COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT, KENTUCKY 40601

Eugene Goss
MMISSIONER OF HIGHWAYS

ADDRESS RE.

August 17, 1970

H-2-18

MEMORANDUM TO: A. O. Neiser,
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report; "Final Performance Report on Experimental Use of Thermoplastic Pavement-Striping Materials;" KYHPR-64-18*; HPR-1(6), Part II

The report submitted herewith concludes a series pertaining to thermoplastic stripes. The significant findings from the study were evident in Report No. 4 (issued September 19, 1966); however, there were continuing phases of evaluation which have now matured.

A thermoplastic (Prismo Hot-Spray Plastix) was applied on the Kentucky Turnpike (centerline only) last summer at a cost of 23 cents per foot (CH13555, June 19, 1969). The nominal thickness (sprayed, 4-inch width) was .09 inch. This work was also experimental, and the terms of the contract provide a two-year guarantee of satisfactory performance. Prismo Universal has advertised, more recently, a price of 13 cents per lineal foot (500,000 feet, minimum).

A companion study (KYHPR-64-19, "Durability of Traffic Paint on Portland Cement Concrete Pavements") is scheduled for completion this year. Unfortunately, we have not yet discovered a satisfying solution to the problem.

"Grooving of Pavements" (KYP-69-18) before painting (centerlines) appears to enhance rainy-night visibility; but we do not yet know if it will improve durability of the paint.

We are still interested in studying multiple applications of paint and the use of large beads for rainy-night conditions.

Respectfully submitted,

Jas. H. Havens,
Director of Research

Attachment
cc: Research Committee

Research Committee:

Assistant State Highway Engineer, Research and Development
Assistant State Highway Engineer, Planning and Programming
Assistant State Highway Engineer, Pre-Construction
Assistant State Highway Engineer, Construction
Assistant State Highway Engineer, Operations
Assistant State Highway Engineer, Staff Services
Assistant Pre-Construction Engineer
Assistant Operations Engineer
Executive Director, Office of Computer Services
Executive Director, Office of Equipment and Properties
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Director, Division of Rural Roads
Director, Division of Traffic
Division Engineer, Bureau of Public Roads
Chairman, Department of Civil Engineering, University of Kentucky
Associate Dean for Continuing Education, College of Engineering
All District Engineers

RESEARCH REPORT

FINAL PERFORMANCE REPORT ON EXPERIMENTAL USE OF THERMOPLASTIC PAVEMENT-STRIPING MATERIALS

REPORT No. 5

KYHPR-64-18*; HPR-1(5), Part II

by

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and

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DEPARTMENT OF HIGHWAYS
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in cooperation with the
U.S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

February 1970

ABSTRACT

This study was undertaken in order to: 1) evaluate the performance of thermoplastic striping materials, 2) compare their performance on both portland cement concrete and bituminous concrete pavements to that of conventional traffic paints, and 3) to evaluate the economics of thermoplastics in terms of cost per mile per day of useful life. The performance of two brands of thermoplastic striping materials and conventional traffic paints applied at nine test sites in both rural and urban areas is reported herein. Application procedures, site locations, repair histories and materials specifications are included. Accumulative costs for each material at all sites for a seven-year period are summarized in Table 4.

The performance of thermoplastics placed on bituminous concrete was superior to that placed on portland cement concrete pavements. Epoxy primers were of aid in providing adherence of thermoplastics to portland cement concrete pavements; however, the epoxies were not capable of penetrating surface laitance. Visibility of the thermoplastic stripes decreased with age due to accumulation of road scum.

INTRODUCTION

Conventional paint stripes, even though beaded, become nearly invisible on rainy nights -- that is, when the need for guidelines is most critical. Glass beads become ineffective when covered with water. Paints have been placed at greatly increased film thicknesses and in multiple applications in efforts to increase wear resistance and to elevate the beads above the water film. More recently, pavements have been grooved before striping -- to improve drainage. Raised pavement markers such as buttons, dots, discs, beaded tapes, etc. have been reportedly employed to varying degrees of success. The majority of raised marker systems have a high initial cost, are difficult to install, and break or loosen under the action of traffic and snow-removal equipment.

In the early 1950's, highway engineers expectantly awaited development of hot-melt thermoplastic striping materials which could be applied at thicknesses in the order of 1/8-inch. It was anticipated the materials would offer longevity and performance commensurately equal to that of paints on a cost-per-mile-per-day basis and might provide relief from frequent restriping in high traffic areas. Some of the earlier formulations remained tacky long after installation and did not perform effectively due to collection of road scum. Subsequent formulations were placed in Lexington and Frankfort in 1957 and '58; however, their performance was not satisfactory, and their costs were greatly disproportionate to that of paint.

In matters pertaining to safety, economic benefits cannot always be the sole basis for judging materials. Attitudes in that regard to that matter were appropriately stated by G. M. Williams, Assistant Commissioner for Engineering, in a Bureau of Public Roads' Circular Memorandum dated August 31, 1961. Pursuant to the cited memorandum, the Department of Highways established a number of experimental projects for the purpose of evaluating performance and costs of thermoplastics in comparison to conventional traffic paints. Thermoplastic materials produced and placed by two manufacturers were compared to conventional traffic paints purchased and applied by the Department of Highways. The manufacturers were permitted complete freedom in preparation of the pavement surfaces and all other work deemed necessary or essential to performance of their material. This report summarizes the work performed, observations and serves to finalize the project.

PROJECT DESCRIPTION AND TEST INSTALLATIONS

The overall objectives of this study were to: 1) evaluate the application and performance characteristics of thermoplastic pavement-striping materials, 2) compare performance of those materials with performance of paint stripes applied and renewed in accordance with prevailing Departmental practices, and 3) evaluate the economics of these striping materials in terms of cost per mile per day of useful life. Experimental materials utilized in this study were limited to two commercially more prominent brands known as "Perma-Line" and "Catatherm". Separate specifications were prepared for each experimental material used at Sites 1 through 4 (Appendix A). Perma-Line is manufactured by Perma-Line Corporation, and Catatherm is manufactured by Cataphote Corporation.

The manufacturers were permitted a rather wide latitude relative to materials formulation and application procedures. Each specification included the particular supplier's own warranty for performance. Provision was made for drop-on application of glass beads at rates of one pound per 100- and 120-foot length of 4-inch wide line, respectively, for Catatherm and Perma-Line. The specification for Perma-Line did not require premixing glass beads into the material prior to application; whereas, the Catatherm specification called for premixing at a rate of not less than 800 pounds of beads per ton of material. Each material was to be placed in thicknesses of not less than 3/32-inch at line edges and not less than 1/8-inch at the center of the line.

Some of the pecularities which have been observed in performance of conventional traffic paints are: 1) consistently better performance on bituminous concrete pavements than on portland cement concrete pavements, 2) relatively poor performance on new portland cement concrete, and 3) re-painting over old stripes enhances durability. In view of these observations, both bituminous concrete and portland cement concrete pavements which had been in service for a period of time were selected as test sites. The project, as initially conceived, involved 4 test sites (1 through 4) of 4-lane, interstate highway -- 2 sections of portland cement concrete pavement and 2 sections of bituminous concrete pavement -- 2 (one of each type) in an urban area and 2 in a rural area. Stripes were applied at these sites in October and November 1962.

Control paints and the two experimental striping materials were applied as edgelines and centerlines at each site. All stripes were 4-inches wide and the edgelines were placed 3-inches from the pavement edges in a continuous stripe. Centerlines were placed in 15-foot lengths at 40-foot intervals (15-foot line, 25-foot skip). Centerline stripes were located in such a manner that new stripes were not placed over old stripes. In addition, continuous transverse stripes were placed at the beginning of each project. Ten transverse lines were placed as described in the following table. Typical site layouts are shown in Figure 1.

Single Applications

2 lines - Catatherm (1 white, 1 yellow)

2 lines - Perma-Line (1 white, 1 yellow)

2 lines - Ky. Paint (1 white, 1 yellow)

Double Applications (3 days apart)

2 lines - Ky. Paint (1 white, 1 yellow)

Triple Applications (3 days apart)

2 lines - Ky. Paint (1 white, 1 yellow)

As a result of early performances of the experimental materials at the original sites and developments in use of epoxy resins as primers, five additional sites (5 through 9) were selected, and installations thereon were made in May and June 1965. Perma-Line and Kentucky paint stripes were placed at Sites 5, 6 and 7 and only Perma-Line was used at Sites 8 and 9. All sites are shown in Figure 2 and are described more specifically as follows:

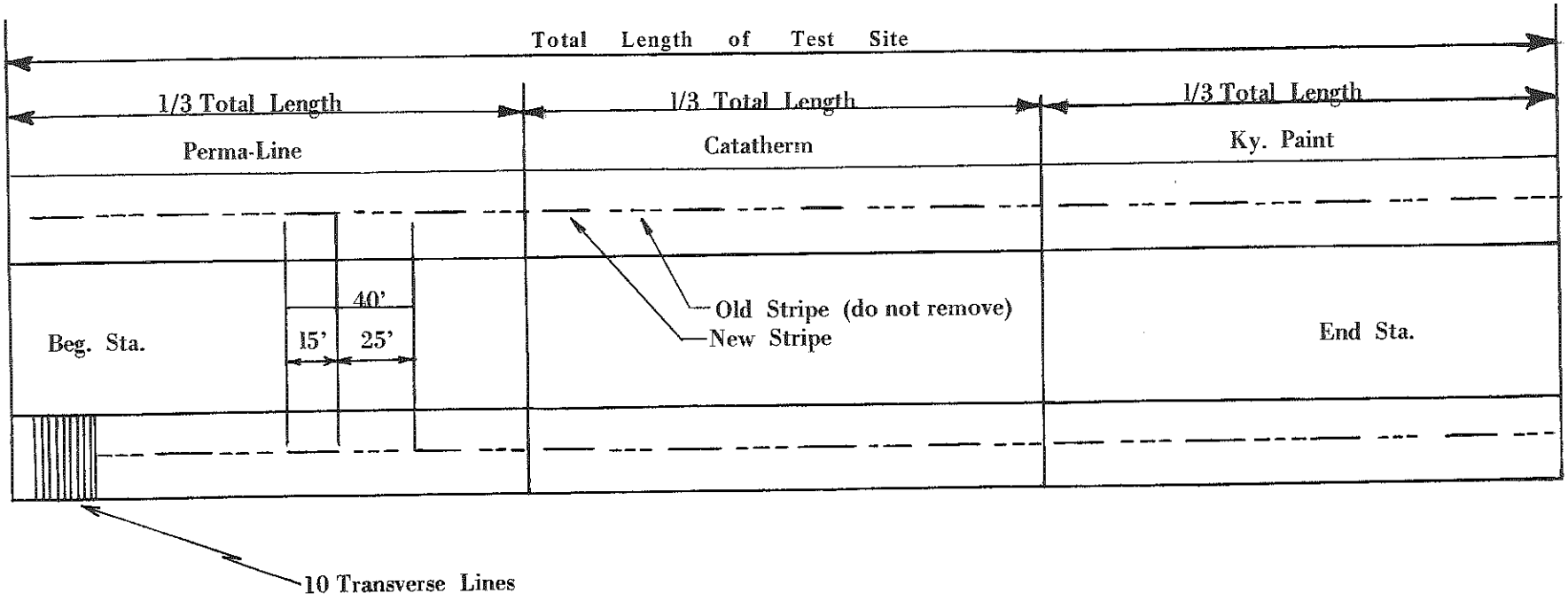
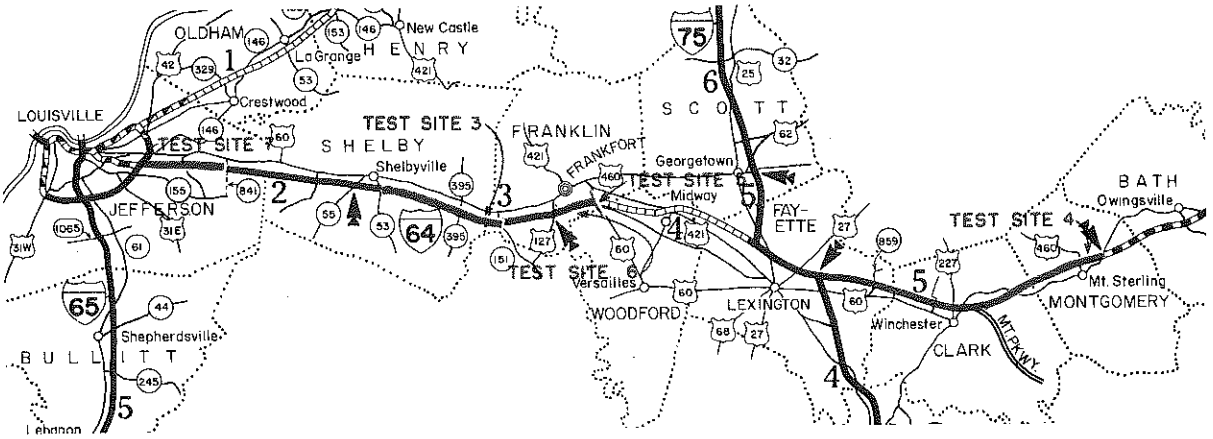


Figure 1. Typical Test Site Layout

TEST SITES

Experimental, Thermoplastic, Pavement-striping Materials

Blue, Installed in 1962
Red, Installed in 1965



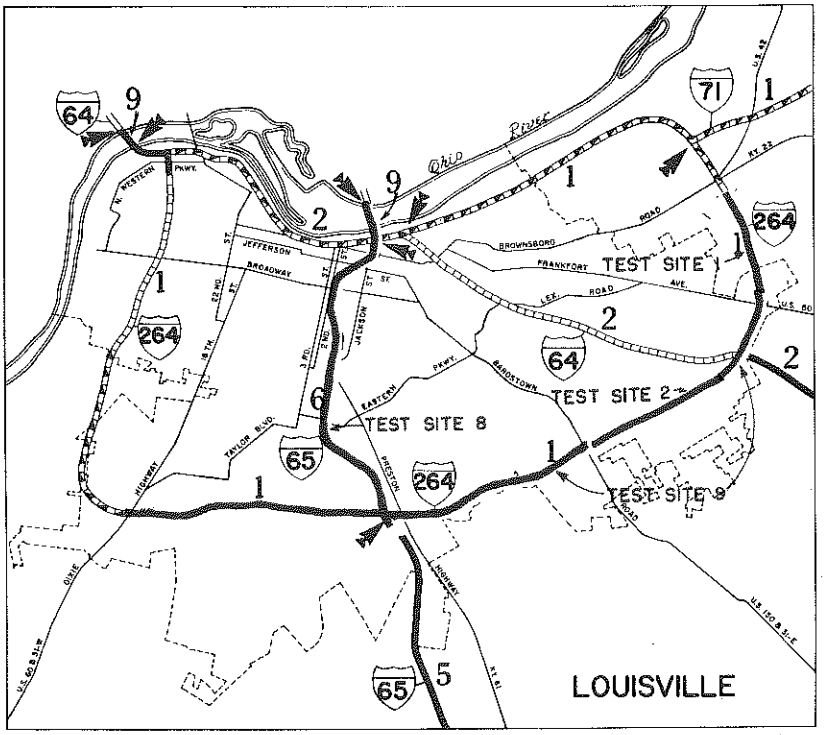


Figure 2. Locations of Test Sites

TEST SITE 1

Jefferson County; I 264-1(25)20, SP 56-898; Watterson Expressway; north end of US 60 Interchange, extending northwardly, Sta. 28+00, 1.458 miles; PCC pavement.

** Subsection 1; Sta. 28+00 to Sta. 53+67; 0.486 mi.
*** Subsection 2; Sta. 53+67 to Sta. 79+33; 0.486 mi.
* Subsection 3; Sta. 79+33 to Sta. 105+00; 0.486 mi.

TEST SITE 2

Jefferson County; I 264-1(24)16, SP 56-898; Watterson Expressway; 1.231 miles (net); BC pavement.

Section A - East end of Bardstown Road Interchange, extending eastwardly, Sta. 515+00 to Sta. 547+00; 0.606 miles, BC pavement.

* Subsection 1; Sta. 515+00 to Sta. 525+67; 0.202 mi.
** Subsection 2; Sta. 525+67 to Sta. 536+34; 0.202 mi.
*** Subsection 3; Sta. 536+34 to Sta. 547+00; 0.202 mi.

(Subsections 1 & 2, 1067 ft. ea.; Subsection 3, 1066 ft.)

Section B - East end of Taylorsville Road Interchange; extending eastwardly, Sta. 585+00 to Sta. 603+00; 0.341 miles, BC pavement.

* Subsection 4; Sta. 585+00 to Sta. 591+00; 0.1137 mi.
** Subsection 5; Sta. 591+00 to Sta. 597+00; 0.1137 mi.
*** Subsection 6; Sta. 597+00 to Sta. 603+00; 0.1137 mi.

(Subsections 4, 5, and 6, 600 ft. ea.)

Section C - East end of Breckenridge Lane Interchange; extending eastwardly, Sta. 633+00 to Sta. 648+00; 0.284 miles, BC pavement.

* Subsection 7; Sta. 633+00 to Sta. 638+00; 0.0947 mi.
** Subsection 8; Sta. 638+00 to Sta. 643+00; 0.0947 mi.
*** Subsection 9; Sta. 643+00 to Sta. 648+00; 0.0947 mi.

(Subsections 7, 8, and 9, 500 ft. ea.)

TEST SITE 3

Franklin-Shelby Counties; I 64-3(14)34, SP 37-905, SP 106-806; Louisville-Lexington Road; east end of KY 53 Interchange extending eastwardly, Sta. 1418+00 to Sta. 2081+00; 11.965 miles (net); PCC pavement.

*** Subsection 1; Sta. 1418+00 to Sta. 1628+63; 3.99 mi.
* Subsection 2; Sta. 1628+63 to Sta. 1839+36; 3.99 mi.
** Subsection 3; Sta. 1839+36 to Sta. 2081+00; 3.99 mi.

(Sta. 1989+04 BK, EB = Sta. 1988+40 BK, WB = Sta. 2020+00 AH)

TEST SITE 4

Clark-Montgomery Counties; I 64-5(16)93, SP 25-422, SP 87-557; Lexington-Catlettsburg Road, EKTP Interchange, extending eastwardly, Sta. 430+00 to Sta. 1053+00; 11.80 miles; BC pavement.

* Subsection 1; Sta. 430+00 to Sta. 637+67; 3.933 mi.
** Subsection 2; Sta. 637+67 to Sta. 845+34; 3.933 mi.
*** Subsection 3; Sta. 845+34 to Sta. 1053+00; 3.933 mi.

ADDITIONAL PERMA-LINE THERMOPLASTIC LINE NOT PART OF ORIGINAL EXPERIMENTAL PROJECT BUT INCLUDED IN THIS STUDY FOR COMPLETENESS.

TEST SITE 5

Franklin-Woodford Counties; US 60, SP 37-45, SP 120-15; Frankfort-Versailles Road; Eastern Junction US 421, extending eastwardly for 3.6 miles, Sta. 7+00 to Sta. 198+50; 3.63 miles; PCC pavement.

* Center-Line of WB Lane
*** Center-Line of EB Lane

TEST SITE 6

Franklin County; I 64; SP 37-905, Louisville-Lexington Road; US 127 extending eastwardly to US 60, Sta. 2385+00 to Sta. 2620+00; 4.45 miles; PCC pavement.

* Center-Line of WB Lane
*** Center-Line of EB Lane

TEST SITE 7

Jefferson County; I 64; SP 56-273; Louisville-Lexington Road; from Watterson Expressway, I 264, extending eastwardly to Jefferson Freeway, KY 841, Sta. 190+00 to 520+00; 6.25 miles; PCC pavement.

* Center-Line of WB Lane
*** Center-Line of EB Lane

TEST SITE 8

Jefferson County; I 65; SP 56-798; North-South Expressway; from south end of Waterson Expressway Interchange extending northwardly to north end of Ohio River Bridge, Sta. 2155+00 to Sta. 100+00; 7.53 miles; PCC pavement.

*** Center-Lines and Edge-Lines

TEST SITE 9

Jefferson County; I 264; SP 56-898; Watterson Expressway; from Junction US 31W at Shively to north end of US 60 Interchange excluding Test Sites 1 and 2, Sta. 0+29.6 to Sta. 28+00; 12.66 miles; BC pavement.

*** Center-Lines and Edge-Lines

ALLOCATIONS OF SUBSECTIONS

* Control-Kentucky Paint
** Catatherm
*** Perma-Line

CATATHERM INSTALLATIONS

Thermoplastic stripes were applied through an extruding die. Catatherm centerline and edgeline stripes were placed by two, automatic, truck-towed applicators (Figure 3); and transverse stripes were placed with a hand-liner (Figure 4). In order to promote better adhesion, pavement surfaces were primed by spraying an adhesive just ahead of the striping operation. The bonding agent was referred to as "Perma-Seal". This material was applied with a push-type spray unit. Drop-on beads were applied to the hot, in-place Catatherm about 4 inches behind the applicating die. In the beginning, rate of bead application was quite irregular as a result of beads jamming in the chain-driven dispenser. These irregularities were distractingly noticeable under nighttime driving conditions and remedies were needed. Jamming of the dies by loose aggregate troubled edgeline operations near unpaved shoulders. The bonding qualities of Catatherm on PCC surfaces were checked at various locations soon after application and found to be unsatisfactory. Large sections could be loosened readily by use of a blade and could be peeled from the surface (Figure 5). Operations were suspended and then resumed after token reassurances were obtained. Representatives of the company were of the opinion the material was performing satisfactorily and, to support their opinion, were willing to increase the first-year performance guarantee from 90 to 100 percent. Upon resumption of operations, adhesive was applied at a much heavier rate and was broomed onto the PCC surfaces. Bonding on bituminous surfaces was dependent upon the hot thermoplastic melting the contacting bituminous material.

PERMA-LINE INSTALLATIONS

Perma-Line initial installations at Sites 1 through 4 were made with one hand-liner shown in Figures 6 and 7. An automatic liner was brought to the job; however, mechanical difficulties prevented much use of it. The drop-on bead dispenser on the hand-liner was located 4 inches behind the extruding die and cut off automatically when the die was raised at ends of lines. Beads were hand dispensed onto the last 4 inches of each line, and the bead dispenser functioned erratically. Nighttime inspection revealed uneven bead distribution throughout all lines and high bead concentrations at ends of lines (hand applied beads).

Figure 3. Catatherm Automatic Liner

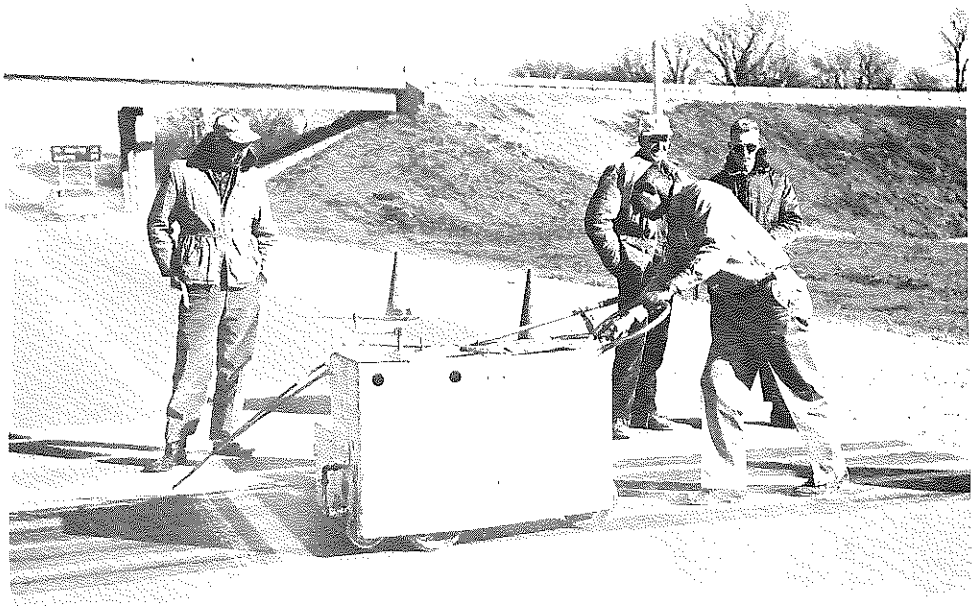


Figure 4. Catatherm Hand Liner

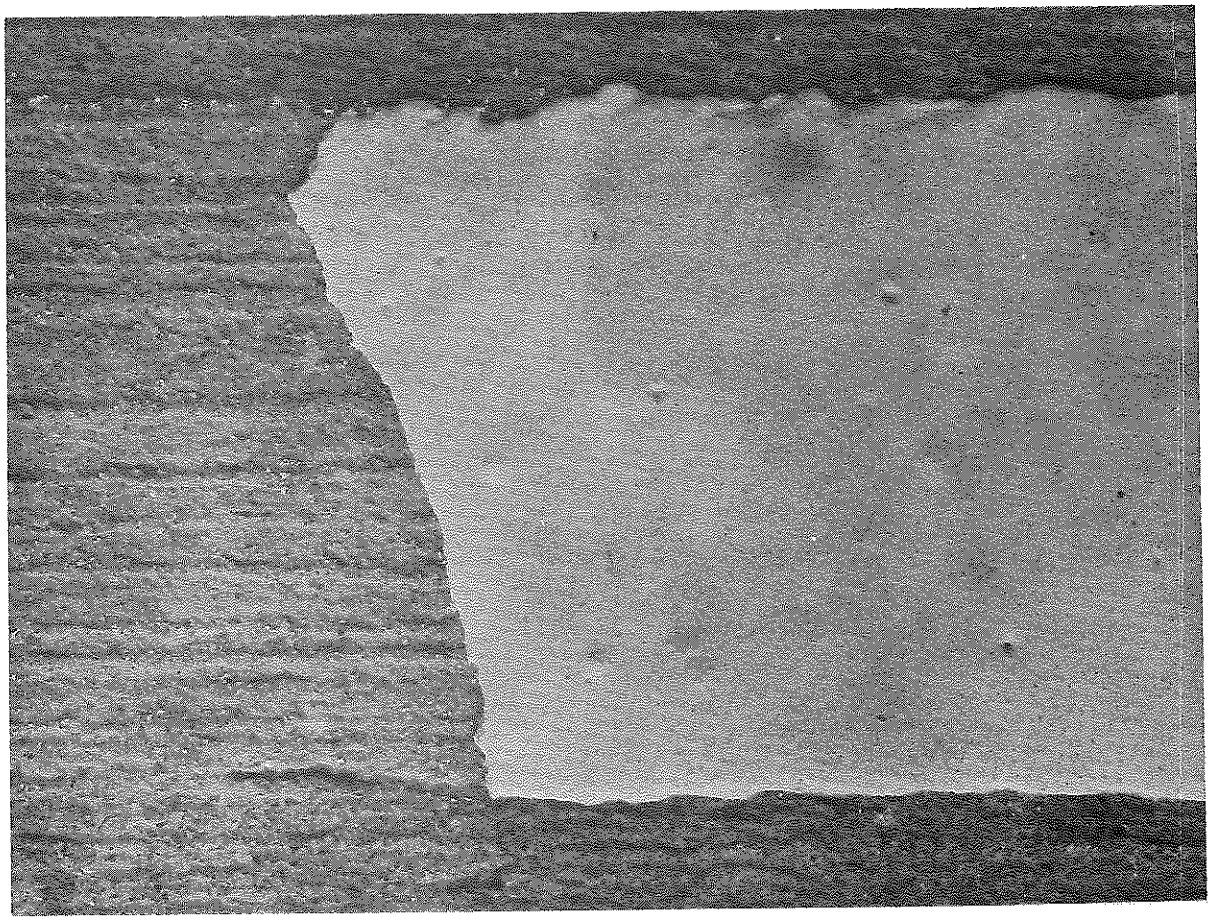


Figure 5. Poorly Bonded Catatherm Section

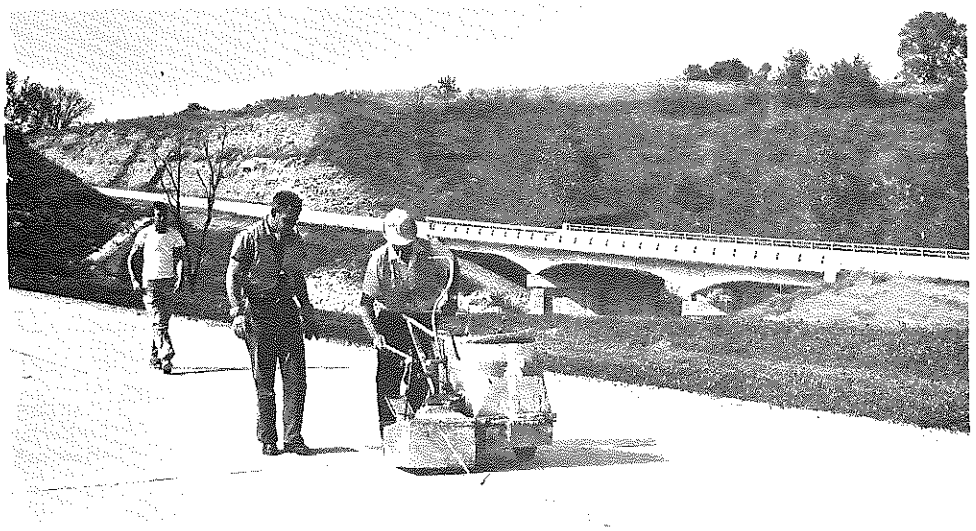


Figure 6. Perma-Line Hand Liner

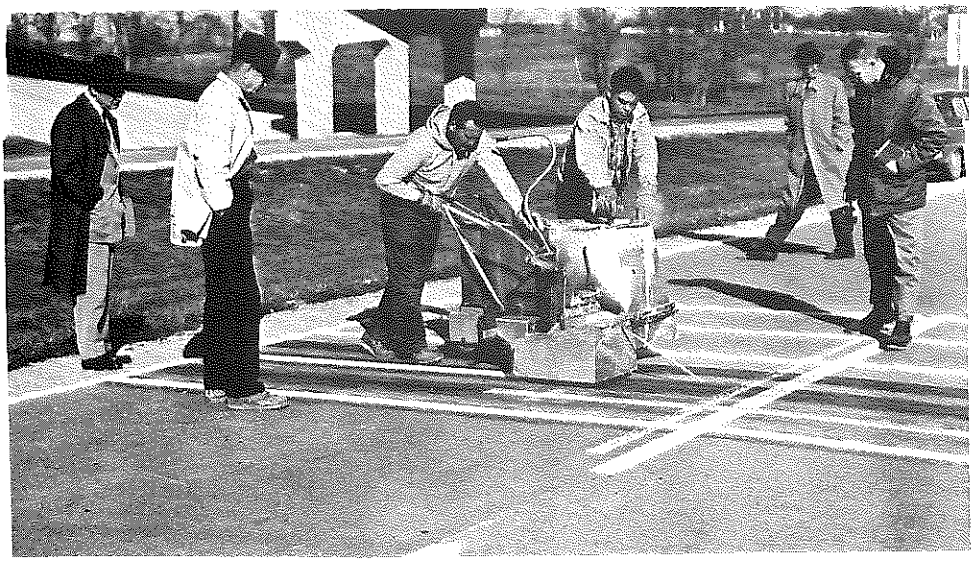


Figure 7. Perma-Line Hand Liner

A bonding material (Pliobond: phenolic resin, nitrile rubber, toluene, MEK) similar to that used for Catatherm was applied at the beginning of each day by use of a Kelly-Creswell, self-propelled striper. Adhesive for the Perma-Line operation was applied at much heavier rates than were used for Catatherm. In some cases, adhesive which had been applied the preceeding day was utilized, providing there had been no intervening precipitation.

The 1965 Perma-Line operations (Sites 5 through 9) were improved considerably over previous operations through use of a truck-mounted, automatic liner shown in Figure 8. An air blower was mounted in front of the machine and was sufficiently powerful to remove dust, small rocks, and other light debris from the surface. A spray nozzle, for application of an epoxy primer, was mounted just behind the blower. A two-component system composed of two parts epoxy and one part catalyst was used. The system contained a quantity of retarder sufficient to extend the pot life to approximately 16 hours at normal atmospheric temperatures. The time-of-set for the epoxy in place was in the order of 15 to 20 minutes; heat from the thermoplastic accelerated the rate of set. Epoxy was applied in sufficient quantity to obtain good coverage throughout a width of 9 to 10 inches. A period of approximately 5 seconds elapsed between application of the primer and thermoplastic.

The striping material was applied through a die which was fed from two kettles maintained at 425°F. Position of the die was controlled by a steering mechanism which permitted a 6-foot latitude in location transversely to the direction of travel. An average speed of 1.5 miles per hour was maintained during striping operations. Average daily (6 hr. day) footages of stripe placed were limited to 25,000 feet due to heating capacities of the kettles. Drop-on beads were applied about 12 inches behind the applicating die, and good coverage and distribution was obtained. The thermoplastic hardened about 3 minutes after application.

The blower was not powerful enough for removal of heavy debris from bridge decks, and those areas were broomed. In some instances, stripes were not placed over the primer because of misalignment on sharp curves (predominantly on ramps). On occasions, rocks lodged under the die and scarred the stripe. General workmanship at Sites 8 and 9 was inferior. Edgelines were frequently irregular and, in instances, contained large bulges. Excess striping material occasionally flowed from the die and the stripe was not reshaped. Unsightly stains and drippings were common throughout and prior to acceptance, the contractor was required to correct obvious faults.

CONTROL INSTALLATIONS

Control (Kentucky Paint) stripes were placed by Departmental crews using in-stock, beaded paints. Centerline stripes at Sites 1 through 4 were placed in accordance with then (1962) prevailing practices -- beaded paint without the addition of drop-on beads. Due to limited wear normally attributed to outer edges of multi-lane pavements, drop-on beads were considered essential for initial, nighttime visibility of the edgelines. Drop-on beads were used on all control stripes placed in 1965 and were placed at a rate of 2 pounds per gallon of paint. Figures 9 and 10 are views of equipment used for control striping, and Figure 11 is a view of a typical control section.

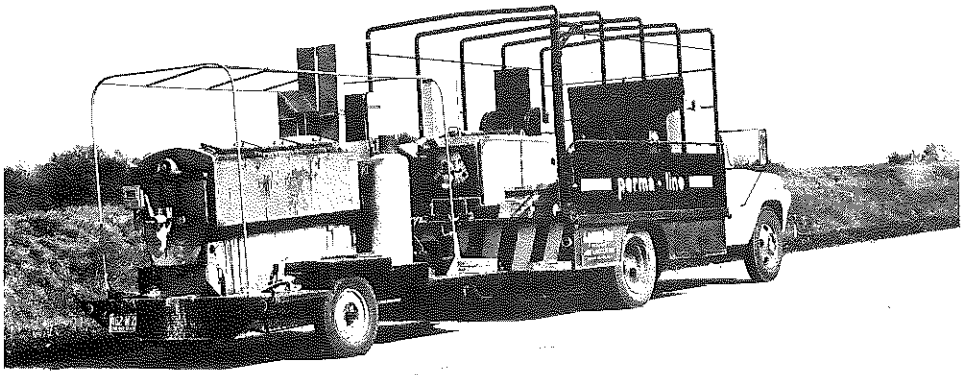


Figure 8. Perma-Line Automatic Liner

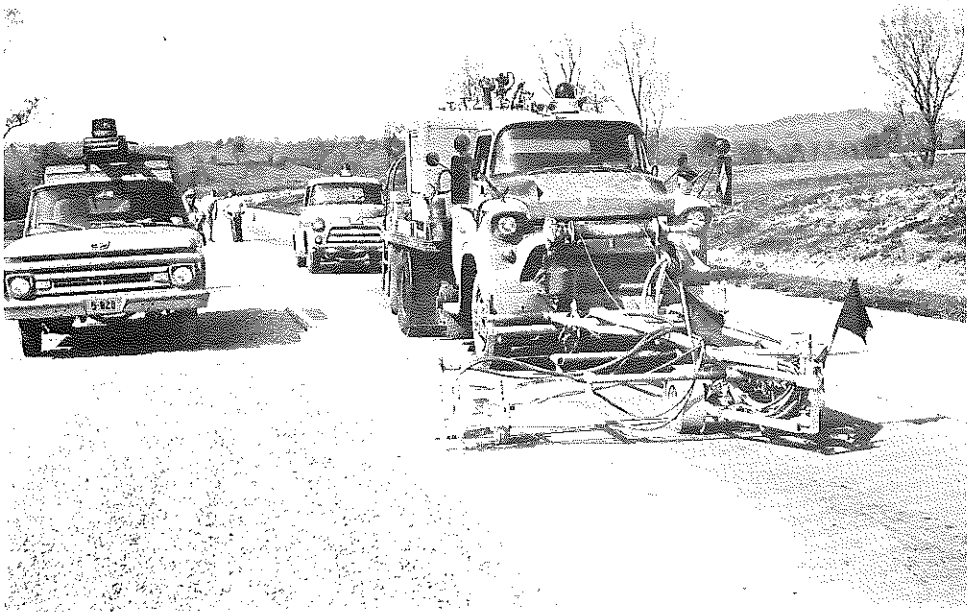


Figure 9. Kentucky Paint Applicator

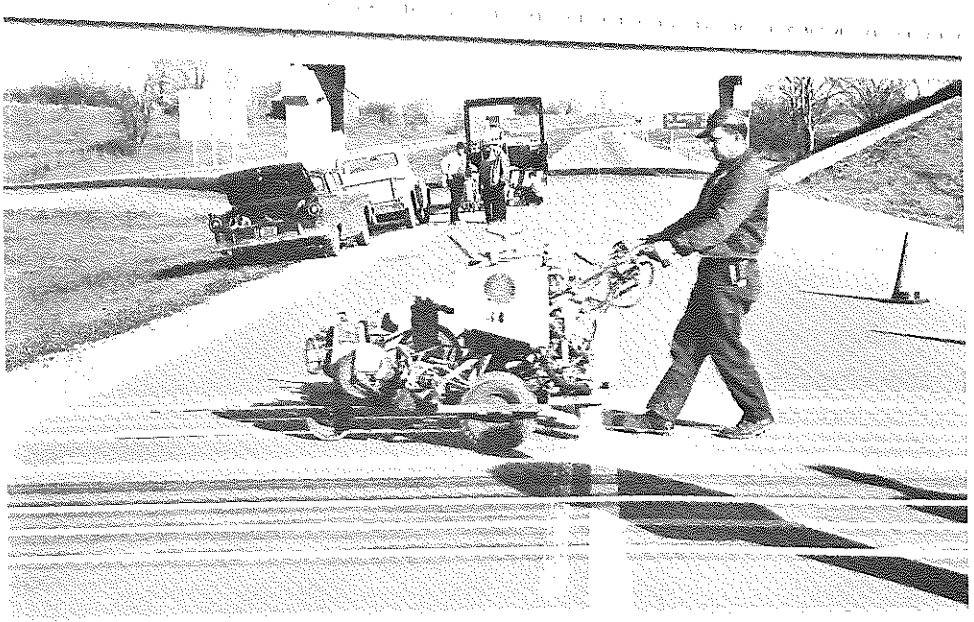


Figure 10. Kentucky Paint Applicator

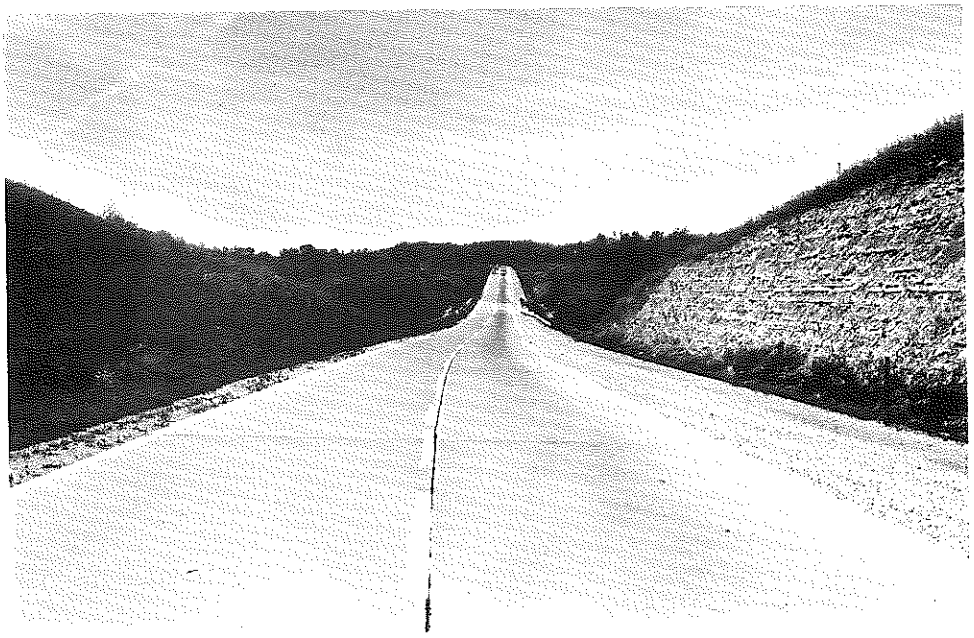


Figure 11. View of Typical Control Paint Line

Application rates for intermixed, beaded paints had been about 15 gallons per mile (based on a continuous 4-inch line) and were suspected as being too thin. In an effort to secure longer lasting stripes and sufficient binder to receive drop-on beads, an average rate of 25 gallons per mile was used for control stripes at Sites 1 through 4. Place-to-place rates varied between 18 to 35 gallons per mile and even heavier rates were used for transverse lines. Normal rates of application of 15 gallons per mile were used for control stripes placed at Sites 5, 6 and 7.

REPAIRS, PERFORMANCE, AND GENERAL OBSERVATIONS

Upon completion of striping operations at each site, all stripes were thoroughly inspected during daylight hours and casually inspected under nighttime conditions of driving. Additional work was specified for Sites 4, 8 and 9 prior to their acceptance. Approximately 580 feet of Catatherm line at Site 4 were deemed unsatisfactory due to inadequate beading. The contractor's attempts to overlay or retrace the lines proved equally unsuccessful. Sites 8 and 9 were reworked for removal of stains and splotches as well as removal of bowed lines and replacement thereof with satisfactorily aligned lines. Excerpts from Final Construction Inspection Reports for the test sites, excluding 5, 6 and 7, are included in Appendix B.

Thermoplastic stripes were generally more visible than paint stripes during daylight as well as nighttime hours. A few sections of painted stripes compared quite favorably in all respects with the thermoplastics. Deposits of road scum following light rains or snows temporarily reduced the nighttime visibility of edgelines, and this situation was more pronounced on urban bituminous concrete pavements. These deposits were generally removed during heavy downpours. Thermoplastic edgelines impounded water which, in many locations, extended 18 inches onto the roadway and remained long after other sections had dried. Edgelines caused abnormal accumulation of de-icing salts and, in other instances, created hazardous icing conditions. Drainage outlets were cut at intervals through edgelines to partially alleviate those conditions.

In general, visibility of conventional paint stripes gradually decreases with age and repainting is necessary at one-half to three-year intervals. Stripe performance is governed by paint quality, line location, pavement type, and traffic volume. On the average, centerline stripes placed on PCC pavements require repainting each year; whereas, stripes placed on BC pavements require repainting only once every 2 years. Edgelines generally require repainting every 2 years on PCC pavements and every 3 years on BC pavements. Exceptions naturally exist and schedules for repainting cannot be firmly established.

Attrition of high-quality paint is usually a result of wear, flaking, or fading. Fading is more prominent on BC pavements and may result from asphalt bleeding through the paint or its being tracked onto the stripe. Bond between paint and bituminous surfaces is normally quite good and may be attributed to solvents within the paint fusing the two materials. Flaking occurs predominately on PCC pavements and is probably a result of a low degree of bond. Surface laitance also contributes to loss of stripes, and this is particularly true of relatively new PCC surfaces. Paint stripes placed on PCC surfaces which were

treated with Pliobond generally had better performance records than those placed on untreated surfaces. The Pliobond, however, was not effective in the presence of surface laitance.

Thermoplastic stripes developed one or more transverse cracks at expansion joints. The plastic stripes performed appreciably better on BC pavements than on PCC surfaces. Heat from freshly placed thermoplastic softened the bituminous surface sufficiently to aid in bonding the two materials. This added feature naturally was not available on PCC pavements, and bond failures were more numerous. Thermoplastics do not bond adequately to PCC pavements and use of a primer is essential. Bond is governed primarily by properties of the primer, pavement surface texture, and climatic conditions. The presence of laitance would place an additional requirement on the penetrant -- that being, the primer must be capable of penetrating the laitance and bonding it to sound concrete. Primers utilized on projects reported herein were not effective in that respect. Situations resulting from poor bond or excessive spalling are noted in Figures 12 and 13.

Portions of the plastic lines that came loose remained on the roadway for some time and presented a cluttered and potentially hazardous view at night. Loosened centerline stripes did not present a real problem since those portions were broken or removed by the action of traffic. Edgeline stripes that loosened presented more of a problem in that many of the sections were blown or washed onto the shoulders and remained there. The resulting array of reflective surfaces presented a much greater distraction than did missing sections of centerlines or edgelines. Deteriorated experimental stripes were replaced in accordance with provisions of the warranties, and the replaced footages were not always of sufficient length to fully restore all lines. Footages of missing lines which were not covered by warranty were restored by Departmental forces with conventional traffic paints.

Rather extensive performance surveys were conducted periodically between the time of initial installations (Sites 1 through 4) and July 1966. Thereafter, only missing footages and repairs per section or subsection for each of the nine sites were tabulated annually. Performance histories through July 1966 are summarized in Appendix C. Tables 1 and 2 include annual performance and repair histories for thermoplastic lines installed at Sites 1 through 4. Footages and percentages listed under columns headed, "Line Judged Unsatisfactory" resulted from inspections conducted by Departmental personnel. The manufacturers were quite faithful to provisions of their warranties and each made additional repairs to footages which in their judgment appeared marginal in performance. These additional repairs which were made, even though not covered by warranty, are reflected under the columns headed "Line Repaired".

Performance histories for Perma-Line stripes placed at Sites 5 through 9 are included in Table 3. Material requirements for these stripes were basically the same as those for Perma-Line stripes placed at Sites 1 through 4. The essential difference between the initial and later Perma-Line installations was that an epoxy-resin primer was specified for the later series. In addition, the warranty was altered and specified in part: the successful bidder shall guarantee 90% of a unit for 1 year, 80% of a unit for 2 years, 60% of a unit for 3 years, and 50% of a unit for 4 years. A unit was again defined as any length of highway having installed thereon 2,000 lineal feet of line of specified width in any combination or pattern.

Figure 12. Typical Results of Poor Bond and Spalling

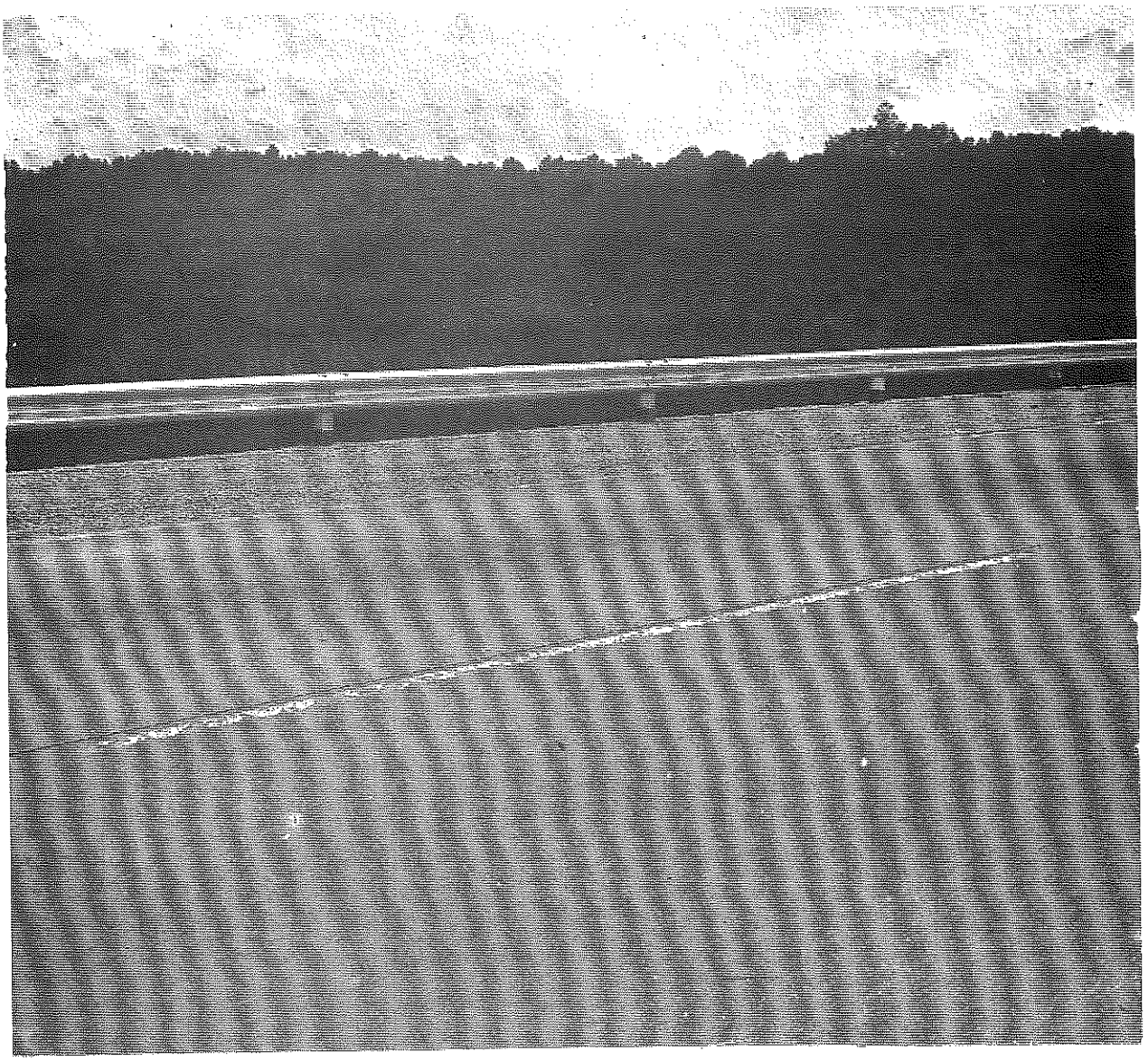


Figure 13. Typical Section Resulting from Poor Bond

TABLE 1

PERFORMANCE AND REPAIR HISTORY OF PERMA-LINE
THERMOPLASTIC FOR SITES 1, 2, 3 AND 4

Test Site	Pavement Type	Footage of Line	1963						1964		1965		1966		1967		1968		1969	
			Line Judged Unsatisfactory		Line Covered by Warranty*		Line Repaired**		Line Judged Unsatisfactory											
			Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%
1	PCC	12,192	117	1.0	0	0	117	1.0	13	0.1	333	2.7	813	6.7	1,278	10.5	1,315	10.8	2,106	17.3
2	BC	10,292	2	0	0	0	202	2.0	1	0	1	0	1	0	253	2.5	397	3.9	***	
3	PCC	100,022	6,178	6.2	0	0	18,145	18.1	1,534	1.5	17,179	17.2	34,846	34.8	41,969	42.0	69,947	70.0	88,874	88.9
4	BC	98,643	41	0	41	0	41	0	275	0.3	459	0.5	660	0.7	832	0.8	900	0.9	920	0.9
TOTAL		221,149	6,338	2.9	41	0	18,505	8.4	1,823	0.8	17,972	8.1	36,320	16.4	44,332	20.0	72,559	32.8	91,900	43.6

* Warranty guaranteed 50 percent of footage to remain four years for centerlines and three years for edgelines. In consideration of a change which lowered the minimum temperature for application from 50°F to 40°F for Test Site 4, Perma-Line agreed to provide a 100 percent warranty for one year at Site 4 in addition to the original provisions.

** Perma-Line replaced additional footage which they judged marginal.

*** Resurfaced.

TABLE 2

PERFORMANCE AND REPAIR HISTORY OF CATATHERM
THERMOPLASTIC FOR SITES 1, 2, 3 AND 4

Test Site	Pavement Type	Footage of Line	1963						1964						1965						1966		1967		1968		1969	
			Line Judged Unsatisfactory		Line Covered by Warranty*		Line Repaired**		Line Judged Unsatisfactory		Line Covered by Warranty*		Line Repaired**		Line Judged Unsatisfactory		Line Covered by Warranty*		Line Repaired**		Line Judged Unsatisfactory							
			Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%	Ft.	%
1	PCC	12,192	65	0.5	65	0.5	1,259	10.3	119	1.0	0	0	317	2.6	912	7.5	0	0	0	0	1,550	12.7	1,766	14.5	2,276	18.7	2,527	20.7
2	BC	10,292	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,012	9.8	1,022	9.9	1,115	10.8	***	
3	PCC	100,022	9,383	9.4	9,383	9.4	36,196	36.2	17,602	17.6	3,831	3.8	29,506	29.5	27,656	27.6	3,176	3.2	3,302	3.3	64,961	64.9	69,552	69.5	80,203	80.2	82,833	82.8
4	BC	98,643	635	0.6	635	0.6	1,091	1.1	977	1.1	170	0.2	1,247	1.3	924	0.9	0	0	0	0	1,472	1.5	1,767	1.8	2,142	2.2	2,178	2.2
TOTAL		221,149	10,083	4.6	10,083	4.6	38,546	17.4	18,698	8.4	4,001	1.8	31,070	14.0	29,492	13.3	3,176	1.4	3,302	0.1	69,695	31.5	74,107	33.5	85,736	38.8	87,538	41.5

* Warranty guaranteed 90 percent of a unit for one year, 80 percent of a unit for two years, and 60 percent of a unit for three years -- a unit defined as any length of a roadway having installed thereon 2,000 lineal feet of line. During construction, Department officials became concerned over poor bonding characteristics of Catatherm. Cataphote agreed to provide a 100 percent warranty for one year if the Department would permit continuation of work.

** Cataphote replaced additional footages which they judged marginal.

*** Resurfaced.

TABLE 3

PERFORMANCE AND REPAIR HISTORY OF PERMA-LINE*
THERMOPLASTIC AT SITES 5 THROUGH 9

Test Site	Pavement Type	Footage of Line	1966		1967**		1968**		1969**	
			Line Judged Unsatisfactory							
			Ft.	%	Ft.	%	Ft.	%	Ft.	%
5	PCC	7,170	1,140	15.9	2,019	28.2	4,775	66.6	4,916	68.6
6	PCC	8,835	19	0.2	519	5.9	3,225	36.5	4,080	46.2
7	PCC	12,375	45	0	498	4.0	7,340	59.3	11,407	92.2
8	PCC	186,109	165	0.1	2,481	1.4	12,498	6.8	27,430	15.0
9	BC	309,737	316	0.1	853	0.3	3,142	1.0	***	
TOTAL		524,226	1,685	0.3	6,370	1.2	30,980	5.9	47,833	22.3

* Warranty guaranteed 90 percent of a unit for one year, 80 percent of a unit for two years, 60 percent of a unit for three years and 50 percent of a unit for four years -- a unit being defined as any length of a roadway having installed thereon 2,000 lineal feet of line.

** By mutual agreement between the Department and Perma-Line, warranty repair provisions were not followed and replacement footages were placed at other sites.

*** Resurfaced.

The performance of stripes placed at Sites 8 and 9 was excellent but was only fair at Site 6. Restorations in accordance with provisions of the warranty were not necessary at any time during the 4-year period. Unfortunately, Site 9 was resurfaced near the end of the warranty period, and potential economic benefits were lost. At the time of resurfacing, various subsections had been in service from 6 to 12 years. No variation in performance of the thermoplastic stripes relative to pavement ages was discernible. No replacements were necessary for Site 7 during its first two years. At the end of the first year, 423 feet of stripe would have been required at Site 5 to restore it to a 90 percent level. At the end of the second year, 585 feet would have been required to restore Site 5 to an 80 percent level; however, these footages were not replaced those years. High percentages of line were judged unsatisfactory during the third-year inspection at Sites 5 and 7. Placement of footages covered by warranty was considered insufficient to restore the markings to an acceptable level; therefore, missing lines were restored with conventional paint. By mutual agreement between the Department and Perma-Line, footages which should have been placed the first, second and third years at Site 5 and third year at Site 7 were lumped; and the combined footage was placed at a new location on US 60 between Frankfort and Versailles. Consequently, the percentages of unsatisfactory line listed for those years in which repairs were deferred are accumulative. Considering all factors, Perma-Line was requested to place 1,674 feet of line in the fall of 1969. Perma-Line elected to place 3,000 feet of centerline stripe at a site on US 60 between Frankfort and Versailles and thereby fulfilled their warranty agreement in a recompensing way.

Generally, control centerline paint stripes were repainted at yearly intervals at Sites 1 through 7. Edgeline control stripes were repainted at one to two year intervals during earlier years of the study and then yearly beginning in 1966. At that time, the Division of Traffic established guidelines regarding the use and location of edgelines. In addition, the policy relating to beading was altered. Pre-mixed beads were excluded and drop-on beads were specified to be placed at rates of 5 and 6 pounds respectively per gallon of paint for beads having refactive indices of 1.65 and 1.50.

As may be noted from Tables 1 and 2, the performance of the experimental striping materials was excellent for those installations on bituminous concrete surfaces (Sites 2 and 4). Performance of the thermoplastics was considered fair at Site 1 and extremely poor at Site 3. ADT's for Sites 1 and 3 averaged 11,000 for the years 1962 through 1969; the ADT at Site 1 was slightly greater than that for Site 3. The pavement at Site 1 was completed early in 1959 and that at Site 3 was completed near the end of 1961. It is quite possible that surface laitance was still present throughout Site 3 and thereby led to the high attrition rate there. The wide variation in performance of Perma-Line at Sites 5 through 8 (all PCC) does not correlate with ADT, pavement ages at time of striping, or a combination of the factors. Pavement temperature and moisture variations may have been the primary cause or causes of the differing performance; however, there are insufficient data to substantiate that possibility. Performance of the material at Site 9 (BC) was exceptionally good; but, unfortunately, the site was resurfaced three years later. Only minor damages were attributed to snow removal equipment.

COST ANALYSIS

Various methods may be employed in performing a cost analysis for the experimental striping materials versus conventional traffic paints. Interest may be

considered as a very tangible factor wherein the difference in cost of placement of thermoplastics and conventional paints might be invested at some rate and thereby yield sufficient monies to provide for perpetual repainting at some predetermined intervals of time. On the other hand, interest may be considered as an influencing factor for use in computing the minimum number of years thermoplastics must perform at a specified service level, under provisions of the warranty, versus paints placed at intervals depending upon individual route requirements. Therein, the minimum life expectancy of the thermoplastics on a break-even basis should equal the number of years at which the present worth of painting at given intervals equals the initial cost of thermoplastic, assuming that costs of maintaining the thermoplastic at the desired level will be borne by the manufacturer.

In addition, factors such as time savings, increased operating capacity, reduction in accident rate, etc. might be included in the cost analysis in the event sufficient data were available. Relatively new thermoplastic stripes are generally appreciably more visible on wet nights than are the conventional paint stripes. As a result, the potential of accidents might decrease sufficiently even at higher possible average speeds. Consideration of such factors could possibly be used as a basis for justification of sizeable increases in expenditures for improved striping materials. It might also be determined that more visible materials having a life expectancy of 1.5 to 3 times that of traffic paints may be justified effectively on a break-even basis. It is obvious that numerous factors other than initial and annual maintenance costs might be considered in the event reliable data were available.

Customarily, interests that may be derived from monies invested as a result of savings from utilization of a more economical material or approach are generally not considered when dealing with tax-derived funds. Ideally, monies derived from taxes should equal anticipated expenditures and all savings should either be utilized for other programs or returned in the form of reduced taxes. Due to lack of appropriate information relative to possible considerations, the costs analysis included herein is based solely on accumulative annual expenditures for each site from the date of installation through 1969.

The costs of control paint stripes at the various sites ranged from 0.85 to 1.97 cents per lineal foot. These figures included costs of paint, beads, labor and equipment. Costs varied somewhat from District to District and more directly for various rates of application or film thickness. The bid unit prices for Catatherm and 1962 and 1965 Perma-Line installations were 38.20, 39.80 and 32.32 cents per lineal foot respectively. These prices included warranty provisions for restorations to the specified service levels at no additional costs to the Department and therefore, cannot readily be compared to costs for the paint stripes. Unit costs for the thermoplastics also probably included overhead and profits, whereas, these factors are excluded in the cited unit costs for paint stripes.

Accumulative yearly costs for all installations are tabulated in Table 4. Figures shown for the control paint stripes are based on re-striping at yearly intervals; therefore, accumulative costs were computed as the product of the original unit costs and years of service. Thermoplastic lines which were judged unsatisfactory and not covered by warranty were assumed to have been replaced at a unit cost equal to that for the original installation. The accumulative yearly

TABLE 4

ACCUMULATIVE YEARLY COSTS (cents per lineal foot)

Site	Paint Type	1962	1963	1964	1965	1966	1967	1968	1969
1	Perma-Line Catatherm Ky. Paint	39.80 38.20 1.97	40.198 43.2376 3.94	40.2378 44.2568 5.91	41.2726 47.1968 7.88	42.8662 49.2378 9.85	44.3786 49.9434 11.82	44.4980 51.5898 13.79	47.0850 52.6090 15.76
2	Perma-Line Catatherm Ky. Paint	39.80 38.2 1.33	40.5960 38.2 2.66	40.5960 38.2 3.99	40.5960 38.2 5.32	40.5960 42.0416 6.65	40.5960 42.0808 7.98	40.5960 42.4336 9.31	
3	Perma-Line Catatherm Ky. Paint	39.80 38.2 0.85	47.0038 50.2736 1.70	47.6008 60.3480 2.55	53.8096 69.9128 3.40	60.8144 85.8280 4.25	63.6800 87.6312 5.10	74.824 91.8256 5.95	82.2666 92.8448 6.80
4	Perma-Line Catatherm Ky. Paint	39.80 38.2 0.86	39.80 38.5528 1.72	39.9194 38.9840 2.58	39.9990 39.3368 3.44	40.0786 39.573 4.30	40.1184 39.6906 5.16	40.1582 39.8474 6.02	40.1582 39.8474 6.88
5	Perma-Line Ky. Paint				32.32 0.90	35.5843 1.80	36.8771 2.70	40.6909 3.60	40.6909 4.50
6	Perma-Line Ky. Paint				32.32 0.90	32.3846 1.80	34.2268 2.70	44.1167 3.60	47.2517 4.50
7	Perma-Line Ky. Paint				32.32 1.97	32.32 3.94	33.6128 5.91	45.2480 7.88	45.2480 9.85
8	Perma-Line				32.32	32.3523	32.7725	34.5178	37.168
9	Perma-Line				32.32	32.3523	32.4169	32.6431	

unit costs for sites having no lines judged unsatisfactory and those sites which were restored to 100 percent service level remained equal to the unit costs of the original installation. Accumulative yearly unit costs for sites which were not restored or judged 100 percent serviceable were based on additional costs that would have to be borne by the Department to fully restore the sites. Herein, it was necessary to assume that once some portion of the site was restored, it would serve indefinitely. Of course, that assumption injects a bias; and, therefore, figures for the thermoplastic installations are lower than might actually be expected.

CONCLUSIONS

Freshly placed thermoplastic stripes were definitely more visible on wet nights than were the paint stripes. Increased visibility of the thermoplastics was attributed to the fact they were much thicker than the paint lines and, therefore, their surface beads were normally above the water film. Visibility of thermoplastics reduced in time as a result of accumulation of road scum and possibly some loss of surface beads. In general, thermoplastics remained more visible on wet nights than paints, and the two were equally as visible under dry, daylight conditions.

Durability of the thermoplastics was superior when placed on bituminous concrete surfaces and good to poor on portland cement concrete surfaces. Epoxy primers provided greater adhesion than did previous primers; however, the epoxies were not capable of penetrating surface laitance. Condition of the surface at the time of installation were noted to be of much greater significance than type of primer.

It is generally concluded that thermoplastics may prove economical when placed on bituminous concrete surfaces having relatively high volumes of traffic. Service life of the stripes would probably be governed by time of resurfacing rather than wear or performance of the thermoplastic. It would be necessary to place greater emphasis on factors other than durability in order to justify use of thermoplastics on portland cement concrete surfaces, regardless of traffic densities thereon.

APPENDIX A

SPECIFICATION

SPECIFICATIONS

FOR

REFLECTORIZED THERMOPLASTIC PAVEMENT MARKING
MATERIAL (CATATHERM)

1. GENERAL

These specifications cover reflectorized thermoplastic pavement material of a type that is applied to the road surface in a molten state, by mechanical means. The material, when properly applied, shall be plainly visible to the motorist both day and night. Nighttime visibility shall be by reflex-reflection induced by ordinary automobile headlights.

2. SCOPE

These specifications shall be the standard for such requirements as material characteristics, method of application, retention of characteristics, guarantee, application rate and packaging.

3. MATERIAL CHARACTERISTICS

a. The material shall be a pure, hot-melt, essentially non-volatile thermoplastic compound especially developed for traffic markings.

b. The thermoplastic marking material shall be installed in both white and yellow color at various widths depending upon its use, and thickness from 3/16th inch to 1/8th inch uniformly applied, such as Catatherm or an approved equal.

c. White thermoplastic material after drying shall be pure white, free from dirt or tint. Yellow thermoplastic material after drying, shall be Federal Yellow in shade, as specified in Federal Specifications TT-P-115, Section E-1C. The reflectorized material shall have the property of angular reflectivity.

d. The material shall harden sufficiently within 8 minutes at 90°F and 5 minutes at 50°F after application to allow traffic over the line without pick up or impression.

e. The temperature versus viscosity characteristic of the plastic material shall remain constant through repeated reheatings; and shall be the same as the master batch. There shall be no obvious change in color of the material as a result of repeated reheatings, or from batch to batch.

f. In the plastic state, the material shall not give off fumes which are toxic or otherwise injurious to persons or property. The material shall not break down or deteriorate if held at the plastic temperature for long periods of time, or by reason of repeated reheating to the plastic temperature.

g. Not less than 75% of the spheres shall meet the following requirements:
   (1) The surface of the spheres shall be smooth, lustrous, and free from film scratch and pits.

(2) The spheres shall be clear and transparent and shall not be oblate in shape or fused spheroids (Roundness of beads may be tested by means of the Wald Roundness Tester).
(3) The spheres shall show high autocollimating efficiency. Not more than 1% shall be black, amber or milky.
(4) The spheres shall be of such size, shape and character as to permit their embedment in the freshly applied thermoplastic compound so as to secure their proper retention and permit the immediate refracting and reflecting of headlight rays.

h. After application and proper drying time, the material shall show no appreciable deformation or discoloration under normal traffic nor under air and/or road temperatures ranging from minus 20° to plus 130°F.

i. Glass beads shall be uniformly mixed throughout the material at the rate of not less than 800 pounds of beads per ton of material. Immediate reflectance shall be accomplished by an application of beads to the surface of the compound at the time the thermoplastic material is applied. These beads shall be applied uniformly at a rate of one pound of beads per 100 ft. of 4" wide line. The applied beads shall show an immediate average reading of not less than 30 when tested by a Hunter Night Visibility Meter in accordance with ASTM D1011. A mechanical beader of approved design must be used.

j. The stripe shall have a uniform cross section and shall maintain its original dimensions and placement. The exposed surface shall remain free from tack. Ductility of the material shall be such as to permit normal movement with the road surface without chipping or cracking, and such as to prevent dimensional distortion as a result of traffic impact within the temperature range specified. The stripe shall not be slippery when wet.

k. The softening point of the thermocompound shall not be less than 200°F as measured by the ball and ring method (ASTM designation: E28-58T). The density of the material shall be uniform throughout and not more than 120 pounds per cubic foot.

l. The compound shall not deteriorate by contact with sodium chloride, calcium cnloride, or other mild acids, alkalis or other chemicals used against formation of ice on roadways or streets or because of the oil content of pavement materials or from oil droppings from traffic.

m. The thermoplastic compound must conform to the following acceleration tests:

(1) Water absorption of the compound prepared as actual installation. 24 hours immersion at 25°C shall not absorb more than one half of one percent water by weight.
(2) Color retention of thermocompound: After 100 hours exposure to ultra violet light being the equivalent to accelerated sunlight exposure, there shall be no darkening of color when subjected to the "Standard method of test for colorfastness of plastics to light", ASTM D620-57T.
(3) Cracking tests comprising the following consecutive exposures: 8 hours at minus 20°F, 8 hours at 70 to 76°F, 8 hours at 120 to 130°F. There shall be no cracking, checking, flaking or separation from the substrate.

n. There shall be no aggregate used in the thermocompound other than reflective glass beads. (The term aggregate is defined here as any material having a plus 200 mesh grain size.) The pigment used for the thermocompound shall be of a high grade pure titanium dioxide. The pigment shall be supplemented by a high quality finely ground white calcium carbonate with a compressive strength of 5000 pounds per square inch. The pigment shall be uniformly dispersed throughout the thermoplastic compound.

o. Throughout the life of the base material it shall have at least the following range of percent reflectivity as measured with the Hunter Multi-purpose Reflectometer or its equivalent using magnesium as a standard. (ASTM designation D97-55).

White:	Day and Night	75 - 85% reflectivity
Yellow:	Day	65 - 75% reflectivity
	Night	75 - 80% reflectivity

p. To insure the best possible adhesion, the compound, as specified shall be installed in a melted state at a minimum temperature of 375°F, and the material shall not scorch or discolor if kept at this temperature for several hours.

q. The material used shall be a product especially compounded for traffic stripes, and shall be applied by the contractor using factory trained specialists.

4. APPLICATION

a. The material shall be applied to the pavement surface by an extrusion method wherein one side of the shaping die is the pavement and the other sides are contained by, or are a part of, suitable machinery for heating, mixing, and controlling the flow of the material. The finished lines shall have well defined edges and be free of waviness. All of the equipment necessary to the preheating and application of the material shall be so designed that the temperature of the material can be controlled within the limits necessary to its pourability for good application. The equipment shall be so designed to permit agitation of the material to prevent scorching, discoloration or excessive high temperatures of any part of the material.

b. The equipment shall be so equipped as to permit preheating of the pavement immediately prior to application of the material.

c. The applicator shall be mobile and maneuverable to the extent that straight lines can be followed and normal curves can be made in a true arc.

d. The applicator shall be capable of containing a minimum of 125 pounds of molten material.

e. The shaping die shall be so constructed that the top surface of the line will form a slight arch. The minimum thickness of the line as viewed from a lateral cross section shall be not less than 3/32nds of an inch at the edges, nor less than 1/8th of an inch in the center. The measurements shall be taken as an average throughout any 36-inch section of the line. Any line or lines in excess of 3/32nds inch, which may be specified in the invitation to bid, shall be subject to the same method of determining line thickness.

f. The material, when formed into traffic stripes, must be readily renewable. When an application is made over an existing stripe the total line thickness shall meet the minimum requirements established by the Vendee, subject to specifications outlined in the previous paragraph. The new line when applied over an old line of compatible material, shall bond itself to the old line in such a manner that no splitting or separation takes place during its useful life.

g. When a new line is to be laid over an old line the vendor reserves the right to inspect the existing line before making the new application or guaranteeing his material.

5. PACKAGING

The material shall be packaged in strippable cartons which contain 50 pounds net of the material. The carton shall be clearly marked so as to indicate the contents, color of material, manufacturers name, batch number of the material, and manufacturers batch number. The cartons must conform to the minimum specifications set forth by the I.C.C.

6. WARRANTY

a. The thermoplastic material outlined in these specifications shall be warranted against failure due to defective materials and workmanship in manufacture. The material shall be guaranteed to perform a useful service of not less than nine times the useful service of a good quality paint stripe applied under similar road surface conditions.

b. ALTERNATIVE GUARANTEE (For approved pavements carrying 30,000 vehicles per day or less)

The successful bidder shall guarantee to replace, without cost to the customer, that part of the pavement markings installed under this contract which, in the opinion of the Engineer in charge, have not remained to perform useful service as follows:

(1) Crosswalks and Stop lines

90% of the total of any one intersection for 1 year
75% of the total of any one intersection for 2 years
50% of the total of any one intersection for less than 3 years

(2) Lane Lines, Edge Lines, and Center Lines:

90% of a unit for 1 year
80% of a unit for 2 years
60% of a unit for 3 years

A "unit" is defined as any length of highway having installed thereon 2,000 lineal feet of line of specified width in any combination or pattern.

SPECIFICATIONS
FOR
FURNISHING LABOR, MATERIALS AND EQUIPMENT
TO INSTALL THERMOPLASTIC COMPOUND PAVEMENT
MARKINGS (PERMA-LINE)

DESCRIPTION: Traffic reflectorized stripes shall be placed in the lines of roadways as shown on the plans or specified and the stripes shall be installed along the centerline and edges of driving pavements, and in other locations as steering lines, lane lines, stop lines and crosswalk lines as shown on the plans or as directed.

I. GENERAL

This specification is intended to set minimum limits of the nature, characteristics and method of application for thermoplastic compound pavement marking material. The term "thermoplastic compound" in these specifications is used to define a substance machine applied to the pavement surface in a hot molten state and which, after cooling to the ambient temperature, forms a traffic marking stripe of a quality and appearance as specified in subsequent sections of these specifications.

II. SCOPE

Under these specifications the contractor shall furnish all of the material, equipment and labor to apply thermoplastic compound for pavement markings.

This specification shall be the standard for the following requirements:

A. Material
B. Material, hot characteristics
C. Material, cold characteristics
D. Method of application
E. Drying time
F. Retention of characteristics
G. Samples for test
H. Qualifications of contractor
I. Warranty

III. DETAILED SPECIFICATIONS

A. Material

1. The material shall be a product especially compounded for the traffic marking.

2. The material shall be a thermoplastic compound, consisting of dolomite thermoplastic resin and other materials, all to be light and stable.

3. The filler, to be incorporated with the resins as binder, shall be a white, calcium carbonate with a compressive strength of five thousand pounds (5000 lbs.) per square inch. The pigment used shall be T-102 Titanium Dioxide.

4. The composition and quality of the material shall be such as to produce an excellent weather and wear resistant traffic line marking.

5. The material shall be delivered to the job site in containers as processed by the manufacturers.

6. Each material container shall be clearly and adequately marked to indicate the color of the material, the process batch number or similar manufacturer's identification and the manufacturer's name and location.

7. The property of the material that gives power to reflect light shall be accomplished by automatically applying reflectorizing beads to the surface of the completed line at a uniform rate of approximately one pound of glass beads to every 120 ft. of 4" lines, and to other widths in the same proportion.

8. Beads applied to the surface of the completed stripe shall be applied by an automatic bead dispenser attached to the liner in such manner that the beads are deposited almost instantly upon the completed line. The bead dispenser shall be equipped with an automatic cut-off control synchronized with the cut-off of the setting material.

B. MATERIAL, HOT CHARACTERISTICS

1. At the pouring temperature, the material shall have stable chemical and physical characteristics.

a. In the molten state, the material shall not give off fumes which are toxic or otherwise injurious to persons or property. The material shall not break down or deteriorate if held at the pouring temperature for long periods of time, or by reason of repeated reheating to the pouring temperature of the compound.

b. The temperature versus viscosity characteristics of the material shall remain constant through repeated reheatings, and shall be the same from batch to batch. There shall be no change in color of the material as a result of repeated reheatings or from batch to batch.

c. The pigmented binder shall be well dispersed and free from all skins, dirt, foreign objects, or such ingredients as will cause bleeding, staining or discoloration, due to dissolution of asphalt in the pavement.

C. MATERIAL, COLD CHARACTERISTICS

After application and proper drying, the material shall show no appreciable deformation or discoloration under local traffic conditions and in an air and/or road temperature range of 10 degrees Fahrenheit to 120 degrees Fahrenheit.

1. The stripe shall maintain its original dimensions and placement. The exposed surface shall be free from tack. Cold ductility of the material shall be such as to permit normal movement with the paved surface without chipping or cracking; and such as to prevent dimensional distortion as a result of traffic impact within the temperature range specified.

2. The stripe shall not be slippery when wet. The material shall not lift from the pavement during freezing weather.

3. The stripe shall have a uniform cross section. Pigment shall be evenly dispersed throughout the material. The density and character of the material shall be uniform throughout its thickness.

4. Material shall not deteriorate by contact with sodium dioxide, sodium chloride, mild acids or alkalis or other chemicals used in street cleaning or road clearing operations (such as snow and ice removal).

5. The white thermoplastic material, after drying, shall be pure white, free from dirt or tint.

6. The yellow thermoplastic material, after drying, shall be "Federal" yellow in shade, as specified in Federal Specifications TT-P 115, Section E-1c.

D. METHOD OF APPLICATION

1. The contractor shall buff surfaces to clean off dirt, glaze and grease where necessary.

2. There shall be sprayed on the surfaces, where the lines are to be installed, just prior to installation of the lines, a binder sealer for adhesion. The binder sealer material shall be sprayed in sufficient quantities to entirely cover the surface on which thermoplastic line is to be laid.

3. The material shall be applied to the pavement by an extrusion method, wherein one side of the shaping die is the pavement and the other sides are contained by, or are part of suitable machinery for heating, mixing and controlling the flow of the material.

4. The machinery shall be constructed so that all mixing and conveying parts, up to and including the shaping die, maintain the material at the pouring temperatures. The pouring temperatures shall be such as to assure a permanent bind between the material and the pavement surfaces and in no case shall be less than 375°F.

5. Machinery shall be so constructed as to assure continuous uniformity in the dimensions of strip. The thickness of the material on the pavement shall be no less than 3/32 inch nor more than 1/8 inch, measured as an average in any one foot of length.

6. The material may be installed in variable widths from 4" to 12".

7. Shaping die shall include a cutoff device, remotely controlled to provide clean, square stripe ends to provide a method for applying "skip" lines. The use of pans, aprons or similar appliances, which the die overruns, will not be permitted.

8. The material, when applied, shall have uniform dispersement of binder, color pigment and glass beads for reflectorization on the surface.

9. The air temperature, at the time of application of the compound shall not be less than 55°F, and the ground temperature not less than 45°F.

E. DRYING TIME

1. Under this specification the term "drying time" shall be defined as a minimum elapsed time after application, after which the stripe shall have, and retain, the characteristics required by the preceding section. In addition, the drying time shall be established by the minimum elapsed time after application, after which normal local traffic will leave no impression or imprint on the new stripe.

2. The drying time shall not exceed a characteristic straight line curve; the lower limits of which are five minutes at 45°F, the upper limits of which are 20 minutes at 90°F, both ambient air temperatures measured at a maximum relative humidity of 70%.

F. RETENTION OF CHARACTERISTICS

The thermoplastic material used under this specification shall be so compounded and applied as to retain, for the life of the stripe, the original characteristics of bond to the road surface, ability to resist distortion by traffic impact or normal climate changes and resistance to natural discoloration.

G. SAMPLES FOR TEST

1. Each bidder shall be prepared to submit samples of the thermoplastic compound he proposes to install in the shape of a line 4" wide and 12" long, on a base acceptable to State Engineers, for the purposes of laboratory testing of hot and cold characteristics.

2. State Engineers may elect to accept a certification from a commercial testing laboratory, which, in the opinion of the Engineers, is adequate proof that the material and method of application are in compliance with this specification.

3. In addition to the above, each bidder shall be prepared to make a sample installation at a site to be selected by State Engineers, to demonstrate that the method or machinery used for the application produces a line of uniformity satisfactory to these specifications.

H. QUALIFICATIONS OF CONTRACTOR

1. The successful bidder shall be prepared to furnish information to prove that there has been successfully installed by his personnel and equipment and/or by the personnel and equipment of the original material manufacturer, thermoplastic pavement marking compound in substantial single quantities (totalling more than 1,000,000 sq. ft.) in towns, cities, highways, bus terminals, parking lots, etc. throughout the United States.

2. The contractor shall use only men who are experienced in the work of installing thermoplastic compounds.

3. The contractor shall use only application methods and equipment as approved by the original material manufacturer.

I. WARRANTY

1. Thermoplastic compound pavement marking material furnished and installed under this specification shall be guaranteed by the contractor against failure due to wear or poor adhesion, which results from defective materials or methods of application.

2. The contractor shall guarantee, in writing, at least 50% of the footage he has installed at each location to remain in place and be in an effective condition for at least four years for center lines, three years for lane lines and two years for stop lines and crosswalks. The contractor shall replace, at his expense, any pavement markings which, in the opinion of the State Engineers, fail to meet the conditions guaranteed.

IV. BIDDING

The contractor shall bid his price per linear foot for the thermoplastic compound pavement marking material to be installed in place by the contractor. The State reserves the right to make additions or deletions to the locations shown on the invitation; such additions or deletions not to exceed 20% of the total approximate value of the contract. Exact footage applied will be determined at time of application and the contractor will be paid on the basis of this exact footage at the quotation per linear foot. In the event the application of the thermoplastic compound becomes unduly delayed by weather or other conditions such as to prevent the completion of the work the contractor will be paid for the number of linear feet of compound installed multiplied by the quoted cost per linear foot.

V. Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided.

APPENDIX B

FINAL CONSTRUCTION INSPECTION REPORTS

FINAL INSPECTION REPORTS

The following is a compilation of remarks from Final Construction Inspection Reports.

Test Site No. 1

Catatherm — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested at this time. However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and to the extent intended by the proposal and specifications governing this contract.

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this report.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

* Maintenance Acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

Perma-Line — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested at this time. However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and to the extent intended by the proposal and specifications governing this contract.

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this report.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

* Maintenance Acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

Test Site No. 2

Catatherm — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested at this time. However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and the extent intended by the proposal and specifications governing this contract.

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this report.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

* Maintenance Acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

Perma-Line — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested at this time other than the following: Sub-Section 9, eastbound lane, Sta. 464+50 to 648+50 left edge line, poorly reflectorized. This line to be satisfactorily repaired.

However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and to the extent intended by the proposal and specifications governing this contract.

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this project.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

In the event final estimate is prepared and ready for submission prior to satisfactory accomplishing the above noted repairs, then with the written consent of the "Bonding Company" a semi-final estimate may be submitted paying all money due on final estimate less a lump sum of $400.00 which shall be withheld and paid on final estimate when such repair work has been satisfactorily completed.

* Maintenance Acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

Test Site No. 3

Catatherm — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested, at this time, other than the following: Sub-Section 3, eastbound lane, Sta. 1857+50 to 1860+43, right edge line, poorly reflectorized. This line to be satisfactorily repaired.

However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and to the extent intended by the proposal and specification governing this contract.

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this report.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

In the event final estimate is prepared and ready for submission prior to satisfactorily accomplishing the above noted repairs, then with the written consent of the "Bonding Company" a semi-final estimate may be submitted paying all money due on final estimate less a lump sum of $700.00 which shall be withheld and paid on final estimate when such repairs have been satisfactorily completed.

Perma-Line — Date of Report: Dec. 7, 1962

Satisfactorily completed - No additional work requested, at this time, other than the following: Sub-Section 1, eastbound lane, Sta. 1463+50 to 1467+00 right edge line, poorly reflectorized. This line to be satisfactorily repaired.

However, it is to be understood by all parties concerned that this inspection and acceptance is only to the extent authorized and to the extent intended by the proposal and specifications governing this contract,

All deficiencies noted in memo dated November 19, 1962, to Director of Construction from Director of Research have been satisfactorily corrected unless specifically noted above within this report.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract. "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

In the event final estimate is prepared and ready for submission prior to satisfactorily accomplishing the above noted repairs, then with the written consent of the "Bonding Company" a semi-final estimate may be submitted paying all money due

on final estimate less lump sum of $850.00 which shall be withheld and paid on final estimate when such repair work has been satisfactorily completed.

* Maintenance acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

Test Site No. 4

Catatherm

Date of Report: Jan. 3, 1963

Satisfactorily completed except as noted below:

As this was an experimental pavement striping project, construction methods and results were studied and reviewed by the Research Laboratory. Reviewing a report from the Research Laboratory under the date of December 11, 1962, of which you received a copy, you will note there was approximately 440 ft. of striping that was found to be poorly reflectorized or non-reflectorized. The contractor was required to rework the sections listed by the Research Laboratory plus an additional section of approximately 130 ft., making a total of approximately 580 ft. reworked. When this final inspection was made, Mr. Riley of your office advised that he and representatives of the Research Laboratory had made a night inspection after these stripes had been reworked, and that the results were unsatisfactory because they were poorly reflectorized; therefore, the contractor is to rework these stripes again. Since it is too late in the season to do this type of work, it is the recommendation of this office that maintenance acceptance be made of the striping that has been completed satisfactorily. For the 580 ft. which was not completed satisfactorily, it is suggested that a $750.00 retainage be held until all work has been completed satisfactorily.

Attention of all concerned is directed to the following "quote" from the specifications governing this contract: "Before final payment of the stripe work, the contractor shall furnish security for this work in the form of a surety bond, or by depositing cash or securities in the sum of 10% of the contract bid price for the stripes and guaranteeing the maintenance of the material for the stipulated period as herein provided".

* Maintenance Acceptance report will not be submitted at this time; however, they shall be submitted upon completion of period of guaranty and release of security as referred to above.

FINAL CONSTRUCTION INSPECTION REPORT

The following is a compilation of remarks from the Final Construction Inspection Report for the thermoplastic installations listed below.

Test Sites 8 and 9

Perma-Line

Date of Report: August 3, 1965

Satisfactorily completed with the following work required.

Remove and replace line right hand gore I-65 and 264 east entrance ramp 4' solid. Remove splotch where material ran out of alignment of lines--Remove stains of material which are in the lanes. Correct skip line in southbound lane, Jefferson exit. Remove all large bows and replace lines.

Plan Sheet 2 - Specifications Section III-E Warranty:

The successful bidder shall guarantee to replace, without cost to the customer, that part of the pavement markings, installed under this contract which, in the opinion of the Engineer in charge, have not remained to perform useful services as follows: 90 percent of a unit for 1 year; 80 percent of a unit for 2 years; 60 percent of a unit for 3 years; 50 percent of a unit for 4 years. A unit is defined as any length of highway having installed thereon 2000 lineal feet of line of specified width in any combination or pattern. The replacement material installed under this guarantee shall be guaranteed the same as the original material, from the date of the original installation. A maintenance bond in the amount of 10 percent of this contract should accompany the final estimate.

APPENDIX C

PERFORMANCE

CONDITION OF PROJECT

Test Site 1

I 264-1(25)20; PCC Pavement

Transverse Lines

The lines were applied November 2, 1962. The Kentucky paint lines were repainted during the spring of 1963 and spring of 1964. The lines were inspected July 7, 1966 and notations of the condition of each line follows:

Line 1: White Kentucky Paint (3 applications of paint and drop-on beads at 3-day intervals) - Approximately 15 percent of line had spalled and bond of the remainder ranged from good to poor. Needed repainting.

Line 2: White Kentucky Paint (2 applications of paint and drop-on beads at 3-day intervals) - Spalling of 25 percent of the line had occurred. A large portion of the drop-on beads was missing. Needed repainting.

Line 3: White Kentucky Paint (1 application of paint and no drop-on beads) - This line was completely missing except for a three-foot portion in the outer lane. Needed repainting.

Line 4: Yellow Kentucky Paint (3 applications of paint and drop-on beads at 3-day intervals) - The reflectance of line was good, but 10 percent of line was missing. Bond of remaining portions appeared poor. Needed repainting.

Line 5: Yellow Kentucky Paint (2 applications of paint and drop-on beads at 3-day intervals) - Extensive spalling (40 percent) of line had occurred. Needed repainting.

Line 6: Yellow Kentucky Paint (1 application of paint and no drop-on beads) - Except for a 3-foot portion in the outer lane, line was completely missing and needed repainting.

Line 7: White Perma-Line Thermoplastic - Condition of line was good. A few bubble-craters were present. Bonding was excellent; reflectance was good; and no visible wear or damage was noted except for three 1-inch spalled areas.

Line 8: Yellow Perma-Line Thermoplastic - Large bubble-craters imparted a splotchy appearance to the line. Reflectance and bonding were good and line was rated fair.

Line 9: White Catatherm Thermoplastic - Appearance of line was good. A large number of small bubble-craters were present and alligator cracking had occurred in the center of the right lane.

Bonding was excellent and no spalled or chipped portions were noted.

Line 10: Yellow Catatherm Thermoplastic - Appearance of line was fair. This line had an extreme number of transverse and alligator cracks over the entire length and a large number of large bubble-craters were present. There were no missing portions and the bond was good.

Subsection 1, Catatherm Thermoplastic

The lines were applied November 1, 1962. On April 9, 1963, 65 feet (0.5 percent) of the line in this subsection were missing or badly spalled and considered unsatisfactory. On July 17, 1963, Cataphote repaired the 65 feet and all other lines that did not appear satisfactory. Approximately 1,259 feet (10.3 percent) of line were reworked.

On March 25, 1964, 119 feet (1.0 percent) of line were adjudged unsatisfactory and reflected damage incurred during the winter of 1963-64. Cataphote's warranty did not apply in this particular instance, but July 28, 1964, Cataphote voluntarily repaired all sub-standard line which amounted to 317 feet (2.6 percent).

On April 13, 1965, 912 feet (7.5 percent) of the line were judged unsatisfactory and represented damage incurred during the winter of 1964-65. Cataphote guaranteed 60 percent of a unit for 3 years. A roadway 842 feet in length and having a dashed centerline and two edgelines represents 2,000 lineal feet of line. Due to the small amount of footage considered unsatisfactory in 1965, Cataphote's warranty did not apply and no repairs were made.

On July 7, 1966, this subsection was inspected and the appearance was fair. A large number of bubble-craters were present and portions of line ranging from 1 to 6 inches were missing at expansion joints. Some edge spalling was noted, but bond and reflectance were good. A total of 1,550 feet (12.7 percent) of line were unacceptable.

Cataphote's warranty expired and repair of missing footage with thermoplastic at the Department's expense was not recommended. Missing thermoplastic was replaced with Kentucky paint. Repainting was postponed until the following year.

Subsection 2, Perma-Line Thermoplastic

The lines were applied November 1, 1962. On April 9, 1963, 117 feet (1.0 percent) of line were considered unsatisfactory and was repaired by Perma-Line on May 6, 1963.

On March 25, 1964, 13 feet (0.1 percent) of line were considered unsatisfactory. Perma-Line's warranty did not apply and no repairs were made.

On April 13, 1965, 333 feet (2.7 percent) of line were considered substandard. This line was not covered by warranty and no repairs were made.

On July 7, 1966, the overall condition was good. There was some spalling along the edges and portions up to 6 inches in length were missing at joints.

Small craters were present, but no alligator or transverse cracking was noted. The bond of all portions was good. A total of 813 feet (6.7 percent) of line were considered unsatisfactory.

Perma-Line guaranteed at least 50 percent of the line at each location to remain in place at least 4 years for centerlines and 3 years for edgelines. The warranty for the edgelines had expired and only that portion dealing with the centerlines remained in effect.

Subsection 3, Kentucky Paint

The lines were applied by the Traffic Division of the Kentucky Department of Highways October 24, 1962. The centerlines were repainted during 1963, 1964, and 1965; and the edgelines were repainted in 1964 and 1965. During inspections July 7, 1966, the appearance of the centerlines was good, but the edgelines were very dim and needed repainting.

TEST SITE 2

I 264-1(24)16; BC Pavement

Transverse Lines

Transverse lines were applied November 2, 1962. The transverse lines of Kentucky Paint have not been repainted. The lines were inspected July 7, 1966, and notations of the condition of each line follows:

Line 1: White Kentucky Paint (1 application of paint, and drop-on beads) - Line was completely devoid of paint and needed repainting.

Line 2: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - The left-lane portion was visible but badly worn and right-lane portion was devoid of paint. Repainting was recommended.

Line 3: White Kentucky Paint (3 applications of paint at 3-day intervals, and drop on beads) - Paint in right-lane portion was missing and paint in left-lane portion was badly worn. Needed repainting.

Line 4: Yellow Kentucky Paint (1 application of paint, and drop-on beads) - Line was completely devoid of paint and needed repainting.

Line 5: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - Paint was completely missing except for a small portion in left lane. Needed repainting.

Line 6: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads) - Paint in inner lane was very dim and the paint in the outer lane was missing. Needed repainting.

Line 7: White Perma-Line Thermoplastic - Line was in fair condition. The bond and reflectance were good but line was worn in the outer-lane wheel tracks.

Line 8: Yellow Perma-Line Thermoplastic - Line had good overall appearance. The bond was good but a small amount of spalling had occurred in the outer lane.

Line 9: White Catatherm Thermoplastic - Line was in poor condition. Some cracking was noted and the line was badly worn in outer lane.

Line 10: Yellow Catatherm Thermoplastic - Some transverse cracking was present and the line was worn in the outer-lane wheel tracks. The bond and reflectance were good; but general condition of line was poor.

Subsections 1, 4, and 7; Kentucky Paint

The lines were applied October 22-23, 1962. The centerlines were repainted during the spring of 1963 and the edgelines were repainted December, 1964.

On July 7, 1966, the overall appearance of these subsections was fair. Both centerlines and edgelines needed repainting.

Subsections 2, 5, and 8; Catatherm Thermoplastic

The lines were applied October 22-23, 1962. All lines in these subsections were considered satisfactory when inspections were made April 8, 1963; March 25, 1964; and April 13, 1965.

On July 7, 1966, the overall appearance of these subsections was fair. Transverse cracking appeared along all lines of all subsections with the exception of the left edgeline on the westbound lane of Subsection 5. Transverse cracks averaging 1/32 inch in width extended across the line and were spaced from 1-1/2 to 10 inches apart. Bond was generally good; although Subsections 2 and 5 had areas of extreme edge spalling. Snow-plow damage was noted and reflectivity of the scraped areas was poor. Footage totaling 1,712 feet (16.6 percent) were considered unacceptable. Cataphote's warranty had expired and needed repairs were made at the Department's expense. Thermoplastic edgelines were restriped with Kentucky paint.

Subsections 3, 6, and 9; Perma-Line Thermoplastic

These lines were applied October 22-23, 1962. On April 8, 1963, 2 feet of line in these subsections were considered unsatisfactory. On May 6, 1963, all lines that did not appear satisfactory were repaired. A total of 202 feet (2.0 percent) was reworked.

During inspections March 25, 1964, and April 13, 1965, 1 foot of line was missing and no repairs were made.

On July 7, 1966, the appearance of these subsections was excellent. No cracking was noted, but Subsections 3 and 6 exhibited some edge spalling. The bonding and reflectivity were good. One foot was scraped during snow and ice removal and considered unsatisfactory.

TEST SITE 3

I 64-3(14)34; PCC Pavement

Transverse Lines

Transverse lines at this site were applied October 19, 1962. The Kentucky paint lines were repainted during the spring of 1963 and 1964. The lines were inspected June 29, 1966 and notations of the condition of each line follows:

Line 1: White Kentucky Paint (1 application of paint, and drop-on beads) - Extensive spalling over 50 percent of the line has occurred and repainting was needed.

Line 2: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - At the time of inspection, 50 percent of the line had spalled and this line needed repainting.

Line 3: White Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads) - Over one-half of the line had spalled and needed repainting.

Line 4: Yellow Kentucky Paint (1 application of paint, and drop-on beads) - The line was worn over entire length and needed repainting.

Line 5: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - General condition of the line was good except for small amount of spalling. Repainting was recommended.

Line 6: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads) - Extensive spalling on the outside lane had occurred and needed repainting.

Line 7: White Perma-Line Thermoplastic - Extensive spalling of over 35 percent of the line had occurred and appearance was poor. A close examination revealed small alligator cracks and numerous small craters. Bond of the line varied from poor to good.

Line 8: Yellow Perma-Line Thermoplastic - The left lane portion had spalled extensively and the bond of that portion was poor. Bond and appearance in the right lane was satisfactory. A few craters were present. The overall appearance of the line was very poor and of all the thermoplastic transverse lines this line was in the worst condition.

Line 9: White Catatherm Thermoplastic - A large number of craters and alligator cracks were present. In the left-lane portion, bond was poor and excessive spalling had occurred. Appearance was very poor.

Line 10: Yellow Catatherm Thermoplastic. The overall condition was very poor. Wide alligator cracks were present. Due to poor bond, this line had edge spalling in the left lane.

Subsection 1, Perma-Line Thermoplastic

These lines were applied during October and November, 1962. On April 10, 1963, 6,178 feet (6.2 percent) of line were considered unsatisfactory. This footage, along with all other lines that did not appear satisfactory, was repaired during early May, 1963. Approximately 18,145 feet (18.1 percent) was reworked.

On April 7, 1964, 1,534 feet (1.5 percent) were considered unacceptable. Perma-Line's warranty did not apply and no repairs were made.

On April 15, 1965, 17,179 feet (17.2 percent) were unacceptable and the subsection was rated substandard in overall appearance. This footage was not covered by warranty and no repairs were made.

On June 29, 1966, appearance of this subsection was poor. Many areas showed poor bond particularly in areas receiving drainage--e.g., the inside of super-elevated curves. In many areas, it was possible to pull up large portions of line. A high percentage of line had spalled onto the recently paved bituminous shoulders. A total of 34,846 feet (34.8 percent) of line were considered unsatisfactory.

The unsatisfactory footage was not covered under the warranty provisions. Replacement with thermoplastic at the Department's expense was not recommended. The attrition rate in two winters had been great, and it was considered uneconomical to replace the missing footage with the thermoplastic. Missing portions had reached a point of becoming distracting to motorists and the section was painted with Kentucky paint.

Subsection 2, Kentucky Paint

The lines were applied October 12, and October 15, 1962. The centerlines were repainted during the springs of 1963, 1964, 1965 and 1966. The edgelines were scheduled for repainting in 1964. Because of the poor alignment of the original application, repainting was postponed to allow additional time for edgelines to wear off.

On June 29, 1966, the overall appearance was fair. Centerlines had been repainted and appeared excellent, but the edgelines were devoid of paint in many areas. In other areas, the edgelines were excellent and their appearance was superior to the appearance of the thermoplastics. Repainting of edgelines was postponed in 1965 until the shoulders of the pavement were paved with bituminous concrete. The shoulders were paved during the spring of 1966 and the edgelines were scheduled for repainting.

Subsection 3, Catatherm Thermoplastic

The lines were applied October, 1962. On April 10, 1963, 9,383 feet (9.4 percent) of line was considered unsatisfactory. This line was reworked during

July, 1963. Cataphote, in connection with their warranty provisions, repaired or replaced all lines in the subsection that did not appear satisfactory. A total of 36,196 feet (36.2 percent) of line were reworked.

On April 8, 1964, 17,602 feet (17.6 percent) of line were considered to be unacceptable; and of this, 3,831 feet were covered by Cataphote's warranty. Cataphote volunteered to repair all unsatisfactory footage. When repairs were completed, 29,506 feet (29.5 percent) of line had been reworked.

On April 15, 1965, the subsection ranked poor in overall appearance. A total of 27,656 feet (27.6 percent) of line were considered unsatisfactory and reflected damage during the winter of 1964-65. Cataphote was allowed 800 feet of unsatisfactory line for any selected 2,000 feet of line or 842 feet of roadway length. There were 15 areas in this subsection that exceeded the tolerance. The excess over 800 feet for each area, according to the guarantee, had to be replaced at no cost. The Cataphote Corporation was committed to replace or make restitution for 3,176 lineal feet of line and on November 11, 1965, Cataphote satisfied the warranty provisions by repairing 3,302 feet of line. This left 24,354 feet (24.3 percent) of line in an unsatisfactory condition beginning the 1965-66 winter season.

On June 28, 1966, this subsection was inspected and the overall appearance rated very poor. Bond was generally poor especially in the left-edge and centerlines. A high percentage of footage was missing. In many places, it was possible to pull up large portions of line. Transverse cracks and large craters were present and extensive edge spalling had occurred. Portions of spalled lines were strewn on the recently paved shoulder creating a hazardous condition. Footage totaling 64,961 feet (64.9 percent) was unacceptable and none was covered by warranty provisions.

The large quantity of missing footage imparted a disordered and unsightly appearance to the roadway and the subsection was considered a complete failure. Cataphote's warranty did not apply. The subsection was restriped with Kentucky paint.

TEST SITE 4

I 64-5(16)93; BC Pavement

Transverse Lines

The lines were applied November 27, 1962. Transverse lines of Kentucky paint were not restriped. The lines were inspected April 20, 1966 and notations of the condition of each line follows:

Line 1: White Catatherm Thermoplastic - A large number of alligator and transverse cracks were present and the line was rated fair. Bond and reflectivity were good.

Line 2: Yellow Catatherm Thermoplastic - Reflectance and bond were good and no spalling was noted. A large number of large craters were present and alligator as well as transverse cracking and occurred over the entire line. Appearance of this line was fair.

Line 3: White Perma-Line Thermoplastic - This line was in an excellent condition. Bond and reflectance were good; no spalling was noted; and no cracks were present.

Line 4: Yellow Perma-Line Thermoplastic - Bond and reflectance were good and no cracking had occurred. The overall appearance of this line was excellent.

Line 5: White Kentucky Paint (1 application of paint, and drop-on beads) - This line was worn and dim and needed repainting.

Line 6: Yellow Kentucky Paint (1 application of paint, and drop-on beads) - This line was worn and needed repainting.

Line 7: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - The portion of line in outside lane was worn and needed repainting. The portion on the inside lane was in good condition except for some cracking and edge-spalling.

Line 8: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads) - This line was in an excellent condition even though some edge-spalling had occurred. The line did not need repainting.

Line 9: White Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads) - Large portions of the second and third application of paint had flaked off--exposing the first application. The overall condition of the line was excellent, and the line did not need restriping.

Line 10: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads) - No flaking had occurred and the

overall appearance of the line was excellent.

Subsection 1, Kentucky Paint

The lines were applied November 15-16, 1962. The edgelines had not been repainted, and the centerlines were repainted during spring, 1964.

On June 30, 1966, the appearance of the centerlines and edgelines was poor and the lines needed repainting.

Subsection 2, Catatherm Thermoplastic

The lines were applied during November, 1962. On April 12, 1963, 635 feet (0.6 percent) of line were considered unsatisfactory. On July 18-19, 1963, Cataphote repaired or replaced all lines in this subsection that did not appear satisfactory. A total of 1,471 feet (1.5 percent) of line were repaired and included 380 feet (0.4 percent) of new line applied over a recently installed, full-width patch.

On April 10, 1964, an inspection was made and 977 feet (1.0 percent) of line were considered unsatisfactory, and of this, 170 feet were covered by guarantee. Cataphote volunterred to repair all substandard footage and 1,247 feet (1.3 percent) were reworked.

On April 20, 1965, 924 feet (0.9 percent) were considered unacceptable and almost all occurred on bridge decks. None of the unsatisfactory footage was covered by warranty and no repairs were made.

On June 30, 1966, bond was excellent except on bridge decks. The condition of this subsection was considered good. The shoulders were paved with bituminous concrete and portions of the edge markings were covered with asphalt. Transverse cracks from 2 to 6 inches apart were noted over a majority of the surface. Longitudinal cracking of a large number of centerlines was noted and cracking was caused by separation of the underlying construction joint. Approximately 12 centerline strips were spalled in the westbound lane. The amount of line considered unacceptable was 1,944 feet (2.0 percent) and almost all occurred on bridge decks, except for 472 feet that had been covered by full-width patches. The guarantee did not apply and no repairs were made.

Subsection 3, Perma-Line Thermoplastic

Perma-Line started work on the subsection November 15, 1962, but because of menacing weather, received permission to postpone work until the spring of 1963. All work was completed on April 26, 1963. Of line that was placed in 1962, 41 feet were reworked April, 1963. In addition, 150 feet of line were reapplied over a bridge deck patch.

On April 10, 1964, line considered unsatisfactory was 809 feet (0.8 percent) and included 534 feet (0.5 percent) of line covered by an overlay patch on the pavement. The warranty did not apply and no repairs were made.

On April 20, 1965, 1,441 feet (1.5 percent) of line were judged unsatisfactory and included 982 feet (1.0 percent) of line covered by an overlay patch on the pavement. The missing footage was not covered by warranty and no repairs were made.

An inspection of this subsection was made June 30, 1966, and the overall appearance was excellent. Bond on bridge decks was only fair and bond elsewhere was good. Paving the shoulders with bituminous concrete left portions of the edgelines covered with asphalt. Footage totaling 2,266 feet (2.3 percent) was unacceptable and this included 1,606 feet (1.6 percent) of line covered with full-width pavement patches.

The missing footage did not impart a disordered appearance to this subsection. Warranty did not cover replacement of the lines and no repairs were made.

TEST SITE 5

U.S. 60; SP 37-45, SP 120-15; PCC Pavement

Centerline of Eastbound Lane, Perma-Line Thermoplastic

The lines were applied June 25, 1965. On June 29, 1966, appearance of the lines was good except for the spalling of 76 centerline stripes which represented 16 percent of the total. The spalled lines were predominate at interchanges.

Centerline of Westbound Lane, Kentucky Paint

The lines were painted in May, 1965 and were repainted during October, 1965 and June, 1966. The appearance of the lines on June 29, 1966 was excellent.

TEST SITE 6

I 64, SP 37-905, PCC Pavement

Centerline of Eastbound Lane, Perma-Line Thermoplastic

These lines were installed June 25, 1965. During inspections on June 29, 1966, some spalling was noted at the ends of several skip-dash lines and three lines were extremely spalled. The overall condition of these lines was excellent.

Centerline of Westbound Lane, Kentucky Paint

These lines were applied during May, 1965 and were repainted during October, 1965 and June, 1966. On June 29, 1966, the appearance of these lines was excellent.

TEST SITE 7

I 64; SP 56-273, PCC Pavement

Centerline of Eastbound Lane, Perma-Line Thermoplastic

The lines were applied June 25, 1965. On July 7, 1966, very little spalling was noted; and the overall condition was excellent.

Centerline of Westbound Lane, Kentucky Paint

The original application of paint was made in May, 1965 and the lines were repainted in October, 1965 and June, 1966. The appearance of the lines on July 7, 1966, was excellent.

TEST SITE 8

I 65; SP 56-798, PCC Pavement

Perma-Line Thermoplastic

The lines were applied during May-June, 1965. During an inspection on July 7, 1966, 11 center stripes were missing at one location and spalling of several other center stripes was noted. This site was considered excellent in overall appearance.

TEST SITE 9

I 264; SP 56-898, BC Pavement

Perma-Line Thermoplastic

The lines were applied during May-June, 1965. During an inspection on July 7, 1966, longitudinal cracking of a number of skip-dash lines caused by the separation of the underlying construction joint was noted. Spalling of the thermoplastic was noted on the concrete ramps and where thermoplastic was installed over existing paint. The overall condition was excellent.