are necessary for proper application of the materials and documentation of the daily work, operating properly? YES NO
3. Does foreman have the equipment required to conduct the daily quality assurance reviews (wet film gauge, temperature humidity gauge, temperature gun, magnifier, folding rule, sample plates, gallon pail, and mixer)? YES NO
4. Does foreman check air temperature, pavement temperature and humidity at least three times a day? YES NO
5. Does foreman maintain a diary to document all data collected and any changes in conditions that may affect the quality of the markings? Review the diary for any deviation from environmental requirements and roadway conditions during the past 2 weeks. YES NO
6. Are the following devices on the paint and supply truck operating properly and in good condition (rotating or flashing lights, flashing arrow board, vehicle mounted signs)? YES NO
7. Is equipment available to load and unload materials? YES NO
8. Are bead boxes recycled? YES NO

MATERIALS:

1. Is the paint stored in an area where it is not exposed to direct sunlight? YES NO
2. Are glass beads stored in a dry area? YES NO
3. Is paint and glass bead sampling conducted properly? YES NO
4. Are samples sent to the lab within one week of receipt and properly identified? YES NO
5. If paint is more than two months old, was it mixed thoroughly before sampling or use? YES NO N/A

OPERATION:

1. What is the painting speed? MPH (Verify by pacing) YES NO
2. Are lines generally straight and uniform? YES NO
3. Are paint line edges clean and sharp on the roadway? (Minimal overspray)
   - Left Carriage (LC) White YES NO N/A
   - Left Gun Yellow YES NO N/A
   - Right Gun Yellow YES NO N/A
   - Right Carriage (RC) White YES NO N/A
4. Is width of line within + 1/4 inch of requirements? YES NO
5. Are center line (yellow) paint guns adjusted to provide a 6 in. (+ 1/2 in.) space between lines? YES NO N/A
6. Are lane lines offset 4 in. to the right of pavement joint (+ 1/2 in.)? Multi-lane roadways only. YES NO N/A
7. Are edge lines 4 in. (+ 1/2 in.) from edge of pavement? Expressways / Freeways only. YES NO N/A
8. Is skip line paint cycle adjusted to a 40-foot pattern (+ 6 in.)? Length_____ YES NO N/A
9. Is skip line 10 feet in length (+ 3 in.)? YES NO N/A Length_____
10. **This test is now optional.**What is the wet film thickness for center and lane lines? Take three (3) readings with a wet film thickness gauge using the notch method (use steel gauge). Place the gauge on the plate in the direction of the paint being applied and clean the gauge after each measurement (ex. inside edge, center, and outside edge, 15-18 mils).
    - Left Carriage (LC) White _____ _____ _____ mils
    - Left Gun Yellow _____ _____ _____ mils
    - Right Gun Yellow _____ _____ _____ mils
    - Right Carriage (RC) White _____ _____ _____ mils
    - Is variance between both yellow guns 3 mils or less? YES NO N/A
11. This test is now optional. What is the wet film thickness for edge lines? Take three (3) readings with a wet film thickness gauge using the notch method (use steel gauge). Place the gauge on the plate in the direction of the paint being applied and clean the gauge after each measurement (ex. inside edge, center, and outside edge, 12-14 mils).
    - Left Carriage (LC) Yellow mils _____ _____ _____ mils
    - Right Carriage (RC) White mils _____ _____ _____ mils
12. Do lines have uniform paint coverage? YES NO
13. What are the heat exchanger temperatures? Left _____ Right _____
14. What is the paint temperature at the paint guns?
    - Left Carriage (LC) Left Gun _____ N/A
    - Right Gun _____N/A
    - Right Carriage (RC) N/A _____

15. Measured glass bead rate, goal is 7.0 lbs/gal. (+ 1/4 lb.)? Measure all three guns at the same time.

	MEASUREMENTS (ml)	PASS/FAIL
L.C. Left Gun	____, ____, ____, ____, ____	____
Right Gun	____, ____, ____, ____, ____	____
R.C.	____, ____, ____, ____, ____	____

16. Are glass beads evenly distributed over the entire line?

L.C.	Left Gun	YES	NO	N/A
	Right Gun	YES	NO	N/A
R.C.		YES	NO	N/A

17. Are glass beads properly embedded? (60% + 5)

L.C.	Left Gun	YES	NO	N/A
	Right Gun	YES	NO	N/A
R.C.		YES	NO	

18. Is the spacing of the vehicles in the line painting operation sufficient to obtain adequate drying time for the paint (90 to 120 seconds)? YES NO

REVIEWER COMMENTS:_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

DISTRICT PAINT CREW COMMENTS:_____

_____

_____

_____

_____

_____

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_____

_____

_____

Voice of Our Customer Survey (Optional)

Conduct only at the request of the paint crew

The Bureau of Maintenance and Operations considers you our Key Customer in the area of pavement markings. Your honest and thoughtful responses to this short survey will be a useful tool in the continuous improvement of our Traffic Line Paint Program.

Please evaluate these needs according to your satisfaction with our performance.

How satisfied are you with:	**Not Satisfied**				**Very Satisfied**
1. Equipment	1	2	3	4	5
2. Material					
• Paint	1	2	3	4	5
• Beads	1	2	3	4	5
• Totes	1	2	3	4	5
3. The overall direction of the Traffic Line Painting Program?	1	2	3	4	5

4. What changes would you make to improve your crew's productivity?

PAINT CREW QUALITY ASSURANCE REVIEW FORM

DISTRICT: _____ COUNTY: _____

PAINT MACHINE NUMBER: _____

FOREMAN: _____

STATE ROUTE: _____ SEGMENT: _____ OFFSET: _____

DATE: _____ TIME: _____ WEATHER: _____ TIME: _____

PAVEMENT TEMPERATURE: _____ ° AMBIENT TEMPERATURE: _____ °

RELATIVE HUMIDITY: _____ %

1. Is the roadway surface clean and dry? Yes _____ No _____
2. Are the pavement, ambient temperatures and relative humidity being monitored and documented at least three times a day? Yes _____ No _____
3. What is the application speed? _____ MPH
4. Are centerline guns adjusted to provide a 6-inch space between lines? (+ 1/2 inch)
   Yes _____No _____N/A _____
5. Are lane lines 4 inches to the right of the pavement joint or seam? (+ 1/2 inch)
   Yes _____No _____N/A _____
6. Are edge lines 4 inches from the edge of the pavement? (+ 1/2 inch) Yes _____No _____N/A _____

PAINT and BEAD GUNS									
Questions Continued	**2.2.4. Left Outside**			**2.2.5. Left Inside**			**2.2.6. Right**		
	Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
7. Are the edges of the lines clean and sharp on the roadway?									
8. Are the lines being applied uniformly?									
9. Are glass beads evenly distributed over entire line?									
10. Are glass beads properly embedded (std = 60% + 5%)?									
11. Width of the lines being applied (std = W + 1/4”)									
12. Length of the skip line pattern (std = 40’ + 6”)									
13. Length of the skip line (std = 10’ + 3”)									
14. Paint temperature at the guns (std = 110°F + 10°F)									
15. Measured glass bead application rate (std = 7# + 1/4#)	Lbs./Gal			Lbs./Gal			Lbs./Gal		
16. What is the quantity of paint used and length of lines applied for the day?	Gal. Ft.			Gal. Ft.			Gal. Ft.		

Glass Beads Disbursement Rates

Bead Volume in milliliters per 5 seconds for a 4” wide line at 7.00 pounds per gallon of paint.		
15 mil Wet Film Thickness	**Speed (MPH)**	**12 mil** Wet Film Thickness
± 15ml		± 15ml
400	**10.0**	320
420	**10.5**	336
440	**11.0**	352
460	**11.5**	368
480	**12.0**	384
500	**12.5**	400
520	**13.0**	416
540	**13.5**	432
560	**14.0**	448
580	**14.5**	464
600	**15.0**	480
620	**15.5**	496
640	**16.0**	512
660	**16.5**	528
680	**17.0**	544
700	**17.5**	560
720	**18.0**	576
740	**18.5**	592
760	**19.0**	608
780	**19.5**	624
800	**20.0**	640

Bead Volume in milliliters per 5 seconds for a 6” wide line at 7.00 pounds per gallon of paint.		
15 mil Wet Film Thickness	**Speed (MPH)**	**12 mil** Wet Film Thickness
± 15ml		± 15ml
600	**10.0**	480
630	**10.5**	504
660	**11.0**	528
690	**11.5**	552
720	**12.0**	576
750	**12.5**	600
780	**13.0**	624
810	**13.5**	648
840	**14.0**	672
870	**14.5**	696
900	**15.0**	720
930	**15.5**	744
960	**16.0**	768
990	**16.5**	792
1020	**17.0**	816
1050	**17.5**	840
1080	**18.0**	864
1110	**18.5**	888
1140	**19.0**	912
1170	**19.5**	936
1200	**20.0**	960

GLASS BEAD GUN ANGLE HOW-TO GUIDE

The purpose of this How-To Guide is to demonstrate how to make a template to adjust the angle of the glass bead gun for optimal line painting.

1. RESEARCH SUMMARY

As you know, glass beads are projected into wet line paint at the time of application to create a retroreflective surface, aiding driver visibility and improving roadway safety.

However, anecdotal evidence suggests that variances in the speed of line painting trucks and the angle of their bead gun diffusers affects the depth at which the glass beads are embedded into the paint, which then affects the retroreflectivity and durability of the painted line.

Glass beads that are embedded too deeply do not refract and reflect light as effectively as those embedded less deeply. Glass beads that are not embedded deeply enough are more easily destroyed over time by weather and the wear of traffic.

A study was developed to answer this research question: Is there a particular truck speed and bead gun angle that together optimizes the embedding of the glass beads for both visibility and endurance?

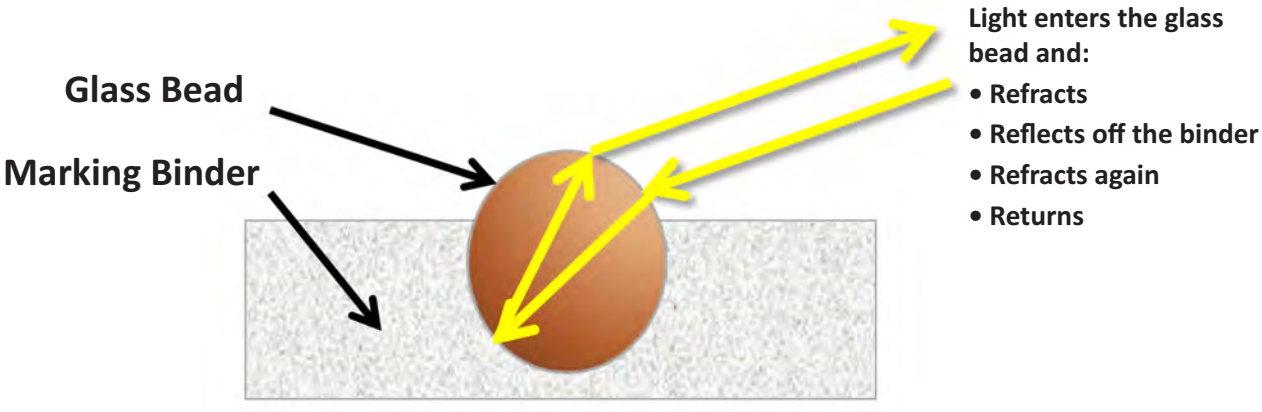


Figure 1: Glass Bead Functionality

During 2008 and 2009, PennDOT contracted with The Thomas D. Larson Pennsylvania Transportation Institute at The Pennsylvania State University (PTI) to study the application of glass beads to paint lines. The research project, or study, was developed to use a certain procedure to obtain certain goals. The goals of the study were to optimize (given current waterborne paint and glass bead specifications):

- Truck application speed;
- Glass bead gun angle.

The methodology was developed to determine optimal speed-angle combination based upon:

- Field measurements;
- Laboratory experiments.

The results of tests of pavement markings done by other researchers around the country were read, and the knowledge gained was used to develop an experimental plan to test and measure pavement marking performance.

The testing was divided into two components: outdoor testing and laboratory testing. For the outdoor testing, 18 white longitudinal pavement markings were applied at PTI's test track facility. Bead gun angles and paint truck speeds were varied for the applications of these lines. As these lines were painted, 36 test plates were fastened to the ground and painted at the same time with the same variances in bead gun angle and paint truck speed.

The 36 test plates were brought into the lab and tested. Half of the plates were placed in an outdoor lab with full exposure to weather for one year, while the other half of the test plates were tested using a load simulator.

Remember, the task is to find the best balance between retroreflectivity and durability. Deep embedment of the glass beads increases durability, but reduces retroreflectivity.

The study found that higher paint truck speeds and forward-facing bead gun angles resulted in greater, or deeper, embedment of the glass beads. However, the level of embedment may be too great, adversely affecting retroreflectivity.

The study concluded that the maximum retroreflectivity over a one-year period of time occurred with the paint truck moving at 12 MPH and the bead gun angle at -20 degrees. Other application parameters, such as lower truck speeds or more rearward-facing bead gun angles, may have resulted in higher retroreflectivity right after application, but that higher retroreflectivity may have broken down over time due to insufficient embedment, exposing the glass beads to wear.

Based upon the study's composite ratings of truck speed and bead gun angle combinations, the bead gun angle that has the highest performance for speeds up to 15 MPH is a -20 degree angle.

How to Apply the Research Results

Applying the research conclusion can be distilled to two steps:

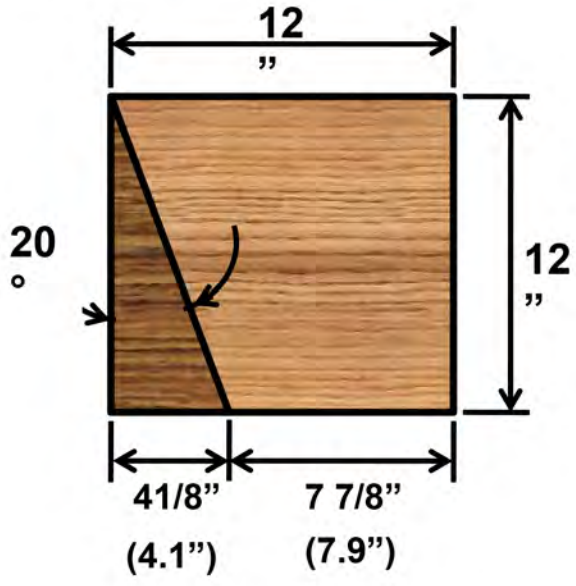
- Make a template.
- Use the template to adjust the bead gun angle.

The sections that follow will show how to make a template for setting the bead gun angle.

Create a Glass Bead Gun Angle Template

A Glass Bead Gun Angle template can be made from any thin, flat, but sufficiently rigid material such as plywood or an old traffic sign. The steps for making the template are (see Figure 2):

1. Cut the material to a 12" x 12" square.
2. Measure 4-1/8" along the bottom from the bottom left corner and mark.
3. Draw a diagonal line from the measured mark to the top left corner.
4. Cut the material along the diagonal line.



The smaller of the two pieces of material may be used with the point to the top, or the larger of the two pieces may be used by turning it around so that the shorter side (the bottom in the diagram) is to the top.

Figure 2: Bead Gun Angle Template

Adjust the Bead Gun Angle

Adjusting the bead gun angle is straightforward when using the template. Follow these four steps:

1. Park the paint truck on a level surface.
2. Drop the paint carriage to its lowest position (see Figure 3).

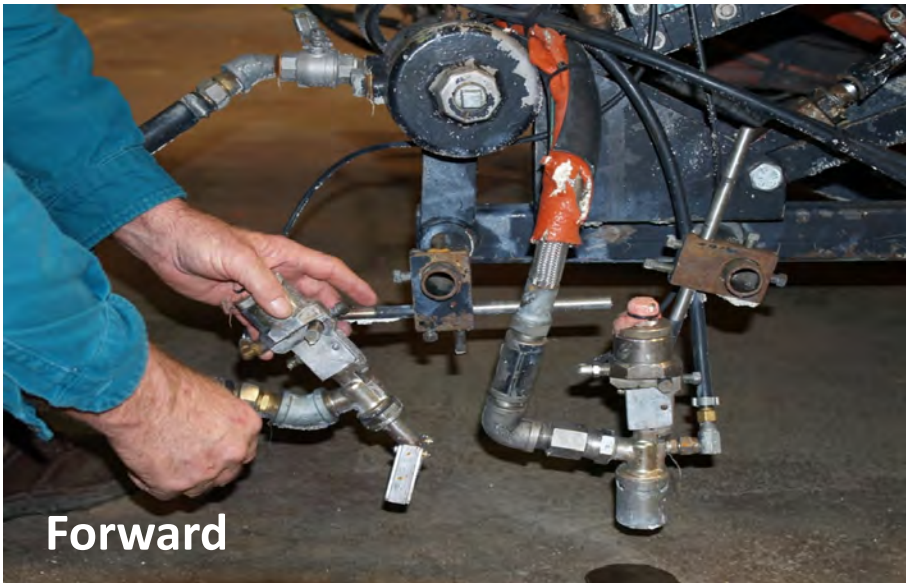


Figure 3: Paint Carriage

The white line marked Forward on the picture indicates the direction of travel.

3. Hold the template on the ground and against the glass bead gun diffuser (see Figure 4).
4. Adjust the bead gun so that the diffuser is aligned with the template diagonal (see Figure 4).

The white arrow in Figure 4 points to the flat part of the diffuser that is to be aligned with the template when adjusting the glass bead gun angle. The diffuser shown in Figure 4 is a custom made model. Not all bead guns use the same diffuser.

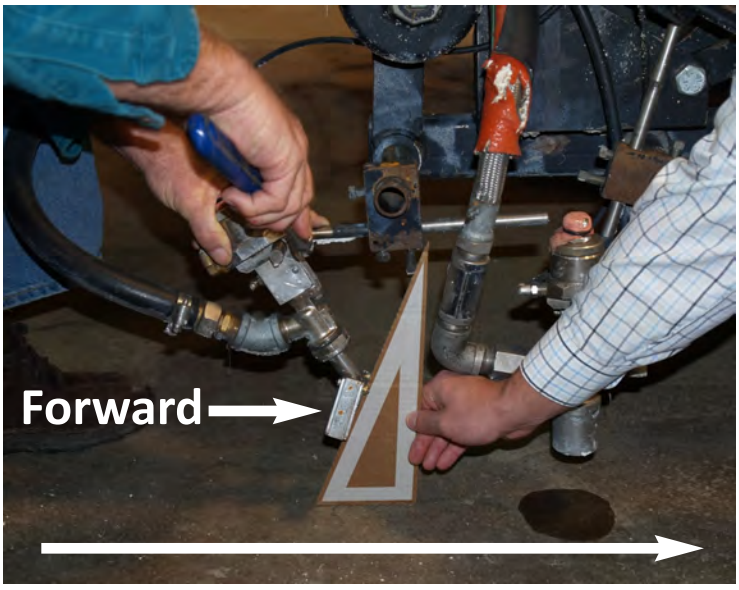


Figure 4: Adjusting Bead Gun using the Template

Whatever nozzle is used, the template can be used to calibrate the angle of application of the glass beads. Remember to align the part of the diffuser that directs the glass bead flow with the template.

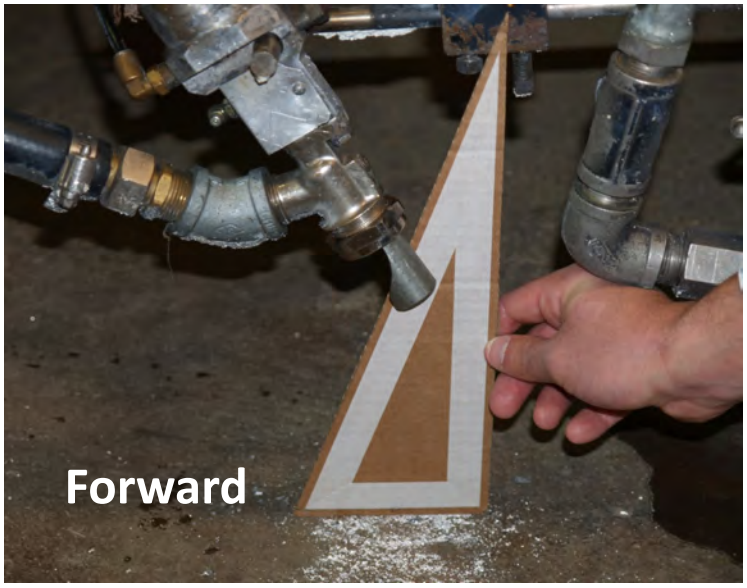


Figure 5: Aligning Bead Gun Diffuser with Template

Paint Line Complaints

District	Date of Complaint	Name of Complainer	County	SR	Segment	Date Last Painted	Details of Complaint

METHOD OF SAMPLING GLASS BEAD MATERIAL BY PROBE (SAMPLE THIEF)

This method covers sampling of glass bead material in 2000 pound cardboard box containers using a sample probe (sample thief or rod) about 48" long (see attached sketch).

Equipment & Chemicals:

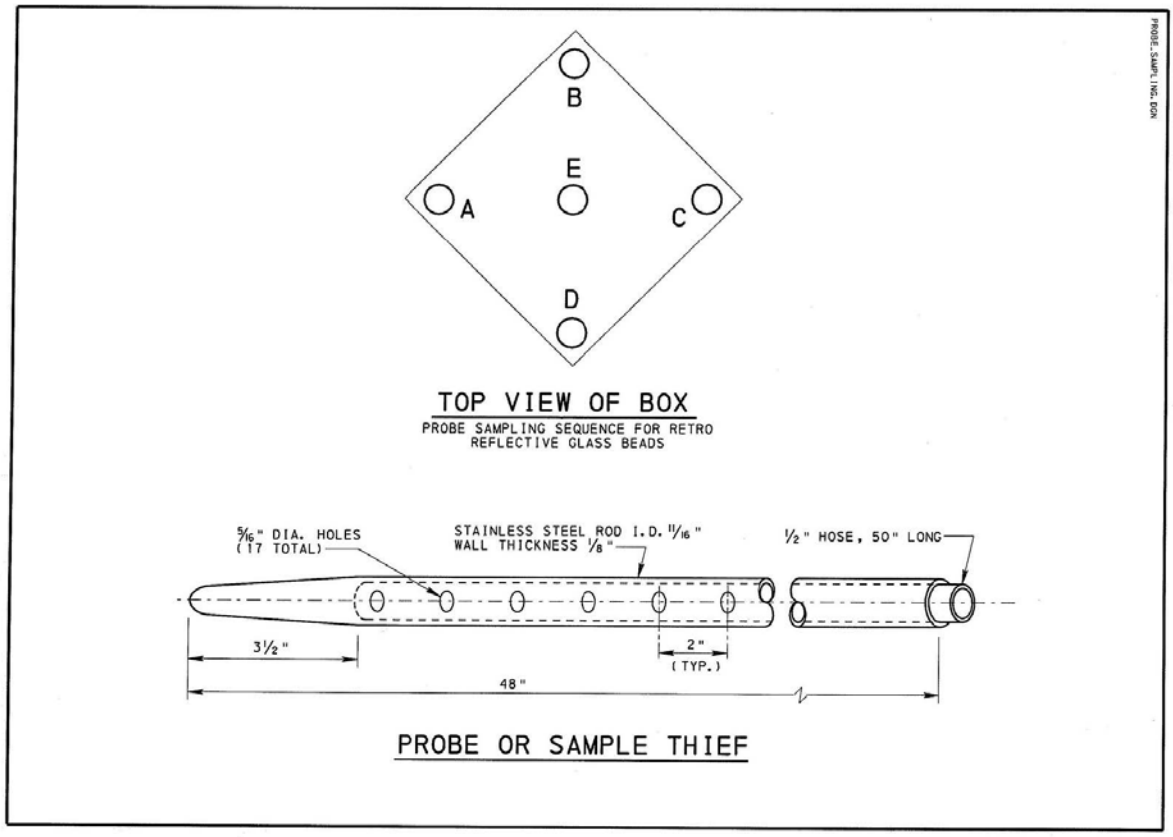
1. Sample "thief" or "probe".

Safety Concerns:

1. It is recommended that safety glasses be worn whenever testing is performed using chemicals, solvents or fine particles (glass beads).
2. Be sure to immediately sweep up any beads spilled onto the floor to avoid slipping.

Procedure:

1. First be sure that the inside of probe is clean to avoid contamination of the sample, by pulling the rubber hose out of the outer tube and checking to be sure no material is on the rubber hose or inside the probe.
2. Put the rubber hose back into the probe.
3. Dip the probe slowly (with the rubber hose inside it) in corner number (A) of the container, all the way down until it touches the bottom of the container, pull the rubber hose slowly out of the probe so the material flows inside the probe through the bottom holes first. Shake the probe a little to allow as much material as possible to get inside the probe.
4. Remove the probe slowly from the container and pour the material slowly in a sample-collecting bag.
5. Put the rubber hose back inside the probe after you are sure that the probe and hose are clean.
6. Repeat steps 3, 4, and 5 in corners B, C, D, and in the center (E) of the container (as shown in the diagram of the top view of the bead box), and every time, pour the specimens in the same sample-collecting bag.
7. This method may be used for sampling material in 50lb bags or drums by using a shorter probe about 24" long and taking the sample in five different places in the bag or drum.
8. **The thief must always be used in the vertical plane.** Using it horizontally will not compensate for segregation and give erroneous results.


PROBE SAMPLING BOX
B
E
A
C
D
TOP VIEW OF BOX
PROBE SAMPLING SEQUENCE FOR RETRO REFLECTIVE GLASS BEADS
5/16" DIA. HOLES (17 TOTAL)
STAINLESS STEEL ROD I.D. 11/16" WALL THICKNESS 1/8"
1/2" HOSE, 50" LONG
3 1/2"
2" (TYP.)
48"
PROBE OR SAMPLE THIEF

HS-2 (11-11)

GUIDELINES FOR REQUIRED INFORMATION FOR POLICE ARREST

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

CHECK ALL BOXES THAT APPLY

Location of Incident:

County: _____ Township/Boro.: _____ Local Name: _____

S.R.: _____ Seg/Off: _____ Milepost: _____

Description of Vehicle:

☐ Car ☐ Truck ☐ Tractor Trailer ☐ Motor Home ☐ Motorcycle ☐ Other: _____

Truck Co. Name (if applicable): _____

Color: _____ Make: _____ Model: _____

Plate # (Vehicle/Trailer): _____ / _____ State: _____ Other Markings: _____

Driver:

☐ Male ☐ Female Age: _____ Hair Color: _____ Clothing: _____

Number/Description of Occupants: _____

Travel Direction: ☐ North ☐ South ☐ East ☐ West

Descriptive Statement: (Include: Who, What, When, Where, Why and How)

Date: _____ Time: _____ ☐ AM ☐ PM Weather: _____

Can any witnesses identify the driver? ☐ **Yes** ☐ **No**

Descriptive of Work Zone:

Warning signs in place? ☐ **Yes** ☐ **No** **Flagger?** ☐ **Yes** ☐ **No** **Operation Type?** ☐ **Moving** ☐ **Stationary**

Regulatory Posted Speed? _____ MPH

	NAME	ADDRESS	TELEPHONE NUMBER
WITNESSES			

Reported By: _____ **Date:** _____ **Reported to Police** ☐ **Yes** ☐ **No**

If Yes: Police Barracks: _____ **Officer's Name:** _____

Guidelines for Required Information For Police Arrest Form

The attached form will be used to assist police and report near misses in work zones. Please follow these guidelines when filling out this form:

1. Note as much information as possible – details are imperative.
2. List witnesses.
3. Call the police immediately after the incident.
4. Immediately after the incident fax a copy to the Safety Press Officer in your District Office.
5. Violations of Sections 3102 and 3326 of the Pa. Motor Vehicle Code should also be considered by police. In addition, if obscene language is used, police can file a charge for disorderly conduct.

OS-672 (6-09)

pennsylvania
DEPARTMENT OF TRANSPORTATION

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION NOTIFICATION OF

❒ DELIVERY DATE REVISION (Section A)
❒ LIQUIDATED DAMAGES ASSESSMENT (Section B)

TO: (CONTRACTOR NAME)	CONTRACT NUMBER:
	CONTRACT PERIOD:
	PURCHASE ORDER NUMBER:
	ORDER DATE:

❒ **Section A: DELIVERY DATE REVISION**

It is necessary for the Department of Transportation to delay the contract delivery date of the subject Purchase Order. Delivery is revised to be completed between ___/___/___ and ___/___/___.

If this contract contains a Liquidated Damages Clause, liquidated damages will not be assessed for the period of delay but will be assessed if the revised date is not met.

❒ **Section B: LIQUIDATED DAMAGES ASSESSMENT**

In accordance with the Liquidated Damages Clause contained in the subject contract, the Department of Transportation is hereby providing notification that delivery against the subject Purchase Order was not received within the time limits specified in the Delivery Clause. Delivery should have been made no later than ___/___/___ (we have included an additional 10 calendar days to allow for mailing time unless the order was faxed or transmitted electronically.)

Delivery was completed on ___/___/___ which was ___ days beyond the required delivery date. Because of the delay, we are assessing liquidated damages in the amount of $ _____. This amount will be deducted from your Invoice Number _____, dated ___/___/___.

ADDRESS: Pennsylvania Department of Transportation	X_____ ___/___/___ SIGNATURE (MAINTENANCE MGR./DESIGNEE) DATE CONTACT PERSON: CONTACT PHONE NUMBER:

Straight Bill of Lading

Shipper

PennDOT

Item	Hazard Class	ID Number	Description	Packing Group	Quantity/Gallons
1 2		NMFC# 149980-06 LTL Class 55	Waterborne Paint, White	III	
3 4		NMFC# 149980-06 LTL Class 55	Waterborne Paint, White	III	
5					
6					
7					
8					
9					
10					

This is to certify that the above-named materials are properly classified, described, packaged, marked and labeled, and is in proper condition of transportation according to the regulations of the Department of Transportation.

Shipping Papers for Paint Truck

Additional Handling Instructions

Operator Name/Signature: _____ Date: _____