Criteria for Successful Thermoplastic Application

- Specifications should be carefully prepared.
- Use properly maintained equipment.
- Totally understand job requirements.
- Maintain daily application & inspection records.
- Clean and dry pavement is required.
- Do not mix alkyd and hydrocarbon thermoplastic.
- Rapidly turn over material.
- Pavement and air temperatures should be above 50F.
- Apply primer (where recommended) and thermoplastic at correct thickness.
- Residual primer solvent must evaporate prior to thermoplastic application.
- Do not overheat material.
- Verify material temperatures & calibrate kettle thermometers.
- Apply materials at proper bonding temperatures.
- Monitor drop-on glass bead application rate and embedment.
- Observe finished appearance and bonding.
- Maximize material and traffic safety procedures.

CONTENTS

1. INTRODUCTION

Throughout the world hot-applied thermoplastic is the preferred durable pavement marking system, providing exceptional traffic control and total life-cycle cost performance value.

Successful applications of all types of coatings, including thermoplastic, are the result of a happy marriage of chemistry, material handling, surface preparation and application techniques. Each of these elements requires sound judgment, planning and execution.

While most coatings applications are performed in controlled environments, striping crews perform their work under continually varying conditions such as changes in temperature, humidity, pavement types, traffic and travel. It is understandably discouraging to both application crews and project engineers when a thermoplastic application process does not function properly. Such occurrences can be avoided by having well- defined material and application specifications, well- maintained application equipment, as well as following sensible, cooperative inspections procedures.

The objective of this handbook is to provide sufficient information to enhance the opportunities for successful hot-applied thermoplastic pavement marking applications. It is intended to be of benefit to the public, contractors, application crews, project engineers and inspectors.

Both the government and the contractor want performance, the government to maximize its investment value, and the contractor to maximize his efficiency. Correctly specified and applied, thermoplastic pavement markings will achieve these goals.

Standards for product, surface preparation, material handling, and application techniques must be clearly understood and faithfully implemented by everyone involved. Doing the job right, the first time, is the best “shortcut” to success. No one profits when traffic must again be interrupted for line repairs.

2. THERMOPLASTIC DEFINED

Thermoplastic pavement marking material is a 100% solid, environmentally and user safe compound containing binder, pigments, filler and glass spheres which liquefies when heat is applied.

Glass spheres provide continuous, bright night time retroreflectivity; pigments provide color and opacity; fillers, such as calcium carbonate, add bulk; and binders, consisting of plasticizers and resins, provide toughness, flexibility
and bond strength while holding all the components together.

THERMOPLASTIC TYPES
Hydrocarbon thermoplastic is made from petroleum- derived resins. Because it is compatible with oil and diesel fuel, it is best used for long-line applications.

Alkyd thermoplastic is made from wood-derived resins, a renewable natural resource, which is impervious to oil and diesel fuels.

- Higher retroreflective values
- Greater resistance to cracking
- The ability to be applied directly following paving operations

- Oil impervious
- More durable

Properly formulated, both alkyd and hydrocarbon thermoplastics are equally heat stable and easily applied.

Hot-applied thermoplastic materials are normally supplied in either granular or block forms in 50 lb bags or boxes with a minimum one-year guaranteed shelf life.

Hot-applied thermoplastic is prepared for road deposition in a melting apparatus where the granular or block material is introduced and heated until it liquefies at temperatures exceeding 400F. An agitator blends the ingredients until the thermoplastic is transferred into a screed, ribbon or spray device where it is then shaped into its specified width and thickness as a line, legend or symbol. Glass spheres are immediately applied to provide initial retroreflectivity.

When applied on asphaltic concrete, thermoplastic material develops a thermal bond via heat-fusion. When applied on Portland Concrete Cement and on oxidized or aged asphaltic concrete, and a recommended sealer is properly applied, a tenacious mechanical bond is achieved.

Of available preform thermoplastic markings, Flametape is the only product which exhibits the same oil impervious qualities of hot-applied alkyd thermoplastic and is also pre-beaded. It is normally thermally-bonded to the pavement by preheating the substrate with a torch, then positioning and applying heat to the marking itself.

Providing that all necessary conditions are met concerning temperature of material and substrate, absence of moisture, road preparation and minimum thickness, you can achieve excellent markings life-cycle performance using any of these thermoplastic products.

3. APPLICATION EQUIPMENT

Application equipment should meet the criteria of the specification. The engineer may be responsible for approving such equipment, whether it be mobile or portable, prior to the start of work. Equipment used to apply primer/sealers and clean the pavement may also be inspected and approved by the engineer.

A contractor's equipment components should meet the following criteria:

a. Melting Kettle(s) must be capable of:

   - Heating thermoplastic material to its application temperature evenly, without scorching;
   - Maintaining temperatures above 400F. The heating mechanism of the kettle must employ a heat transfer medium consisting of oil or hot air.
   - The burner flame must not contact the material vessel surface.
   - A temperature gauge must be visible on the outside of the kettle to indicate the temperature of the thermoplastic material. The material gauge must not be confused with the heat transfer medium (oil temperature) gauge.
   - Material temperatures should be monitored frequently with an external, calibrated thermometer.

b. Mixing and Agitating Equipment- Melting kettles and portable applicators:

- Must be equipped with material agitators.
- Must be capable of thoroughly mixing the material at a rate which will ensure even disbursement and maintenance of uniform temperature distribution.

c. Priming Equipment – On pavement surfaces that are to be primed before the application of the thermoplastic material, the primer material shall be sprayed on the surface at the specified rates recommended by the manufacturer of the primer/sealer material. The spray equipment for the primer application may be mounted directly on a mobile type thermoplastic applicator or may be a separate, portable push- or mobile-type spray machine. All of the priming equipment should be inspected and checked to ensure that it is completely operational and capable of disbursing the primer/sealer at the rate prescribed by the manufacturer.

d. Glass Bead Dispenser – Both mobile and portable thermoplastic application equipment are required to be equipped with a drop-on or a pressure-type bead dispenser. The glass beads are to be evenly dropped-on to the hot thermoplastic stripe immediately after its application, embedding and anchoring at a depth of 60%. The purpose of glass spheres is to provide initial night time retroreflectivity of the pavement marking which, without them, would be barely visible to the motorist. The bead dispenser shall be inspected frequently to ensure proper operations and to ensure uniform rates of bead application over the entire marking surface.

e. Extrusion Dispensing Devices – Used to screed/extrude thermoplastic material onto the pavement. The front and sides of the device should be in direct road contact to shield from air and wind.

f. Ribbon dispensers - Heated and suspended above the road surface, applying a forced extrusion, well-defined thermoplastic line.

g. Spray Dispensing Devices - Thermoplastic spray pattern shall result in a uniformly thick, well-defined and securely-bonded stripe as specified. Compressed air must be dry when mixing with molten thermoplastic.

4. THERMOPLASTIC MARKING WORK

It is essential that the contractor's application personnel be completely familiar with the contract responsibilities as well as the performance specifications.

Basic work consists of:

1. Pavement cleaning
2. Primer application (if required)
3. Melting and extruding or spraying the thermoplastic material on to the pavement in a molten state at temperatures between 400F and 440F, and 4) an immediate glass sphere drop-on application properly applied at the recommended rate according to the specification.

A thermoplastic line, properly placed within the specification requirements, will melt, wet and fuse with underlying pavement to form a positive physical lock with the binder portion of the bituminous mix or the primed Portland cement. If the pavement is unclean or wet; or if air, surface and material temperatures are lower that specified (see Section 6); or if other requirements are not met; this mechanical bonding will not be accomplished. If this occurs, the full service life of the marking will not be realized. It is essential that the engineer notify the contractor on a timely basis of any work deficiencies.

Contractor and Project Engineer should both maintain a comprehensive diary recording daily weather patterns, road conditions and work performance.

5. THERMOPLASTIC CONCERNS

Seven basic modes of thermoplastic concern can be identified- bond, abrasion, shaving, cracking, blistering, thickness and retroreflectivity.

a. Bond- A loss of the entire thickness of strip because of its failure to adhere or bond to the pavement. This failure mode is normally due to an improper installation technique such as low temperatures, dirty pavement, moisture, improper primer/sealer application, scorching of the material, improper mixing, etc. All of these failures are construction related. Where asphalt is on the backside of thermoplastic material removed by snow lows, an adequate mechanical bond is definitely indicated. Excessive pressure, by the leading edge of the blade, causes thermoplastic and pavement to be dislocated from the main body of the substrate. Lack of adequate bond is evidenced by clean separation of the thermoplastic from the pavement surface.

b. Abrasion- This is a gradual wearing away of the material from the top down, by traffic debris and abrasions on the roadway distributed by traffic, wind and rain, etc. Abrasions are not directly related to application or construction. However, since the life of the marking is proportionate to its overall thickness, the application of markings thinner than specified will result in earlier abrasion losses.

c. Shaving- A cutting or shaving away of the thermoplastic line and pavement by snowplows. Shaving is common on the leading edge of skip stripes where 2 to 8 inches of line loss is normal during the first winter's use. Shaving failures are not related to

construction or installation; however, they can be minimized by proper line location and snowplow use.

d. Cracking- The appearance of cracked lines may be due to pavement cracking or temperature stress. Durability will usually not be affected. If excessive cracking immediately appears, without pavement cracking or repeated extreme temperature changes, material may have been under- or over- heated prior to application, or embrittled by excessive bead application.

e. Blistering- An excessive amount of holes larger that ¼ inch in diameter. Generally caused by water or solvent being entrapped beneath the newly applied thermoplastic. Residual solvent or pavement dampness can result in a physical degradation of the thermoplastic by evidencing blistering, particularly if primer is applied too thick or overlayed before evaporating.

f. Thickness – Materials applied thinner than specified will shorten life expectancy and can cause premature bond and retroreflectivity failures. Specifying a 90 mil minimum application optimizes thermal bonding, retroreflectivity, improved wet weather visibility and durability. If overlaying new thermoplastic longlines to rectify a thickness deficit, require the removal of recently applied drop-on beads to ensure proper bonding.

g. Retroreflectivity- Absence of initial retroreflectivity is caused by a failure to embed protruding glass spheres securely in molten thermoplastic or by the complete submersion of spheres. Loss of retroreflectivity can be due to inadequate thermoplastic opacity, insufficient percentage of glass spheres, poor spherical characteristics, improper sphere gradation or suspension.

Refer to Section 7 Completed Appearance for other troubleshooting solutions.

6. SUCCESSFUL APPLICATION PERFORMANCE

Because bond failures are construction related, they can be minimized by proper engineering controls. This can be accomplished through correct and frequent inspection at the project site. The following guidelines are intended to assure successful installation performance.

a. Marking Location- To minimize damage from snowplow blades and from substrate failure, thermoplastic markings must be placed directly on the lane, preferably 2 inches from the shoulder and construction joints
   - Do not apply edge line markings directly over the joint formed between the roadway and the adjoining shoulder.
   - Do not apply skip line markings over the longitudinal joint between travel lanes.

b. Equipment- A daily inspection of equipment should be made to ensure that it is operable and within the specification requirements. Breakdowns of equipment during the day may cause thermoplastic materials or primers to be subsequently held too long or heated improperly. This can result in parts of the job failing to meet the overall specifications and longevity requirements of the road marking material.

   Intermittent malfunctions of equipment can also cause inconsistent performance of small sections of lane lines within a limited area. Continuous uniform operation of all

equipment used to make thermoplastic applications is of extreme importance. Keep equipment clean and free of material residue build-up.

c. Materials- Material specifications should be reviewed completely. Materials should arrive at the job site pre-inspected and approved. It is the function of the government testing laboratory to determine whether or not the material meets the requirements of the material specifications. Field samples of material may be retained by the project engineer for quality verification.

   Material packaging shall have accurate batch number designations. The material type and formulation should be distinctively shown on the container:
   Alkyd or Hydrocarbon and Extrude or Spray.

   Although alkyd and hydrocarbon materials will fuse to one another on the road, they are incompatible in a melting kettle. Failure to completely clean out kettles during material change-overs can cause severe equipment problems.

d. Pavement Surface- Pavement surfaces must be clean, dust free and dry. Remove poorly adhering existing markings and curing compounds. Air and surface temperatures shall be at least 50F during applications.

   Heavy deposits of existing painted pavement markings, polymer traffic tapes, and built-up roadside accumulations of dirt, etc. will all require removal. In some cases, an air blast will be sufficient to clean the surface. In others, more effort or different methods such as abrasive blasting or mechanical removal will be needed. New thermoplastic applications should successfully bond to worn existing thermoplastic lines or perform thermoplastic markings. All pavement should be more than visibly dry. Subsurface moisture can be present in amounts sufficient to affect proper bonding. Early morning dew and fog conditions will usually cause dampness. If excess pavement moisture exists, it will usually result in blistering the hot- applied marking. Blisters will form as surface bubbles which may or may not have burst open. They are easily spotted, and if the condition occurs, marking operations should be stopped until pavement dries.

   The surface temperature should be verified with a surface or noncontact infrared thermometer at the start of each day's work. In cool weather, the surface temperature should be checked periodically throughout the work day. If at any time during work, the surface temperature falls below the recommended road surface temperature for the mode of application, all marking operations should stop.

e. Air Temperature- Air wind chill factors below 65F will adversely affect the road bonding strength of ribbon gun applications.

f. Primer Application- Primer should be approved by the thermoplastic material manufacturer. If specified prior to the thermoplastic application, the primer must be applied to all pavement surfaces at manufacturer's recommended application rates. It must set for the specified cure or evaporation time prior to thermoplastic being applied.

   Primed pavement surfaces must be striped within the specified set time or within the same working day. If the primed surfaces are not striped within these time limits, they must be reprimed prior to the thermoplastic application at the prescribed rate denoted by

the manufacturer. If an approved epoxy primer is used, proportional mixing must be checked and thermoplastic application must occur before epoxy has cured.

Improper primer/sealer application will cause bond failure between the thermoplastic and substrate. Improper application may also result in physical degradation of the thermoplastic material by excessive pin-holing and blistering of the line. This degradation may occur through extraction of the binder by the solvent system contained in the primer/sealer promoted by improper drying time an application rates.

g. Thermoplastic Application- The thermoplastic striping material must be extruded or sprayed onto the pavement surface at a material temperature range between 400F to 440F depending on ambient weather conditions. Material temperature is measured preferably at the point of road contact.

   Drop-on spheres must be immediately mechanically deposited after applying the thermoplastic line. If the glass spheres are not adhering to the thermoplastic line, all operations should immediately be suspended until the problem can be corrected. Drop-on beads anchor and retroreflect best at 55-60% embedment.

   Applying thermoplastic at proper applications temperature (400F+) is one of the most critical factors affecting the mechanical bond to the substrate. If the road temperature is 50F, then the recommended application temperature for the thermoplastic striping is 440F. If the road temperature is at 77F, the thermoplastic material may be applied at a lower temperature.

   Applications on Portland cement surfaces should always exceed 425F in order to maximize penetration and bond strength.

   The thermoplastic material temperature in the kettles, applicators, or exiting the dispensing device, can be verified with a noncontact infrared thermometer.

   Discrepancies of 10F may be tolerated, but in no case should a 10F discrepancy be tolerated if this shows as 10F below the minimum recommended application temperature.

   The resin binders used in alkyd and hydrocarbon thermoplastic materials increasingly degrade at temperatures of 450F and above. If thermoplastic materials are held at 450F and above for more than 4 hours, it can be expected that the material viscosity and temperature relationships will not be constant. In no case should the material be held for more than 4 hours at the maximum application temperature.

   Note: Minimize material remaining in kettle at end of work day and blend a minimum of 80% fresh material for the next day. It may be necessary to inventory thermoplastic boxes to draw down molten material due to bad weather, equipment malfunction, etc.

   On resurfacing projects, water may be sprayed on newly applied thermoplastic for rapid line hardening. Allow about 40 seconds before water is sprayed. Do not wet surfaces to be striped.

h. Thermoplastic Thickness- The specified alkyd or hydrocarbon thermoplastic thickness may vary from 30 to 125 mils. The service life of a thermoplastic marking is directly

related to its thickness. A thin line will wear out much faster than a thicker line. To ensure that the proper thickness is being applied, both the wet and the dry line thickness of the line may be routinely checked.

Wet thickness is inspected immediately after the line is applied by inserting a thin, graduated machinist rule or similar instrument into the molten thermoplastic to the depth of the pavement substrate. The line thickness is simply determined by visually noting the depth of penetration. The most accurate determination of thickness can be accomplished by laying a metal panel or black duct tape in the dispensing device path.

After the application is made on the panel, it is removed and the total material thickness and panel can be measured with a micrometer. Subtract the panel thickness measured to calculate the true thickness of the thermoplastic line applied.

The thermoplastic thickness should be uniform and consistent throughout the total length of the job. Overall discrepancies in the application rate and the total thermoplastic thickness will affect the durability and performance of the line.

i. Raised Pavement Markers- Molten thermoplastic will provide an excellent bond for raised pavement markers applied over thermoplastic lines or directly on the pavement. Epoxy adhesives do not adhere well to new thermoplastic line application.

j. Profiled Thermoplastic Lines- For enhanced wet and dry night visibility as well as markings which provide full time audible and physical driver alerts, AQUALITE thermoplastic formulations and dispensing systems are available. These markings incorporate 2-inch long, 500 mil thick “bumps” whose frequency can be customized to differentiate bridge approaches, dangerous curves, or gore areas.

k. Inlaid Thermoplastic- Specifically formulated thermoplastic may also be inlaid applied in grooved pavements.

Thermoplastic material, particularly oil impervious alkyd material, when immediately applied on newly laid asphaltic concrete pavement surfaces will partially embed itself for maximum durability while sufficiently protruding above pavement for added wet night visibility.

l. Thin Line- Effective thermoplastic lines can be applied economically as thin as 30mil thick where the roadway has a limited life expectancy.

m. Flametape- is a heat fused perform thermoplastic pavement marking which combines all the advantages of hot-applied alkyd thermoplastic (i.e., bonding, fuel imperviousness, and exceptional retroreflective properties) with the convenience of pliant polymer perform tapes (i.e., shapes, rolls, and asphalt inlay). It is available in 90 mil or 60 mil thickness.

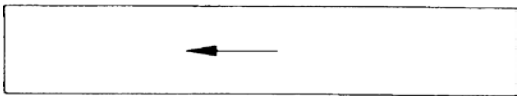
7. COMPLETED APPEARANCE

The applied thermoplastic markings should be inspected continually for overall workmanship. Markings should be of the specified width, with clean cut edges. White, yellow, red, black, and other colors should appear distinct. The drop-on glass sphere application should appear uniform on the entire marking surface. Over saturation with glass spheres can cause excessive live embrittlement and premature abrasion. The hardened thermoplastic should resist deformation, dirt pick up, etc. by traffic within 2 to 10 minutes of application.

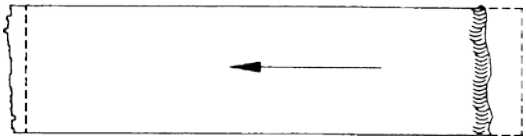
If there is a concern the marking locations will be subject to excessive contact with diesel fuels, grease, oil drippings or pavement oil use alkyd thermoplastic material.

The marking should be firmly bonded to the pavement surface. If the thermoplastic marking can be easily removed for the pavement with the use of a putty knife, and little or no bituminous substrate is on the back of the marking, then it can be assumed there is not a sufficient bond to the substrate. There must be fusion with the bituminous pavement to ensure maximum mechanical bond strength. Concrete bond strength can be checked by attempting to force separation with a stiff putty knife.
Stretch marks in screed extrude line usually result from too low application temperature. These stretch marks may also be present if the extrusion device is not maintaining temperatures to ensure maximum flowability and line uniformity.
Refer to the following Line Quality Chart for answers to possible field situations.

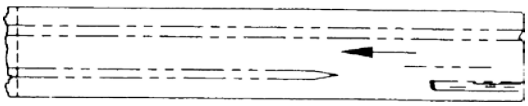
Extrude Applications



Proper Thermoplastic Line Application
Strip is applied straight, has a sharp edge, correct color, width, thickness, bonding, and uniform retroreflectivity.

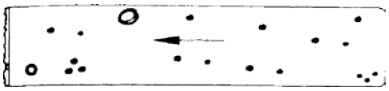


No Adhesion (Bulge forms at beginning of line)
1. Material temperature too low.
2. Marking speed too fast.
3. Road too gritty.
4. Road too cold.



Roughened, Pitted Line
1. Foreign objects in line.
2. Overheating forms crust.

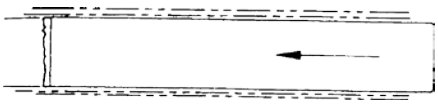
3. Foreign objects caught in die.



Gas bubbles in line.
1. Moisture or solvent trapped in line.
2. Material is overheated.

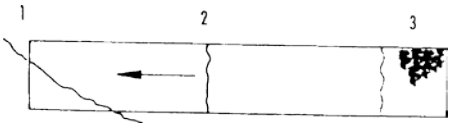
Crumbly Edges; Line Gaps
1. Material is too cool.
2. Marking speed is too fast.
3. Material thickness too thin.

Line Swollen; Skewed and Rounded Line Start
1. Material is too hot.



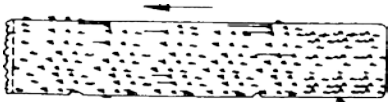
Material Shadows on Sides
1. Heavily undulated road surface.
2. Die not riding evenly on substrate.

Wavy Line
1. Strong road surface camber.
2. Poor driver/operator direction.
3. Strong road surface undulations

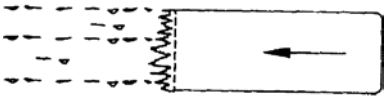


Line Cracks Immediately or In Future
1. Pavement is cracked (unaffects durability).
2. Temperature stress from overheating.
3. Material applied too cold.

4. Material applied too thin.
or pavement oil use alkyd thermoplastic material.



Crumbly Edges; Rough Line Surface
1. Material temperature is too low.
2. Material is overheated or scorched.
3. Moisture in road.



Jagged Line Endings; Drops Within Gaps
1. Die not closing properly.
2. Foreign objects caught in die.

Spray Applications
Excessive Overspray (Light dusting is normal.)
1. Too much atomizing pressure.
2. Air leaking through blow=back spray line.

Hesitation at Start
1. Moisture or air in spray line.
2. Material is either too hot or too cold.

Lumps in Line
1. Material is too cool, comes out as globs.

8. SAFETY

Your safety and the protection of others is of primary importance. Think and practice safety all the time. If there is an accident, no matter how minor, it must be reported immediately. Responsibilities should be met in a professional manner.

In case of accidental contact with hot thermoplastic, use cold or iced water to immediately cool affected areas. Follow instructions on the Material Safety Data Sheet and/or seek immediate medical attention.

APPROXIMATE THERMOPLASTIC YIELDS

Derived quantities are based on 4” wide Hydrocarbon and vary with material specific gravity, application methods, and pavement texture. (Alkyd has approximately 2.5% less yield due to specific gravity of material.)

Spray (Air or Airless) and Ribbon/Extrude

Mils.	Ton/mile	lb/LF	LF/ton
60	.528	.200	10,000
90	.792	.300	6,667

Screed/Extrude – Dense Grade Substrate

Mils.	ton/mile	lb/LF	LF/ton
60	.620	.235	9,000
90	.910	.345	6,250
125	1.173	.444	4,500

Screed/Extrude – Open Grade Substrate

Mils	ton/mile	lb/LF	LF/ton
60	.788	.300	7,500
90	.996	.377	5,400
125	1.227	.465	4,300

Word and Symbol Messages (thermoplastic lbs.)

Sq. ft.	60 mil	90 mil	125 mil	
STOP	23.5	15.66	23.5	32.63
ONLY	23.0	15.33	23.0	31.94
XING	23.0	15.33	23.0	31.94
RIGHT	29.5	19.66	29.5	40.97
AHEAD	28.5	19.00	28.5	39.58
LEFT	23.0	15.33	23.0	31.94
TURN	23.5	15.66	23.5	32.63
EXIT	23.0	15.33	23.0	31.94
STRAIGHT ARROW	12.5	8.33	12.5	17.35
TURN ARROW	15.5	10.33	15.5	21.53
COMBO ARROW	28.5	19.00	28.5	39.58
RXR	69.0	46.00	69.0	95.76
R	5.7	3.83	5.7	7.98
SCHOOL	35.0	23.33	35.0	48.61