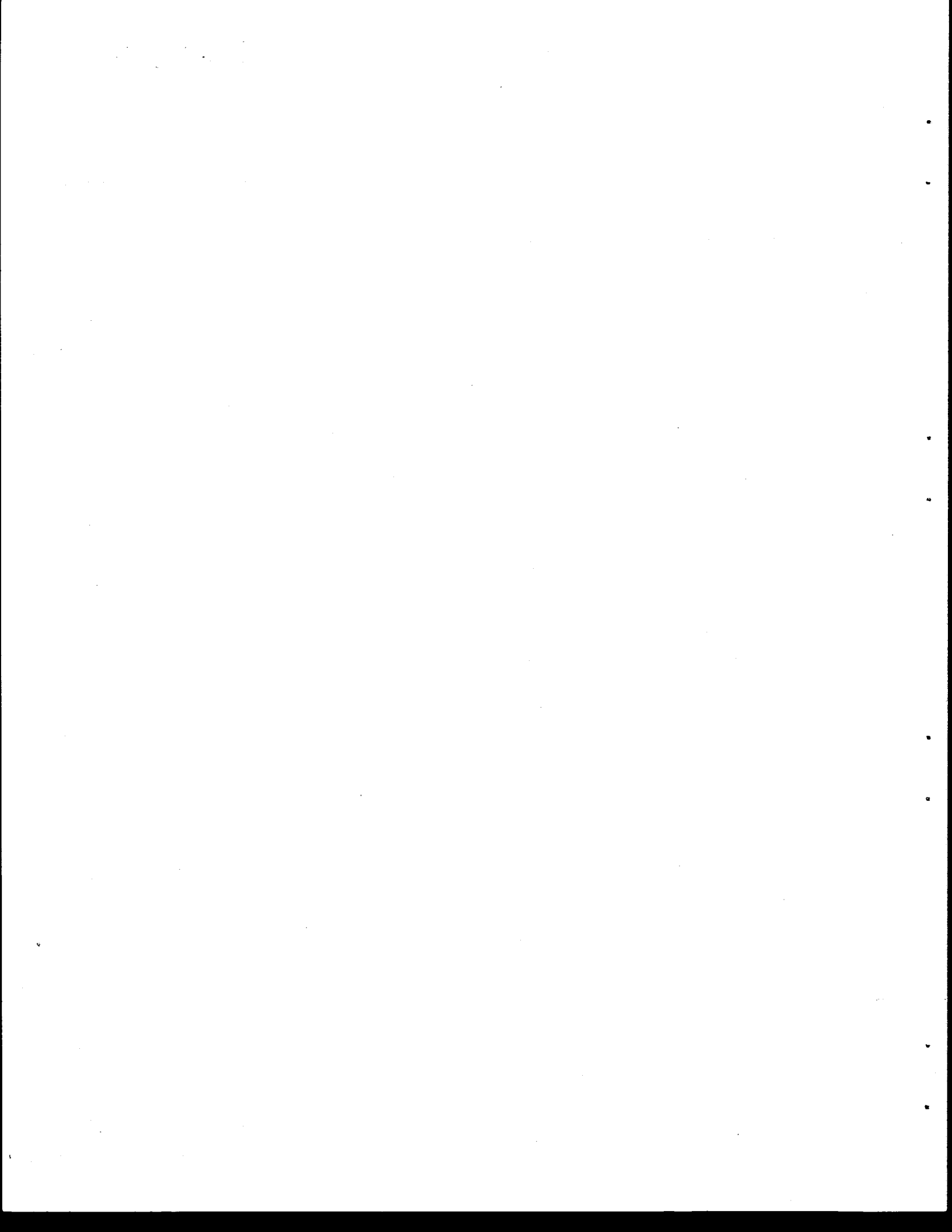


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Temporary Pavement Marking Material Installation Procedure  
for Wet and Cold Pavement Conditions

by

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Final  
Research Report 349-1F  
Research Study Number 2-18-83-349

Sponsored by the Texas  
State Department of Highways and Public Transportation  
In cooperation with  
U.S. Department of Transportation  
Federal Highway Administration

Texas Transportation Institute  
Texas A&M University System  
College Station, Texas  
November 1983



## SUMMARY OF RESULTS

The results of the study will aid the department in installing pavement markings through construction zones in wet and cold conditions so that they will provide a useful service life and leave no shadow markings if traffic control must be moved during construction. In general, temporary tapes (construction grade) and raised pavement markers (RPMs) provide effective pavement markings in construction zones. The pressure sensitive tapes provide adequate durability in most cases.

Two problems exist during installation. One is when the ambient temperature is below 45°F and the other is when there is visible moisture on the road surface. Wet road surface is a more severe installation problem than cold ambient temperature. For a possible solution to both of these problems, masonry nails can be used to tack down both RPMs and temporary tape. One company makes plastic RPM's with holes for construction zone delineation. Experimental products are presently being developed to solve both of these problems.

Shadow markings are created by (1) grinding pavement markings off the road surface, (2) primer residue from temporary tapes, or (3) fading of the surface around the markings. These have not been deemed as severe by most of those interviewed. Several solutions to these problems are addressed in this report.

## IMPLEMENTATION

Because of the increasing number of construction and modification projects of major Texas Interstates and Primary and Freeway Roads and because of the legal implications of faulty or missing pavement markings, it is important that the results of this study be implemented as soon as possible. As new products are developed, tested, and accepted for construction markings, their use by the department should be undertaken.

## DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. The report does not constitute a standard, specification, or regulation. The products mentioned in this report are not endorsed, but are reported as examples and should be considered as generic only.

## METRIC CONVERSION FACTORS

### Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>

### TEMPERATURE (exact)

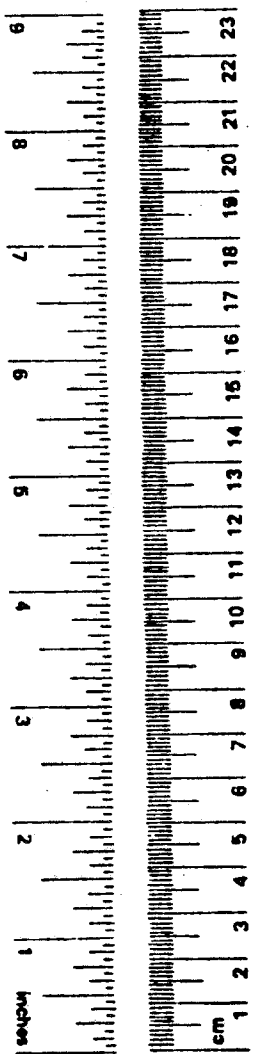
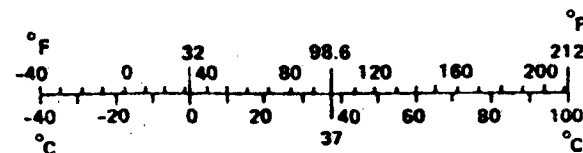
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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### Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>

### TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F
----	---------------------	-------------------	------------------------	----



\* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10:286.



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## I. Introduction

The object of this report is to accumulate and consolidate into one reference source the current state of technology with respect to the materials and application procedures used for temporary pavement markings. A problem exists for the Texas SDHPT and other states, which project 2-18-83-349 "Improved Adhesion of Temporary Pavement Marking Materials" addressed, namely the application of temporary pavement marking material on cold and/or wet pavement conditions. An additional concern being addressed was whether ghost shadow markings was a major problem and what could be done to avoid the ghost markings.

## II. Research Methodology

To conduct the study, a telephone interview technique was chosen as the most appropriate method of obtaining the desired information. Even though it is more costly, accurate and complete responses can be obtained, which is not possible with other approaches. The more direct approach can prompt the interviewee to a more complete response or a response which would not be provided using more indirect methods. Five sectors (areas) were surveyed to obtain the state of the art in temporary pavement marking materials. These five sectors were:

1. The Texas SDHPT Districts and File D-6,
2. Adjacent and selected other states DOTs or Highway Departments,
3. Temporary Pavement Marking Suppliers,
4. Temporary Pavement Marking Installation Contractors, and
5. Temporary Pavement Marking Manufacturers.

The inclusion of these five areas would insure that we determined all of the problems of temporary pavement markings and products developed or being developed which would aid in solving the problems associated with them. The

objectives for contacting the particular sector will be discussed in the following sections. In the rest of this report the term 'temporary pavement markings' refers to all types to include raised pavement markers which will be referred to as RPMs or markers.

A. The Texas State Department of Highways and Public Transportation (SDHPT)

All of the districts, Houston Urban, and File D-6 (Austin) were solicited and asked to participate in the project. A detailed questionnaire used in this project is contained in Appendix A. In summary form, the main emphasis of the SDHPT questionnaire was to determine (1) if any pavement markings other than those specified by SDHPT were being used in construction or maintenance projects, (2) if they were using anything else, what were they using; (3) were they having problems retaining the pavement marking materials when they were installed in cold weather (<45°F); were they having problems retaining the pavement marking materials when they were installed after a rain; (5) what are they currently doing to combat the problems attained in (3) and (4); (6) with pavement markings that were staying down or the more permanent types of marking materials (paint, thermoplastic, etc.), were they leaving ghost markings when traffic control was changed; and (7) if they were having ghost marking problems, what were they doing to remedy the situation. These seven items formed the core of this research project. The magnitude (of the problem and the manner) in which the individual districts were dealing with them would dictate the questions to be asked and the answers to be obtained from the suppliers of pavement marking materials, installers of both temporary and permanent pavement markings and the manufactures of temporary and permanent pavement marking materials. Besides the types of pavement marking materials, the adhesives and/or sealants used during installation were also under consideration in this project. The types of materials to be used in construction areas are specified in Item 662 "1982 Standard

Specifications for Constructions of Highways, Streets and Bridges." This item states that "the material used in placement of standard markings in construction areas shall be distinctly visible when dry from a minimum distance of 300 feet in daylight conditions and from a minimum of 160 feet when illuminated by automobile low-beam headlights at night." This specification allows for the use of paint, thermoplastic, epoflex, epoxy paint, and cold thermoplastics in construction areas. Most of these material types are of the long-durability type.

B. Department of Transportation (DOT) in Selected States

Besides the SDHPT, additional information from other states were obtained to determine (1) whether they have similar problems as the SDHPT, and (2) how these other states have solved these problems, if indeed they have. To accomplish these goals, the same questionnaire administered to The Texas SDHPT was also administered to contact personnel in the following states:

California - Jim Bakley	Florida - Ted Campbell
Louisiana - Mr. Baker	Maine - Douglas McCobb
Minnesota - Ron Hoffman	Nebraska - Neil Kennedy
New Jersey - Dorothy Andris	Washington - Robert Truitt

This cross section of states was selected as a representative sample of states to compare with Texas. This sample was selected because of the difference in ambient temperature (heat/cold), humidity (wet/dry), and frequency and severity of freeze/thaw cycles. These states are representative of all states with regards to pavement marking materials and installation procedures. Both California and New Jersey made extensive use of pavement markings. Their questionnaire is identical to the questionnaire in Appendix A.

### C. Suppliers of Temporary Pavement Marking Materials

Several suppliers of temporary pavement marking materials, which are known to the department and are members of the Institute of Transportation Engineers, were contacted. The emphasis in this telephone interview was on (1) the recommended marking materials and adhesives for construction areas, (2) those suitable for installation in cold temperature, (3) those suitable for installation in wet weather, and (4) those types which would be less susceptible to leaving shadow markings when traffic control needed to be changed. The six suppliers contacted are the largest suppliers of temporary pavement marking materials to the state. The detailed questionnaire is contained in Appendix B.

### D. Temporary Pavement Marking Materials Installation Contractors

A list of installation contractors was developed using a list of prequalified contractors compiled by File D-6 (Construction Division). The number of installation contractors contacted represented approximately 10 percent of the prequalified contractors. They were selected based on their geographical location in Texas and in the United States. These contractors are responsible for installing the majority of the pavement markings in the state of Texas. One of the contractors is located in Louisiana which has similar problems as southwest and central Texas. These areas are characterized by warm temperatures and high humidity. The other contractor is located in North Dakota where there are cold temperatures and long freeze/thaw periods. The installation contractor telephone interviews were designed to determine (1) the types of pavement marking materials and adhesives to be used in construction areas, (2) the materials and installation procedures used to apply the pavement markings in cold weather, (3) the materials and installation procedures used to apply the markings on wet pavement, and (4)

the procedure used to remove existing pavement markers to avoid shadow markings. The detailed questionnaire is contained in Appendix C.

#### E. Manufacturers of Pavement Marking Materials

The major manufactures of pavement marking materials were interviewed. These manufacturers produced paint, thermoplastic (both hot and cold), and raised pavement markers. The telephone interview was designed to determine (1) the recommended pavement marking materials to be used in construction zones, (2) the recommended materials for application in cold conditions, (3) the recommended materials for application on wet pavement, (4) the recommended adhesive or material to avoid shadow markings, and (5) experimental products presently being developed or to be developed in the near future which address the problem areas covered in this research project. The detailed questionnaire is contained in Appendix D.

#### F. Cost Comparisons of Various Types of Pavement Marking Materials.

Various types of pavement marking materials may be used for temporary markings. These materials may be used for both temporary and permanent pavement markings. The calculations used to compare the various types of markings which could be used, and presented in the results section of this report, used the prices of the various types of materials for the Texas SDHPT. Other states material costs are included for comparison purposes in Appendix G.

### III. Results

The results of the telephone interviews are discussed in the following sections. These results will be discussed in the same order as presented in the research methodology section. The detailed results are presented in tabular form in Appendix F. A detailed discussion of the individual question responses are discussed in each section.

## A. State Department of Highways and Public Transportation Responses

The responses of the SDHPT contact personnel are discussed for each question.

Question # 1 - Do you use different pavement marking materials at construction sites other than those specified by the Department?

Nineteen responded no, five responded yes, and two did not respond to the question. The responses to this question may be biased because the contact personnel may be partially afraid to respond that they are not using specified marking material. At the onset of the interview, the researcher pointed out that the objective of this project was to compile the current practices in the field so all districts can benefit from what other districts are doing. Some individuals may have been afraid or repressed by the department administration; however, the specifications are so broad that almost all marking materials qualify for construction zones.

Question # 2 - If so, what materials do you use in construction zones?

A majority of 10 that answered this question indicated that they used different manufacturer's stick-on tape. Five used some type of paint, three nailed down reflective raised pavement markers, and two used hot thermoplastic. It should be noted at this time that the number of responses to question # 2 will not correspond exactly with those answering to question # 1 due to multiple responses. Those five individuals which responded they did not use specified materials indicated they (1) nailed down reflective pavement markers, or (2) used an experimental latex paint.

Question # 3 - What is the type of pavement marking material you normally use in your district?

Sixteen indicated they used some form of stick-on tape in construction zones. Of those that indicated the specific type of tape six used 3-M construction grades, one used a felt-back tape, and one used a foil-back tape.



Additionally 13 used paint and 1 used reflective raised pavement markers. In all other cases, eight used some form of thermoplastic, seven used paint, and four used reflective raised pavement markers.

Question # 4 - What type of adhesive (epoxy) do you use with each type of pavement marking (temporary only)?

Seven replied that their product required no adhesive whatsoever. The others are not sure whether this type of pavement marking does not require any adhesive but does require a sealant to the pavement or some other chemical which starts the bonding action, similar to that required by 3M. Without these sealers or tac-coat, the bonding action will not commence. The tac-coat reacts with the adhesive or the pre-formed tape or with the hot-thermoplastic to make it adhere to the pavement. Five responded that they did not know specifically the type of adhesive used, except that it was whatever they had in the warehouse at the time. Three responded that they used large nails or spikes to attach reflective raised pavement markers to the pavement or travelway. This form of attaching either raised pavement markers or preformed tapes is recommended for use on asphalt pavements only. A potential hazard to motorists tires exists if the markers were to brake, leaving the spikes exposed. At present there exists no data to document the severity of the problem or to prove that danger exists. The three districts which responded they used this method were pleased with the results obtained. Three also responded that they used the standard two-component epoxy used to attach raised traffic buttons or markers. One responded that he did not know what adhesive was used.

Question # 5 - Do you have any trouble applying it (the epoxy) in cold weather (T<or=to45°F)?

Fifteen said they do not apply pavement marking material when the ambient temperature is below 45°F. Nine indicated that they apply pavement marking materials when the ambient temperature is below 45°F and above 32°F (freezing). One that indicated he applies pavement markings below 45°F said that he would not apply markings to hot-mix asphalt if the temperature is below 45°F.

Question # 6 - If so, how do you counteract this problem?

Four of the fifteen that indicated they would not apply pavement markings at ambient temperatures below 45°F, said they would wait until the temperature was near 50°F. Of the nine that said they would apply markings at temperatures below 45°F, two indicated they would use a pear-burner to heat the pavement where they would apply the pavement marker. Two said they would apply the markings and reapply those that came loose. Two also indicated that when temperatures were below 45°F, they would use paint to mark the construction zone. One said he would use an adhesive designed for cold temperature installation. One said he would nail reflective raised pavement markers down.

Question # 7 - Do you have any trouble applying these (pavement markings) wet: when visible moisture is on the road surface, three hours after a rain, or three to six hours after a rain?

Nineteen responded that they have trouble applying pavement markings when there is visible moisture on the road surface. Five said they never apply on wet pavement and one said he had no problems applying on wet pavement.

Question # 8 - If so, how do you counteract this problem?

A preponderous number of respondents (22) said they would either have trouble applying markings on wet pavement or never apply on wet pavement, and also said they would wait until the pavement surface dries (approximately 3 hours). One used cones to keep traffic off pavement markings until the

adhesive dries, and one said that on wet pavement, reflective raised pavement markers nailed down work extremely well. One indicated that on wet asphalt temporary tape works well.

Question # 9 - Do you have a problem taking the pavement markings off the road? (Does it remove easily?)

Twelve responded they had problems removing pavement markings from the pavement. Of those twelve, one indicated he had more trouble removing pavement markings in hot weather, one has more problems when he uses the foil back tape, one when using paint, and one when pavement markers or buttons have been used. These tend to either leave the epoxy pad or take asphalt with the marker leaving a hole in the pavement. Ten indicated they had no problem with stripe removal when stick-on tape was used. One indicated that the felt-back tape was the easiest to remove.

Question # 10 - Do you have a problem with a particular pavement marking material or adhesive leaving a shadow marking?

Nineteen said they have problems removing the pavement markings without leaving a shadow. Four said that paint was the hardest to remove and three said raised pavement markers were the most difficult. Four said that stick-on tape was the easiest to remove, one indicated that pavement markings remove easier in warm weather and one said he had no problems at all with stripe removal.

Question # 11 - How do you counteract either of these problems?

Fourteen said that they would do nothing but let the shadow marking wear off. Four said they overlaid with asphalt; one said that the use of an emulsion compound helps get rid of the shadow marking. One (1) said that sand blasting off the markings will permanently discolor or scar the pavement.

B. Department of Transportation in Selected States.

As stated previously, the questionnaire administered to the Texas SDHPT was also used in the other state DOTs' telephone interviews.

Question # 1 - Do you use different pavement marking materials at construction sites other than those specified by the department?

Three indicated that they did, three did not respond either positively or negatively. The three that indicated they used different materials than those specified have been using some experimental construction pavement marking materials. One is a plastic tape, one is a natural rubber traffic button, and the last is the stimsonite construction raised pavement marker (#66).

Question # 2 - If so, what materials do you use in construction areas?

Four use some type of raised pavement markers. One is the low-profile 2X4 (947) and the other is the new type temporary construction marker introduced by Stimsonite. One uses an experimental L-shaped plastic marking material with an adhesive back. The material elongates for traffic and returns to its original shape. One, Maine DOT, uses an epoxy marking material similar to the "glow" button. The respondents indicated this has very limited use on construction areas and are using it namely as a permanent marker. One uses an experimental rubber 1/2" X 4 traffic button which must be installed at temperature above 50°F.

Question # 3 - What is the type of pavement marking material you use in your department?

Seven said that they used some form of cold thermoplastic tape. One used 3-M construction grade, one used 3-M "Stamark", and one used scotch foil-back tape. Five said they used raised pavement markers. CALTRANS uses RPMs if they are going to be in place more than one week. And five responded that they used paint.

Question # 4 - What type of adhesive (epoxy) do you use with each type of pavement marking (temporary only)?

Three indicated they used self-adhesive raised pavement markers, one indicated he used the standard two-component epoxy, two said they did not know, and two did not respond to this question at all. An analysis of the types of marking systems used by the two states that did not know (CALTRANS and Florida DOT) indicated they use either a primer or sealer with their 3-M tape and stamark and two-component epoxy for their RPMs. The two that did not respond (Nebraska DOT and Maine DOT) appear to use self-adhering marking systems.

Question # 5 - Do you have any trouble applying it in cold weather (temperatures  $< \text{or} = 45^{\circ}\text{F}$ )?

Six indicated they have problems installing pavement markings at ambient temperature less than  $45^{\circ}\text{F}$ . One, Louisiana DOT, said they did not have a problem because most of their applications are on hot mix which tends to negate the effects of low ambient temperature. One said he has problems installing RPMs in cold temperature.

Question # 6 - If so, how do you counteract this problem?

Two responded they avoided installing pavement markings in temperatures below  $45^{\circ}\text{F}$ . Two said they did not specifically know what was done in the field to counteract the problem with low temperature. One said they warmed RPMs before applying the epoxy on the marker prior to installation.

Question # 7 - Do you have any trouble applying these pavement markings wet: when moisture is visible on roadway surface, three hours after rain, or three to six hours after rain?

Four said they have problems installing pavement markings on wet pavement. One, Minnesota DOT, indicated that the foil-back tape when applied

on wet pavement will come up immediately, and one, New Jersey DOT, never applies pavement markings on wet pavement.

Question # 8 - If so, how do you counteract this problem?

Two indicated they blow-dry the pavement prior to installation, one reapplies stripes or markers that come up, and one said they wait until the pavement dries naturally.

Question # 9 - Do you have a problem taking the pavement marking off the road? (Does it remove easily?)

Six indicated the 3-M foil-back tape removes easily, whereas one CALTRANS said that the 3-M foil-back tape is harder to remove than all other 3-M tape grades. One, New Jersey DOT, said that tapes should be avoided in areas where there is high traffic volume or where the tape has been perforated because the tape will tear apart and come up in pieces. Washington DOT said that foil-back tape installed on roadways for long periods of time can be easily removed when heat treated. Florida DOT indicated that when tape has been installed they generally have no problem with shadow markings, however, sometimes the tape will lift asphalt with it when removed.

Question # 10 - Do you have a problem with a particular pavement marking material or adhesive leaving a shadow marking?

Six indicated they have problems with shadow markings and two said they did not have shadow marking problems. New Jersey DOT and Washington DOT indicated they did not have shadow marking problems using similar products, 3-M foil back tape (mainly) and limited use of RPMs.

Question # 11 - How do you counteract either of these problems?

Four said they let the shadow markings fade away on their own, CALTRANS said that asphalt emulsion can be used to cover up the shadow and Louisiana said in their opinion the shadow marking is not a problem to address. Two, Maine DOT and New Jersey DOT, did not provide any solutions to this problem.

### C. Suppliers of Temporary Pavement Marking Materials

This section will discuss the recommended products and procedures used for installing temporary pavement markings. The suppliers have explained the products recommended to be used in construction zones, which can be applied in both wet and cold climate conditions. The same format used to discuss the response in the two previous sections will also be used in this section.

Question # 1 - What types of pavement marking materials do you recommend for construction areas?

The following materials are recommended for construction zones: Catapol prefabricated tape, aluminum foil tape, Stimsonite RPM #66; 3-M construction grade tape, and 3-M plastic tape. These five types of temporary pavement markings provide a sufficient variety that all types of traffic control situations can be adequately addressed.

Question # 2 - What type of adhesive (epoxy) is recommended for use with these materials?

Mostly the prefabricated tapes or cold thermoplastic are self adhesive. Some RPMs which have butyl pads are also self adhesive. The majority of the RPMs use the 2 component epoxy. Some 3-M tapes also use an adhesive made by Prismo called Prisma1 and another type is a melted bituminous product. Jack Shockey of Stimsonite calls it "bitumen" and recommends it for applying RPMs.

Question # 3 - Can it be applied in cold temperatures (T < or = to 45°F)?

The following pavement marking materials or adhesive can be applied in cold ambient temperature:

- 1) Catapol tape
- 2) Melted bituminous material
- 3) 3-M tapes

Two other products may be used however one cannot be applied below 50°F (aluminum foil tape) and the other needs to be heated if applied below 45°F (Prismal).

Question # 4 - If so, what do you recommend using below that temperature ( $T < \text{or} =$  to 45°F)?

The following products can be used in the following temperature ranges according to the suppliers of these products:

$T > \text{or} =$ to 50°F	aluminum foil tape
40°F $< \text{or} =$ to $T < \text{or} =$ to 50°F	melted bituminous material (minimum temperature not known) Prismal-must be heated for application - minimum application temperature not known
30°F $< \text{or} =$ to $T < \text{or} =$ to 40°F	Catapol tape (min. $T = 32^\circ\text{F}$ ) Type I and IM two-component epoxy (min. $T = 30^\circ\text{F}$ )
20°F $< \text{or} =$ to $T < \text{or} =$ to 30°F	one supplier has indicated that 3-M tape can be applied down to 20°F. The authors questions this temperature without proper test data to support this temperature

Question # 5 - Can it (pavement marking) be installed (applied) on wet pavement?

All five suppliers contacted agreed that none of the products discussed previously are recommended to be used on wet pavement.

Question # 6 - What do you recommend for application on wet pavement?

In an emergency the suppliers recommended using any 3-M grade tape. The 3-M plastic tape can be applied to wet pavements; however, the service life is only a few weeks. Two suppliers, Robert Newton of Renco Supply and Mike Kaderli of Kendall Co., recommended letting the road surface dry to the touch.

Question # 7 - Will the pavement markings leave a ghost (shadow) marking when taken off the road or moved?

When epoxy is used as the adhesive, a shadow marking will result. According to Jon Harvey of Southwestern Materials, the use of the Stimsonite # 66 will diminish the shadow marking because the marker is designed to break up



and blend into the pavement. This may be true over a long period of time, but what if the traffic control needs to be changed in a relatively short period of time (2 to 3 months)? This question was not answered.

Question # 8 - What do you recommend best to avoid the shadow markings?

Several products could be used to avoid the shadow markings according to these suppliers. These products are: removable tape, non-setting thermoplastic, and 3-M tape on concrete. The 3-M tape on asphalt leaves a marking but it will eventually disappear. All other products will leave markings, and therefore, the suppliers recommended to let them fade out. The main reason for this is that presently there is no commercial product that can be used to eliminate these shadow markings.

#### D. Temporary Pavement Marking Installation Contractors

Eight installation contractors were contacted to participate in this study. This represented approximately 10 percent of the installation contractors which have pre-qualified to bid for the SDHPT. Response from six of these installation contractors were obtained. The six installation contractors contacted install over half of all the contracted pavement markings for the Texas SDHPT.

Question # 1 - What pavement marking materials do you install (or recommend) at construction areas?

Eight responses obtained indicated that some form of temporary tape used in construction zones. One of those said the 3-M #5710 tape was preferred, two preferred a foil back tape, Flexalite, and one indicated a paper back tape was good to use in the construction zones. Two use some form (hot or cold) of thermoplastic, two use raised pavement markers, and two use paint.

Question # 2 - What type of adhesive (epoxy) do you use with those pavement markings?

Most of the preformed tapes are self-adhesive, which was reflected in the responses when three indicated this type of adhesive. Two use the two-component epoxy in construction zones. One uses the P-46 Primer when installing tape, and one responded he never uses any adhesive when putting down temporary markings.

Question # 3 - Do you have any problem applying them when: there is visible moisture on the roadway, three hours after rain, and three to six hours after rain?

Eight responses indicated there is a problem when there is visible moisture on the pavement. In general the contractors said they never install pavement marking systems on wet roads. One responded that he has no problem using a two-component epoxy on wet pavement.

Question # 4 - What adhesive do you recommend to use when applying to wet surface?

Two prefer to use the standard two-component epoxy system. One uses the P-46 primer when installing temporary tape, and one said the only sure application procedure is to air blow the surface dry.

Question # 5 - Do you have any problems applying these pavement markings in cold temperatures ( $T \leq 45^{\circ}\text{F}$ )?

Two installation contractors indicated they have major problems with cold temperature. One indicated the trouble is with thermoplastic on concrete and one with application on surface treatments. Two replied they had no trouble with application on hot mixes in cold temperatures. One other said he had no trouble whatsoever with temperatures less than  $45^{\circ}\text{F}$ , he recommends 3M-#5710 tape.

Question # 6 - What do you use (or recommend) in cold temperature?

Two recommend using paint in cold temperatures, one recommends using a rapid set (Type I) one component epoxy when applying RPMs. Randy Rector,

Reece Inc., responded that when using foil back temporary tape in cold temperatures you could (1) reapply that portion that comes up or (2) nail down portions of the temporary tape that does not seem to adhere well to the pavement surface.

Question # 7 - Do you have any problems with shadow markings when using these types of adhesive or pavement markings?

Four indicate they have problems with shadow markings when they have to remove the pavement markings. Four indicated they did not have any problems with shadow markings left on the roadway surface.

Question # 8 - If so, what do you recommend to use to avoid the ghost (shadow) markings?

One recommended using 3-M #5710 temporary tape, removal of which would not leave shadow markings. One responded that any prefabricated tape could be used to minimize the possibility of shadow markings. Another indicated that when temporary tapes are installed using a primer, when removed the primer will leave a residue that results in a shadow marking; therefore, if at all possible the use of a primer should be held to a minimum.

#### E. Manufacturers of Pavement Marking Materials

The main objective for interviewing the eight manufacturers of pavement marking materials was to determine the problem they perceived by installing pavement marking materials on wet pavement and/or in cold temperature and the recommended products they formulated for solving these problems. Also an added objective was to find out whether there were any experimental products currently under study or planned in the near future which would help in the installation of the pavement markings under these conditions.

Question # 1 - What pavement marking material does your company recommend to use in construction zones?

Five responses involved construction grade foil back tape. Five responses indicated raised pavement markers, of which one referred to the Stimsonite # 66, and another referred to the Ferro marker which is the same as a Stimsonite 88. Three responses favored the use of a pliant polymer tape (Scotchlane # 5710) which has a service life of up to 12 months. Two favored either paint or thermoplastic installed 30 mils thick if they are permanent or will be overlaid to cover up the pavement markings. One indicated that removable paint should be used in construction zones.

Question # 2 - What type of adhesive (epoxy) do you use with these pavement marking materials?

Three responses favored the use of the standard 2 component epoxy and two responses favored the use of a melted Bituminous material developed in England. Two responses indicated that if preformed tape is being used in construction zones installed at ambient temperatures above 50°F, a primer should be used. Two responded that pressure-sensitive adhesive should be used with RPMs and preformed tape, and one indicated that the manufacturer's recommended sealant should be used.

Question # 3 - Can they be applied in cold temperature ( $T \leq 45^\circ\text{F}$ )?

The majority of the responses (two each) indicated that (1) pressure sensitive tape and markers, (2) two-component epoxy, (3) foil tape on new asphalt and (4) hot thermoplastic are all suitable materials for installation in cold temperature. Other materials which could be used are (1) preformed tape (use primer), (2) melted Bituminous material, and (3) masonry nails for RPMs.

Question # 4 - What does your company recommend to use for applying pavement markings in all weather?

The most popular response (3) was pressure sensitive RPMs and tape which can be installed at temperatures below 35°F. The second most popular response was nailing down the RPMs. Other responses were: the use of the standard two-component epoxy, heating of the roadway surface prior to installation, using either the melted Bituminous material or the hot thermoplastic which can be applied in temperature below 32°F. It should be noted, however, that no pavement markings be should be installed at temperature below 50°F, according to ASTM.

Question # 5 - Can they be applied to wet pavement?

Three responded that various products are made which can be applied to wet pavement. Three others said that at present there is no product which can satisfactorily be applied to wet pavement.

Question # 6 - What does your company recommend to use for applying pavement markings to wet pavement?

The two most predominant responses was (1) nailing RPMs to the pavement and (2) heating the surface before installation. Other responses included: (1) use the standard two-component epoxy, (2) air dry the surface, (3) use construction tape with the proper adhesive system, (4) use epoxy paint when you need non-removable markings, and (5) the use of sealant and/or primer require dry pavement.

Question # 7 - Will this adhesive or pavement marking material leave ghost markings when removed?

There was no predominant response to this question. The list of responses included: (1) all will leave some shadow marking after an extended service period, (2) grinding to remove pavement markings will leave shadow markings,

(3) cold thermoplastic tape leaves a shadow marking, (4) primer and sealant will leave a residue, and (5) melted bituminous adhesive does not leave a shadow marking because it blends into the asphalt.

Question # 8 - What does your company recommend to use to avoid the ghost markings?

Three responses indicated that temporary tape would not leave a shadow marking, noting that this is diametrically opposed to the response to question # 7. The melted bituminous material on asphalt would not leave a shadow because it blends in; however, it will leave a shadow on concrete. RPMs attached to the roadway surface with masonry nails would not leave any markings. One manufacturer noted that if an over-cured epoxy was used to attach RPMs, when they were removed, no shadow would result; however more markers would be lost due to impact.

Question # 9 - Is your company at present or in the near future, considering developing a pavement marking material or an adhesive which would solve all these problems discussed previously?

One manufacturer did not provide any response except that they were developing a product which addresses the wet/cold installation problem. One is developing a removable paint, another is developing an epoxy which can be applied to a wet surface such as bridge piers another is developing a pliant polymer temporary tape, and finally, one manufacturer is trying to develop a plastic permanent construction grade tape.

#### F. Cost Comparisons of Pavement Markings

The ultimated comparison between the temporary pavement marking concepts involves calculating the service life cost of each. Service life cost is defined as the present value of the total cost of the marking system including the installation, maintenance, and if required, removal of the marking. For the present calculations here the discount rate was assumed to be 12% and the

service life three-years. The three-year service is an average service life of all four types of pavement marking materials. Four marking systems were compared; conventional paint, hot applied thermoplastics, prefabricated materials and the conventional acrylic reflective pavement markers nailed down to asphalt paving. The estimated costs of one - mile of each system are shown in Table 1.

The present value of one mile length of two kinds of longitudinal markings were compared. The first was an intermittent line characteristic of the stripes separating lanes on conventional highways, i.e. a 10 foot stripe starting every 40 feet. The corresponding spacing for the raised pavement markers was every 80 feet. The other kinds of markings were a solid line characteristic of the stripes delineating neutral zones between opposing traffic. In this case, the raised pavement marker spacing was 20 feet. The latter, or solid line, was assumed to survive twice as long because traffic more rarely crosses the solid lines.

The results of the cost comparisons are very conclusive, at least for the assumed three-year service life. Conventional paint is most expensive primarily because of the frequency at which it must be replaced. Prefabricated materials were better and their off the shelf cost is rapidly being reduced. The hot applied thermoplastic is next but there remains a lingering doubt as to whether the residual stripes can be removed for the cost shown. The raised markers are seen to be much less expensive than any other system.

It should be noted that the raised reflective markers will lose some of their cost advantage for shorter service life durations. If the construction zone is for a 6-month time period paint is the most cost efficient system.

TABLE 1

COST COMPARISONS OF DIFFERENT TYPES OF PAVEMENT MARKING MATERIALS

Discount Rate = 12% per year Three year service life

Paint \$0.196/ft/4" Line (initial cost), Replaced quarterly

\$1.95/ft (or \$0.96/ft - 6 mo. replacement)

@ 10' stripe, 30' gap - \$2,574/mi Lane Stripe

Solid Stripe = \$5,089/mi Replacement at 6 month intervals

Hot Applied Thermoplastic \$0.65/ft/4" Line (initial cost) Replaced every 2 years - 6 months

Estimating the removal cost to be one quarter of the initial installation cost.

(10' stripe, 30' gap)

$0.65 + 1/5 PV (.65 \text{ in } 2 \frac{1}{2} \text{ years})$

= 0.75/ft or \$990/mi

with removal cost  $\$990 + \$158 = \$1148/\text{mi}$

Solid Stripe - \$2,059/mi

Replaced every 5 years i.e.  $3/5xPV$

with removal cost  $\$2,059 + 631 = \$2,690/\text{mi}$

Prefabricated Materials

\$1.17/ft/4" Line (initial cost) Replaced every 3 years

10' stripe, 30 gap-Lane-strip \$1,544

solid stripe - \$3,089



TABLE 1. (Continued)

Raised Reflective Pavement Markers W/Nails

Initial: cost = \$3.50 each in place

2.00/marker 1.50/marker for holes drilled and masonry spikes

33% replacement after 18 months at \$4.00 each

the 4.00 replacement cost takes into account the initial sunk cost plus cost fo selectively placing the markers.

80' spacing (lane stripe) = \$306/mile

20' spacing (solid line) = \$611/mile

But their convenience and the possibility for reuse makes them the overwhelming choice based on service life costs.

#### IV. Results and Conclusions

The results of this study indicate that in general there are many fine products available to use as pavement markings in construction zones, (Appendix H) some of which can be installed on both cold and wet pavements. Some current manufacturers are currently developing new products which can be used in these conditions. In addition, other states are evaluating new experimental types of pavement markings. In general, the results indicate that most of those interviewed did not perceive shadow markings as being a problem; however, they have provided some remedies to this problem.

Specifically the following conclusions have been developed from this study:

1. There are several pavement marking materials to be used in construction areas. These products are (1) preformed construction grade tape, (3M-#5710), (2) raised pavement markers (Stimsonite #66), and (3) epoxy paint, if control does not have to be changed for several months. The preformed tapes include all forms of tapes discussed in this report. These three types of markings were recommended by the majority of respondents. Other types may be acceptable for use and are discussed in the report.

2. There are basically two types of acceptable adhesives to be used in the construction area, (1) the pressure sensitive type used on both preformed tapes and some raised pavement markers and (2) the standard two-component epoxy. One method which is still basically experimental (not widely accepted) is the use of masonry nails to attach RPMs and tack construction grade tape to asphalt pavement in construction zones. The pressure sensitive adhesive and the two-component epoxy is not as versatile with respect to installation in

adverse conditions as are the masonry nails. There is a safety factor to consider in the use of the nails which should be taken into consideration.

3. Wet pavement is a major problem because there are very few products which can be installed when there is visible moisture on the road surface. After the surface has either air-dried or thermal-dried (approximately 3 hours after a rain), all types of pavement markings can be applied.

4. When there is visible moisture on the road surface, there is only one acceptable method of installing the pavement markings. Masonry nails may be used to attach either the construction tape and/or raised pavement markers to wet asphalt. If this is not acceptable, a waiting period of several hours should be initiated.

5. Whereas cold ambient temperature is a problem in pavement marking installation, it is not as severe as wet pavement. Several methods and/or products can be used which will negate the adverse effect of the cold pavement temperatures. These various installation methods are, (a) use a pear-burner to heat the pavement prior to installation; (b) formulate the standard two-component epoxy so that it overcures generating excess heat which will warm the pavement and prevent the epoxy from becoming brittle too quickly; (c) when placing RPMs, heating the RPM before applying the epoxy helps overcome the effects of cold; (d) use hot thermoplastic as a pavement marking material in cold weather installation; (e) use nails to tack the pavement marking to the road surface; (f) certain temporary tapes (Catapol and 3M) can be applied to 20°F reported by the suppliers, even though ASTM says that pavement markings should not be installed in temperature below 50°F.

6. Most of the individuals that were contacted did not perceive the shadow (ghost) markings that are left on the roadway after the pavement markings have been removed to be a problem. They said the the major cause of these shadow markings are, (a) grinding or sand blasting to remove old

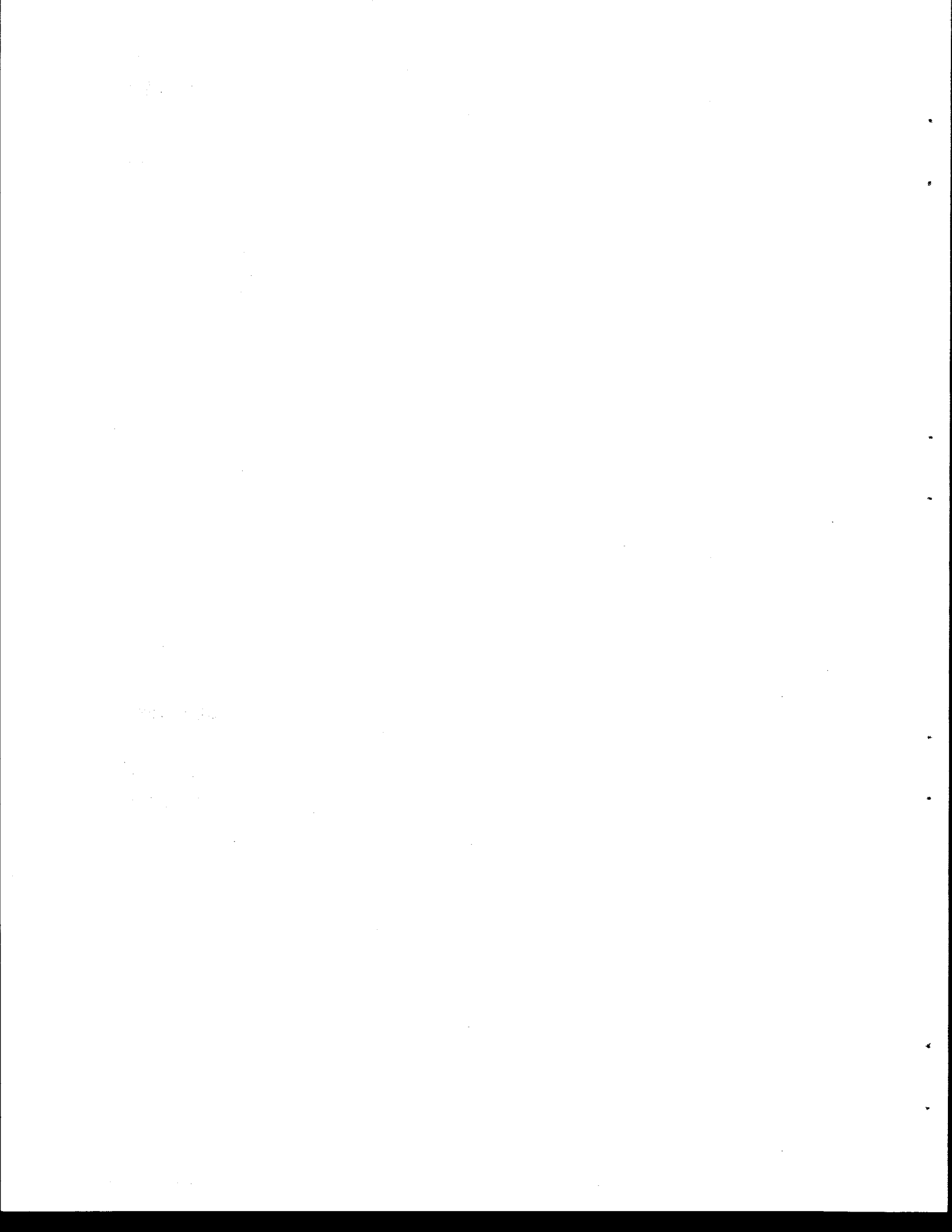
markings, (b) primer residue from temporary tape or (c) discoloration from protection by the pavement marking material. In general, they indicated that over time all shadow markings will either fade or wear off the road surface.

7. Some possible solutions to this problem include: (a) attach temporary tape without using a primer, (b) nail down both RPMs and temporary tape, (c) overlay with asphalt, and (d) on asphalt, use either an asphalt emulsion or melted bituminous material. The bituminous material is currently under investigation in Texas.

8. The results of the cost comparison indicate that for construction projects of more than 6 months duration on asphalt, the reflective raised pavement markers with spikes is the most cost efficient system. For construction projects of shorter duration, and where there is no change in traffic flow or traffic control, paint is the most cost efficient. In all other cases the hot thermoplastic materials are the most cost efficient.

9. Several experimental products are currently being developed or tested which will partially solve these problems. One is a pliant pavement marking tape which elongates under traffic then returns to its original shape; another is an all epoxy marking material similar to the "glow button", a natural rubber traffic button 1/2" high which must be installed above 50 F. Other types of developmental products are (a) pliant polymer pavement marking materials, (b) a removable paint for temporary markings, (c) epoxy which can be used where visible moisture is present, and (d) a plastic permanent tape.

Appendix A  
SDHPT Interview Questionnaire

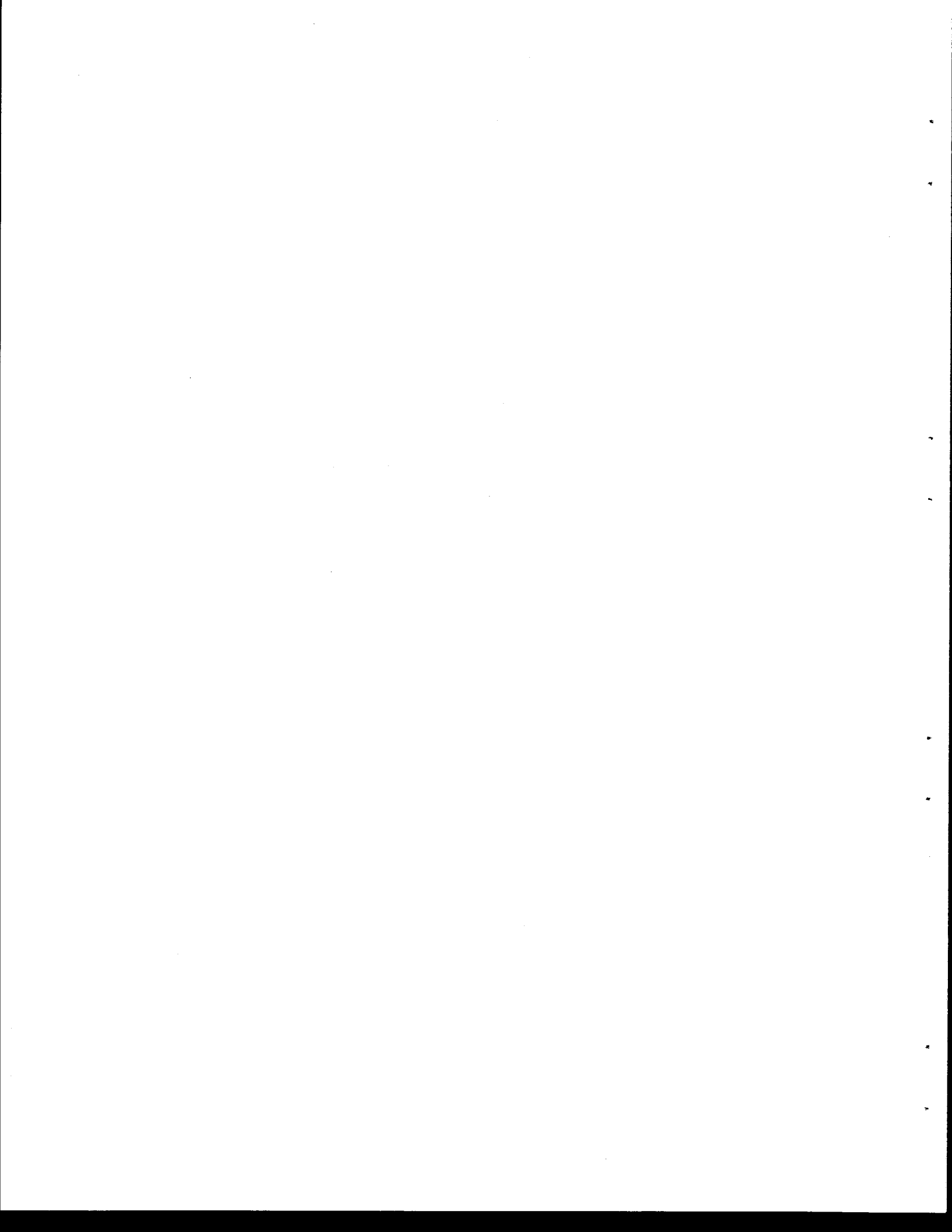


## SDHPT Questionnaire

### Col. No.

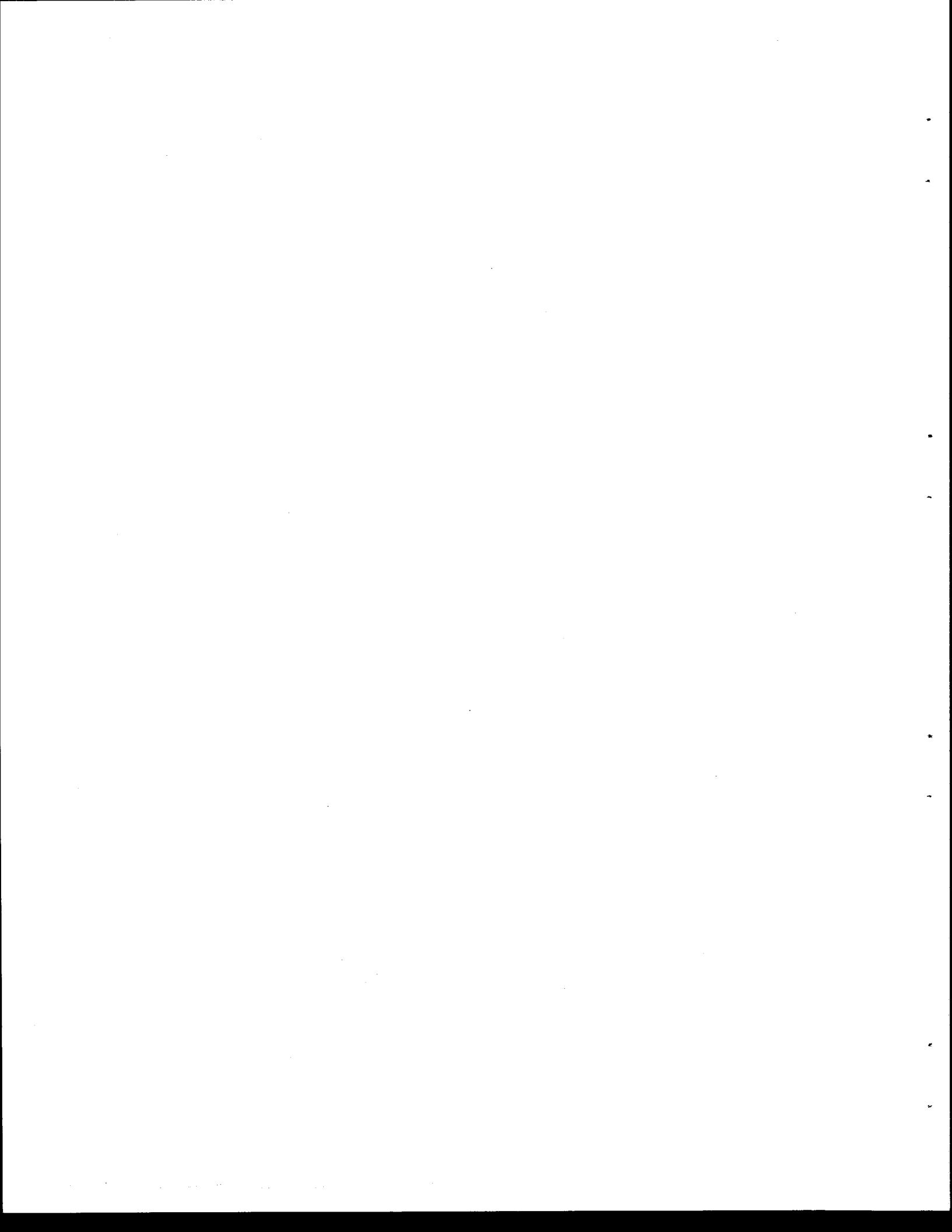
- 1 District #
- 2 City
- 3 Name of Respondent:
- 4 Title:

1. Do you use different pavement marking materials at construction sites other than those specified by the Department?
2. If so, what materials do you use in construction areas?
3. What is the type of pavement marking material you normally use in your district?
4. What type of adhesive (epoxy) do you use with each type of pavement marking (temporary only)?
5. Do you have any trouble applying it in cold weather (<45°F)?
6. If so, how do you counteract this problem?
7. Do you have any trouble applying these wet:  
Visible moisture on roadway surface?  
Three hours after rain?  
Three to six hours after rain?
8. If so, how do you counteract this problem?
9. Do you have a problem taking the pavement marking off the road (does it remove easily)?
10. Do you have a problem with a particular pavement marking material or adhesive leaving a shadow marking?
11. How do you counteract either of these problems?





Appendix B  
Other States DOT Interview Questionnaire



Other States SDHPT Questionnaire

Col. No.

- 1 State
- 2 Name of Respondent:
- 3 Title:

1. Do you use different pavement marking materials at construction sites other than those specified by the Department?
2. If so, what materials do you use in construction areas?
3. What is the type of pavement marking material you normally use in your district?
4. What type of adhesive (epoxy) do you use with each type of pavement marking (temporary only)?
5. Do you have any trouble applying it in cold weather (<45°F)?
6. If so, how do you counteract this problem?
7. Do you have any trouble applying these wet:  
Visible moisture on roadway surface?  
Three hours after rain?  
Three to six hours after rain?
8. If so, how do you counteract this problem?
9. Do you have a problem taking the pavement marking off the road (does it remove easily)?
10. Do you have a problem with a particluar pavement marking material or adhesive leaving a shadow marking?
11. How do you counteract either of these problems?

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100

100

100

100

100

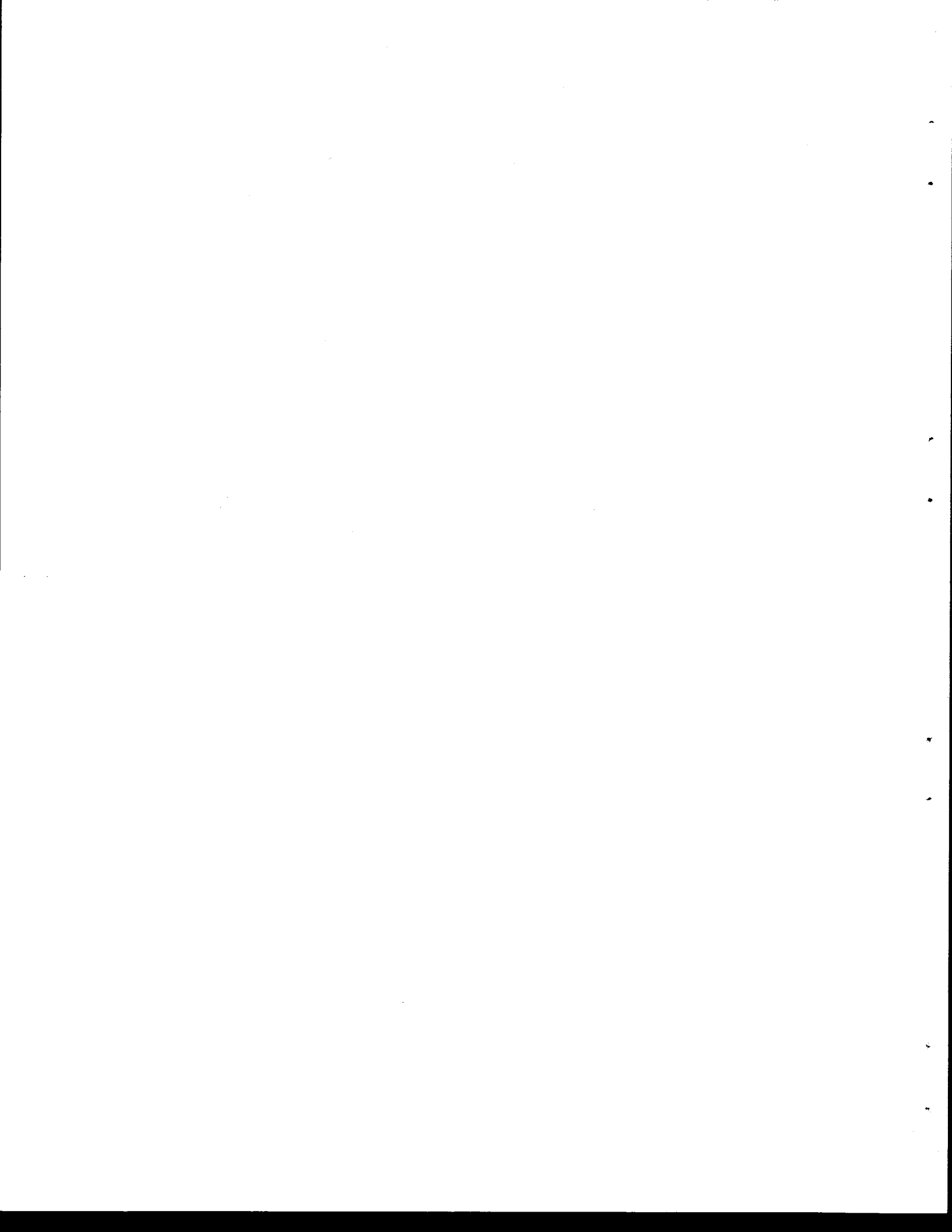
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100

100

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Appendix C  
Suppliers Interview Questionnaire



## Suppliers Questionnaire

Firm:

Name of Respondent:

1. What types of pavement marking materials do you recommend for construction sites?
2. What type of adhesive (epoxy) is recommended for use with those materials?
3. Can it be applied in cold weather (<45°F)?
4. If so, what do you recommend using below that temperature?
5. Can it be installed (applied) on wet pavement?
6. What do you recommend for wet pavement?
7. Will the pavement markings leave a ghost marking when taken off the road or moved?
8. What do you recommend to use to avoid the shadow markings?

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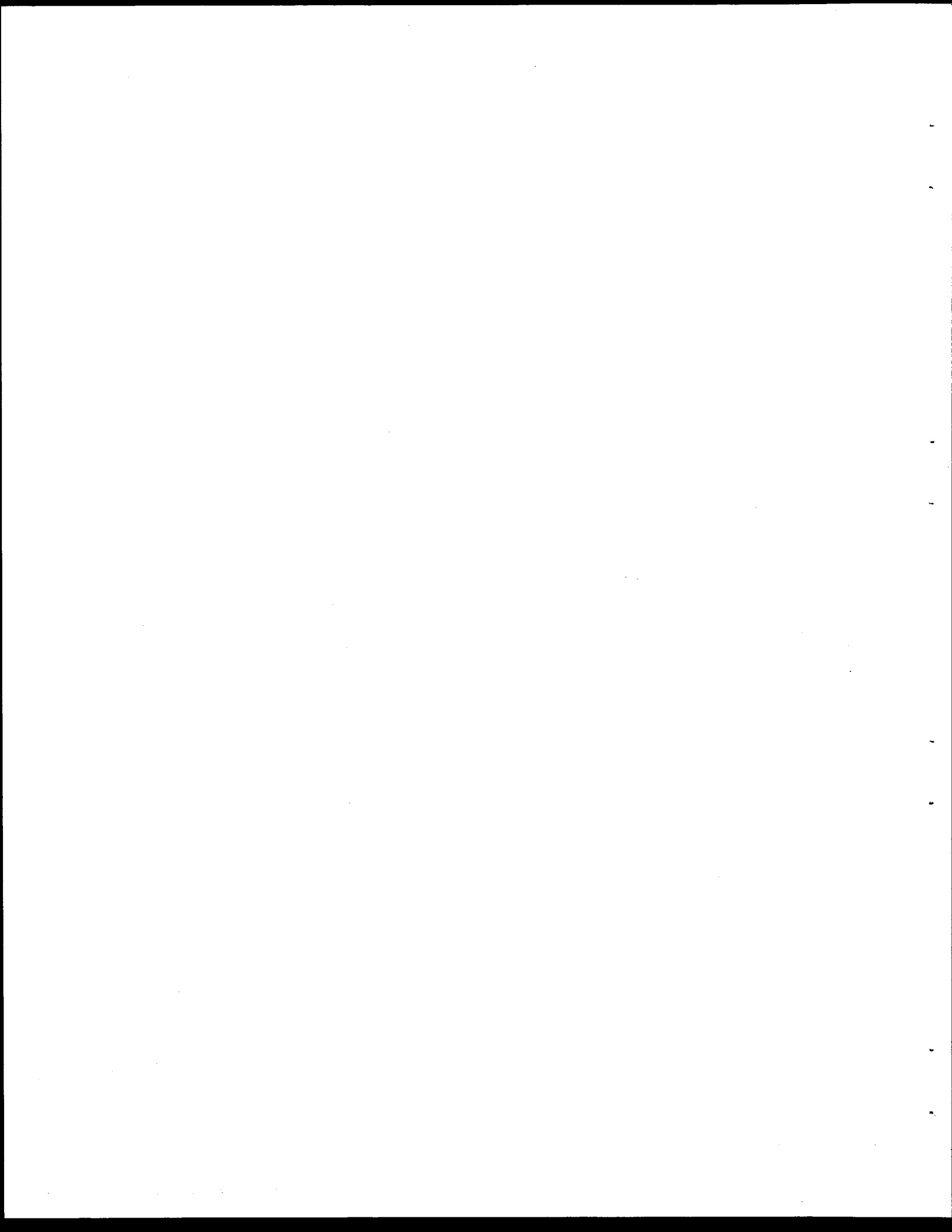
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Appendix D  
Installation Contractor Interview Questionnaire

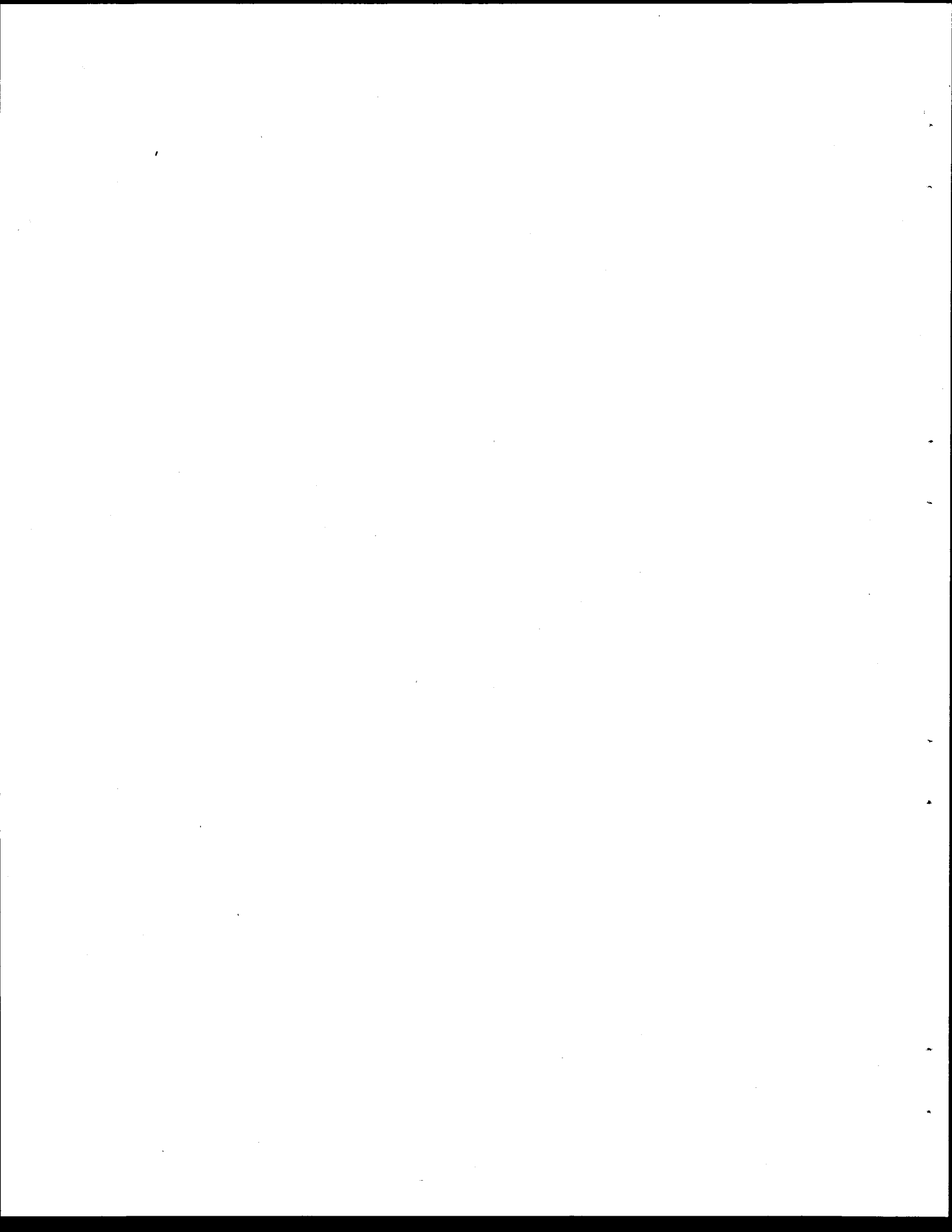


## Installation Contractor Questionnaire

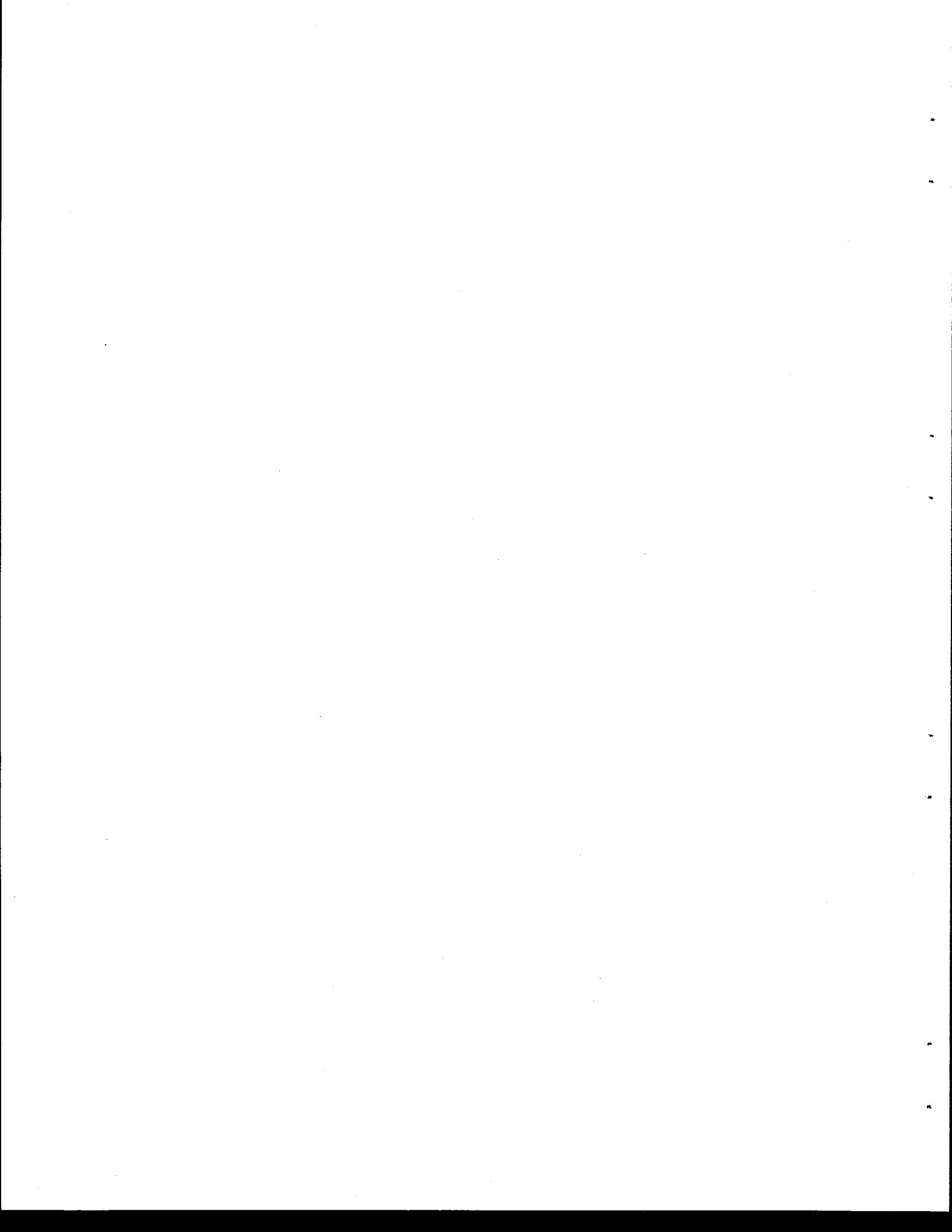
Firm:

Name:

1. What pavement marking materials do you install (or recommend) at construction sites?
2. What type of adhesive (epoxy) do you use with those pavement markings?
3. Do you have any problems applying them when:
  - There is visible moisture on roadway?
  - Three hours after rain?
  - Three to six hours after rain?
4. What adhesive do you recommend to use when applying to wet surfaces?
5. Do you have any problem applying these pavement markings in cold temperatures (<45°F)?
6. What do you use (or recommend) in cold temperatures?
7. Do you have any problem with ghost markings when using these types of adhesives or pavement markings?
8. If so, what do you recommend to use to avoid the ghost (shadow) markings?



Appendix E  
Manufacturers Interview Questionnaire

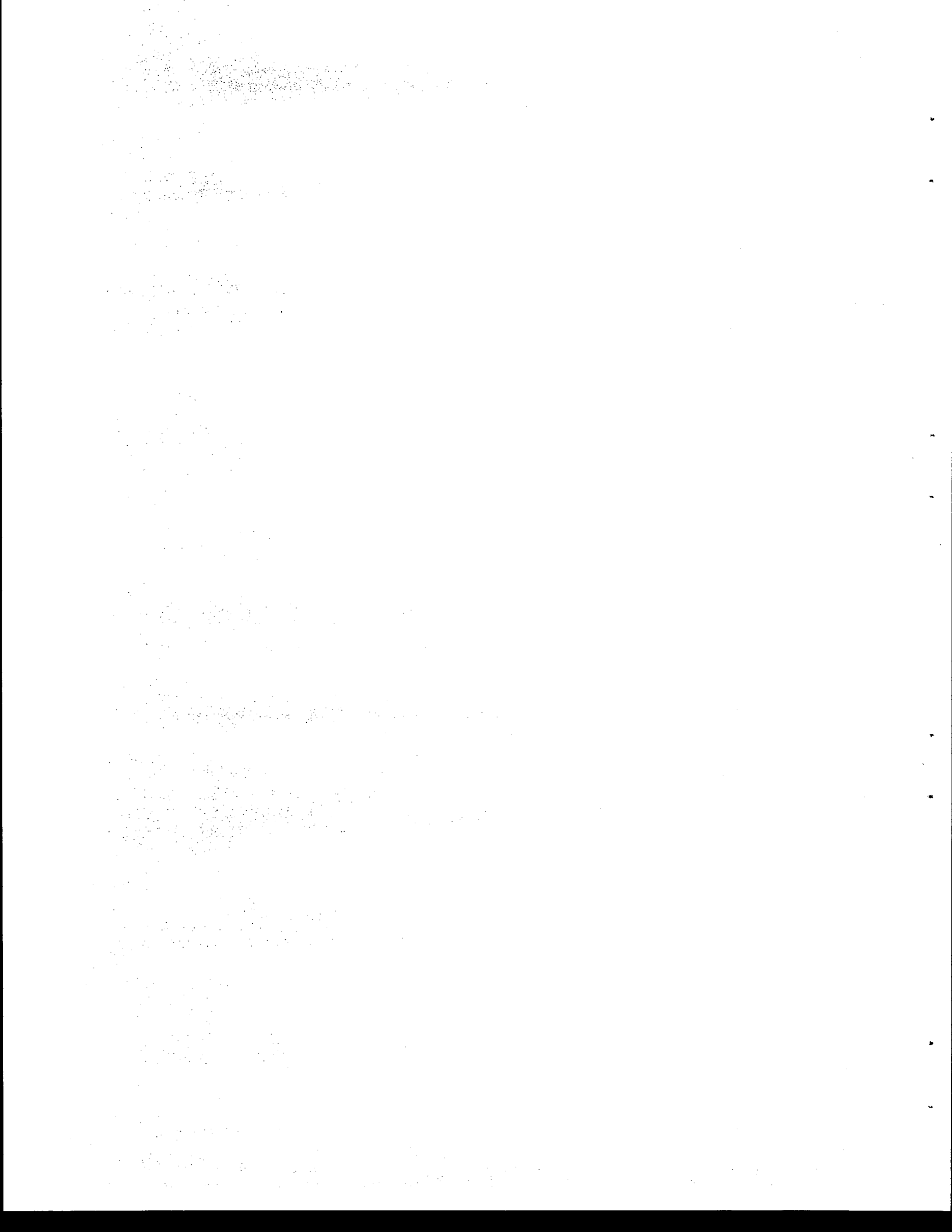


## Manufacturers Questionnaire

Firm:

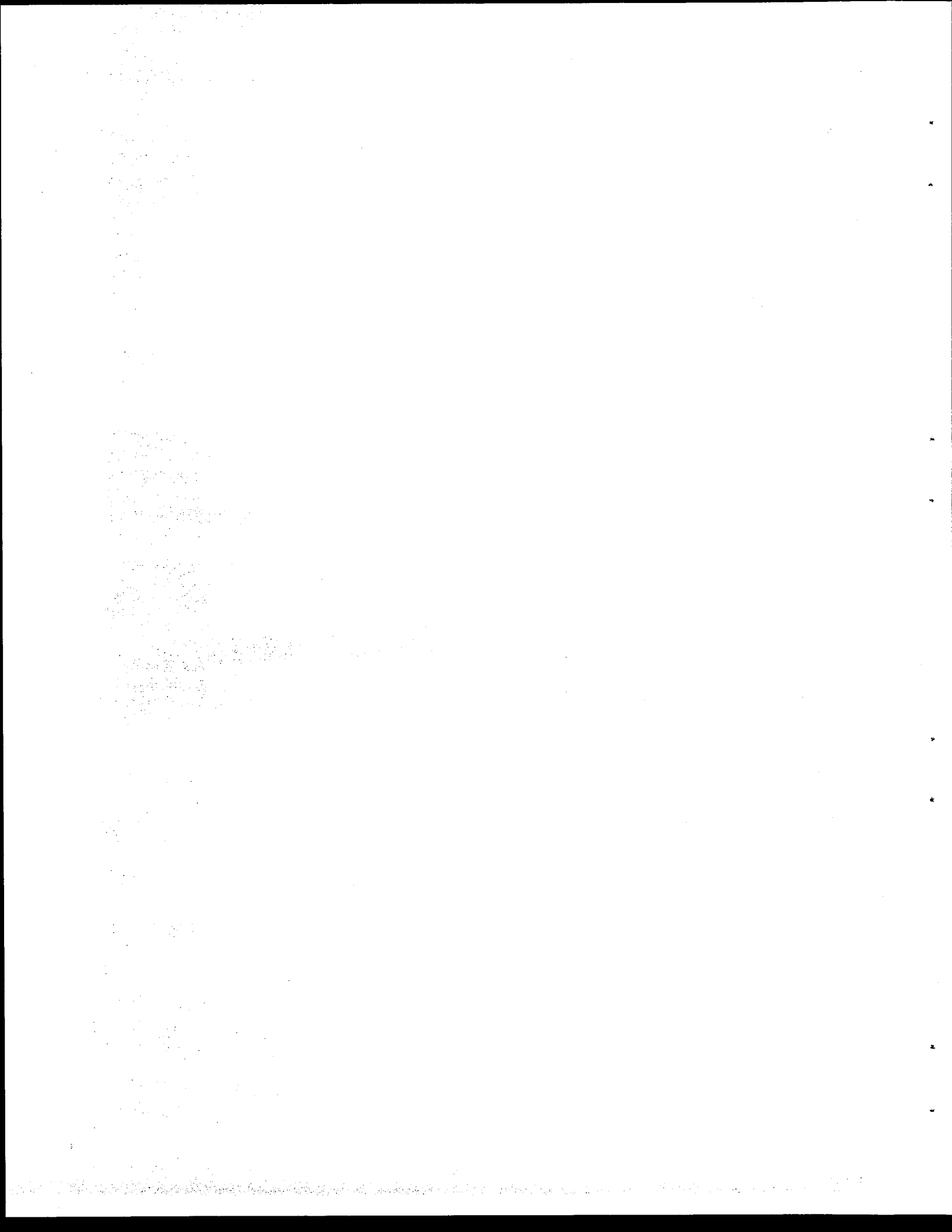
Name:

1. What pavement marking material does your company recommend to use in construction sites?
2. What type of adhesive (epoxy) do you use with these pavement marking materials?
3. Can they be applied in cold temperatures (<45°F)?
4. What does your company recommend to use for applying pavement markings in all weather?
5. Can they be applied to wet pavement?
6. What does your company recommend to use for applying pavement markings to wet pavement?
7. Will this adhesive or pavement marking material have ghost markings when removed?
8. What does your company recommend to use to avoid the ghost markings?
9. Is your company, at present or in the future, considering developing a pavement marking material or an adhesive which would solve all these problems discussed previously?





Appendix F  
Consolidated Survey Responses



## SDHPT Responses

### Question Number

### Responses

1  
19 - No  
5 - Yes  
2 - Did not reply

---

2  
10 - Stick-on tape  
- 3M  
- Prismo  
- Plank  
- Preslab  
5 - Texas paint  
3 - Nailed reflective raised pavement markers  
2 - Hot thermoplastic

---

3  
In construction zones  
16 - Stick-on tape  
13 - Texas paint  
6 - 3M construction grade  
1 - Felt-back tape  
1 - Foil-back tape  
1 - Reflective raised pavement markers  
  
In all other cases  
8 - Thermoplastic (both hot and cold)  
7 - Texas paint  
4 - Reflective raised pavement markers

---

4  
7 - No epoxy or adhesive required  
5 - Whatever adhesive is in the warehouse  
3 - Nails for raised pavement markers  
3 - Two component epoxy  
1 - Do not know

---

5  
15 - Do not apply when temperature is below 45 F  
9 - Apply when temperature is below 45 F  
1 - Does not apply if pavement is a hot mix

---

6  
4 - Wait until it warms up  
2 - Apply heat (pear-burner)  
2 - Reapply if markers come up  
2 - Paint  
1 - Nail reflective raised pavement markers  
1 - Use adhesive designed for cold installation

SDHPT Responses (con't)

Question Number

Responses

7

- 19 - Have trouble applying wet
  - 5 - Never apply when wet
  - 1 - No problem applying wet
- 

8

- 22 - Wait until pavement dries (approx. 3 hrs.)
  - 1 - Uses cones to keep traffic off until pavement markings dry
  - 1 - Nail reflective raised pavement markers
  - 1 - Temporary tape on asphalt works well
- 

9

- 12 - Have problems removing markers from pavement
  - 10 - No problems when stick-on tape has been used
  - 1 - More difficult to remove in hot temperature
  - 1 - More difficult when foil back tape is used
  - 1 - Extremely difficult when paint has been used
  - 1 - More problems when buttons are used
  - 1 - Felt-back tape easiest to remove
- 

10

- 19 - Have a problem removing the marker without leaving a shadow
  - 4 - Paint hardest to remove
  - 3 - Raised pavement marker extremely difficult
  - 1 - If stripes have been left on for long periods of time
  - 4 - Stick-on tape no problems
  - 1 - No problem in warm weather
  - 1 - No problem at all
- 

11

- 14 - Do nothing, let the shadow marking wear off
- 4 - Overlay with asphalt
- 1 - Use of emulsion compound helps
- 1 - Sand blasting leaves a permanent mark on asphalt

Adjacent States DOT Responses

1

- 3 - yes
- 3 - no
- 2 - no response

Adjacent States DOT Responses (con't)

Question Number

Responses

2	4 - Use Raised Pavement Marker in construction zones 1 - Use an experimental L-shaped plastic marking material, adhesive-back 1 - Uses an epoxy marking material 1 - Uses 1/2" natural rubber button which must be installed above 50°F
3	7 - Uses 3-M tape 5 - Raised Pavement Markers 5 - Paint 1 - Construction grade 1 - Stamark 1 - Scotch foil-back tape
4	3 - Self-adhesive pavement marker 2 - Do not know 1 - Standard epoxy
5	6 - Have problems installing markings in temperatures below 45°F 1 - Does not have a problem because they apply on hot mix 1 - Never applies on cold temperature 1 - Have problems installing raised pavement marker in cold weather
6	2 - Avoid cold temperature 2 - Do not know what is done to avoid the problem 1 - Warms the raised pavement marker before installation
7	4 - Have problems installing pavement markings on wet pavement 1 - Foil-back tape comes up immediately if applied on wet pavement 1 - Never applies markings on wet pavement
8	2 - Blow-dry pavement 1 - Reapplies stripes or markers that come up 1 - Wait until pavement dries

Adjacent States DOT Responses (con't)

Question Number

Responses

9

- 6 - 3-M foil tape removes easily
- 1 - 3-M foil tape in hard to remove
- 1 - Tape not to be used on roads with high traffic volumes or when the tape has been punctured because it will break into pieces
- 1 - Use heat on foil type tape to get it to come up after being installed for long periods of time

10

- 6 - Yes they have problems with shadow markings
- 2 - No problem with shadow markings

11

- 4 - Let the shadow markings fade from pavement
- 1 - Use asphalt emulsion to cover shadow markings
- 1 - Shadow markings not a problem

Supplier Responses

1

- 1 - Catapol - Prefabricated tape
- 1 - Aluminum foil tape
- 1 - 3-M Plastic tape
- 2 - RPMs (Stimsonite #66)
- 1 - 3-M Plastic tape

2

- 2 - Self-adhesive materials
- 2 - Two-component epoxy
- 1 - Prisma1
- 1 - Melted Bituminous Material

3

Catapol tape applied above 32°F, aluminum foil-tape-applied at or above 50 F, Melted Bituminous-can be applied below 45 F, 3-M tape can be applied below 45 °F, Prisma1 needs to be heated

4

Type I-M Epoxy (rapid set) down to 30°F, 3M tape-can be applied down to 20°F, Prisma1-can be applied cold, however minimum temperatures not known Catapol tape-down to 32°F

Supplier Responses (con't)

Question Number

Responses

5 None of the above materials is recommended to be put down of wet pavement

6 In an emergency use 3-M tape. 3-M plastic tape can be applied wet - lasts a few weeks 2 - Let surface dry to touch

---

7 Use removable tape  
Non-sticking thermoplastic  
3-M on concrete, leaves some but dissappears  
Let them fade out

---

8 Use removable tape  
Non-setting thermoplastic  
3-M on concrete leaves no scars  
Let them fade out

Installation Contractors Response

1 8 - Temporary tape  
3 - 3M (5710) tape  
2 - Foil back tape (Flexalite)  
2 - Thermoplastic  
2 - Raised pavement markers  
2 - Paints

---

2 3 - Self-adhesive  
2 - 2 component epoxy  
1 - P-46 Primer with tape  
1 - Never uses adhesives for temporary cases

---

3 8 - Have problems, never apply on wet pavement  
1 - No problem when using 2 component epoxy

---

4 2 - Standard 2 component epoxy  
1 - P-46 Prime  
1 - Blow dry surface

## Installation Contractors Responses

<u>Question Number</u>	<u>Responses</u>
5	2 - Yes, they have problems with cold 2 - Yes, cold temperature on concrete 2 - No problem with cold temperature on asphalt 1 - Yes, when using thermoplastic 1 - No problem at all with cold 1 - Yes, on surface treatments
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6	2 - In cold weather use paint 1 - Use a type 1 (rapid set) two-component epoxy 1 - Nail RPMs 1 - Reapply cold thermoplastic that comes up
<hr style="border-top: 1px dashed black;"/>	
7	4 - Yes they have a problem with shadow markings 4 - No, they do not have a problem
<hr style="border-top: 1px dashed black;"/>	
8	2 - Pre-fabricated tape 1 - 3-M #5710 1 - P-46 Primer will leave a residue when tape is pulled up

## Manufacturers Responses

1	5 - Construction foil-back tape 4 - Raised pavement marker 3 - Pliant Polymer tape (Scotchlane 5710) 2 - Paint/Thermoplastic (30 mil if later overlaid) 1 - Reflectorized flexible posts 1 - Ferro marker 1 - Model 66 (Stimsonite) 1 - Removable paint
<hr style="border-top: 1px dashed black;"/>	
2	3 - 2 component epoxy 2 - Pressure sensitive tape adhesive 2 - Primer, when temperature is above 60°F or for preformed tape 2 - Bituminous material 1 - Manufacturers recommended sealant



Manufacturers Responses (con't)

Question Number

Responses

3

- 2 - Pressure sensitive
- 2 - Two-component epoxy
- 2 - Foil tape on new asphalt
- 2 - Hot thermoplastic
- 1 - Preformed tape; Primer must be used
- 1 - Melted bituminous material
- 1 - Masonry nails

4

- 3 - Pressure sensitive (RPMs and tape) (T<,or=to35°F)
- 2 - Nailed down RPMs
- 1 - Two-component epoxy
- 1 - Surface can be heated
- 1 - Melted bituminous material (T<or=to 32°F)
- 1 - ASTM recommended no markings placed down with temperatures less than 50°F
- 1 - Hot thermoplastic (T<or=to 32°F)

5

- 3 - Yes, these can be applied to wet pavement
- 3 - There is no satisfactory product which can be installed on wet pavement

6

- 2 - Heat road surfaces
- 2 - RPMs nailed down
- 1 - Air-dry road surface
- 1 - Tape with proper adhesive system
- 1 - Epoxy paint for not-removable markings
- 1 - Primer/sealant require dry pavement
- 1 - Two-component epoxy

7

- 1 - Yes, after extended service period
- 1 - Grinding leaves shadow markings
- 1 - Bituminous materials will not leave shadow markings
- 1 - Cold tape leaves no shadow markings
- 1 - Primer/sealant will leave residue

Manufacturers Responses (con't)

Question Number

Responses

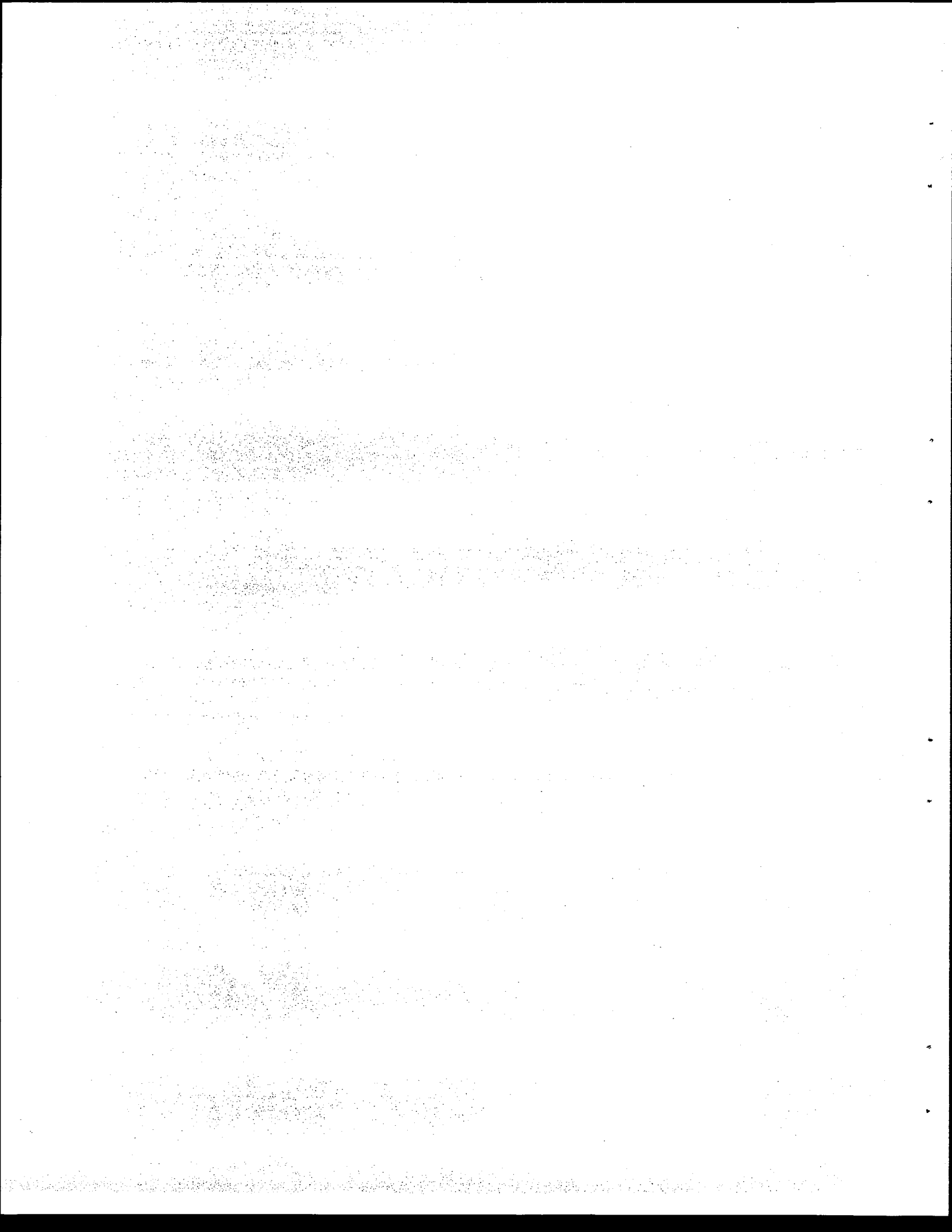
8

- 3 - Temporary tape
  - 1 - Two-component epoxy over cured will not leave much of a shadow marking but more markers will be lost due to impact
  - 2 - Melted bituminous material
  - 1 - RPMs with masonry nails
- 

9

- 1 - Developing a product which addresses the cold/wet problem
- 1 - Removable paint
- 1 - Epoxy used on bridge piers
- 1 - Pliant polimer temporary tape
- 1 - Plastic pavement tape

Appendix G  
Annotated Bibliography



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Traffic Engineering & Control

FOCUS ON ROAD MARKINGS AND MATERIALS

March 1970: 551 p.

An introductory article by J.T. Duff discusses the five papers which review road marking materials and practices in England, Western Germany, the Netherlands and the United States. "Road Markings in the United Kingdom," J.G. James reviews past and present practices; "Road Markings in the Federal Republic of Germany," Siegfried Giesa gives a comparison of the costs, life and reflectivities of paints and plastics; "Test Stripes of Durable Road Markings", H. Schram describes performance tests in the Netherlands; "Practice and research in the United States", Robert E. Conner includes Discussion of New Marking Standards" and "Delineator Effectiveness for Median Visibility", Jason C. Yu continues the discussion of United States studies in regard to reflective delineators.

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Highway Research Board Bulletin

PAVEMENT-MARKING MATERIALS: AN ANNOTATED BIBLIOGRAPHY

1952: 128

An annotated bibliography is presented of 234 references arranged by year of issue on pavement marking materials.

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Highway Res. Circular

USAGE OF PAVEMENT MARKING MATERIALS BY GOVERNMENT AGENCIES IN THE UNITED STATES

April 1968: 20 p.

Data obtained by sending a questionnaire to all states and selected cities and countries indicate that in 1965 state highway departments used approximately 8,000,000 gallons of white paint, 4,000,000 gallons of yellow paint, and 66,000,000 pounds of glass beads. It is estimated that 26% of the white paint was used in edge striping. Cities and counties combined are estimated to have used approximately 5,700,000 gallons of white paint, 3,800,000 gallons of yellow paint, and 41,000,000 pounds of glass beads. The use of paints of colors other than yellow and white, raised button markers, and thermoplastic materials for pavement marking is increased.

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Baumann, FH

REVIEW OF TRAFFIC-PAINT RESEARCH

Highway Research Board Bulletin

1952: 31 p.

In the early years of the present century it became apparent, with increasing demand for traffic stripes, that paints must be developed which had certain special properties. This paper is an outline of the recorded research for the formulation and testing of traffic-marking paints. Consumers' and manufacturers' opinions on improved properties of traffic paints point the way for additional research. Author

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Keese, CJ; Benson, FJ

THERMOPLASTIC STRIPING COMPOUNDS

Highway Research Board Bulletin

1952: 59 p.

In 1949, the Texas engineering experiment station inaugurated a research project to develop a compound for striping pavements which would produce stripes with longer service life than those now in general use. The Road Research Laboratory in England during World War II developed a satisfactory striping compound of a mixture of rosin, mineral oil (a plasticizer for the rosin), pigment, filler, and sand. The mixture is heated to 135 C and placed, while hot, to a thickness of about 1/8 in. Stripes laid in Texas in accordance with the British formulation proved to be too soft, were subject to rather severe discoloration by the adhesion of road dust and tire film to the surface of the stripe, and showed poor adhesion to portland-cement concrete. But the results were sufficiently encouraging to warrant a decision to study modification of the British formulation. The striping compound produced by adding alkyd resin to the rosin-plasticizer mixture has shown excellent characteristics. The stripe does show discoloration under traffic, and studies are currently under way in an attempt to improve this characteristic. The rosin striping compound has been rated for service life by laying transverse stripes on asphaltic-concrete and portland-cement-concrete pavements. Glass beads have been incorporated in parts of the stripes. Four of the rosin-base stripes have been in service for 12 to 14 months. Eight rosin-alkyd resin stripes have been in service for 6 to 8 months. And a large number of others have been in service for lesser periods of time. Results to date indicate that the rosin-base stripes will have a service life of two to three times that of the comparative paint stripes. Ingredients in the rosin-base stripe are such that the cost of the materials compares favorably with the cost of paint. Author

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Burch, RA

PERFORMANCE TEST: PAVEMENT MARKING MATERIALS

Highway Research Board Bulletin

1952: 98 p.

The possibility of finding a method to make awards for pavement marking materials on a performance basis is explored. It is intended to apply pavement marking materials applied by vendors transversely to a heavy traffic volume highway in order to get accelerated wear and shorten required time of test. The material tested was of the pre-mixed reflectorized type. Methods of rating performance of these materials are discussed. A method to arrive at a numerical value of cost is presented. It is concluded that more work is needed to develop a convenient practical field method to evaluate the performance and characteristics of material. Development of a direct-reading photometer would be helpful.

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Schram, H

TEST STRIPES OF DURABLE ROAD MARKINGS

Traffic Engineering & Control

March 1970: 543 p.

Recent developments of road marking materials in the Netherlands and performance tests carried out are described. The physical qualities tested are defined and then results of the tests are briefly discussed. [rr1(a)]

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United States Patent Office

U.S. PATENT SPECIFICATION NO. 3,421,911. PLASTICIZER FOR SULFUR ROAD MARKING MATERIAL

January 1969

REPORT NO: 3

Plasticized sulfur road-marking compositions prepared by reacting a major amount of elemental sulfur and a minor amount of diacyl disubstituted glycol polysulfide plasticizer are described. (RRL)

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Highway Research Information Service

ADHESIVES, BONDING AGENTS AND THEIR USES

February 1970: 2 p.

These references on adhesives, bonding agents and their uses include: Theory and Practice of Organic Coatings, Application and Technology of Epoxy Resins, Guides to Structural Adhesives and use of Epoxy Compounds with Concrete, Epoxy Resin Paving Cements, Epoxy Bonding compounds as Shear Connectors in Composite Beams, Traffic Line Markers, Structural Repair and Material, Adhesion Testing, and Effectiveness of Epoxy Resin and Polyester Resin to Strengthen Fractured Granite.

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Dale, JM

DEVELOPMENT OF IMPROVED MARKING MATERIALS-LABORATORY PHASE

Highway Research Board

1967: 24 p.

Laboratory tests and field studies were conducted on the performance characteristics of conventional pavement marking materials currently in use. A discussion was presented of their shortcomings and studies conducted on the physical nature of reflective materials, with particular emphasis on performance characteristics under various types of water films. A new pavement marking was designed and tested with encouraging results. A systematic approach for the design of a pavement marking system has been developed wherein one qualifies the surface to be marked, determines the water film thickness to be encountered, and then selects one of the several marking systems that will perform under the imposed conditions. Pavement markings may fail by mechanisms other than loss of their upper surface. A glass bead system having a uniform size gradation matched to the binder thickness could be used in these cases. Experiments were conducted to determine the effectiveness of silicone-treated glass beads and the optimum depth of imbedment for glass beads to maintain maximum retroreflection. The feasibility of applying a surface coating of small beads to a carrier (p-gravel) was investigated as a way to obtain a large-diameter reflecting material that would protrude through submerging water films. The researchers developed a new system: one quarter-in. diameter glass beads are imbedded in the pigmented epoxy binder. The markers' ability to be visible at night when wet was judged excellent. The low-profile marker is not likely to be damaged by snow plows. Implementation of the concepts presented should provide a more visible pavement marking that will increase the safety aspects of the highway, particularly on rainy nights.

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Missouri State Highway Commission

INVESTIGATION OF PAINTS AND GLASS BEADS USED IN TRAFFIC DELINEATION MARKERS-  
PHASE 2

January 1972: 54 p.

A Missouri dispersion resin-varnish paint and a Missouri chlorinated rubber-alkyd paint were used as a guide to determine the relative wear resistance qualities of several proprietary high heat paints. The ratings were based on field evaluations of the wear resistance of transversely-placed paint stripes. The results indicated a wide range of life expectancies for the various proprietary paints. One high heat paint, type "g", was equal to or better than the Missouri paints and the other high heat paints evaluated. The general appearance rating system was used to visually evaluate the transverse stripes. This rating system was used in a previous paint study and was found to correlate best with actual stripe life for pavements in the state of Missouri. Visual evaluation of abrasion and chipping, as described in ASTM, was also used. (FHWA)

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Lanz, LJ

ROAD MARKING MATERIALS, 2ND INTERIM REPORT

Mississippi State Highway Department

July 1973: 41 p.

This report of road marking materials in an interim report on a type "b" state study. Traffic paint, thermoplastic and raised markers are discussed, and merits and shortcomings noted in evaluations are listed. Results of paint and bead studies were published in a previous report for this study but are included for comparisons. Thermoplastic sections have been in service for eleven years in the state and all but two sections are still in service. Results show the state can plan on ten years service for thermoplastic installations. Raised ceramic and reflective markers have been in place on Mississippi roadways for over three years and experience with these markers is limited. Estimated annual loss rate is 2-5% of reflective markers and 5-10% of ceramic markers. Many of these markers failed because of poor bond. Traffic is detrimental to ceramic markers in curves and in areas with much lane crossing. Replacement of ceramic markers is necessary in several locations where up to fifty percent are missing in one-half mile stretches. Raised reflective markers are recommended to supplement paint or thermoplastic stripes to provide lane delineation during inclement weather. Reflective markers must be used with ceramic markers to provide night time delineation. (FHWA)

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Rooney, HA; Shelly, TL

COATINGS AND PAVEMENT MARKING MATERIALS

California Division Highways

1935: 42 p.

The state of California Division of Highways has continued evaluation of zinc rich primers for use on structural steel. The organic vehicle type described in this report has proven in laboratory and field tests to be essentially equal in durability to the inorganic vehicle type, without the sophistication in application and liability to early failure caused by faulty application of the latter. Formulations have been made for 20-30 second dry to no pick-up heated traffic paints, and specifications of a performance type are being prepared. Formulations for four types of concrete curing compounds and a rapid dry heavy equipment and truck enamel are discussed. (FHWA)

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Lanz, LJ

ROAD MARKING MATERIALS 1ST INTERIM REPORT

Mississippi State Highway Department

July 1972: 32 p.

Traffic paint, thermoplastic and raised markers are discussed: merits and shortcomings noted in evaluations are listed. Results of paint and bead studies were published in a previous report; however, they are included for comparisons. Thermoplastic sections have been in service for ten years in the state and all but one are still in service. Raised ceramic and reflective markers have been in place on Mississippi roadways for less than two years and experience with these markers is limited. Ninety-eight percent of reflective markers and ninety-four percent of ceramic markers remain in place after one year service. Many of these markers failed because of poor bond. Traffic is detrimental to ceramic markers in curves and in areas with much lane crossing. Replacement of ceramic markers is necessary in several locations where up to thirty percent are missing in one-half mile stretches. Combinations of paint, thermoplastic and ceramic markers are recommended with raised reflective markers for low, medium and high volume roads to provide effective delineation for all conditions except snow. (FHWA)

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Federal Highway Administration

FIRST REPORT OF A CONTINUING TYPE B STUDY-AN EVALUATION ROAD MARKING MATERIAL

REPORT NO: Study 52

Seventeen commercial traffic paint formulations were supplied which were evaluated on three types of roadway surfaces with the present state specification paints as a control. The state paint was used for studies of

film control. The state paint was used for studies of film thickness and application rates for beads. Some sections of test paints have been in place for less than a year; therefore a complete evaluation was not attempted. The study of glass marking beads indicates better reflection is obtained with glass spheres having a high index of refraction. Six pounds of beads per gallon and fifteen mils wet film thickness provided the most durable stripe. Bisymmetric beads provide better initial reflectance because they do not become covered with paint during application as do most other beads. When the existing stripe is missing or very poor, the fifteen mil film thickness stripe should be placed. Author

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Elkin, BL; Belensiefer, WL

#### TRAFFIC MARKING MATERIALS EXPERIMENT

Indiana State Highway Commission

REPORT NO: Hpr-1 (8)

Various traffic and bead combinations were evaluated. The paint and bead combinations were applied to portland cement concrete and bituminous surface and were allowed to weather approximately one year. Two types of white traffic paint and three types of reflective glass spheres were used. Two rates of application (4#/Ga and 6#/gal.) were used. The conclusions are as follows: (1) an adequate film, 12 to 15 mils thick, of rubber base applied to a clean, dry surface is suggested; (2) a bead comparable to #2 of this report at the rate of 4 lbs to the gallon should be used; and (3) the effectiveness of traffic stripe cannot be established during daylight hours. After one year deterioration in which the stripe had lost approximately 50% of its beads, it was still a serviceable guide in morning fog when visibility was limited to 50 feet. (FHWA)

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Rizenbergs, RL

#### DEVELOPMENT OF SPECIFICATIONS FOR REFLEX-REFLECTIVE MATERIALS, JULY 1970

Federal Highway Administration

REPORT NO: 65-37; PB-196004

Evolutionary changes in highway design, automobiles and retro-reflective products prompted Kentucky to undertake a study to update specification requirements for signing materials, delineators and coating compounds. The study was primarily concerned with geometric relationships between the driver, headlamps and traffic signs; investigation of reflectivity, color, durability and other properties of available reflective materials; adoption of commercially available testing apparatus to measure material properties; and development of test procedures. A review of specific sign viewing conditions on the road indicated the appropriateness of reflectivity testing at 0.5 degrees and 0.2 degrees angles of divergence. These angles, however, limit examination of materials at viewing distances in excess of 300 feet to the sign. Selection of a maximum angle of incidence of 30 degrees was found to be more than adequate to insure the performance even in the most extreme

situations of sign viewing. An esna reflex photometer was found to be an acceptable tool for reflectivity testing. The adoption of the device, however, required substitution of association instrumentation and development of testing procedures. The data on some color materials compared favorably and on others differed significantly, but the data could be corrected to yield comparable values. Color requirements for commonly used sign sheeting materials were defined in terms at cie chromaticity coordinate limits. A colorimeter was acquired to serve as a quality control tool for specific materials. To enhance nighttime reflectance of highway signs under wet conditions sign materials were required to exhibit smooth, flat surfaces. A glossmeter was adopted for testing surface sheen of materials to insure the desired texture. Accelerated weathering tests were conducted on various brand-name retro-reflective materials. An 800-hour weatherometer test was judged to be sufficient for durability testing of sign sheeting and coating compounds and that they should retain 80% of minimum specified reflectivity. A revised specification for reflex-reflective materials was prepared. Author

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## Colorado Department Highways

### REFLECTIVE TRAFFIC BEAD STUDY-FOURTH INTERIM REPORT

REPORT NO: 1484-6

Results of the traffic bead study performed on I-70 near Bennett, Colorado, continue to show that the small uniformly-graded glass beads that float on a xylol solution are superior in both brightness and durability to the traffic beads that the state has been using. The floating beads, when applied to a paint stripe at a rate of four pounds per gallon of paint, will outperform nonfloating type beads when applied at a rate of six pounds per gallon. The greatest cause of bead failure on concrete pavement has been the chipping of the paint from the concrete surface. This is caused mostly by the buildup of the old paint stripe to a point where there are a number of layers of paint. The action of traffic on this slab of paint causes cracking and eventual chipping. The need for restriping is usually dependent on daytime appearance rather than nighttime reflectance of stripes. Tests performed in 1968-1969 indicate that both the small, single-size gradation of the new type bead and the floating characteristics are responsible for the improvement in nighttime brilliance over the old irregular bead. Contrary to the initial premise that various graded, floating beads would not be as durable as various size beads with high index, the new bead appears to be just as durable as the old bead. Author

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## NCHRP Synthesis of Highway Practice

### PAVEMENT TRAFFIC MARKING

Center-line and edge marking of the 3.8 million miles of the U.S. Highway System has led highway agencies to try to increase the durability and decrease the drying time of traffic paint, as well as to obtain a less expensive paint. Although durability has been improved by better selection of pigments and vehicles, other factors that influence the performance of traffic are less easy to control, including the substrate, pavement surface preparation, humidity and temperature during and after application, and application

equipment. The present report is a synthesis of traffic-marking practices found to be most effective from the standpoint of serviceability. The main chapter headings are the following: introduction (history, development of traffic paint, individuals involved in pavement marking, organizations involved with traffic marking materials), materials (traffic marking material, raised markers), procurement (paint purchasing, contract pavement marking), equipment--procedures--policies (paint striping equipment, equipment for heated paint, high-pressure spraying systems, paint-line protection devices, materials supply, crew size, grooving of pavement for increased night visibility, paint removal, requirements and warrants for striping), and performance--evaluation--problems--research and development (current research, future research).

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Bollag, M

RUNWAY MARKINGS - A SAFETY FACTOR

June 1972: 111 p.

Modern airport runway requirements and practices are discussed. The requirements discussed include: visibility by day in diffuse lighting (i.e., sufficient whiteness), adequate night reflection value, color stability, durability, antiskid properties, heat resistance up to 200 C., imperiousness to aircraft fuels and lubricants, good adhesion, and prompt applicability assuring noninterference with flight operations at airports of high traffic density. Some of the techniques used for meeting these requirements are briefly reviewed. (iaa)

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Payne, HF; Bransford, TL; Gartner, W

CRACKING OF ASPHALTIC CONCRETE ADJACENT TO TRAFFIC STRIPES

Highway Research Board Proceedings

1959: 366 p.

It is well known that certain sections of asphaltic concrete roads have developed severe cracking adjacent to the traffic stripe. Preliminary investigation of this problem indicated that the traffic stripe, was considerably harder and more cohesive than the road surface, particularly at 140 F, and this was believed to be a factor in the cracking problem. The difference in hardness was measured by a modification of the penetrometer used for determining the hardness of bitumens. A variety of traffic paints was tested in the laboratory on slabs of typical sand-asphalt and sand-asphalt-aggregate mixes. In all cases, the hardness of the composition was greater over the traffic stripe than over the composition itself. The difference in hardness increased with rise in temperature and was particularly evident at 140 F. The slabs were supported on a 20 gage steel panel and the assembly was flexed slightly at 140 F to stimulate the action of moving traffic. Flexing was continued until cracks developed; in all cases, the cracks were adjacent to the traffic stripe. The cracks followed the stripe closely in the sand-asphalt mixes and when aggregate was added, the crack went around any aggregate particle directly under the edge of the stripe. Tests with an

experimental thermoplastic traffic paint made to have low cohesive strength showed that cracking developed at lines of weakness in the slab and not adjacent to the traffic stripe. No tests were made to determine the durability of this paint under service conditions. This investigation has shown that the difference in hardness and cohesive strength of asphalt concrete and this material coated with conventional traffic paints is a major factor in the cracking which occurs adjacent to the traffic stripe. Inasmuch as cracking occurs in certain locations and not in others when the same paint is used, it is apparent that variations in road composition or structure are contributing factors. Additional studies are being made of the road structure and special traffic paints to obtain further information of this problem.  
Author

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Highes, PC

#### EVALUATIONS OF THERMOPLASTIC PAVEMENT MARKINGS

Minnesota Department of Highways

1970: 30 p.

Thermoplastic is evaluated as a pavement marking material in Minnesota. Comparative costs and service levels on conventional specification traffic paint and thermoplastic pavement marking materials are reported. Guidelines for using the more economical material are given. Some of the more important findings and conclusions are that thermoplastic should not be used as a pavement marking material on concrete pavements in Minnesota, but in general, thermoplastic can be used economically on bituminous pavements which have average daily traffic per lane ranging from 2,000 to 7,000. Author

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Beddor, B; McGurrin, J; Lowery, M; DeGoes, J

#### NCSA STATISTICAL DATA SYSTEMS MANAGEMENT

National Highway Traffic Safety Administration Department of Transportation

Computer system analysis, design and programming in support of large statistical data bases established by the National Center of Statistics and Analysis, National Highway Traffic Safety Administration. The statistical data bases include the Fatal Accident Reporting System (FARS), the National Crash Severity (NCSS), and the National Accident Sampling System (NASS). On-line editing and updating of the base takes place from a number of NASS teams established around the country, while the FARS and NCSS operate in a batch edit/update mode. Statistical analysis is performed by both the application of the Table Producing Language (TPL) and the Statistical Analysis System (SAS).

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Dale

LOW-COST PAVEMENT MARKING MATERIALS BASED ON PLASTICIZED SULFUR

Southwest Research Institute

A practical pavement marking material shall be developed at a significantly lower unit cost based on plasticized sulfur with performance equal to or better than rapid-dry traffic paint.

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Gurney, GF

EVALUATION OF LONGLIFE PAVEMENT MARKING MATERIALS

New York State Department of Transportation Engineering Research and Development Bureau

Objectives are to demonstrate the year-round delineation provided by long-life pavement marking materials compared to traffic paints, which normally do not last through the winter. Sprayed and extruded thermoplastic and sprayed epoxy were installed on concrete and asphalt pavements in 1978, 1979 and 1980. The performance of these materials will be evaluated over several years.

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Pigman, JG; Agent, KR

EVALUATION OF PAINT-STRIPE BEADS

Kentucky Department of Transportation

September 1978: 41 p.

REPORT NO: RR-504; PB-292649/1st

The report presents an evaluation of paint stripes and glass beads. The results from previous phases of this study indicated that large-scale, experimental evaluation of a 1.65 refractive-index bead and a large-gradation, 1.52 refractive-index bead was warranted. Poor embedment of beads, however, precluded the evaluations because the quick-drying paint used did not allow beads to be properly embedded. After progressive thinning of the paint with solvent, adequate bead embedment was obtained. Drying time, of course, was longer. Attempts were made to obtain good embedment without extending the drying time. This included testing of a paint having a lower viscosity and by trials at lower temperatures and thinner applications. These efforts were not successful. A survey of other states indicated that over half of the 42 respondents were having a problem similar to that being experienced in Kentucky.

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McShnae, WR;Crowley, KW; Lee, B; Casey, TW

TRAFFIC CONTROL IN OVERSATURATED STREET NETWORKS

Polytechnic Institute of New York

NCHRP REPORT NO:194: 152 p.

This report discussed the scope, magnitude, and root causes of the congestion/saturation problem as determined by a questionnaire survey of traffic engineering professionals and by an extensive set of personal and telephone interviews. In general, the root causes of congestion--as perceived by these practitioners--are founded in lack of alternate routes, in land use policies that generate the traffic patterns, and in vehicle-pedestrian conflicts that aggravate the situation. Measures of saturation were identified from a complete review of the relevant literature, a thorough analysis of candidate measures, and a program of field work via time-lapse photography. The results of this work were then used to define a set of appropriate measures and to develop definitions of the various levels of saturation. A range of treatments was studied via simulation--the UTCS-1 model simulator was used extensively--analytical methods, and some supportive fieldwork. The various candidate treatments and remedies are discussed in terms of three major categories: 1. Signal: Minimal-response signal policies. 2. Signal: Highly responsive signal policies. 3. Nonsignal: Other treatments in a signalized environment. This report also contains a set of guidelines developed for the treatment of traffic congestion on street networks. The guidelines provide both a tutorial and an illustrated reference in what techniques to consider and how to consider them systematically.  
Author

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Chatto, DR; Shelly, TL

DEVELOP AND EVALUATE A SUBSTITUTE FOR CHROME YELLOW IN YELLOW TRAFFIC LINE STRIPES

California Department of Transportation

June 1978: 34 p.

REPORT NO: FHWA-CA-78-TL-18; PB-289623/1st

Chrome yellow has been used as the standard yellow pigment in yellow traffic paint for many years. Recently, in view of ever increasing environmental awareness and continuing investigations into the toxicity of lead and chromate compounds, a study was required to find if a suitable non lead-chromate pigment were available. /FHWA/ Sponsored by California Department of Transportation and conducted in cooperation with the Federal Highway Administration.



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Robnett, QL

OPEN-GRADED ASPHALT FRICTION COURSE LANE MARKING SYSTEM

Georgia Institute of Technology School of Civil Engineering  
Federal Highway Administration Department of Transportation

The primary objective of the research project is to develop a lane marking system that has good visibility, has porosity similar to open-graded asphalt friction courses, and has good resistance to traffic and snowplow activity. The proposed marking systems developed are compared to narrowly graded aggregate, binder, pigment, glass beads, and void space. The scope of the study included binder compound selection, mixture formulation, laboratory evaluation of various systems, and a two-stage field evaluation of promising systems. Material requirements, suggested laboratory evaluation procedures, and application guidelines were developed as the last phase of the project.

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Texas Transportation Institute

DEVELOPMENT OF PAVEMENT MARKING SYSTEMS FOR SNOWFALL AREAS

February 1978: 65 p.

REPORT NO: NCHRP Project 5-5B

This research effort considered both retroreflective (pavement pretreatment which raise and protect significant portions of conventional paint striped, low-profile expendable markers, markers which yield to scraping action of snowplows and then restore themselves, markers which employ a protective housing to raise a snowplow blade over the reflective element) and light emitting (electrically powered markers, chemically or radioactive powered markers) systems. Installation techniques were developed and experimental quantities of markers were fabricated or obtained for the field test. Some others provide only one-way delineation. The minimal 2-way wet-night visibility needed by drivers can be provided by thermoplastic stripes and the ridged strip system at a low additional cost over that of inadequate paint strips. At costs somewhat higher than those of the minimal systems, one-way flap-type markers such as the 3M and TTI replaceable as well as one-way protected markers such as Stimsonite 99 can be used to provide wet-night guidance equivalent to normal dry-night guidance, even when pavement drainage is very poor. The 2-way rigid electric lighted marker was the most effective and most expensive of all markers tested. Prepared for the Transportation Research Board, National Cooperative Highway Research Program.

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Dale, JM

TEMPORARY PAVEMENT MARKING SYSTEMS

Southwest Research Institute

September 1977: 20 p.

REPORT NO: SWRI Proj. 11-4743

This report documents the laboratory findings only of a study that was undertaken to find additives for conventional traffic marking paint that would make the paint stripe easy to remove by burning and thus make the pavement marking temporary in nature. At the end of the laboratory phase of the project, it was the consensus of the Principal Investigator, the NCHRP Project Panel and the NCHRP Program Director that the program should be terminated. The reason for terminating the project midway in its existence was that it was found in the laboratory that the additives necessary to accomplish the desired results carried with their use a degree of hazard to the personnel expected to use them that was greater than could be reasonably accepted. /Author/ This report was prepared for the National Cooperative Highway Research Program for Project 4-13.

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Croteau, J

FOLLOW-UP: FLOATING GLASS BEADS FOR TRAFFIC STRIPES

New Jersey Department of Transportation

March 1977: 68 p.

REPORT NO: FHWA-NJ-RD-77-007; 77-007-7771; PB-275800/1st

A previous New Jersey study indicated that a new type of specially graded, floatation coated reflective glass bead provided improved traffic stripe performance when applied by gravity feed to a conventional slow-drying paint. This report presents the results of a follow-up study undertaken to determine if the pneumatic pressure bead application technique required for the state's current fast-drying paint would negate the night visibility advantage previously observed for the special bead. The beads studied were of four types: the conventional wide-gradation beads with and without the floatation treatment and uniformly-graded floating and non-floating beads. The various beads were applied as lanelines and edgelines on both concrete and bituminous pavements. Night visibility measurements were made with a Colorado-type photometer. A series of special night visibility photographs were taken to complement these instrument measurements of stripe brightness. Conventional close-up photographs were made to assess the relative embedment of the beads. The collected night visibility data indicates that uniformly-graded, floatation coated glass beads applied using N.J.'s conventional (pneumatic pressure) equipment yield traffic stripes of greater brightness than those reflectorized with any of the other bead types studied. It is recommended that the state adopt the use of the special beads applied at 4

lbs/gallon on blacktop and 5 lbs/gallon on concrete. If adjusting bead application rate to the predominant pavement type is not deemed feasible by Maintenance, 4 lbs/gallon should be used on both pavement types.

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Gerardu, JJA

CONSTRUCTION AND EVALUATION OF THE POROUS ASPHALT EXPERIMENTAL SECTIONS

Study Centre for Road Construction, Netherlands

1977: 192 p.

REPORT NO: S.C.W. Record 2

The general composition of porous asphalt is given and the details are described of 4 experimental test sections together with some variations in applications. The porous asphalt mix consisted of 85% (by weight) of crushed stone (5-15 mm), 10.5% crushed sand (0-13 mm), 4.5% filler, and 4.2% bitumen. The results of examination of core sections, skid resistance and the types of stone employed are tabulated. Observations at these test sections indicate that rutting due to after-compaction by traffic has not occurred. The sections have not become clogged with oil or dirt. In one section however, the voids of the shoulder were contaminated and were cleaned by high pressure water jetting. Snow was found to force into the voids; however, deicing with salts presented no problems. The carriageway markings applied to the porous asphalt consist of ordinary marking paint except in one place where a thermoplastic compound was used. The texture depth was measured on all test sections by the sand-pitch method; values of about 2 mm were obtained. Proceedings of International Symposium on Porous Asphalt, Amsterdam, Netherlands, May 31 to June 2, 1976.

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Bryden, JE

PAVEMENT MARKING MATERIALS: A SUMMARY OF NEW YORK STATE RESEARCH

New York State Department of Transportation

May 1977: 25 p.

REPORT NO: NYSDOT-ERD-77-RR48; PB-268889/AS

This report summarizes pavement marking materials research conducted by New York from 1960 through 1975. Work concentrated on three general classes of marking materials--traffic paints reflectorized with glass beads, raised reflective markers, and alternative pavement markings including thermoplastics. Many paint families and formulations were investigated in several pavement test installations. Modified alkyds with and without chlorinated-rubber provided the best service, with modified alkyds generally the most cost-effective. Pavement pretreatments (acid etching and primary) proved ineffective for improving paint durability on concrete pavements. Studies of hot-applied traffic paints determined that these dried much faster than cold-applied traffic paints, eliminating the need for coning; durability was generally close to that of cold paints. While raised reflective markings

have shown promise for wet-night delineation, several problems have prevented their widespread use. The metal castings are subject to damage by carbide-tipped snowplow blades, and damage the blades. In addition, reflector durability has been poor, due to damage by snowplow blades and nose shoes. Hot-extruded thermoplastic and thermosetting plastic glue-down markings have provided highly variable performance on portland cement concrete pavement. While they have generally performed well on asphalt cement concrete pavement, their use has been limited by high initial cost. Based on this research, and on performance and cost experience gathered through the years, New York's standard pavement marking material (adopted in 1973) is a hot-applied modified-alkyd traffic paint with a specified drying time of 20 seconds, reflectorized with glass beads having a refraction index of 1.50 to 1.65. Sponsored by DOT, Federal Highway Administration.

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Stemmler, RE; Kapka, SJ

ECONOMIC ANALYSIS OF PAVEMENT MARKING MATERIALS ACQUISITION, DISTRIBUTION, AND STORAGE

Ohio University, Athens

July 1976: 125 p.

REPORT NO: FHWA-OH-76-03; PB264425/AS

This research project has developed an inventory control system for the major pavement marking materials in Ohio. Important features of this system include the establishment of a materials requirements planning for specifying a delivery schedule for pavement paint and a reorder point system for controlling glass bead inventory. This system specifies methods and procedures for acquisition, distribution, and storage of these materials from the state's twelve districts. Economic evaluation has dictated recommendations for a change to 55-gallon paint drums, for purchase of drum carts and other specialized equipment, for manpower scheduling on a four-day work week, and for multi-line striping with fast-dry paint. Additional recommendations were made for conversion of old strippers to handle fast-dry paint, for retention of a local evaluation of the proportion of contracted work awarded. The implementation of the materials control system and the related policy and procedure recommendations will result in an estimated savings of over \$100,000 per year. Further savings in the three-million dollar annual budget for pavement marking could result from studies of contractor practices, state record-keeping requirements, and sampling and testing procedures. Sponsored by Ohio Department of Transportation and conducted with DOT, Federal Highway Administration.

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Johansson, F

SAFER NIGHT DRIVING DUE TO THE USE OF ROAD BOUNDARY REFLECTORS

Svenska Vagforeningen

Improved visual guidance along highways is increasingly essential since center line markings and car headlights become dirty much more rapidly due to greater use of studded tires and salt on the roads. Provision of reflectors along road boundaries is one solution. Tests were carried out using 13 different types of reflector-post construction. Reflectors must be washed 5-8 times during the dark part of the year in order to maintain good reflectivity. Only one type, where the reflector is placed inside a horizontal pipe, required no washing. This type has been installed along 26 km of unlit roads in the Gothenburg area. (TRRL)

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Woolman, S; Steinberg, M

POLYMER DELINEATION SYSTEM

Energy Research and Development Administration

REPORT NO: 18; PAT-APPL-589804/ST

A delineation system (traffic lane lines) for highways is described in which polymerizable substances are applied to existing or newly prepared highway pavements. The substances would contain a suitable pigment and may incorporate reflective elements. (ERA citation 02;003378) This Government-owned invention available for U.S. licensing and, possibly, foreign licensing. Copy of application available NTIS.

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Whitefield, FN

A DEVELOPMENT IN ROAD-MARKING MATERIALS: FORMED - IN SITU PLASTIC, RAISED PAVEMENT MARKERS

New South Wales Department of Main Roads, Australia

August 1976

A process has been developed to enable suitably filled polyester resin to be applied in cheap, thin-walled poly-propylene plastic cases to form in situ raised pavement markers. These are self adherent to bituminous surfaces and provide an economic means of lane delineation which is long lasting, hard wearing and visible under wet conditions. This method of application does not appear to have been used elsewhere. The process can be readily adapted to suit a variety of special conditions, and to apply markers of different shapes and colors.

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Shuler, LM

DEVELOPMENT OF OPTIMUM SPECIFICATIONS FOR GLASS BEADS IN PAVEMENT MARKING

Pennsylvania State University

1976: 155 p.

REPORT NO: Project 5-5A

This research effort which reviewed and analyzed worldwide research and practices, attempted to identify those variables that influence the effective utilization of glass beads on pavement markings and evaluate those variables by laboratory and field tests. The effort was also designed to: determine the capability and economics of producing glass beads of specified gradation, composition, shape, etc.; develop practical specifications and criteria for the selection and use of beads for reflectorizing traffic paint markings; and evaluate the probable benefits that would accrue should the proposed specifications be adopted. Major examples of the various uses and practices are listed. The performance of retroreflecting glass spheres in pavement markings is found to be strongly influenced by the binder (paint) in which the beads are embedded. A general pattern of contrast between performance on portland cement concrete pavement and bituminous concrete pavement was noted: higher brightness on concrete, but more rapid wear; less bright but longer lasting on bituminous pavement. No useful wet reflection test lines appeared after exposure to traffic wear. Improved bead application procedures in Pennsylvania are discussed, as well as the cost of beads. Recommendations are presented relating to: binder thickness, gradation, bead-to-binder ratio, surface treatment, and refractive index. This report appeared in National Cooperative Highway Research Project Program Summary Through 1976.

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British Standards Institution

HOT-APPLIED THERMOPLASTIC ROAD MARKING MATERIALS

1967: 16 p.

REPORT NO: BS 3262: 1976

This British standard specifies white and yellow thermoplastic materials which are melted and applied hot to roads, by screeded or sprayed application, as thin superimposed markings for center lines, edge lines, pedestrian crossing stripes and the like; it does not apply to thermoplastic materials intended to be inset into the road surface. Section one deals with general matters, section two with application of the material to the road. The material consists of a light colored aggregate, pigment and extender, necessary. Reflectorized with ballotini of a suitable grading may be used to improve the visibility of road markings at night. (TRRL)

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Litchford

LOW PROFILE MARKERS FOR WET/NIGHT VISIBILITY

North Carolina Department of Transportation Division of Highways

Plastic markers for traffic lanes that are flushed with the pavement surface, some with aluminum backs, others with lucite backs, will be installed. Construction techniques, maintenance problems, and wet/night optical performance will be documented for a period that includes two winters. Reported effects from snowplows, sand/salt applic, freeze/thaw, studded tires are included.

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NCHRP Research Results Digest

CURRENT PRACTICES IN USE OF RETRO REFLECTIVE SIGNING MATERIALS

March 1976: 5 p.

The major findings are presented of a questionnaire survey (of what material combinations are being used and the basis for their selection) which was part of a research effort to define the optimum relationship between sign background and legend luminance as a function of several pertinent variables. The questionnaire elicited information on the types of signing material; practices relating to illumination; inspection and maintenance practices; criteria and methods for refurbishing existing signs, and determining the time of replacement; and the useful life of various sign face materials. Material combinations most frequently used are summarized in a table. The combinations most frequently mentioned were button copy on paint or porcelain enamel and button copy on engineer-grade sheeting. With reference to sign employing direct-applied letters, symbols, or legends, material use was evenly divided between engineer grade and high-intensity sheeting. Findings related to illumination of road signs, photometric specifications, quality control, maintenance and replacement are also discussed.

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Traffic Engineering VOL. 46 No. 1

A MODEL PERFORMANCE SPECIFICATION FOR THE PURCHASE OF PAVEMENT MARKING PAINTS AND POWDERS

January 1976: 43 p.

This specification describes the general and specific requirements for reflective pavement marking programs, provides for the submission of samples, and describes the laboratory and service test procedure which will be used to rate the materials submitted for test. The paints described are classified relative to drying times, and relative to glass bead application methods. Details are given of the application, equipment packing and handling. The properties of glass spheres for reflectorization and the properties of striping powders are detailed. Specifications for road service tests, the samples required, the certification required, the service tests, sampling and

testing, and the acceptance and rejection are outlined. Tentative Revised Standard by ITE Technical Council Committee 4N-S.

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McNaught, ED; Hahn, KC

#### FIELD TESTING OF TWO FAST-DRYING TRAFFIC PAINTS

New York State Department of Transportation

October 1975: 29 p.

REPORT NO: NYSDOT-ERD-75-SR 36; PB-248629/8ST

Problems in achieving specified 60-second drying time using newly adopted heated paint led to evaluation of a faster 20-second drying time paint. In field tests it was compared with the regular New York 60-second paint. Drying time was determined by driving an automobile over the fresh paint until no tracking occurred. Performance was evaluated using ASTM Method D 713 ("Conducting Road Service Tests on Traffic Paint"). It was determined that 1) the 20-second paint essentially met the drying time requirements, 2) the 60-second paint did not meet the drying time requirement under high temperature and humidity, 3) the 60-second paint had slightly better serviceability than the 20-second paint, and 4) bead retention may be a problem for both paints when conditions promote very fast drying. Retention may be improved by locating the bead dispenser closer to the paint spray nozzle. /FHWA/ Prepared in cooperation with the Department of Transportation, Federal Highway Administration.

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Central and Regional Labs of Bridges & Highways

#### TESTS ON PAINT FOR ENGINEERING STRUCTURES AND CARRIAGEWAY MARKINGS

January 1973: 200 p.

In the introduction of this draft procedure a list is given of the organizations dealing with the standardization of paints: (1) permanent study group for paints, varnished and ancillary products (gpem/pv) (2) French standard association (afnor); (3) lcpc who is working in cooperation with the gpem/pv. This publication presents extracts of amalgamated specifications from the lcpc and gpem/pv. A list of the documents necessary for understanding the publication is given. The first part deals with the general condition governing the conduct of the tests: sampling methods, preparation of test samples, application of the paint. Part 2 renews physico-chemical test methods, general physical characteristics, data for the identification of the products, general criteria for the use of the products, quality control tests on films of paint optical characteristics of the films, and ageing tests on experimental sections. Part 3 describes general methods of separation and chemical analysis for pulverised materials. The last part is concerned with the control of glass shots for carriageway marking, sampling and tests. (TRRL)

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Girard, RJ; Murray, LT; Rucker, RM

PAINTS AND GLASS BEADS USED FOR TRAFFIC DELINEATION MARKINGS

Missouri State Highway Commission

This investigation was designed to study the effectiveness of Missouri's traffic delineation system on both concrete and asphalt concrete surfaces and to determine if safe and economical improvements could be made. The investigation was organized into three phases so that elimination of variables could be accomplished with a minimum of samples. Phase 1, a field evaluation of the Missouri standard dispersion resin-varnish paint and a chlorinated rubber-alkyd paint in a transverse stripe, clearly indicated the superiority of the chlorinated rubber-alkyd paint to resist wear. Phase 2, a field evaluation of several proprietary high-heat paints in a transverse stripe, indicated a wide range of life expectancies to exist. Phase 3, a field evaluation of traffic delineation stripes in the proper longitudinal configuration with various types of glass beads applied at 3, 4, and 5 lb/gal (360, 480, and 600 kg/cu m), showed the Missouri type 2 floating bead to consistently rank high in performance. This investigation had produced a superior delineation system that provides economic savings over the system previously used.

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Deforno, JJ

FLOATING BEADS: BROAD OR NARROW GRADATION?

Potters Industries Incorporated

1975: 100 p.

Through the use of theory and in road service tests the 2 most common types of floating beads, narrow and broad gradation, were evaluated. These tests, which included several control lines using a broad-gradation non-floating bead, showed that the broad-gradation floating bead performed best under all conditions. The narrow-gradation floating beads gave good reflectivity under dry conditions but invariably demonstrated poor reflectivity under the slightest rainfall conditions. These effects are demonstrated through the use of wet and dry night photographs of dual centerline test sections.

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Flanakin, HAM

TRAFFIC MARKINGS - A PROCEDURE FOR PUTTING TO USE RESEARCH FINDINGS

District of Columbia Department of Transportation

March 1975: 21 p.

Today, movement of people and goods is being accomplished more by traffic engineering principles than by construction of new and expanded roadways.

Control measures are far less expensive and do not adversely affect the environment. In the revised Manual of Uniform Traffic Control Devices (MUTCD), traffic markings take on a new and more important role. With stabilized street systems, it is important to consider markings of a more permanent nature than conventional traffic paint. From a cost effectiveness standpoint, thermoplastic material stands high above other materials. Justification for installing permanent markings is advanced. There is need for compiling an up-to-date inventory of traffic markings. A procedure for making and maintaining an inventory is assuring adequate traffic markings on a continuing basis is offered. (FHWA)

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Azar, DG; Lacinak, HW, Jr

#### EVALUATION OF THERMOPLASTIC MATERIALS

Louisiana Department of Highways

April 1975: 55 p.

REPORT NO: 71-1CH (B); PB-243039/AS

In order to find a striping material which would last longer and have greater reflectance than the presently used traffic paint, research work was performed using new thermoplastic compound. Installations were made on four types of roadway asphalt. Reflectance readings and field inspections were made periodically of both the thermoplastic material traffic paint. The results obtained showed that the reflectance of one-year-old white thermoplastic material and generally equal to the initial reflectance of the white traffic paint. The reflectance readings of the yellow thermoplastic material and the yellow traffic paint were relatively close after six months of wear. Periodic inspections showed that the thermoplastic compound was much more abrasion resistant than the traffic paint. Laboratory analysis was performed on the thermoplastic compounds in order to develop specifications to be used in quality control. These specifications have been developed and are in this report. (FHWA)

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Montefiore, H

#### CHANGING DIRECTIONS. A REPORT FROM THE INDEPENDENT COMMISSION ON TRANSPORT

Coronet Books, Hodden Paperbacks

1974: 365 p.

This book presents a detailed discussion of all aspects of transport. The need for such a study is briefly discussed and some basic statistics on transport in Great Britain are given. Resource needs are considered together with a projection of resource supply, with particular attention to energy. Details of costs such as accidents, pollution, and the over-use of the natural environment are provided. The need for mobility is discussed and the effects of relative changes in it are analyzed in terms of both locational effects and the effects on different user groups. Techniques used for formulating transport policy and for decision-making are described, with particular

attention to cost benefit analysis and car ownership forecasting. Policy for urban situations is suggested, using physical restriction and subsidy; in rural areas subsidy is particularly important and for the inter-urban travel re-appraisal of the roads program, rail plans and freight movement is necessary. The summary and conclusions suggest a wide range of measures and appendices include additional information such as the position of the three major political parties on transport, urban mobility problems of the elderly, impact of rural life of declining public transport services, transport in Scotland, etc.: mention is made of the TRRL's methods of forecasting future transport. (TRRL)

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Leino, I

#### STREETS CALL FOR KERBS, ROAD SIGNS AND ROAD MARKINGS

Finlands Standsfoerbund

Traffic safety demands that roads be provided with kerbs, road signs and road markings, but economic considerations influence the choice of materials. The types of kerbs currently in use are made of granite, precast concrete and asphalt. Granite is most durable and pleasing, but most expensive. Precast concrete kerbs cost about 50% of granite, and are either recessed into the pavement or affixed to the surface by steel pins or gluing. Asphalt kerbs are still in the experimental stage. Road signs can be bought ready for erection or made by the road authority. Posts are painted yellow or grey and are embedded in concrete or inserted into precast sockets. Illuminated road signs can be lit internally or externally; their drawback is that they are prone to vandalism. Placing on footpaths, so as to allow mechanical footpath maintenance, is difficult due to the distance requirement from the kerb. Gantries are used for groups of signs but are expensive. Road markings are either painted, in which case they have to be renewed at least twice a year, or laid in permanent materials. The cost of this is at least 3-4 times that of painting. (TRRL)

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VanVechten, Ct

#### SELECTING PAVEMENT MARKING MATERIALS BASED ON SERVICE LIFE

District of Columbia Department of Transportation

1974: 80 p.

Samples were tested for purposes of selecting a successful supplier. Measure of performance was calendar procedure dictated only material cost as a measure of effectiveness. This proved inadequate. Total cost, including labor and equipment rentals should be adopted. Application cost is the same for a cheap inferior paint as for a more durable and costlier material. Wear of pavement striping material does not vary in a straight line. Extrapolation of life expectancy on short time tests is misleading. A better weighting process is indicated. A method for selecting successful candidate sample was developed and adopted by Central procurement for awarding contracts. Research into properties and behavior of three generic marking materials (paint, instant setting powder and thermoplastic) is reported.

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Randill, A; Greenhalgh, H; Samson, E

NATIONWIDE PERSONAL TRANSPORTATION STUDY. REPORT NO 9, MODE OF TRANSPORTATION AND PERSONAL CHARACTERISTICS OF TRIPMAKERS

Federal Highway Administration Office of Highway Planning

November 1973: 51 p.

The report presents personal characteristics of all individuals five years old and over who reported making a one-way trip by a motorized vehicle, including automobile (driver and passenger separately), motorcycle, truck, schoolbus, taxicab, bus, subway, train, and airplane. The percent distributions of these trips by mode are related to age, sex, race, and place of residence in unincorporated areas and incorporated places. Paper copy also available is set of 11 reports as PB-242884-SET, PC\$33.00.

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Cabrera, JG; O'Flaherty, CA

DURABILITY OF REFLECTORIZED ROAD MARKINGS

Institute of Highway Engineers

1973: 24 p.

This paper has a two-fold purpose. First, it puts forward a simple yet basic explanation as to how the initiation of "chipping" failure in a reflectORIZED road-marking material is associated with the presence of the glass beads in the composite system. Secondly, it suggests that there may be an optimum bead content and gradation from the point of view of the durability of a road marking, and that this optimum could possibly be different from the optimum for reflectivity. Photographic evidence obtained with the scanning electron microscope is presented in support of the above main theses. Suggestions are made regarding further research needs in this area. Author

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Lielich, RH; Prokopy, JC; Ruina, D

INDUSTRIAL ENERGY STUDIES OF GROUND FREIGHT TRANSPORTATION. VOLUME II, APPENDICES

Peat, Marwick, Mitchell and Company 55 p.

REPORT NO: Final Rpt., PB-236017/OSL

No abstract. See also Volume 1, PB-236016, RRIS 081863.

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Teng, TC; Davis, JH; Wallace, BF

AN EVALUATION OF ROAD MARKING MATERIALS

Mississippi State Highway Department Research and Development Division  
Federal Highway Administration Department of Transportation

A comprehensive evaluation is being made of the paints currently used by the department, and other available paint formulations, in an effort to find a traffic paint that will enable the department to reduce its annual cost on this item. An evaluation of thermoplastic, raised markers, and epoxy paint are now included. Reports issued: Road Marking Materials-Interim Report No. 1, L.J. Lanz, July 1972. Road Marking Materials-Interim Report No 2, Lanz, L.J., July 1973. Final Report is in preparation.

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Dole, JM

LOW COST PAVEMENT MARKING MATERIALS BASED ON PLASTICIZED SULFUR

Southwest Research Institute  
Federal Highway Administration Office of Research and Administration  
Washington, D.C. 20590

April 1982: 31 p.

REPORT NO: FHWA-RD-82-60

This research project was undertaken to develop a practical pavement marking material at a significantly lower unit cost based on plasticized sulfur with performance equal to or better than rapid-dry traffic paint. A yellow formulation was developed and taken through pilot tests and large scale field tests in Texas and Colorado. A white formulation was developed, but it failed to meet the white color standards. The yellow formulation: uses an organic pigment rather than lead chromate which has toxic properties; is more durable than conventional rapid dry traffic marking paint; adheres equally well to both PCC and AC pavements; is virtually smokeless on application and is nonpolluting (100 percent solids system that contains no solvent); conserves energy in that it contains no solvent and very little organic material in the binder; and can be applied at 300F with conventional hot spray equipment. (FHWA)

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Fullerton, IJ

ROADWAY DELINEATION PRACTICES HANDBOOK

JHK and Associates  
Federal Highway Administration Office of Development  
Washington, D.C. 20590

September 1981: 156 p.

REPORT NO: FHWA-IP-81-5

In the context of this Handbook, roadway delineation is defined as a system of devices and or/markings--excluding signs and signals--that regulate, warn, or provide tracking information and guidance to the driver. Intended primarily for use by various levels of design, traffic, and maintenance engineering personnel, the Roadway Delineation Practices Handbook provides practical assistance guidelines in the proper application of available delineation systems. Although not intended to be a state-of-the-art report, the handbook does provide an overview of current developments in the area of roadway delineation techniques. Major topics within the handbook include "Painted Markings," "Thermoplastic and Other Delineators," and "Administrative and Management Considerations." Contained within the discussion of each category of delineation techniques is a discussion of issues relating to uses, materials, application procedures, service life, and maintenance. One of the primary functions of the handbook is to offer guidance for implementing the

provisions of the Manual on Uniform Traffic Control Devices concerning roadway delineation. (FHWA)

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Hubert, R

IMPROVEMENT IN THE DAY AND NIGHT VISIBILITY OF SIGNALLING DEVICES,  
APPLICATIONS OF PHOTOMETRY AND COLORIMETRY

Central Laboratory of Bridges & Highways  
Paris France 0222-8394

June 1981: 54 p.

REPORT NO: 102

This study comes within the scope of the research described in research project IRRD 500733. Its aim is to widen the knowledge of the efficiency of installing devices thanks to a better approach to their photometric and colorimetric properties. It deals with traffic signals and reflecting devices. Measurements were made of the light intensity, color, and ghosting effect of the different types of traffic signals used in France. Based on a bibliographic analysis of the visual efficiency of traffic signals and a comparison of measurement results with draft recommendations by the CIE (International Commission of Lighting), elements are proposed for the drafting of future standards. A measuring method was developed for determining the variation in the light intensity of flashing lights as a function of time for flashes which last approximately 100 microseconds. It is then possible to calculate their effective light intensity by the Blondel-Rey method. Their color is defined using the trichromatic coordinates of the filter. Among reflecting devices, a special study was conducted of carriageway markings, reflecting studs and reflectorized films. The values characterizing the photometric and colorimetric properties of the equipment are defined together with methods of measuring them in the laboratory. (TRRL)

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Dale, JM

DEVELOPMENT OF LANE DELINEATION WITH IMPROVED DURABILITY

Southwest Research Institute  
Federal Administration Offices of Research

June 1981: 37 p.

REPORT NO: FHWA-RD-81-141; 05-3712

A new pavement marking material was developed on this program. The developed material is called epoxy thermoplastic (ETP) for identification and is based on the use of uncatalyzed epoxy resin for a binder, to which conventional extender, fillers, pigments and reflective glass beads (premix and/or drop-on) are added. The material is applied by an airless, low pressure spray system at 450F (232C) as a thin film coating (10 to 20 mils). The epoxy thermoplastic has the following characteristics: sets quickly (5 seconds or less--no coning required); is more durable than conventional traffic marking

paints by a factor of two to ten on both PCC and AC pavements (based on large-scale field tests conducted in Minnesota, Colorado, Texas, and California); can be applied to below freezing pavements in below freezing weather; is virtually smokeless on application; is nonpolluting (100 percent solids system that has no solvent); uses materials that are non proprietary and available from multiple sources; has materials costs comparable to conventional traffic paint (100 percent solids basis); and conserves energy by not using petroleum-derived solvent as compared to traffic paint which is 30 percent to 50 percent solvent. (FHWA)

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Henry, JJ; Anderson, DA; Hayhoe, GF

SKID RESISTANCE OF PAVEMENT MARKING MATERIALS. VOLUME II

Pennsylvania Transportation Institute  
Federal Highway Administration  
Washington D.C. 20590

July 1980: 189 p.

REPORT NO: FHWA-RD-80-199 VOL II; 8005

The skid resistance of typical pavement marking materials is determined. A data base of full-scale locked-wheel skid resistance is presented for typical traffic paints of various formulation, hot spray and extruded thermoplastics, cold preformed plastics, temporary tapes, and some two-part systems. A variety of pavement surface types including dense and open graded asphalt and portland cement concrete are used in the study. In Volume I texture data are presented for field applications and for laboratory samples. Equations are developed for predicting skid resistance from texture measurements. The effects of glass beads, weathering, and polishing are examined in laboratory and field experiments. Based on a simulation, guidelines are developed for the maximum acceptable differential skid resistance between a pavement and the marking materials on it. Both two- and four-wheel vehicles are treated. Volume II of this report contains a complete listing of the data compiled in this project and is available in limited quantities to interested researchers. The data are summarized in Volume I. (FHWA)

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Henry, JJ

SKID RESISTANCE OF PAVEMENT MARKING MATERIALS VOLUME I

Pennsylvania Transportation Institute  
Federal Highway Administration  
Washington, D.C. 20590

March 1981: 127 p.

REPORT NO: FHWA-RD-80-199 VOL-I; 8005;

The skid resistance of typical pavement marking materials is determined. A data base of full-scale locked-wheel skid resistance is presented for



typical traffic paints of various formulations, hot spray and extruded thermoplastics, cold preformed plastics, temporary tapes, and some two-part systems. A variety of pavement surface types, including dense and open graded asphalt and portland cement concrete, are used in the study. In Volume I texture data are presented for field applications and for laboratory samples. Equations are developed for predicting skid resistance from texture measurements. The effects of glass beads, weathering, and polishing are examined in laboratory and field experiments. Based on a simulation, guidelines are developed for the maximum acceptable differential skid resistance between a pavement and the marking materials on it. Both two- and four-wheel vehicles are treated. Volume II of this report contains a complete listing of the data compiled in this project and is available in limited quantities to interested researchers. A summary of all the data which was utilized in the formation of the conclusions is included in tables in Volume I. (FHWA)

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Hofmann, F

MAINTENANCE OF UNIFORM COATING THICKNESS IN THE APPLICATION OF ROAD MARKING MATERIALS

Svenska Vaegfoereningen  
Stockholm Sweden

1981: 184 p.

The long overdue development has been achieved of a road-marking machine which is equipped with a pump the drive of which is governed by travelled distance, for the static delivery of sprayable marking materials. With this there is, in the future, a much greater technical possibility to maintain the specified film thickness over the entire length of the line. The thickness of the marking film is not only dependent on easily controllable factors but also on the following ones which, if at all, are difficult to control: viscosity of the marking material, resistance in the pipes, and the marking speed. In practices it is therefore often necessary to check the film thickness frequently and to adjust settings on the machine accordingly. This is very time consuming and relies a great deal on the responsibility of the marking personnel. Due to a pump which is driven, governed by travelled distance, and which always gives the desired coverage of material per unit travelled distance regardless of the above factors, the disadvantages of the traditional systems can be overcome. This means that a line will have a constant film thickness over its entire length regardless of varying marking speeds, for example. The pump is described in the report. (TRRL) Papers from the 9th IRF World Meeting Roads Into the Future--Road Maintenance--TS5, held in Stockholm, June 1-5, 1981.

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Peroni, G; Pallotta, S

THE "DIRECT READING RETROREFLECTOMETER" PERFECTED BY THE SOC AUTOSTRADE AS AN AID TO VISIBILITY IN NIGHT DRIVING

May 1981: 24 p.

This article describes and illustrates a photometric apparatus for measuring the retroreflection of carriageway paints. The direct reading device simulates electronically the conditions of retroreflected light transmitted to a driver from a carriageway marking at a distance of 30 M, when illuminated by the vehicle headlights. The apparatus comprises two separate pieces of equipment: (1) the camera box containing the photo-optics and accumulators; and (2) an instrument panel incorporating the controls and digital read out display. An example is given of the use of the retroreflectometer in the evaluation of experimental paints containing glass beads before their use on the carriageway. (TRRL)

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McGrath, MA

DURABLE PAVEMENT MARKING MATERIALS. SUMMARY REPORT OF 1981 WORKSHOPS

Dingle Associates, Incorporated  
Federal Highway Administration  
Washington, D.C.

November 1981: 21 p.

REPORT NO: FHWA-TS-81-221

This publication summarizes presentations on the evaluations of six durable pavement marking materials as reported at 1981 workshops. Each material is discussed separately regarding its characteristics, application technique(s), and performance. Their advantages, disadvantages, and ranges of costs are also reviewed. The information presented at these five workshops was based on field testing of the materials in several states. (FHWA)

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Bry, M

THE BEHAVIOR OF CARRIAGEWAY MARKINGS ON SURFACE DRESSINGS

Central Laboratory of Bridges & Highways  
France November 1981: 60 p.

The use of marking products, selected after an acceptance test on a bituminous pavement, gives rise to some problems of durability, especially for the more fluid types. Indeed these products have a tendency to run down the troughs of the surfacing at the time of application, and what remains at the surface is quickly eliminated because of the important shear stresses applied by tires. This article describes the behavior observed on several experimental surface dressing sections involving hot- and cold-coated surface

dressings applied by different methods. The paints show short durability, extruded materials necessitating high proportioning, and decreasing the drainage power of the surfacing. Only gun-applied surfacings give results equivalent to those obtained on bituminous mixtures, for acceptable proportioning and reasonable drainage power. For hot-coated surface dressings proportioning must be at least 4 kg/cm<sup>2</sup> and for cold-coated dressings, the rheology must be the subject of a special study. (TTRL)

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Morren, L

PHOTOMETRY OF REFLECTING ROAD MARKINGS

Association Francaise de l'Eclairage

October 1980: 10 p.

This article discusses the photometry of reflective equipment and especially marking devices for the road surface. The main aspects studied are: (1) close link between lighting and divergence angles; (2) case when lighting and observation directions become nearly close to the ground. The second part of the article describes two methods of measuring reflection: luminance meter and lux meter. (TRRL)

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Bryden, JE; Lorini, RA

EXPERIMENTAL PAVEMENT DELINEATION TREATMENTS

New York State Department of Transportation Engineering Research & Development  
Federal Highway Administration Office of Research  
Washington, D.C. 20590

REPORT NO: FHWA/NY/RR-81/87 June 1981: 41 p.

In 1975, 43 test sections of various delineation treatments were installed in an attempt to develop treatments with better visibility and durability than the color-contrast and synthetic-binder-concrete then used in New York State to delineate shoulders and medians adjacent to asphalt pavements. Materials evaluated were polysulfide and coal-tar epoxies, one- and two-component polyesters, portland cement, acrylic paints, modified-alkyd traffic paint, preformed plastic tape, and thermoplastic markings. Neat applications, sand mortars, and surface treatments were installed in several geometric patterns including cross-hatches, solid median treatments, and various widths of edge lines. Although several materials provided good daytime and wet-weather visibility, most did not provide good night and wet-weather visibility. Thermoplastic pavement markings generally performed very well, providing good visibility under adverse viewing conditions for at least 4 years. Thermoplastic 4-in. wide edge lines appear to provide adequate visibility for most conditions. Wider lines or cross-hatching provide greater visibility where increased emphasis of the shoulder or median is desirable. (FHWA)

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Hoffman, AG

EVALUATION OF RETRO REFLECTIVE MEASUREMENT DEVICES. FINAL REPORT

Mobility Systems and Equipment Company  
Federal Highway Administration Offices of Research and Development  
Washington, D.C. 20590

June 1981: 59 p.

REPORT NO: FHWA-TS-81-213; P8102FR; PB81-243594

The project was conducted to identify and evaluate instruments capable of measuring the retro-reflectance of highway traffic stripes under daylight conditions in the field. Four instruments were identified and evaluated. Two of these instruments are manufactured in Europe. The others were developed in the United States but are not commercially available. All instruments evaluated have some capability for measuring retro-reflectance of highway traffic stripes in the field. Three of the instruments are conveniently useable by field crews for this purpose. (FHWA)

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Hoffman, AG

EVALUATION OF RETRO-REFLECTIVE MEASUREMENT DEVICES. SUMMARY REPORT

Mobility Systems and Equipment Company  
Federal Highway Administration Offices of Research and Development  
Washington, D.C. 20590

June 1981: 21 p.

REPORT NO: FHWA-TS-81-212; P8102SR; PB81-243602

This project was conducted to identify and evaluate instruments capable of measuring the retro-reflectance of highway traffic stripes under daylight conditions in the field. Four instruments were identified and evaluated. Two of these instruments are manufactured in Europe. The others were developed in the United States but are not commercially available. All instruments evaluated have some capability for measuring retro-reflectance of highway traffic stripes in the field. Three of the instruments are conveniently usable by field crews for this purpose. A Final Report containing documentary photographs and detail test data is available from NTIS (PB81-243594). (FHWA)

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Chollar, BH; Applemen, BR

EPOXY THERMOPLASTIC PAVEMENT MARKINGS MATERIAL SPECIFICATION AND TESTING

Federal Highway Administration Office of Research and Development  
Washington, D.C. 20590

December 1980: 106 p.

REPORT NO: FHWA-RD-80-69

This report presents the results of an extensive laboratory program to establish a specification for an epoxy thermoplastic (EPT) striping material which was developed in a contract research study for the Federal Highway Administration by Southwest Research Institute. The present study developed laboratory test procedures to evaluate the significant properties of the EPT material and its components. Properties studied included viscosity, reflectance, thermal stability, softening point, epoxy equivalent weight, and infrared spectrum. Also studied were the effects upon selected EPT properties of variations in the composition ratios of the EPT components and variations in the epoxy resin properties. From a statistical analysis of the results, upper and lower limits for the EPT physical properties were determined. An interim composition performance specification was then established for the procurement of this material based on epoxy resins manufactured by CIBA-GEIGY and various commercial pigments. Analytical procedures for determining titanium dioxide, lead chromate, glass bead, and organic contents were also incorporated into the specification. (FHWA) This staff study is a work unit in Federally Coordinated Program Project II, "Traffic Lane Delineation Systems for Adequate Visibility and Durability."

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Haxo,,Jr.

USAGE GUIDE FOR RAPID-SET EPOXY ADHESIVE (118-AF) FOR TRAFFIC MARKERS

Matrecon, Incorporated  
Federal Highway Administration Office of Research and Development  
Washington D.C. 20590

July 1980: 27 p.

REPORT NO: FHWA-RD-80-32

A new rapid-set, two component epoxy adhesive for bonding traffic markers to roadway surfaces is described and guidance designed for machine mixing and dispensing and has the following principal features: (1) Polymercaptan cure, which imparts rapid-set at low temperatures, (2) Fibrillated polyethylene as the thixotrope, i.e., non-asbestos, (3) Low viscosity which allows good mixing even at moderately low temperatures. The rapid cure should allow sufficient set of the adhesive and the development of sufficient adhesion that traffic can be allowed to contact the markers in less than 15 minutes after being placed at temperatures of 72-82 F (22-28 C ). This guide is designed to furnish users and purchasers detailed information in the following areas: (1) Background on the development of the adhesive, (2) Details regarding the composition of the adhesive, (3) Specific data on properties and experience in the field, including comparisons with the California Rapid-Set Epoxy Adhesive, (4) Guidance regarding its use in the field and precautions regarding handling, and (5) Information regarding raw materials costs. A proposed specification is presented. (FHWA)

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Campbell, PG; Post, MA

## NONTOXIC YELLOW TRAFFIC STRIPING

National Bureau of Standards Washington D.C. 20234  
Federal Highway Administration Offices of Research and Development  
Washington D.C. 20590

January 1978: 70 p.

REPORT NO: FHWA-RD-78-1

A study was carried out to examine the performance characteristics of alternative pigments which might be used in yellow traffic paints if the use of lead chromate were curtailed. Thirty-six yellow traffic paints were prepared using lead chromate and alternative pigments as the yellow color source. Screening tests were used to evaluate the initial color stability and durability characteristics of the paint formulations. The thermal stabilities of selected yellow pigments for use in thermoplastic markings applications were evaluated. Also, outdoor exposures and a small scale field test were used to evaluate the performance of formulations containing lead chromate and alternative pigments. The performance of the alternative organic yellow pigments, as measured by color change under the various exposure conditions, was found to be at least as good as that of lead chromate. (FHWA)

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Anderson, DA; Henry, JJ

## WET-PAVEMENT FRICTION OF PAVEMENT-MARKING MATERIALS

Transportation Research Board

A total of 39 formulations of 11 types of marking materials were studied in the laboratory and in the field. Field skid number measurements were made at three sites by using the Pennsylvania Transportation Institute Pavement Friction Tester. Laboratory and field measurements were taken to determine British pendulum numbers, microtexture, macrotexture, and static coefficient of friction. Laboratory polishing and accelerated exposure testing were also performed. A wet-friction data bank for typical pavement-marking materials was established. Based on an analysis of these data, it was found that wet friction can vary dramatically for different marking materials. The texture of the underlying pavement affects the friction of thinner marking materials (paints), but the wet-friction resistance from the paints can persist even after the aggregate surface is exposed from wear. The wet friction of marking materials exhibits a daily and seasonal variability much like that of the pavement itself, and the variability must be accounted for when skid-resistance measurements are made. (Author) This paper appeared in Transportation Research Record No. 777, Asphalt: Materials, Mixes, and Construction.

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Younger, C

## EXPERIMENTAL EPOXY TRAFFIC STRIPES

New Jersey Department of Transportation  
Federal Highway Administration Department of Transportation

Current striping practices in New Jersey require repainting lines at least twice yearly in high traffic volume areas. Use of a pavement marking material such as epoxy exhibiting a longer life span should prove beneficial from both an economic and safety standpoint. Epoxy resin traffic stripes will be placed on a long viaduct and its performance monitored from a night reflectance and durability standpoint.

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Gillis, HJ

#### DURABLE PAVEMENT-MARKING MATERIALS

Transportation Research Board  
Minnesota Department of Transportation

Work done by the Minnesota Department of Transportation during the past 10 years to develop and evaluate a durable yet economical road-striping material is described. The development of equipment capable of applying a two-component epoxy resin is discussed. Epoxy, polyester, and thermoplastic resins and their cost-effectiveness are evaluated. Field evaluation of the various materials consisted of visual observations, photographs, macrophotographs, and measurements of retroreflectivity. The available data suggest that epoxy can be placed on a high-volume bituminous or portland cement concrete roadway, at a thickness of 10 mils, and provide adequate delineation for 12 months or longer while remaining as economical as paint. The polyester material did not adhere well to portland cement concrete and the aggregate in the bituminous pavement. Thermoplastic was found to be generally unacceptable because it is too susceptible to removal by traffic and snowplows when placed at the manufacturer's recommended minimum thickness of 30 mils, and it does not bond adequately to portland cement concrete. (Authors) This paper appeared in Transportation Research Board Record No. 762, Corrosion, Cathodic Protection, Aggregate Upgrading, Concrete Density, and Pavement Markings.

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Mannadiar, PS

#### REPORT ON USE OF PLASTIC STUDS FOR ROAD MARKING

Indian Roads Congress

The paper discusses in brief existing practices with road marking materials. As an alternative the use of 100 mm diameter plastic studs which are manufactured locally at Madras, India, is investigated. The economic spacing of road studs under the local traffic conditions for ascertaining the minimum number of studs required for every 1 metre length which would give a visual effect of a solid line of the same length is assessed. The guidelines provided by Hobbs and Richardson for the length of stroke and gap have been adopted which proved more economical as compared to the standards prescribed by Indian Roads Congress. It is recommended that the economic stroke length of 0.9 M and gap length of 7.5 M could be adopted. Three plastic studs may be embedded in each stroke with a spacing of 400 mm between center of successive

studs. (TRRL)

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Lipp, H; Kreme, M

#### SAFETY IN ROAD TRAFFIC

The new reflective foil from 3M Deutschland has higher reflectivity and a longer life than conventional reflective foils. The principle of retroreflexion enhances traffic safety at night and makes a significant contribution to the prevention of accidents. Further advantages are the ready adhesion and easy removal of the foil. On motorways the danger of drivers travelling in the wrong direction can be reduced by means of foil markings in the form of arrows. The foil also offers the possibility of conspicuous marking of the way to school. Two types of foil are available, a colored soft aluminum foil scotch-lane and a permanent marking foil stamark with a synthetic base. (TRRL)

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Dale, JM

#### EQUIPMENT FOR APPLYING EPOXY THERMOPLASTIC PAVING MARKING MATERIAL

Southwest Research Institute  
Federal Highway Administration Office of Research  
Washington D.C. 20590

April 1980: 39 p.

REPORT NO: FHWA-RD-79-130

This project was undertaken to prepare a general specification for a spray application system for epoxy thermoplastic pavement marking material. The system used is an airless, low pressure spray system. This report attempts to present the main features of the equipment from the standpoint of both the design and operation. The information presented herein is not a set of rigid specifications, but rather a guide to those who seek to use a system which has been found to be both simple and effective. (FHWA)

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Lycett, CJ

#### EVALUATION OF ROAD MARKINGS UNDER TRAFFIC

Irish Journal of Environmental Science VOL. 1 No. 1

January 1980: 74 p.

An investigation was conducted to establish the performance of seven commonly used thermoplastic compounds and three preformed tape materials on a major Irish Road. The materials were monitored at nine monthly intervals over three years for durability, reflectivity, skid resistance and thickness. The materials were found to be reasonably durable but reflectivity, skid resistance, and color retention required improvement. (TRRL)

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Pulling, NH

HIGHWAY VISIBILITY RESEARCH NEEDS

Transportation Research Board

This article outlines those aspects of the subject of visibility on the highway that the author feels require further research. These include the effectiveness of reflective clothing for pedestrians, the synergistic effects of prescription drugs on driver vision and cognition, how to improve vehicle conspicuity, luminance and contrast requirements for highway signs, establishing priorities for energy-saving curtailment of roadway lighting, revision of eye height standards to compensate for the increasing number of small cars in use, and the need to develop pavement marking materials that are both more durable and easier to obliterate.

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Gerasinovich, M

APPLICATION OF EXPERIMENTAL TRAFFIC MARKING MATERIALS

Pennsylvania Department of Transportation

The aims are to determine what materials significantly effect the characteristics of traffic paint. Areas of special interest are dry time, durability and appearance. This study may also include hot and cold plastic marking materials as applied by the participating companies.

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Kidd, S

COLD PLASTIC AND HOT SPRAY THERMOPLASTIC PAVEMENT MARKINGS

Mississippi State Highway Department  
Federal Highway Administration Department of Transportation

To evaluate "Stamark" cold plastic and hot spray thermoplastic.

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Rijkswegenbouwlaboratorium

ANNUAL REPORT 1978

August 1979: 80 p.

After an introduction on general subjects the work done by the state road laboratory in 1978 is discussed in the following chapters: Soil, Roadbases, Concrete, Flexible pavements, Synthetic Resins, Carriageway marking Materials, Design, Roadstone and Surface Texture, Skidding Resistance, Evenness, Black Ice Warning Systems, Axle Load Measurements, Hydraulic Engineering. Tables and references are appended. (TRRL)

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Day, PB; Leyland, DS

SURVEY OF D.O.T.'S TRAFFIC PAINT COSTS ON 1979

American Transit Association Materials and Research Division  
Washington D.C. 20590

February 1980: 30 p.

REPORT NO: Technical Paper 80-2

This report presents the results of a survey on the use of yellow versus white traffic paint. It was found that in most states the white paint was less expensive than the yellow. A substantial savings could be realized if an all white traffic marking system was permitted by the Federal Highway Administration. Paint costs from each state are presented, as well as by each region. (Author)

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Van Mourik Broekmanweg Netherlands

STATE ROAD LABORATORY REPORT OF ACTIVITIES 1972

After an introduction including general remarks on quality control and maintenance criteria for pavement the work done in 1972 is discussed in the following chapters: soil, roadbases, concrete, asphalt for road construction, asphalt for hydraulic engineering, synthetic resins, carriageway marking materials, stone and texture of road surfaces, skidding resistance, evenness, pavement design, and various investigations. The last two chapters consist of

tables and a list of lectures, publications, internal reports. (TRRL)

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Federal Highway Administration

REFLECTIVE TRAFFIC BEAD STUDY

May 1970: 51 p.

Evaluation of a new floating type of traffic bead by the Colorado Division of Highways shows that these small uniformly-graded beads are superior in both brightness and durability to the coarser traffic beads that the State had been using. The tests were performed on centerline stripes placed both on asphalt and concrete surfaces. During the three year test period, the brightness on 78 test sections was evaluated by human evaluation teams and by a photometer developed during the project. Plans for the construction of these photometers are included in the report as an aid to others who may want to evaluate bead performance. (A) Sponsored by Bureau of Public Roads, Washington D.C.

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Peterson, DE; Welch, BH

STATEWIDE EVALUATION OF PAVEMENT STRIPING OPERATIONS

Utah State Highway Department

August 1973: 33 p.

Factors contributing to a safe and lasting paint stripe along with the increasing costs have made it necessary to initiate this study on maintaining paint stripes and the conduct of striping operations. Understanding the forces that contribute to the major wear on pavement markings will aid initial construction, maintenance and ultimately increase traffic safety for the highway user. A review of previous research combined with reflectivity testing, operational and maintenance review and visibility analysis are of prime concern in this study investigation. The results show a marked difference of paint performance on asphalt and concrete pavements. Initially paint deteriorates faster on asphalt than on concrete surfaces. However, after approximately 32 weeks of wear, paint on bituminous surfaces wears more slowly than on concrete. There is also a noticeable difference in quality shown in direction of viewing the paint stripe. Both on concrete and bituminous pavements, if the stripe is viewed in the same direction as it was painted, the reflectivity and visibility qualities are better than if viewed from the opposite direction. In the comparison of the various paints as to overall quality, the Michigan paint formula showed slightly superior qualities to the Utah paint formula. Data collected was not consistent enough to formulate exact expressions for paint stripe wear; however, the relative degree to which each individual parameter (ADT, Environment, Age, Reflectivity, Substrate and Formula) contributed to wear is significant with 99.9 percent confidence. Optimum painting procedures to obtain paint life expectancies within the safe application practices reinforce most of the presently used techniques. They include a 20 to 25 mil wet film thickness, at least four pounds of beads per gallon of paint, six to eight mph paint speed, gravity fed beads, a truck leading the paint truck equipped with sweeper and

blower for substate cleaning, and adequate safety equipment. Recommendations resulting from this study are primarily a collection of procedural methods for the existing paint stripe operations in Utah's six state highway districts. Administration functions including selection techniques, are outlined for best results. Procedures for determination of proper paint formulation are also pointed out. It appears that during the effective life of the paint stripe, all paint formulations tested have comparable visibility characteristics to the driver. Throughout this report efforts are concentrated towards developing the most economical model to a safe and lasting paint stripe.  
Author

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Wheadon, R

#### HYDRO-STATIC AIRLESS HIGHWAY STRIPING WITH RAPID DRY TRAFFIC PAINT

Western Association of State Highway and Transportation Offices

June 1974: 21 p.

The specifications are presented for rapid dry traffic paint (the cost of which is less than 10 percent more than conventional paint), and a machine is described which can paint from the right or left side as desired by the operator and road conditions. The gun cluster lowers from between the rear axles and has paint and bead guns so arranged to allow painting of simple or double lines with skip cycle of any length desirable, with the major use being the 15 foot paint, 25 foot skip or the 2 foot paint, 2 foot skip at the off ramps. These various patterns are obtained at instant response from the control panel on the machine for either white or yellow paint. Accurate line placement and the application in an area of heavy traffic, uncontrolled access, and other complex traffic situations are described. Freeway painting, the maintenance of the 20 mils thickness, and the truck and its paint capacity are other aspects covered. Specifications are presented for the purchase of the paint striping machine.

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Schram, H; Clee, H

#### EXPERIMENTAL STRIPES OF DURABLE ROAD MARKING MATERIALS

State Road Laboratory

September 1971: 20 p.

Durable road marking materials are particularly suited for marking roads with a high traffic density and busy inter-sections. In the last few years on state highways, 500 to 600 tons of durable road marking materials, chiefly thermoplastic (resinous) compounds, were applied. In June 1968 and in June 1969 experimental sections of various durable marking materials were laid by the manufacturers themselves. These products included thermoplastic compounds, cold hardening compounds on base of methacrylic resin and polyester resin two-components road marking paints, one-component durable paints, cold-plastics, and pre-fabricated marking strips. During application, the temperature and the drying time of the stripes were measured. In the course of an 18 to 21 months' test period periodical measurements of skid resistance

and visual examination of appearance, resistance to abrasion, and night visibility were carried out. In the laboratory additional tests were made for the whiteness number and weathering resistance of the various products. Moreover the thermoplastic compounds were tested for softening point, flow, and brittleness at low temperatures. On the road the pattern product performed in general better than the other types of sufficient skid resistance during the whole test period and showed a remarkably good visibility at night: on the other hand they are often prone to yellowing. Cold-hardening compounds and pre-fabricated strips had an excellent resistance to abrasion and did not turn yellow; they soon become, however, slippery and discolored by dirt. Both last-named materials in non-reflectorized form might be especially suited for the marking of pedestrian crossings in built-up areas because of their high resistance to abrasion. (TRRL)

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Roth, WJ

COLOR CODING STUDY FOR FREEWAY MARKINGS MEDIAN DELINEATION PHASE

Michigan Department of State Highways and Transportation

February 1974: 20 p.

REPORT NO: TSD-231-73

In an effort to determine if gains in driver guidance can be made with the use of white left edgeline and delineation, or if additional driver benefits can be attained using another left edge color than white, which is standard for the right hand edge, a study was conducted in two phases on sites chosen on south bound and north bound curves on US-127. Details are given of the phases of the study and the study area. Two elements of the study showed evidence of association to the addition of white edgelines through the study areas. These are speed changes and lane usage patterns. The speed study analysis, lane usage analysis and the study procedure are described. Conclusions drawn and recommendations made on the basis of the study are reported. Study conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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Highway Research Board

HIGHWAY RESEARCH BOARD ANNUAL REPORT

June 1955: 27 p.

This annual report of the Highway Research Board to the American association of state highway officials gives a summary account of its publication, special projects, visiting and service activities in the preceding year. A listing of committees and publications by subject area is given. In the area of economics, finance and administration projects were underway to determine manpower needs and utilization in highway engineering, to review the purpose and objectives of the research program, to examine tax structure for interstate commerce, to research highway financing and revenue sources, to analyze education and work-study programs, and to investigate the right-of-way acquisition problem. In the area of design, studies were

underway to develop and compile new design practices, to investigate special topics related to bridge design: vibration and deflection, column analysis, toll-plaza design, pile groups, prestressed concrete research. The materials and construction department reported studies on deterioration resistance of bituminous materials, concrete freezing and thawing, the purchase of traffic marking materials. The maintenance department reported studies on shoulder maintenance, cost accounting pavement deterioration, maintenance organization, frost effects, warning devices, bridge and culvert maintenance. The traffic and operations department reported parking studies, traffic attraction analysis, studies on the effect of geometric design, and studies of capacity, speed, pavement-marking, vehicle characteristics, traffic control devices. The soil department reported studies on load-deflection measurements, compaction requirements, pile behaviors, soil stabilization, loading rate and soil strength. Four continuing projects and the cooperative research procedure are described.

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Rural and Urban Roads VOL.11 NO. 4

#### YELLOW VS WHITE DEBATE GROWS OVER TRUE VALUE OF CENTERLINE MARKINGS

April 1973: 58 p.

There is a lack of research to support the use of yellow lines to delineate the separation of traffic flows in opposing directions. The reflectivity of White paint is 53 percent higher than yellow and 107 percent higher after exposure to chemical and water conditions. Tests with a telephotometer under typical highway conditions show that white paint is 1.6 times brighter than yellow. The darkening of yellow lines on exposure to sunlight (based on the photosensitivity of chromate), and the fact that they are one fifth as visible as white light under fog conditions point to need for reevaluation of the decision to change the color of centerlines from white to yellow. It is also claimed that yellow traffic marking paints are more expensive than white paint. The cost of changing the striping system is quoted. To compensate for the poor reflectivity of yellow lines, it may be necessary to use glare beads. This would mean additional costs, as would also the use of the optionally permissible "no-passing zone" pennant sign. It is pointed out that acquittal of violating motorists who can plead lack of clear visibility could lead to increased hazards on the highway.

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Hrb-singer Inc.

#### A SYSTEM FOR MEASURING AND MARKING NO-PASSING ZONE LIMITS

State College, Penn.

1971: 31 p.

REPORT NO:42991

A system for determining the proper pass/no pass zones on two-lane rural highways is described. The system consists of two pickup trucks equipped with a sight distance measuring device, an operator console, paint code computer, and paint spray equipment. A radio distance measuring system is mounted in

the two trucks to monitor the spacing between the trucks as they travel (15-25 mph) along a highway to be marked. The output of the measuring system provided information to the operator of the second truck to maintain the spacing at the selected minimum safe passing sight distance. A flashing light mounted on the leading truck is the target for determining when the truck is not in sight. A second operator in the trailing truck causes marks to be painted on the pavement when the leading vehicle disappears from view, and again when it reappears. These marks are used later by the paint truck crews to mark the appropriate stripes on the road surface.

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Alabama State Highway Department

#### GLASS BEADS FOR TRAFFIC MARKING PAINT

July 1971: 47 p.

As part of a national experimental program undertaken by FHWA, the Alabama highway department evaluated premixed and drop-on glass beads in traffic marking paint placed on test sections of centerline striping installed on two highways in Montgomery with an adt of about 25,000. One pavement was concrete; the other, asphalt. The former was striped at the beginning of April; the latter, during the last two weeks of February, 1970. The test procedure is described in detail, including difficulties encountered in calibrating the dispenser for drop-on beads. Evaluations of appearance, durability, and night visibility were made periodically through the beginning of November. The following conclusions were reached: (1) variability in test-section ratings was small; (2) stripe performance was not affected by pavement cleaning prior to application; (3) high drop-on rates (9.9 and 17.4 lbs/gal) produced good night visibility but poor appearance and durability. (4) the durability advantage of drop-on beads over reflectorized paint was high at the beginning and lower at the end of the evaluation period. (5) on the asphalt surface, the best performance was produced by reflectorized paint with 2:2 lbs/gal of drop-in beads; (6) on the concrete surface, the same result was found.

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Battelle Memorial Institute

#### MINIATURE PLASTIC RETROFLECTORS ARE BEING EVALUATED FOR USE ON HIGHWAY CENTERLINES

May 1970

Strips of reflectors, only 1/8 inch thick, may prevent centerlines being obscured by water on rainy nights, Battelle Physicist Daniel R. Greiser explains. Retroreflectors do not require exact alignment to reflect light to the driver's eyes. The principle was used to make the mirror places on the moon by the Apollo 11 crew to bounce back laser beams sent from Earth. A problem with a number of currently used highway marking devices, Battelle points out, is that their design requires the reflectors to be as much as 3/4 inch above the pavement; at this height, snowplows often chip them off.

Article

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Colorado Department Highways

FOLLOW UP REPORT: COLORADO'S REFLECTIVE BEAD STUDY

October 1969: 32 p.

Evaluation of a new type of traffic bead by the Colorado division of highways shows that small uniformly-graded beads, which have the property of being able to float on a xylol solution, are superior in both brightness and durability to the traffic beads that the state had been using. The division of highways estimates that the purchase of these beads saved the state approximately \$50,000 during the 1967-68 and \$36,000 during the 1968-69 traffic striping season. The new product costs approximately two cents per pound more than the old product. However, evaluation showed that the new product, when placed at the rate of four pounds of beads per gallon of paint, is brighter and more durable than the old product placed at a rate of six pounds of beads per gallon of paint. Hence, only two-thirds the quantity of the new product is required. Tests performed in 1968-69 indicated that both the floating characteristics are responsible for the improvement in nighttime brilliance over the old irregular bead. Contrary to the initial premise that uniformly graded, floating beads would not be as durable as various size beads with high index, the new bead appears to be just as durable as the old bead.  
Author

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Chaiken, B

TRAFFIC MARKING MATERIALS; SUMMARY OF RESEARCH AND DEVELOPMENT

Federal Highway Administration

December 1969

A summary is presented of significant research and development in the field of traffic marking materials. The subject matter is discussed under the following topics: conventional solvent-based traffic paints, rapid-dry markings, semi-permanent markings, markings for improved wet-night visibility, and temporary land markings.

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Chaiken, B

COMPARISON OF THE PERFORMANCE AND ECONOMY OF HOT-EXTRUDED THERMO-PLASTIC HIGHWAY STRIPING MATERIALS AND CONVENTIONAL PAINT STRIPING

Public Roads 135 p.

Thermoplastic was found more economical under high traffic density and limited snowplow activity; bituminous pavements showed thermoplastics to better advantage than concrete surfaces. Selection parameters include traffic density, pavement type, and mean annual snowfall. Specifications and costs are included.



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Waters, CR

METHODS AND APPLICATION PROCEDURES FOR PAVEMENT MARKING

Highway Research Board Bulletin

May 1951

Questionnaires were sent to all the state highway departments containing over 70 items relating to the types of equipment used, methods of application, drying time of paint, use of glass spheres for night reflectance together with other pertinent aspects of pavement marking. Data analysis of questionnaires indicates a growing interest in marking traffic lines on pavements as a means of safety on highways. From 48 states reporting, 18 report that the stripers were designed and built in their own shops, 20 report that stripers were purchased from commercial sources and one state reports that their markings are placed by a contractor. Thirty states report using self-propelled units, nine trail the unit, eight use the pushmobile type. Forty-four states use pressure nozzles while four use the flow type. Thirty-eight states place preliminary markings for the equipment to follow. Thirty-seven states plus four provinces reporting from Canada use reflectorized markings for increased night safety. Dash line length and spacing is according to quality of paint and application methods.

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New Jersey Department Transportation

RED-COLORED PAVEMENT: EVALUATION OF MATERIAL

Federal Highway Administration

The study of red-colored pavement was conducted in two phases: (1) the performance of the materials used to produce a colored surface, and (2) the effect of pavement color on various driver characteristics. The report states that in the experimental red-colored pavement-installed at New Jersey Route 65 and U.S. Route 206-after two years in service the red colored faded. The pavement itself has not seriously deteriorated, and it has fair skid-resistance values. Author

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Michigan Department State Highways

THREE EXPERIMENTS WITH TRANSVERSE PAVEMENT STRIPES AND RUMBLE BARS

October 1972: 54 p.

Speed change was selected as an acceptable indication of the effectiveness of three devices in alerting drivers to an impending danger or maneuvering requirement. Transverse plastic pavement stripes with gradually decreasing spacing and an ABS plastic rumble bar in conjunction with yellow painted stripes were tested. A third experiment used polyvinyl chloride rumble bars. Both kinds of rumble bars caused larger speed reductions than the colored stripes. Paint stripes are applicable for

situations where a highway hazard cannot be readily eliminated. Low-profile rumble bars are recommended for use in construction areas as well as at other locations that require maximum driver-awareness, provided that special precaution is taken not to damage them during winter maintenance.

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Modern Plastics

#### ACRYLIC MAKES A MORE DURABLE HIGHWAY REFLECTOR

June 1970: 56 p.

A new lane reflector, consisting of two injection molded acrylic lenses mounted back-to-back in a steel frame, is said to be capable of withstanding the force exerted by snowplows and to be immune to damage by tire chains and studs. Its predecessors, based on reflective glass beads molded into polyester, has a relatively short wear life and tended to break down. An added dividend of the new acrylic reflectors is that they function as a warning signal to motorists entering a lane against the flow of traffic. The two lenses face in opposite directions; one is clear and the other is red. A motorist going in the right direction sees the road outlined by the white reflection of his headlights returned by the clear lens. If he is in the wrong lane, he sees red reflections. The acrylic lenses are 4 in. long by 1 in. high and about 1 in. thick. The reflecting surface is made up of parallel rows of molded cubes that form optical prisms to concentrate the reflected light into a narrow beam. The lenses are mounted in a 4.5 by 8 in. cast steel frame that has sloping sides to hold them at the proper reflecting angle. The reflectors are embedded in the road surface and anchored with epoxy; they project only 1 1/2 in. above the surface. The reflector is manufactured by Stimsonite division, Amerace Esna Corporation, Elizabeth, New Jersey. Plexiglas acrylic material is supplied by Rohm & Haas Company. MP

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Botts, ED

#### PRETREATMENT OF CONCRETE PAVEMENT FOR TRAFFIC STRIPING

Highway Research Board Proceedings 278 p.

This paper describes experiments on treatment of portland cement concrete surfaces with phosphoric acid for the purpose of securing a better base for traffic marking paint, and the work that has been done toward the adoption of an asphaltic emulsion base for the same purpose. The causes of failure of traffic paints on concrete surfaces, as compared to asphaltic surfaces, also are discussed.

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Lee, C

#### NIGHTTIME CONSTRUCTION WORK ON URBAN FREEWAYS

Traffic Engineering

March 1969

The heavy volume of traffic on freeways in District 07, California division of highways, has led to initiation of nighttime construction. Typical nightwork has included installation of raised pavement markers, removal of cable chain link barriers and installation of double-blocked out metal beam barriers with anti-glare screen, grooving of pavements and paving of additional lanes. Analysis of accident records reveals fewer accidents occur during night construction periods than during ordinary nights. Much of the success is attributable to the use of a minimum 2000 foot taper for lane closure (1000 feet is the normal minimum). For better nighttime delineation, the traffic department is experimenting with illuminated traffic cones. Experience indicates that scheduling construction activities at night eliminates traffic delays and improves traffic safety.

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Australian Road Research Board Conference Proc.

ROAD MAINTENANCE-GENERAL 1970

The papers presented at the general road maintenance session of the conference were as follows: "Bitumen Enrichment," F.A. Prichard;"Use of the PCA Roadmeter for Measuring Road Roughness," A. J. Scala;" Testing of Road Marking Paints with Special Reference to Drying Time," J.C. Giffen, J.C. Rudd. (TRRL)

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Traffic Engineering

A MODEL PERFORMANCE SPECIFICATION FOR THE PURCHASE OF PAVEMENT MARKING PAINTS

March 1972: 24 p.

This model performance specification describes the general and specific requirements for reflective pavement marking paints to be used in pavement marking programs, as well as provides for the submission of samples and describes the laboratory and service test procedure which will be used to rate the materials submitted for test. This is a performance specification. The reflective pavement marking paints considered are described and their physical properties are enumerated.

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Oconnor, DL

DEVELOPMENT OF AN ADHESION FOR TRAFFIC BUTTONS, MARKERS AND JIGGLE BARS

Texas State Department of Highways & Public Transportation

October 1971: 25 p.

A procedure was developed to determine the degree of adhesion obtainable to traffic markers using a standard epoxy adhesive. Bond tests to several different types of markers were performed at 0, 77 and 140 F and also after freezing and thawing. A bond strength of 500 psi at 77 F was selected as the minimum for satisfactory performance.

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Mississippi State Highway Department

AN EVALUATION OF ROAD MARKING MATERIALS

March 1973

The purpose of the study of traffic paint was to make a comprehensive evaluation of the commercial formulations furnished by paint suppliers using the present state specification paint as a control. The study was initiated to find the best paint and methods of application to improve traffic markings and reduce the annual cost of this operation.

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Federal Highway Administration

DEVELOP MORE SIGNIFICANT AND RAPID TEST PROCEDURES FOR QUALITY ASSURANCE  
PHYSICAL TESTS OF SIGNS, MARKING MATERIALS, AND COATINGS

March 1972: 130 p.

Efficient, non-destructive tests for color and visibility of signs and pavement markings and for paint coat thickness are to be developed. Instrumental optical methods, magnetics determinations, radiography, and nucleonics will be included. Four studies are suggested: (1) isolation of the variables affecting the night retro-reflectivity of traffic striping, including: light angle, bead size, bead index, bead concentration, substrate surface irregularity; (2) quality tests of reflectorizing beads; (3) tests capable of measuring paint behavior under jobsite conditions; (4) rapid laboratory test of traffic paint durability.

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George Washington University

REVIEW FOR FEDERAL RESEARCH AND DEVELOPMENT IN PAVEMENT STRIPING MATERIALS

July 1971: 150 p.

This report was made to NASA's technology utilization office by the technology application group of the university's biological sciences communication project, which has been assisting NASA to design and develop its program for applying space-related research and development to cities. The specific task of bscp/tag is to identify existing R&D projects, within and outside NASA, toward the goals of coordinating federally conducted or sponsored research, avoiding duplication, and selecting promising new technologies. The first problem chosen was pavement striping. The main sources of information were found to be the Federal Highway Administration and the Highway Research Board. Existing projects are listed. The main report is eight pages long, and the remainder of the document consists of appendices: project reports, problem statements, excerpts from publications, etc.

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HOT METAL PAINTS FOR TRAFFIC STRIPING

November 1971: 24 p.

Improvements in traffic safety and reductions in highway and street line painting costs are said to be resulting from new hot melt traffic paints being tested in the United States. The new hot melt materials which are sprayed onto streets and highways under pressure at extremely high temperatures, dry almost instantly as the film cools. This eliminates the need for traffic-directing cones or other barriers to stop or slow traffic flow. Elimination of "cone-ing" increases safety. A significant saving is incurred because the cost of the cones and the manpower necessary to place and remove them accounts for approximately 30 percent of the cost of striping by conventional methods. Applied under high pressure, the paints automatically displace water or loose particles on the pavement and also fill indentations. It is possible to achieve film thicknesses of 20 to 200 mils, reports indicate. The hot melt traffic paints still are in the testing stage in many street and road departments, but interest in their application is mounting steadily. Author

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Klarquist, JM; Somerville, GR

TRAFFIC PAINTS BASED ON EPOXY RESINS

Highway Research Board Proceedings

1960: 339 p.

The characteristics of good adhesion, chemical resistance, and inherent toughness found in epoxy resin surface coatings are now well known. These same desirable properties can be incorporated readily into traffic marking paints exhibiting excellent durability. Two general classes of epoxy resin-based traffic paints are discussed: the amine-cured type and the ester type. Field test experience with both types of paint is covered, showing relative advantages of each type. Included is a brief discussion of solvent-free epoxy resin coatings as a new approach to traffic striping paints. Special equipment and techniques allow efficient application of thick durable marking paint. Author

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Rhodes, CC; Cody, LW

A COMPARATIVE STUDY OF THE DROP-IN AND OVERLAY METHODS OF REFLECTORIZING TRAFFIC PAINTS-WITH DISCUSSION

Highway Research Board Proceedings

1957: 370 p.

In the development of Michigan's traffic paint procurement procedures, it became desirable to establish a fixed policy with regard to the use of glass beads for reflectorization. Two methods, drop-in and overlay, were studied in controlled field tests on concrete and bituminous surfaces conducted in much

the same way as the annual performance tests for procurement purposes. Two top quality paints, both white and yellow, were applied in four different wet film thicknesses using the same amount of binder and the same over-all bead grading in the companion stripes for each film thickness. In the drop-in method, 6 lb of beads per gallon of paint were dropped in the wet paint film immediately after application; in the overlay method, 4 lb of beads per gallon of paint were premixed and 2 lb dropped on the prebeaded paint in the stripe. The test was continued for more than a year, with evaluations at approximately three-month intervals. The results indicated little difference in the performance of paints reflectorized by the two methods. In most cases, any observable difference was in favor of the drop-in method when the test stripes were evaluated on the basis of performance over the entire test period. It was also found that thicker films gave longer-lasting stripes, but that life was not increased in proportion to the amount of material used. Author

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Louisiana Department Highways

RAISED REFLECTIVE LANE MARKERS FOR URBAN ROADWAYS

November 1970

REPORT NO: 105 pp

Four representative brands of raised reflective roadway markers were evaluated for one year. Reflectivity of the markers from illumination of automobile headlamps was measured periodically using a luckiesh taylor brightness meter. The reflectivity of all brands dropped immediately to a mean of about 50% of the new reflectivity, then varied above and below this value depending on weather and fouling. The loss of markers from the roadway was evaluated. The epoxy adhesives were satisfactory for plastic markers, all losses were due to failure of the asphalt roadway under the markers. Failure of the plastic markers was negligible. The ceramic markers suffered drastic loss of the reflective elements. Author

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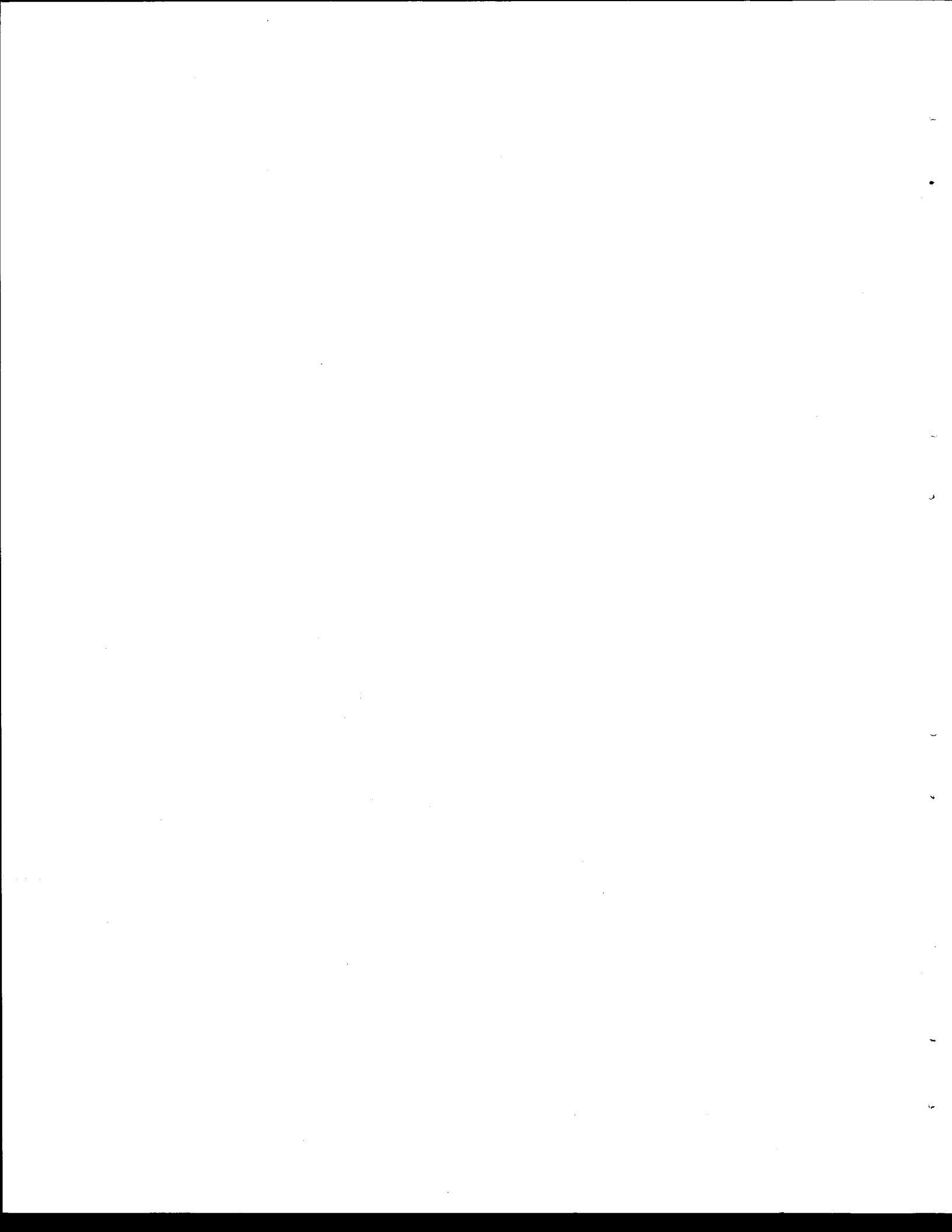
James E. Bryden and Gary F. Gurney

PAVEMENT-MARKING MATERIALS: NEW YORK'S EXPERIENCE

Engineering Research and Development Bureau  
New York State Department of Transportation

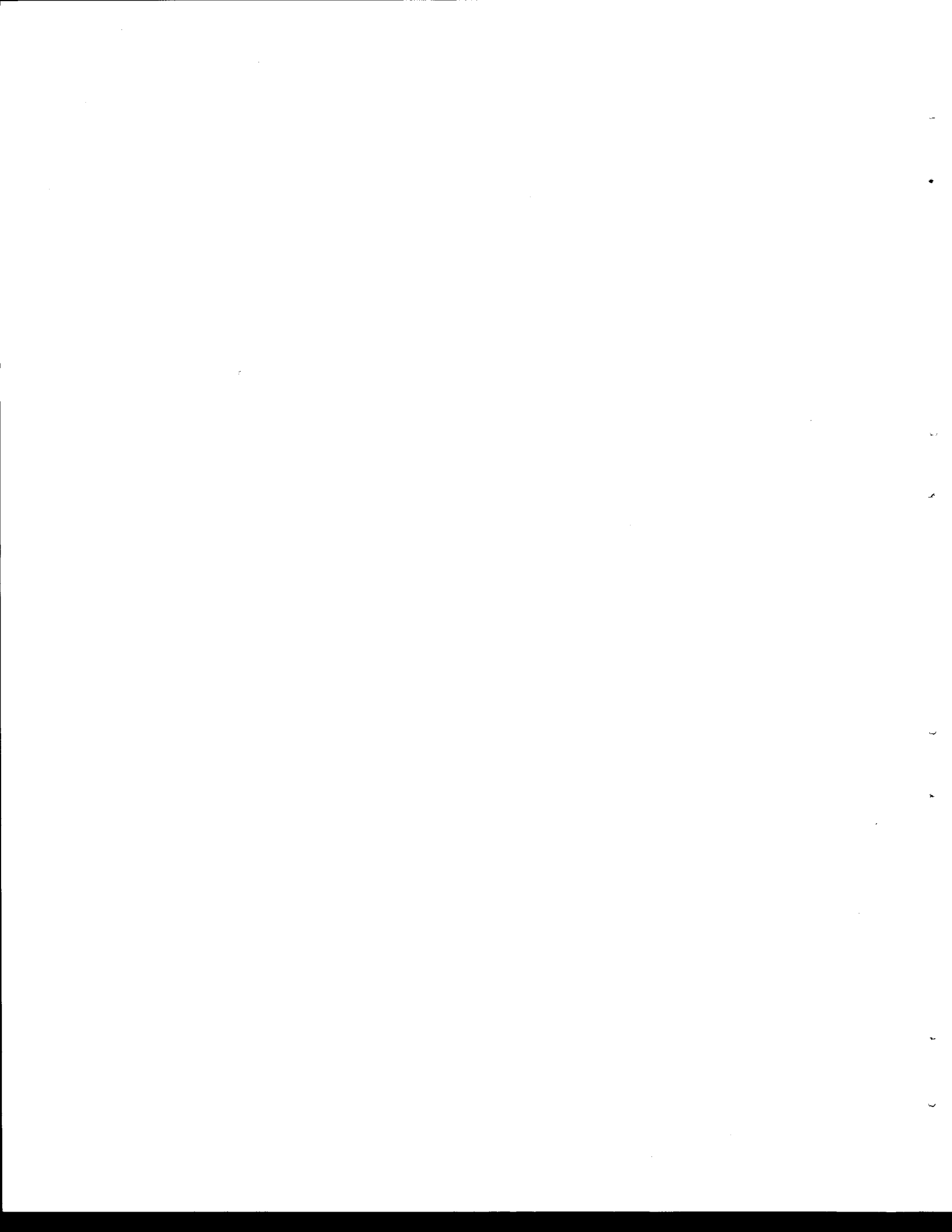
A wide range of striping materials is available for pavement-marking programs. The four basic systems -- traffic paint, thermoplastic, preformed tape, and field-reacted materials -- are described, as well as the various materials used in each system. Important material properties are discussed, including cost, durability, methods of installation and maintenance, visibility, and handling safety. New York State's pavement-marking policies are described. Information on striping costs, material usage, and results of durability studies is provided, based on New York's experience with most currently available marking materials.

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Appendix H  
Cost of Pavement Marking Materials



Cost of Pavement Marking Materials

**SDHPT - Cost Comparisons**

(1977, 78 & 80 Prices)

<u>Prefabricated Materials</u>	<u>Hot Applied Thermoplastic</u>	<u>Paint</u>	<u>Raised Pavement Markers</u>
\$1.58/4" Line (initial)	\$0.65/4" Line (initial)	\$0.196/4" Line (initial)	\$1.15/marker 1.00/marker installation <u>2.15/marker installed</u> .35/holes drilled .50/spikes <u>\$3.00/Total</u> Installation Price

**IOWA - Cost Comparisons**

(1982 Prices)

<u>Prefabricated Materials</u>	<u>Hot Applied Thermoplastics</u>
\$1.17/4" Line (initial)	\$0.65/4" Line (initial)

**MINNESOTA - Cost Comparison**

(1977, 78 & 80 Prices)

<u>Conventional Paint</u>	<u>Epoxy</u>	<u>Epoxy Thermoplastic</u>
.10-.12/ft 15 mils 4" wide	.14/ft 15 mile thick 4" wide	.21/ft 15 mils thick 4" wide
<u>Polyester</u>	<u>Thermoplastic</u>	<u>Prefabricated</u>
.125/ft 15 mils 4" wide	.095/ft 30 mils 4" wide	1.17/ft  4" wide

Marking Material Costs in New York State\*

Application Method	Material Type	Approximate Material Cost <sup>1</sup>	Application Rate	Installed Cost, \$/ft/4 in. line	
				Maintenance <sup>2</sup>	Contract <sup>3</sup>
Traffic Paint	Modified Alkyd	\$3.50/gal	16 gal/mile (15-mil wet)	\$0.027	---
	Chlorinated Rubber	\$5.50/gal	16 gal/mile (15-mil wet)	<\$0.04	---
	Latex	\$5.50/gal	16 gal/mile (15-mil wet)	<\$0.04	---
	Epoxy	\$18.00/gal	16 gal/mile (15-mil wet)	\$0.08	---
Thermo-plastic	Alkyd	\$850./ton	4500 ft/ton (125-mil)	---	---
	Hydro-carbon	\$750./ton	4500 ft/ton (125-mil)	---	\$0.32
	Epoflex	\$2500./ton	36000 ft/ton (15-mil)	---	\$0.15-0.18
Preformed Tape	Plastic	\$0.80/ft	60 mil	---	\$1.25
	Foil (Durable Grade)	\$0.60/ft	---	---	---
Field-Reacted Materials	Epoxy	\$30./gal	16 gal/mile (15-mil)	---	\$0.17-0.25
	Polyester	\$10./gal	16 gal/mile (15-mil)	---	\$0.07
Glass Beads		\$0.22/lb			
Installed on:					
	Traffic paint		6lb/gal (2 lb/100 ft)		
	Thermoplastic		2 lb/100 ft (4-in. line)		
	Field-Reacted (drop-ons)		25 lb/gal		
	Field-Reacted Polyester		15 lb/gal		

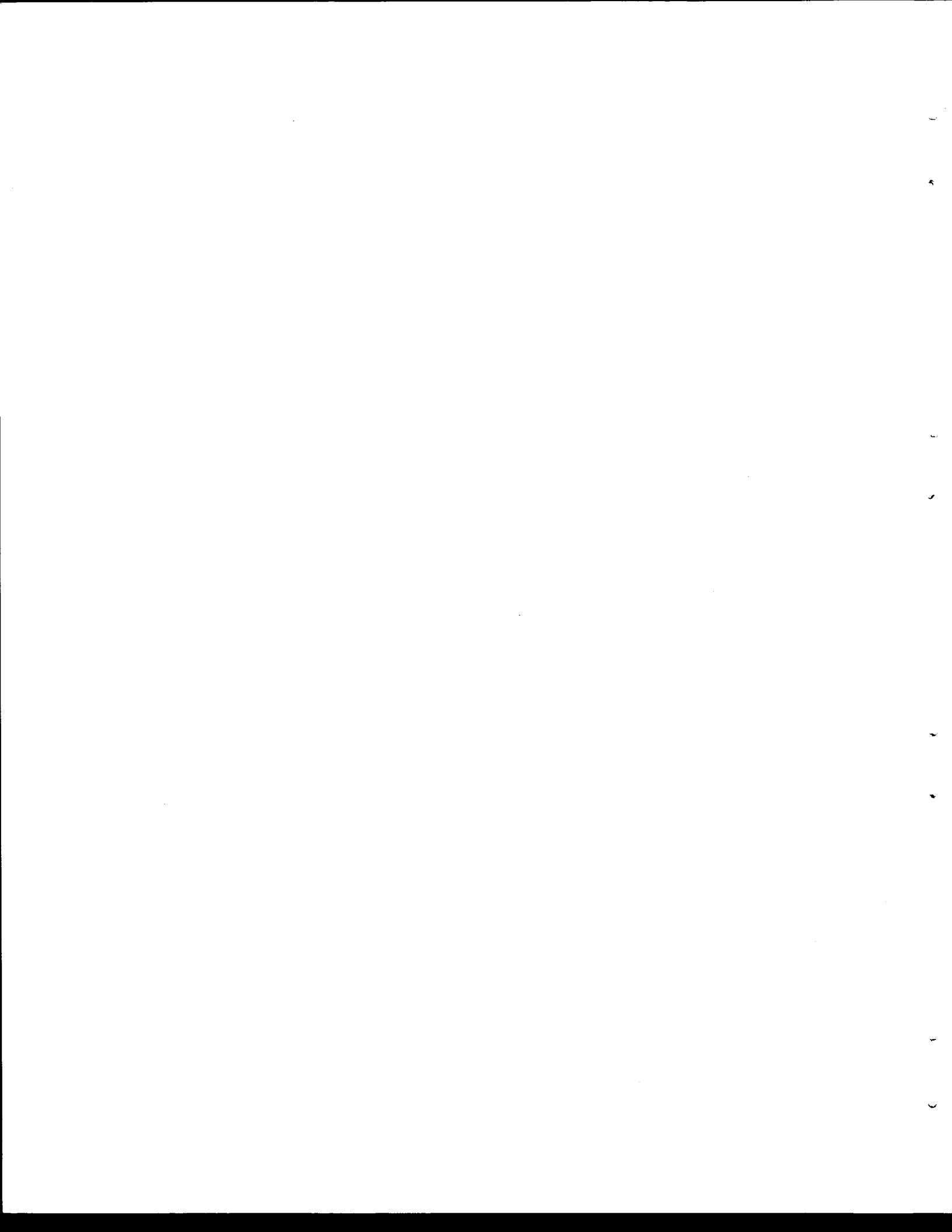
<sup>1</sup>Based on supplier's estimated and actual New York State experience.

<sup>2</sup>Actual or projected New York State costs.

<sup>3</sup>Average or range of typical New York State contracts.

\* Bryden, J.E. and Gurney, G. F. "Pavement-Marking Materials: New York's Experience," Engineering Research and Development Bureau, New York State Department of Transportation, 1984.

Appendix I  
Characteristics of Various Pavement Marking Materials



Characteristics of Various Pavement Marking Materials\*

Application Method	Material Type	Advantages	Disadvantages
Traffic Paint	Modified Alkyd	Lowest initial cost Good dry-night visibility Well-established technology One-component Short dry times available Relatively safe handling Good equipment available	Shortest life Poor wet-night visibility Year-round delineation not always possible Consumes petroleum distillate, contributes to air pollution
	Chlorinated Rubber	Low initial cost Good dry-night visibility Well-established technology One-component Relatively safe handling Good equipment availability Improved durability compared to alkyd	Poor wet-night visibility Year-round delineation not always possible Consumes petroleum distillate, contributes to air pollution Strong-smelling MEK solvent Long dry times-3 min. at best
	Latex (water-based)	Low initial cost Good dry-night visibility One-component Safe handling Good equipment availability Does not use petroleum distillate solvent	Poor wet-night visibility Year-round delineation not always possible Limited field experience Limited supplier competition Susceptible to rain damage during curing
	Epoxy	Most durable paint Good dry-night visibility Relatively safe handling Good equipment availability Moderate initial cost External mixing ensures proper proportions	Limited field experience Use strong-smelling MEK solvent Long dry times--2 min. at best Consumes petroleum distillates, contributes to air pollution

\* Bryden, J. E., and Gurney, G. F. "Pavement-Marking Materials: New York's Experience", Engineering Research and Development Bureau, New York State Department of Transportation, 1984.

