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HIGHWAY RESEARCH REPORT

DEVELOPMENT AND EVALUATION OF RAISED TRAFFIC LANE MARKERS 1953 TO 1968

FINAL REPORT

DND
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STATE OF CALIFORNIA
TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 635152

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads June, 1968

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
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Research Report
M&R No. 635152

June, 1968

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a final research report titled:

DEVELOPMENT AND EVALUATION
OF RAISED TRAFFIC
LANE MARKERS
1953 TO 1968

Herbert A. Rooney
Thomas L. Shelly
Principal Investigators

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

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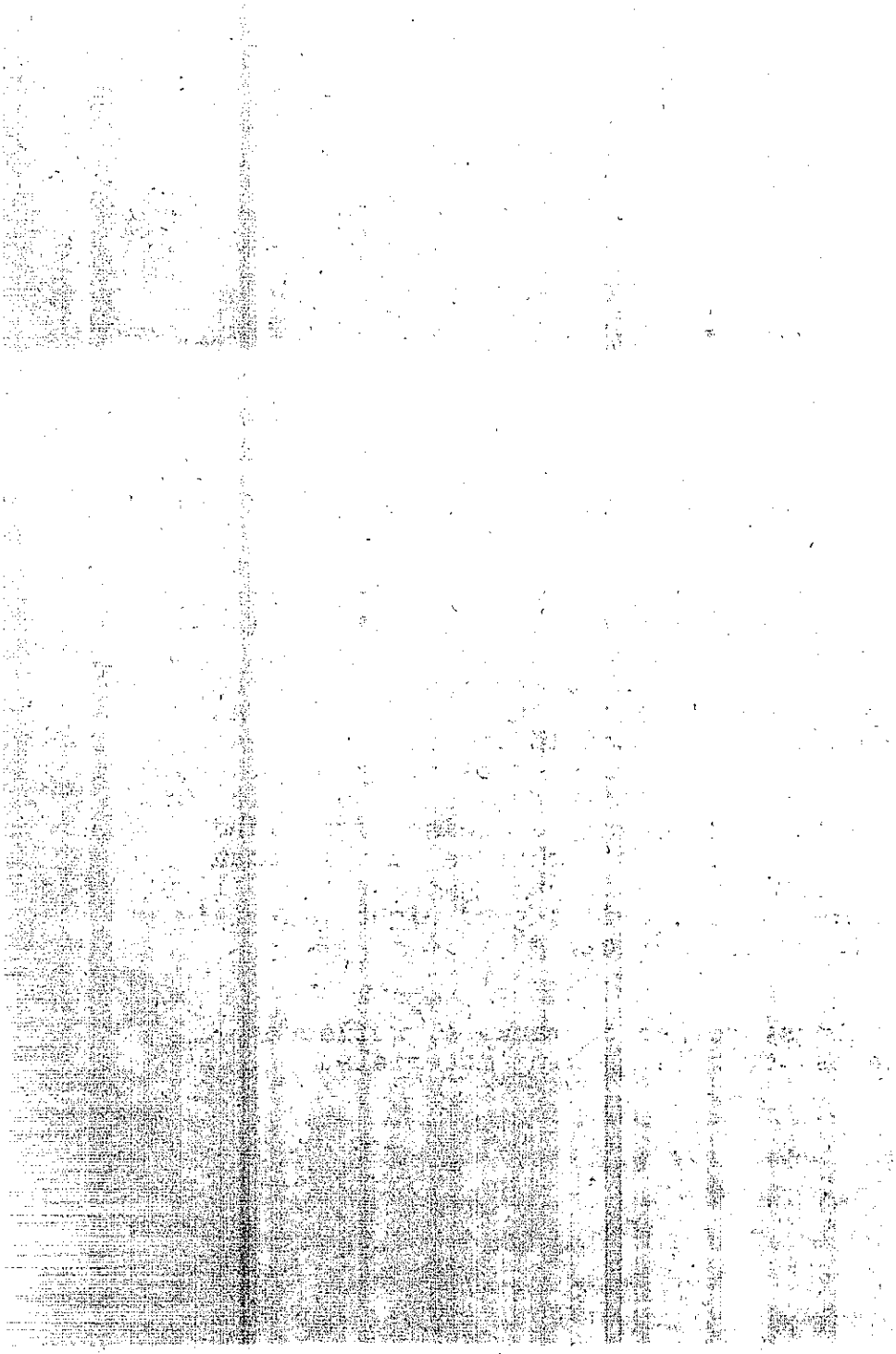

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The Headquarters Traffic Department and the District Traffic and Maintenance Department personnel have been very cooperative and helpful during the many years this study has been underway.

The authors wish also to extend their appreciation to the following personnel from the Materials and Research Department who have participated in this specific project within the last two years for assistance in the laboratory and in the field and for their contributions to writing the specifications and this report: Enrico Maggenti, Frank C. Norris, Bill J. Chapman, Truman E. Burns, Robert N. Field and Charles R. Ledbetter.

This project was performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, Agreement No. D-5-14.

The opinions, findings, and conclusions expressed in this report are those of the authors and are not necessarily those held by the Bureau of Public Roads.

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DEVELOPMENT AND EVALUATION OF RAISED TRAFFIC LANE MARKERS, 1953 TO 1968

INTRODUCTION

The search for a satisfactory highway lane delineator for both daytime and nighttime visibility under all weather conditions has been underway by the California Division of Highways for many years. The conventional beaded paint used has serious disadvantages.

1. The visibility during wet weather is far below an acceptable level, especially on todays high speed roads. This lack of visibility is most critical at night in wet weather when the glass beads become coated with water and are ineffective.

2. The difficulty of restriping on heavily traveled metropolitan freeways requires either a much more durable delineator, or a much faster drying traffic paint which can be applied with less disruption of traffic.

Various forms of raised pavement markings have been tried by the Division of Highways dating back to 1936. The work from 1936 to 1953 was very limited and will not be covered in this report.

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CONCLUSIONS

A system for delineation of highways has been developed and adopted which gives good daytime and nighttime visibility under most weather conditions. Due to the unique climate in most of California where there are long, hot, dry periods it has been necessary to use mostly ceramic markers to maintain good daytime visibility. Polyester markers may be used in cooler areas where temperatures seldom rise above 80°F.

Wear of the ceramic markers is by pitting or general dulling of the surface. Observations to date indicate that this should not become serious for at least 10 years. No measurable wear of the glaze has been observed under accelerated field testing.

The acrylic cube corner reflective nighttime marker is expected to last from 3 to about 5 years depending upon traffic conditions. One of these bright nighttime markers every 24 feet or 48 feet was chosen because it gives better visibility, especially in moderate rain or fog, than a less efficient marker spaced at closer intervals. The cost of placing the marker pattern described is approximately $700 per lane mile.

Satisfactory median delineation has been obtained by the use of yellow raised markers. Yellow reflective markers are placed on 24 foot centers and non reflective yellow markers on 6 foot centers.

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EARLY INVESTIGATION 1953 TO 1964

With the introduction of the epoxy resins to the Division of Highways Materials and Research Laboratory in 1953, a raised line of extruded epoxy was considered. Due to the expense and other application problems, this concept was altered and an investigation made using individual raised markers bonded to the roadway with an epoxy adhesive. These markers were placed in the 15 foot gap between the 9 foot painted stripes to provide night-time delineation in wet weather.

EPOXY AND POLYESTER MARKERS

Beginning in 1954 the Materials and Research Department Laboratory began experimental installations of raised white reflectorized markers to overcome the effect of the accumulation of water which normally obscures a painted traffic line. These markers were first made with epoxy, and later with polyester resins filled with glass beads, various pigments and inert fillers. The first markers were a button shape; four inches in diameter and about three fourths of an inch high. Later wedge shaped markers were used. The markers were bonded to the road surface with an epoxy adhesive.

In this and subsequent years a series of trial installations were also made using various combinations of white beaded and non-beaded white markers either as a supplement to, or as a replacement for the painted stripe. The results were not considered satisfactory for daytime delineation where beaded markers replace the stripe, and it was decided that the best compromise would be to use one or two beaded markers in each gap to supplement the painted stripe, to give better nighttime, wet-weather visibility.

Beaded markers could also be used with a thermoplastic traffic line about 1/8" to 3/32" thick to give a very durable system since the thermoplastic material has a service life of 4 to an estimated 10 years.

The rumble effect of the markers was soon observed to be an aid in keeping the motorist in his lane, and resulted in the painted traffic stripe lasting longer where markers were installed.

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PORTLAND CEMENT MARKERS

An installation was made of wedge shaped, white, beaded portland cement markers in the Spring of 1955 on the then new Elvas Freeway in Sacramento. The pavement was PCC (portland cement concrete). Various spacings of these wedge shaped markers were tried, the extreme distance being 24 feet between markers. No painted traffic stripes were used, and the markers formed the sole delineation. The delineation was effective except for the section where the markers were 24 feet apart, which was marginal. These wedges substituted for a traffic stripe for over 8 years until a traffic stripe was placed to provide more satisfactory delineation where the markers were 24 feet apart. The whole section was striped because it was not considered practical to stripe only the sections where the spacing between markers was 24 feet. Observation showed that the white portland cement wedges provided more effective daytime delineation than those markers in which the binder was polyester or epoxy resin. Constant chalking of the surface of the white portland cement wedge maintained a cleaner white surface. The life of this marker might have been 20 years. They were removed after about 10 years service when the road was widened.

SUMMARY

The following general observations were made at the end of the early phases of this investigation:

1. An epoxy adhesive was satisfactory for bonding the markers to both portland cement concrete (PCC) and asphaltic concrete (AC). Some loss of markers occurred over AC in warm climates, especially where the asphalt concrete was not well compacted. No pins or studs were used to fasten markers to the pavement as they are considered a hazard. Pressure tape has been used for temporary installations of markers.

2. Service life of 20 years could be expected for beaded and non-beaded polyester or epoxy markers on portland cement concrete roads.

3. Markers made with glass beads, white titanium dioxide pigment and either polyester resin or epoxy resin as a binder were not adequate for daytime visibility. Wedge shaped markers made with white portland cement as a binder and containing glass beads and titanium dioxide pigment gave adequate daytime and nighttime delineation but were not sufficiently durable for use on AC.

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4. Field observation showed that one type marker had a much higher percentage loss of the units from the roadway than was expected due to failure in the PCC under the marker. Laboratory investigation shows these markers to have about 70% by weight of polyester resin content which was higher than other markers being used at the time. Further laboratory investigation by cycling markers bonded to concrete between 77°F and -6°F duplicated this type of failure. Markers with resin content in the range of 20 to 40% were found to be more satisfactory in this respect.

5. Laboratory measurements of the coefficient of thermal expansion of various markers produced the following results:

Type Marker	Coefficient of Expansion Inches/Inch/Degree F
Ceramic markers	1 to 2 x 10^{-6}
Polyester markers low resin content	16 to 22 x 10^{-6}
Epoxy markers low resin content	16 to 20 x 10^{-6}
Epoxy markers high resin content	38 x 10^{-6}
Portland cement concrete	4 to 7 x 10^{-6}

These results would indicate why markers made with organic resins in large amounts would be more likely to separate from the roadway by failure of the concrete.

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LATER INVESTIGATIONS, 1964 TO DATE

In 1964 the Materials and Research Department began an investigation of a new type of raised marker, presented by industry, whose reflectivity was based upon the same principle as the reflex reflectors used on guide posts. The reflecting surface was an aluminized acrylic cube corner unit encased in an acrylic plastic shell with the interior of the marker being a filled epoxy resin system. Subsequent investigation was made of a similar reflective marker employing an ABS plastic shell.

An installation of these new markers was made on April 15, 1964 under State Project Work Order No. 43039. One marker was installed in the center of each 15 foot gap between the 9 foot painted stripes. Evaluations made between April 15, 1964 and April 17, 1965 showed that these new markers provide a brilliant delineation in clear and rainy weather at night but very little daytime delineation. Subsequent installations and evaluations indicate the maximum effective life of these reflective markers on heavily traveled freeways is 3 to 5 years.

Studies made in the Fall of 1965 on a large contract job near Vacaville on Interstate 80 indicated that 4 white non-beaded epoxy or polyester buttons, placed 3 feet apart, with a gap of 15 feet between the group of four buttons could be substituted for the painted stripe as a daytime lane delineator. On tangents, a reflective unit was placed in the center of every other 15 foot gap between the groups of white non-reflective (non-beaded) buttons for nighttime delineation.

In December, 1965 Division of Highways Circular Letter No. 65-287 was issued and set the policy for multi-lane freeways, expressways, and two lane rural highways. Traffic lanes were to be delineated by raised pavement markers except in areas that involve snow removal. The pattern used was as described above on the Vacaville installation using the reflective marker on 48 foot centers on tangents and on 24 foot centers on curves.

STAINING OF POLYESTER AND EPOXY MARKERS

Large scale applications of raised markers on freeways specifying polyester or epoxy daytime markers were made early in 1966. During the warm summer months following installation, considerable blackening of the markers was observed, first on the side facing away from the direction of travel, but soon on the side facing traffic as well. This deposit proved to be essentially carbon

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deposit from tires, and was easily removed with slight scrubbing with an abrasive and water. Subsequent observations showed that after only a few hundredths of an inch of rain, the scrubbing action of tires was sufficient to remove the deposit.

At about this time installations of ceramic markers which had been placed early in 1966 were compared with epoxy and polyester markers for relative amounts of staining. The leading edge of the ceramic marker was much whiter than the leading edge of the polyester or epoxy marker. The far edge of both plain ceramic and epoxy or polyester markers showed extreme staining but this was not visible to the motorist on freeways. See Figures 1 and 2.

Another installation of ceramic markers delineating a crosswalk over both AC and PCC was subjected to high traffic density, extreme acceleration and deceleration, and damage from gravel dropped from trucks. Markers were removed from the wheel tracks after one year of service. There was no apparent decrease in overall glaze thickness; however, there was pitting and a general loss of gloss on the surface. There was considerable cracking and some breakage of markers over the AC but only slight breakage over the PCC. This installation represents an acceleration of wear of perhaps 10 to 30 times that which would be expected to occur when markers are used for lane delineation.

At the same time, inspections were made of three large scale freeway experimental installations of ceramic markers which had been under traffic between 5 and 8 months. By counting the pits in each marker for 0.1 mile on each installation it was estimated that if the rate of pitting was uniform, about 5% to 8% of the area of the marker would be affected in 10 years. It is also probable that the glaze will become "frosted" from numerous small impacts. This "frosted" appearance was observed on the crosswalk installation mentioned above. One of these "frosted" ceramic markers was removed from the road and was subjected to the artificial staining test described below and it did not stain appreciably.

LABORATORY EVALUATION OF STAINING

Two attempts were made to develop a test that would duplicate the staining of markers as observed on the roadway. In the first attempt the markers were held against a rotating rubber wheel with a 20 KG load for 10 seconds, which produced a temperature on the surface of the marker of 140°F. In the second attempt the markers were placed in the path of a rolling 4.80/4.00x8 trailer tire which rotated in a circle 7 feet in diameter, and the markers were heated to 150°F with heat lamps. While these methods gave some indication of the tendency of a marker to stain, field evaluation of the same markers in the summer showed that the type of stain produced was different from that produced in the laboratory.

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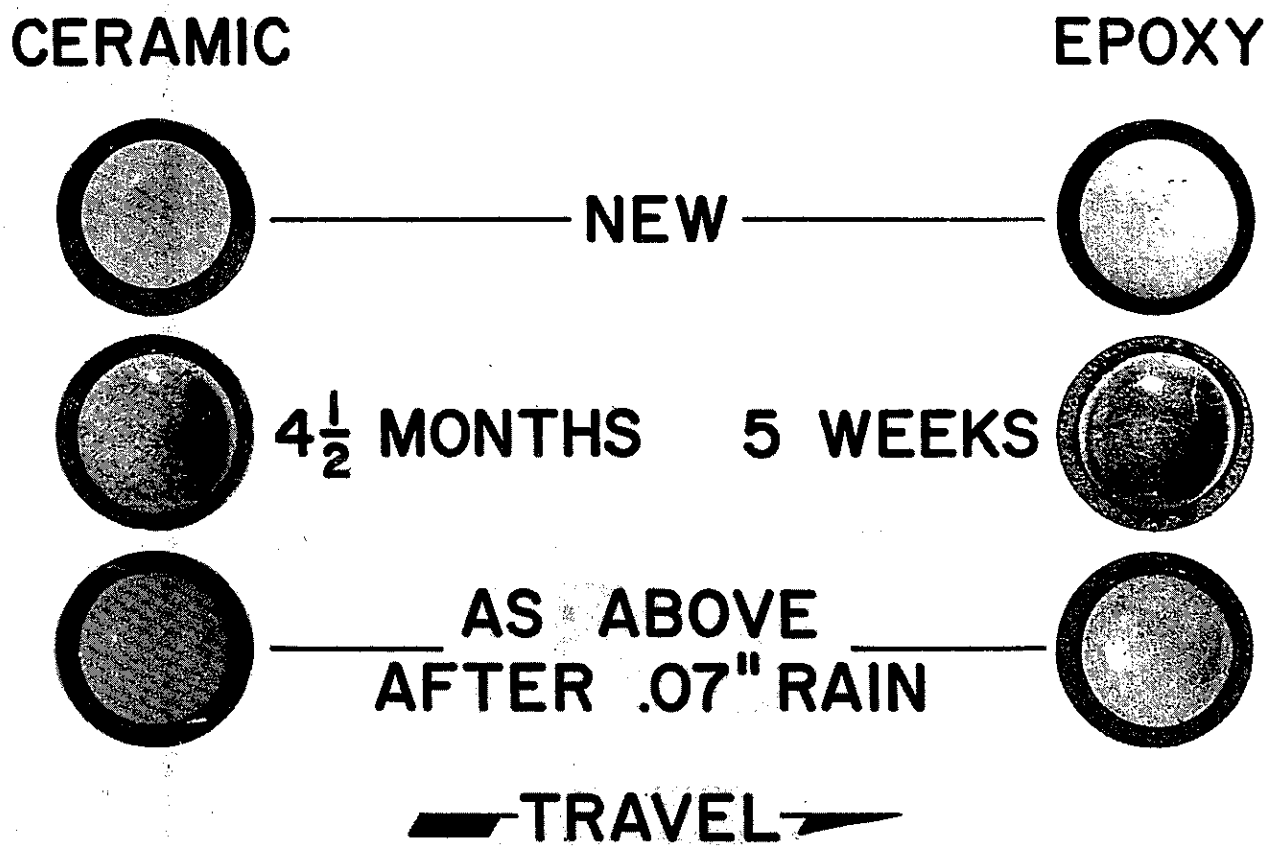

FIGURE 1

Staining of markers during summer months with temperatures generally below 100°F.

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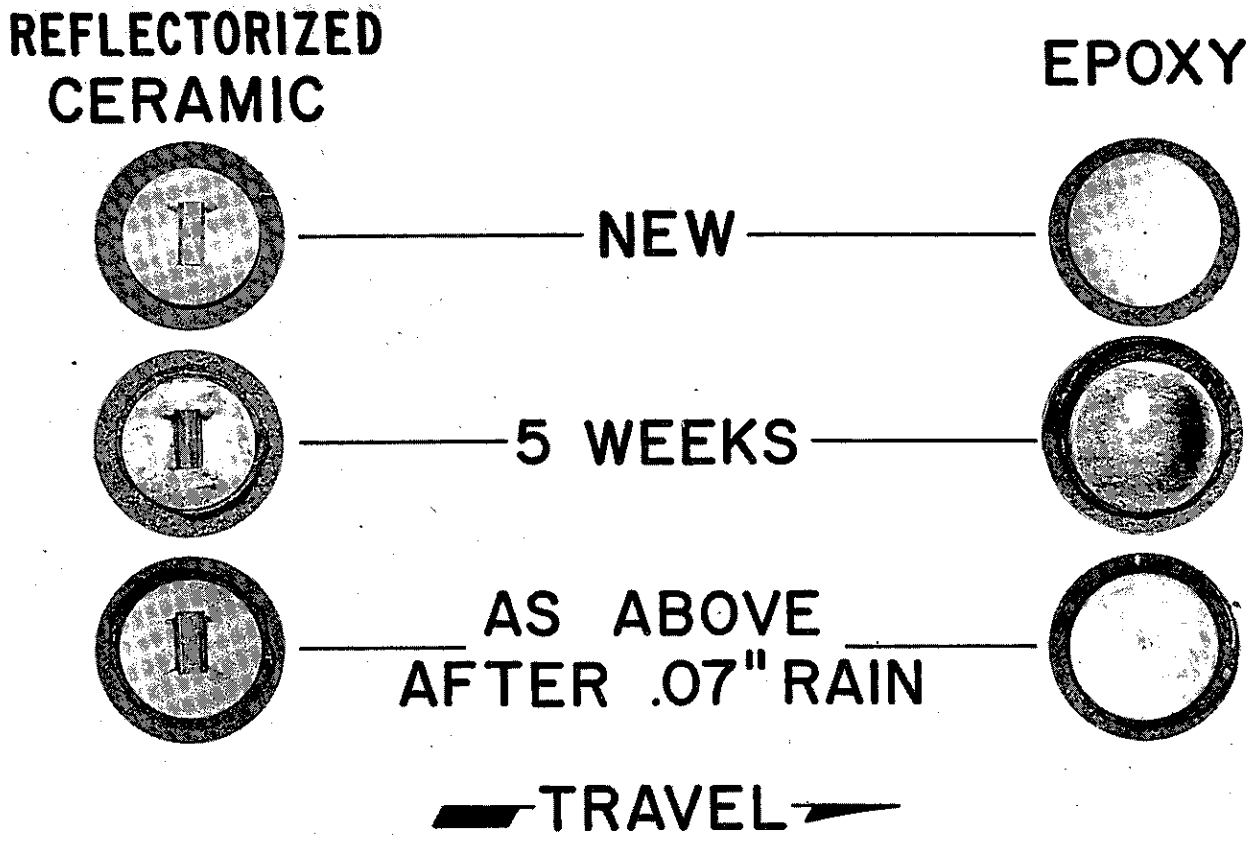

FIGURE 2

Staining of markers during summer months with temperatures generally below 100°F.

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USE OF CERAMIC MARKERS

On the basis of the above experience the State permitted the use of ceramic markers in September, 1966 as an alternate to polyester and epoxy type markers.

Observation of ceramic marker installations over PCC and AC on the crosswalk described above showed that the "standard strength" marker first supplied was possibly not satisfactory for use on AC due to cracking. Ceramic markers with a strength requirement twice the "standard" requirement were obtained and a test installation on a freeway made comparing the "high strength" and "standard strength" ceramic markers. They were placed over a resilient base of a 1/8" thick butyl pad to simulate a yielding substrate. The results showed the high strength ceramic marker to be far less susceptible to breakage. These high strength markers are now specified for AC pavements and no breakage has been reported.

STAINING OF MARKERS UNDER EXTREME TEMPERATURES

A comparison of an installation of various melamine, acrylic, epoxy and portland cement "button" shaped markers was made and photographed 7-6-67 after 6 weeks of service. At this time, the ceramic markers showed very slight staining of the leading edge, while other types showed moderate staining.

An inspection was made in September, 1967 of the above installation as well as a later installation of melamine, epoxy, pyroceram, alkyd, acrylonitrile butadiene styrene (ABS), and ceramic markers. All markers showed moderate to severe darkening at the leading edge. The ceramic and pyroceram markers showed less darkening than the other markers but the difference was less than has been observed on any previous inspections. Weather Bureau records show that there was no rain in August and there were 15 days over 100°F. See Figure 3.

Observations so far indicate that tire staining of markers increases at higher temperatures. With markers formulated with organic binders, this is partly due to the softening of the binder. Hence, markers using softer materials darken more than markers made with harder resins. High tire temperature has been shown to be of less significance than high pavement temperature since a hot tire passing over a relatively cool marker surface causes only moderate tire stain. This was confirmed by observations where ceramic markers and melamine markers were protected from the sun by an overcrossing and were only moderately stained on the leading edge by traffic, compared with those exposed to the sun. See Figure 4.

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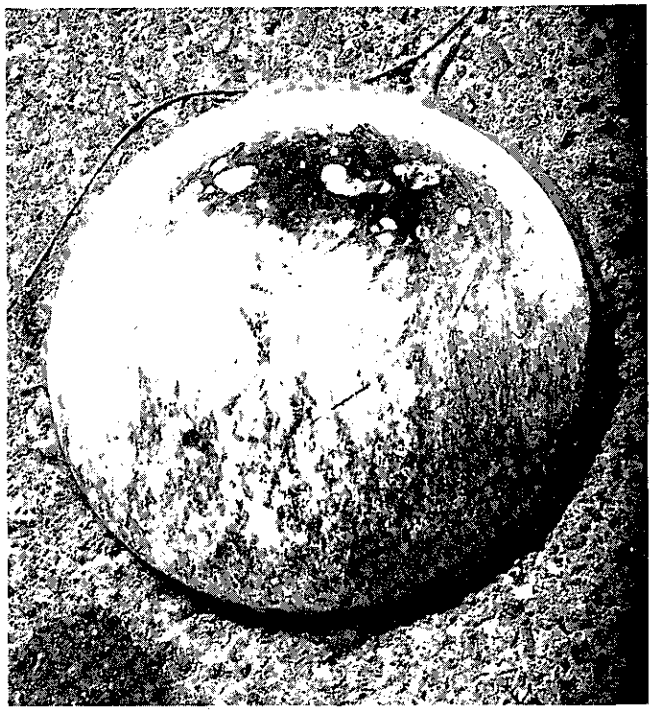
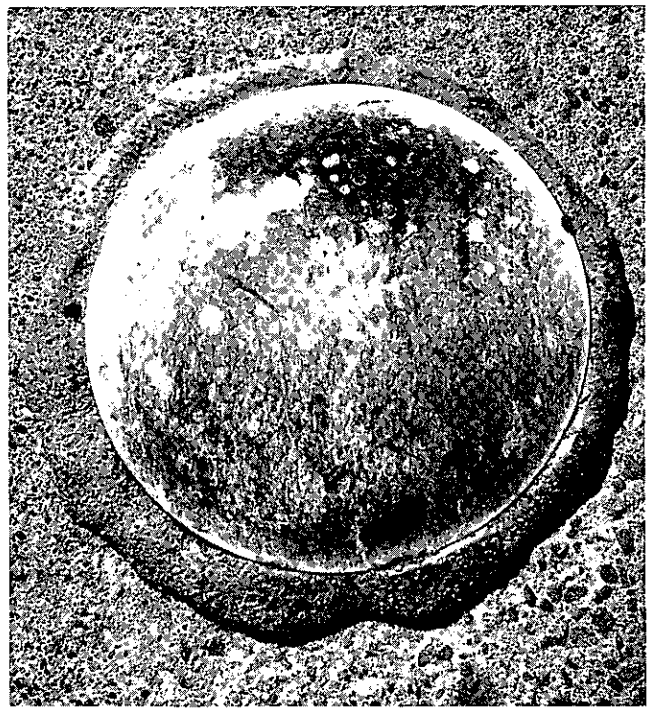


Ceramic Marker



Melamine Marker

TRAVEL →

Polyester Marker

ABS Marker

FIGURE 3

Staining of markers after summer month with 15 days over 100°F.

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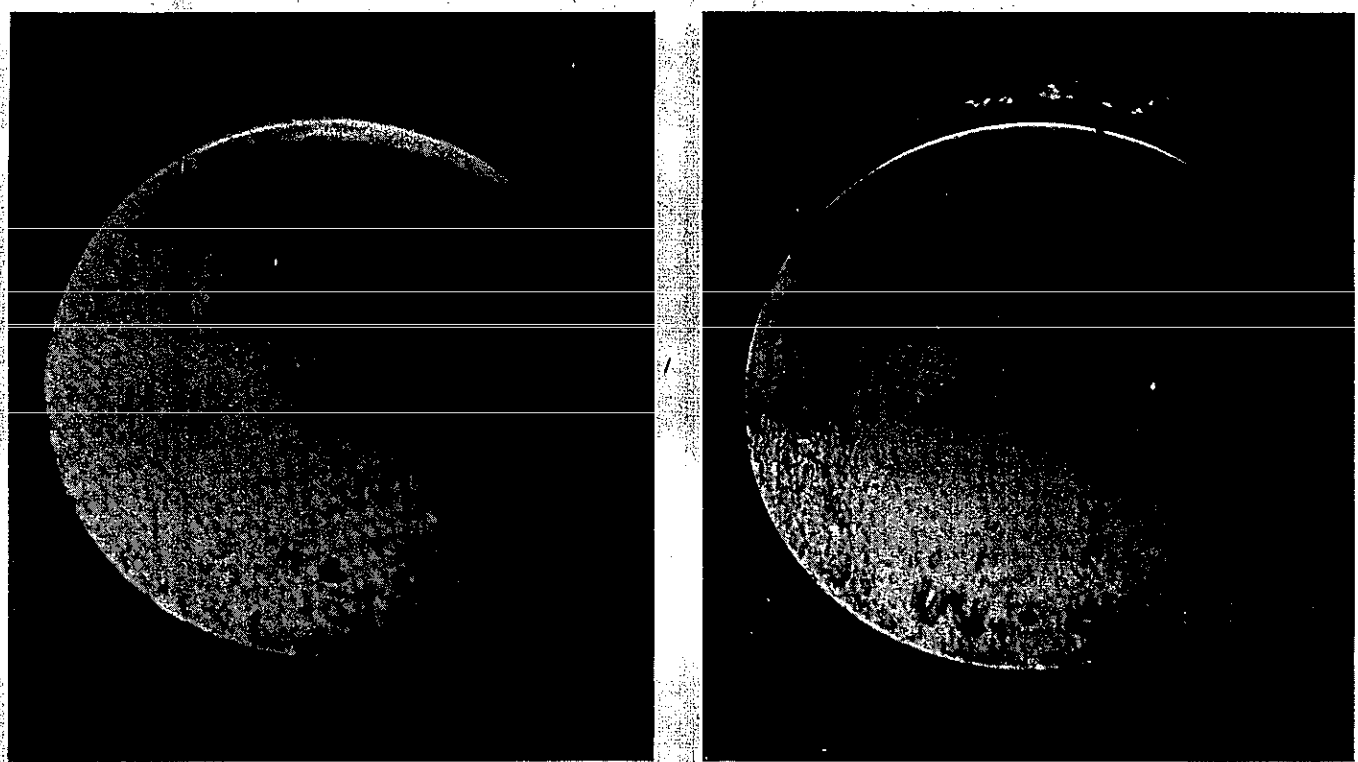

Ceramic Marker

Melamine Marker

FIGURE 4

Markers photographed at the same time as those in Figure 3 except markers were protected from the sun by an overcrossing.

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Unfortunately, an inspection was not made in time to observe the degree and the location of staining on the ceramic markers on a 1/2-mile section of two-way AC roadway after the high temperatures in August, 1967. Rain falling the first part of September had cleaned all markers. An evaluation cannot be made until next summer, (1968). The first inspection made the end of July, 1967 of this installation after one month, showed no staining but this was before occurrence of the 100+ temperatures of August.

LABORATORY EVALUATION OF TOUGHNESS OF MARKERS

In attempting to duplicate the pitting of markers in the laboratory, an abrader was used consisting of a steel cylinder chamber four inches high and four inches in diameter closed by the curved surface of a marker at top and bottom. A single piece of triangle shaped armide carbide 122U3, grade 370 lathe tool tip was enclosed and used as the abrading medium. This chamber was shaken at a speed of twenty times a second for sixty seconds. The pits are made easily visible by rubbing the marker with a cloth wetted with a black dye. The results of the test show that the very hard ceramic or other glass-like markers were most subject to pitting, while the softer epoxy and polyester markers were less affected. The melamine markers showed moderate pitting. Thus it would appear that in general, markers which are hard enough to be stain resistant are more susceptible to damage by pitting. It is hoped that this test will serve as a guide to the toughness of various hard surfaces and be a better indicator of performance than hardness measured by the Moh scale.

STUDDED TIRES

Studded tires, when new, damage all markers to some degree. At constant speed, considerable pitting occurs on the ceramic marker and to a lesser degree on the surfaces of the reflective markers. A skidding studded tire gouges all markers.

The damage to the marker by a partially worn studded tire would probably not be as severe since the studs are reported to wear faster than the tire. Only new studded tires have been used in tests by this laboratory.

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APPENDIX

Appendix I illustrates many of the various types of markers which have been evaluated. A brief discussion is given of each marker.

Appendix II gives the latest special provision describing the installation of pavement markers and includes specifications for the markers and adhesives. Special provisions for pavement markers have been revised several times since their inception as the result of experience and investigation. Future revisions are anticipated.

DISCUSSION OF APPENDIX II AND RELATED ITEMS

INSTALLATION OF MARKERS

Markers can be installed over PCC and AC but there is some doubt at this time that the cohesive strength of newly constructed open graded asphalt mix is adequate to hold a marker. This particular type of AC may harden and densify under traffic until it is strong enough to withstand sufficient tensile stresses.

The special provisions discuss the care required to obtain a good installation. However, the following points are mentioned in regard to adhesion of marker to pavement.

The success of the marker program has been dependent upon a satisfactory method of fastening the marker to the pavement. The use of a good epoxy resin has served this purpose very well. The formulation of a "standard set" adhesive which has proven field durability for many years is given in Appendix II. This specification has been altered slightly in that a particular grade of asbestos has been substituted for colloidal silica as a thixotropic agent. The effect of the asbestos is to maintain viscosity and thixotropy better during storage. There is some indication that the moisture resistance of the adhesive may be slightly impaired by the asbestos. This has not been proven conclusively and is not expected to be serious. Failures of markers to adhere to the roadway when used with a good adhesive are generally caused by the following:

1. Improper proportioning or mixing of the adhesive components.

2. Improper sandblasting of the road surface.

3. Road surface low in cohesive strength such as concrete with a weak mortar on surface, or a weak AC surface caused by

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3. Continued

excessive temperatures or inadequate compaction. (A tensile test of the pavement prior to placing markers on new PCC is being considered.)

4. Excessive coefficient of expansion of the marker.

5. Placement of marker over a working joint or crack. (See Figure 5.)

In order to place markers under traffic in metropolitan areas it is necessary to use an adhesive which will set rapidly in order to minimize disruption of traffic. Sufficient pot life or work life is necessary to permit time to machine-mix and extrude the adhesive, force the marker against pavement surface and make any necessary alignments. For this purpose a "rapid set adhesive" is preferred.

Little "rapid set" or similar fast setting adhesive has been used to date. Several difficulties with the fast setting adhesive are listed:

1. As of the present, many of the ingredients used in the rapid set adhesive are more costly, more likely to produce dermatitis and have a higher viscosity than the components in the slower setting adhesives. This latter factor is reflected in the wider ranges for viscosity given in the attached specification in Appendix II.

2. The wettability of the "rapid set" systems investigated to date has been poor. This has resulted in failure of bond to some reflective markers now being used. Proper selection of the material used to fill the reflective marker shells, or roughening the bottom surface will result in adequate bond even with the poorer wetting, rapid set adhesives. This point is covered in the specification requirement of 400 psi tensile load when tested with the specified rapid set adhesive.

MARKERS IN SNOW PLOW AREAS

Raised markers have not been applied in snow areas except for one location where snow is infrequent and snow plows with rubber tipped blades are used. This installation has been generally successful. Other designs of markers, not yet under test, are intended to guide the snow plow blade over the marker without damaging the reflective surface. The damage from chains however, will probably restrict the use of reflective markers of the type now specified to areas with little or no snowfall.

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FIGURE 5

Marker breakage caused by placement over logitudinal joint.

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Disk shaped markers were recessed in the concrete pavement on one highway in the mountains. Since they were set flush with the surface they were not affected by snow plow blades. Their effectiveness as lane delineators has been rather poor as compared to raised markers but they are considered superior to the painted stripe in the snow area because during the winter months there are several weeks at a time when little or no paint markings are visible. Since some of the disks are beaded and some plain, there is some delineation present most of the time, day or night during clear weather. (See Figure 19.)

Markers shown in Figures 6, 7, 8 and 10 are specified for use by the California Division of Highways. Marker 10 (polyester type) is permitted only in cooler areas where temperatures seldom rise over 80°F.

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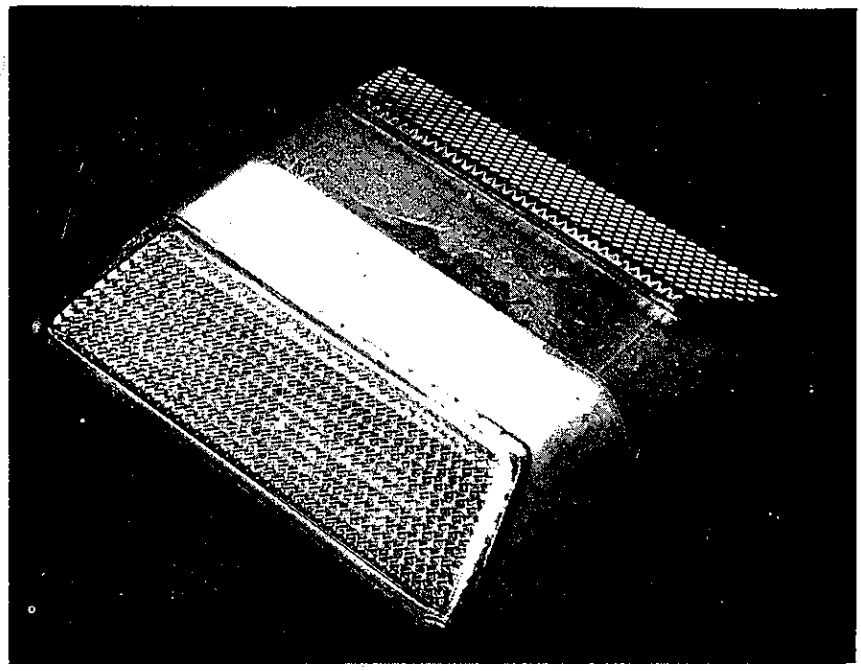

FIGURE 6

Acrylic Cube Corner Reflective Marker

This reflective marker is made of an acrylic shell filled with a thermosetting plastic. The angle of slope has been chosen to give maximum polishing action from tires. The large area and an efficient reflective surface gives the best light return of any practical system so far evaluated. It is effective as a night-time wet weather delineator in all except heavy fog. Under these conditions an independent light source such as is used on air-fields would be required. Service life is expected to be 3 to about 5 years depending on the traffic conditions and level of damage at which it is considered necessary to replace the markers.

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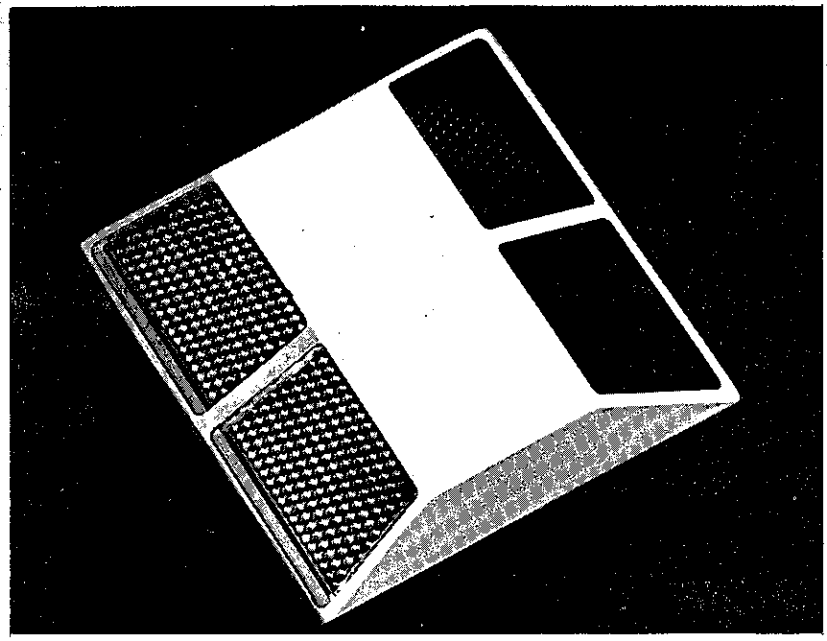

FIGURE 7

Acrylic Cube Corner Reflective Marker

The lens system is similar to 6, however, the shell is ABS which is then filled with a thermosetting resin. Durability of this reflective marker is expected to be equal or better than 6.

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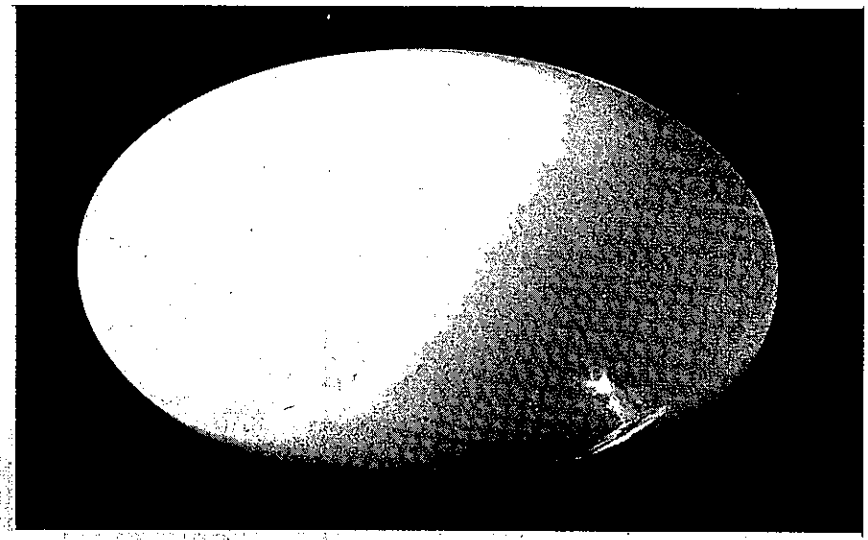

FIGURE 8

Ceramic Marker

This non reflective marker has given the best year around daytime visibility in California where there is very little, if any, rainfall in much of the State for about five months. While the surface is hard and resists staining until temperatures exceed 95 to 100°F, the surface of the marker does pit and becomes "frosted" and eventually this is expected to reduce its visibility somewhat. Service life is expected to be at least 10 years depending on traffic conditions.

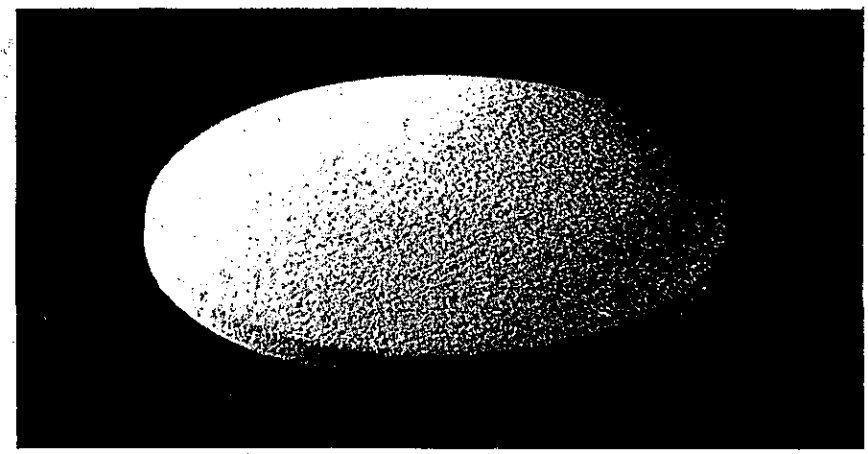

FIGURE 9

Glass Beaded White Button

This reflective marker was used experimentally on many miles of roadway. It verified the concept that a raised, reflectorized marker would substantially improve nighttime wet weather visibility. The daytime visibility of this marker was poor. Service life is expected to be at least 10 years. Nighttime visibility is lower than for the acrylic cube corner reflective markers.

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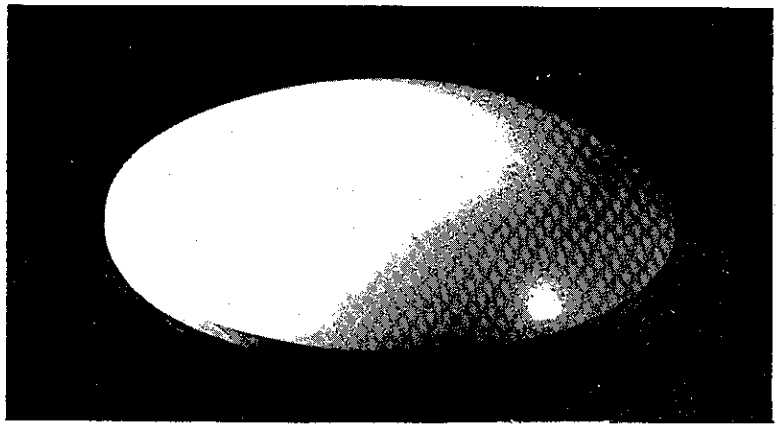

FIGURE 10

Plain White Non-Beaded Epoxy or Polyester Button

This type of marker was used experimentally to evaluate the suitability of replacing the white line for daytime visibility. They have been formulated with epoxy and polyester binders. In areas where temperatures are not excessive and where there is rain or fog at frequent intervals, these markers are satisfactory. The service life is expected to be at least 10 years. Recent formulations of melamine markers installed experimentally show similar properties to epoxy or polyester markers, but they stain somewhat less. Laboratory studies of durability have shown that they pit less than the ceramic markers but more than epoxy or polyester markers. Service life would probably be similar to polyester and epoxy markers although no long term or accelerated field performance data is available.

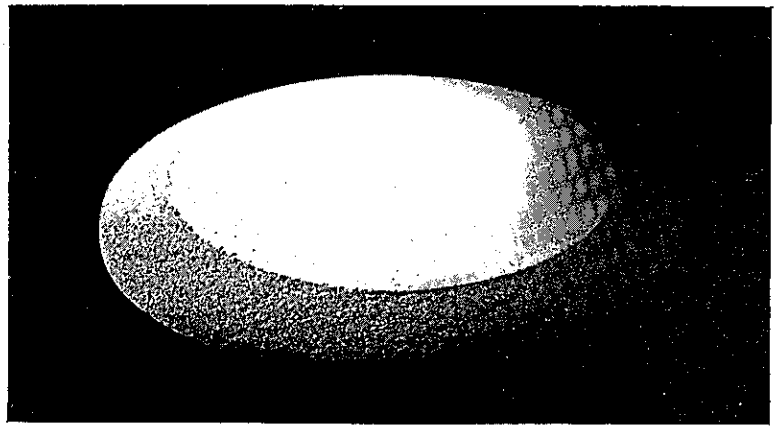

FIGURE 11

Plain White Top Button With Glass Beaded White Rim

This marker made with epoxy or polyester binders was used in a few trial installations to try to achieve a unit which would serve for both daytime and nighttime delineation. It was carefully considered but finally judged inadequate.

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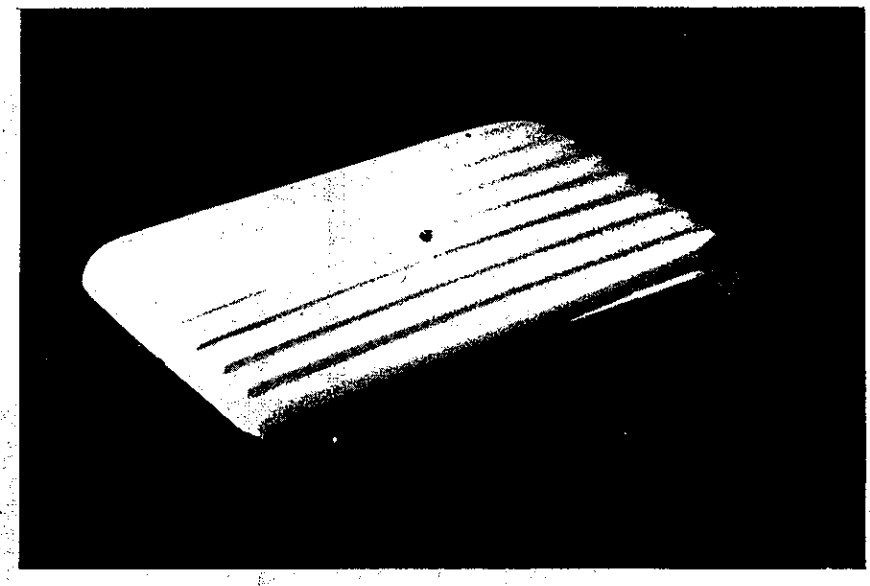

FIGURE 12

One-Way White Non-Beaded Wedge

This marker has been made with portland cement, epoxy and polyester binders. An installation of these markers made with portland cement gave good service for over 8 years and might have lasted 20 years (see text). Portland cement markers were not suitable for use on asphaltic concrete.

Various configurations of this wedge using polyester and epoxy binders were made including a beaded type and a beaded - non-beaded type as in 11 above. A two way wedge was also tried which had equal slopes on both sides. These various wedge systems (except portland cement binder type) gave about the same results as the buttons. They did give more frontal area to the motorist but they cost more and were more difficult to install because of orientation and the care needed to spread the adhesive evenly.

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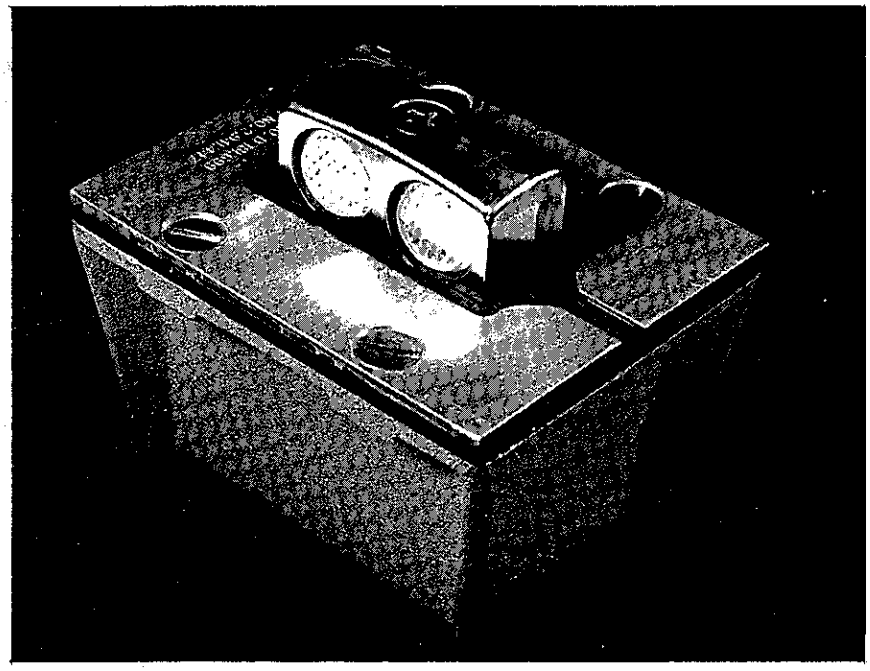

FIGURE 13

Reflective Markers

These are used in England and some areas in Canada. They are installed at the time of paving. The retroreflective lenses are depressed under the pressure of a tire and keep the lenses clean by wiping action. The lens system is also replaceable. None of these markers have been installed in California. A similar type was installed in 1959 in Marin County on U.S. 101 and did not prove durable.

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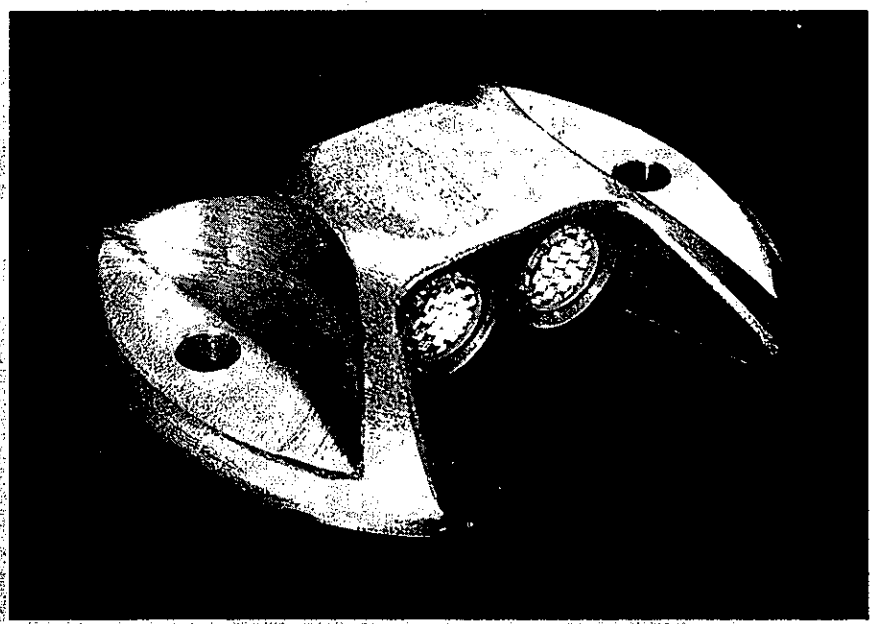

FIGURE 14

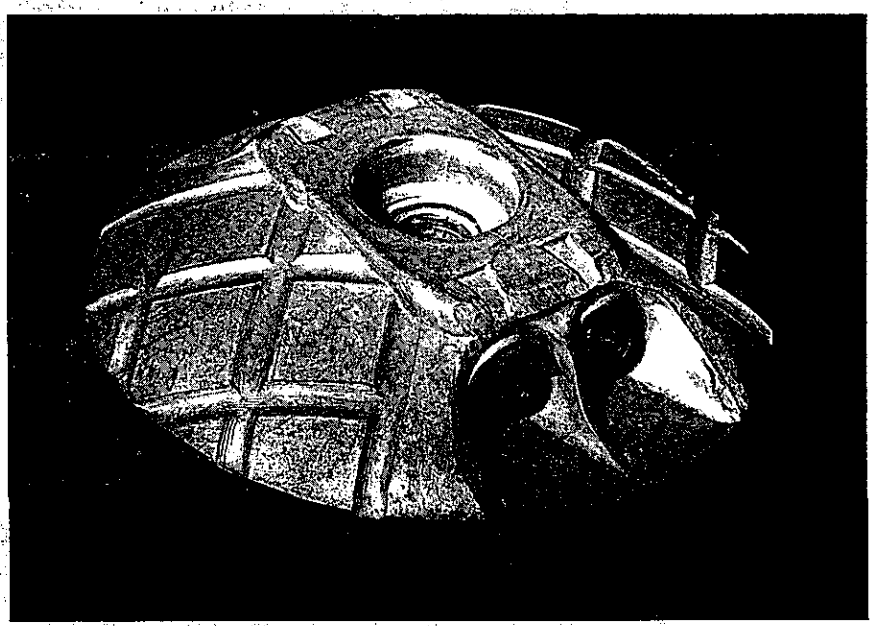

FIGURE 15

These markers are typical of various attempts to mount a prismatic reflector (14) a glass reflector (15) or a reflective tape so as to serve as a reflective marker for nighttime visibility. With all designs the initial reflectance was rather low and decreased rapidly because of the accumulation of dirt or by abrasion.

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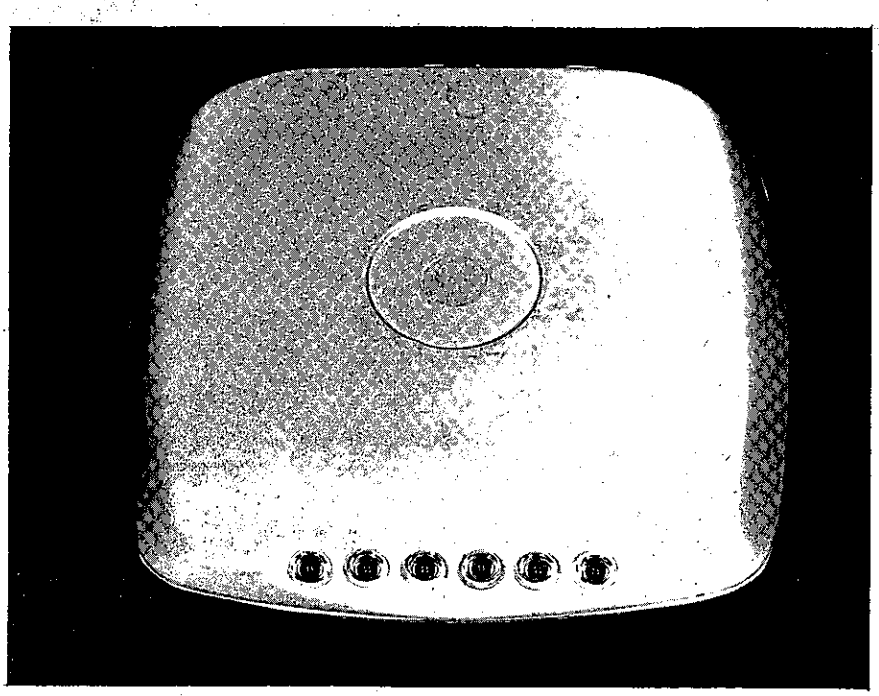

FIGURE 16

Daytime Reflective Markers

This marker consists of reflective glass elements in a body of ABS. The reflective elements are located so as to be cleaned by tire action. The markers give good daytime delineation when clean but stain badly in hot dry weather. The reflective elements give a continuous and softer lighting than the pattern adopted by the State of California. The reflective elements in some early production models dislodged but this has reportedly been improved.

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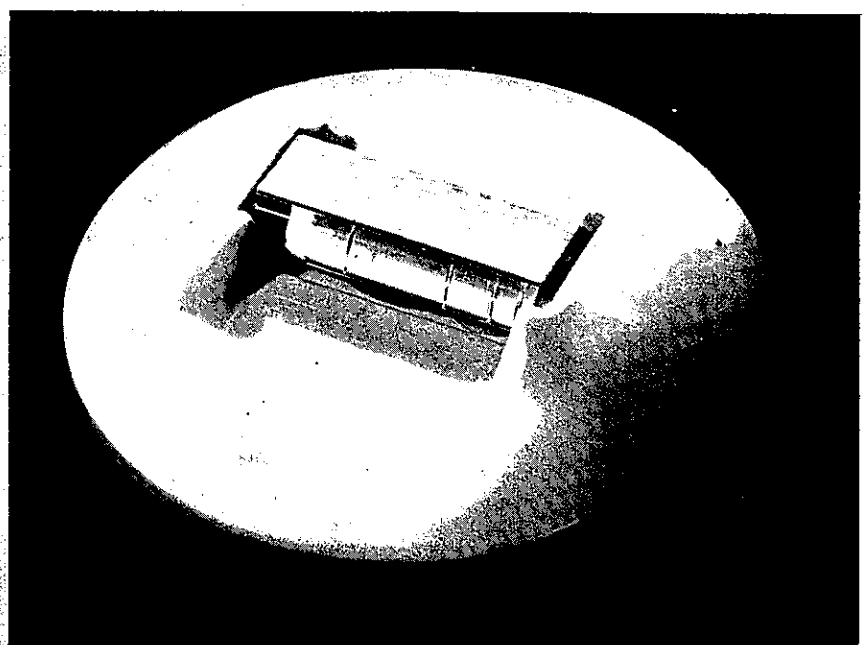

FIGURE 17

Ceramic Daytime Marker With a Reflective Element Consisting of a Glass Encased Reflective Tape.

This design gives a continuous nighttime delineation and good daytime visibility. The reflective elements did not collect as much dirt as was expected but field observation indicated considerable drop in reflectance. Many of the elements broke out of the ceramic base. Some of the broken edges were sharp and could be a possible cause of tire damage. Some alterations of this design have been made to achieve better durability but no altered units have been tested by this Laboratory.

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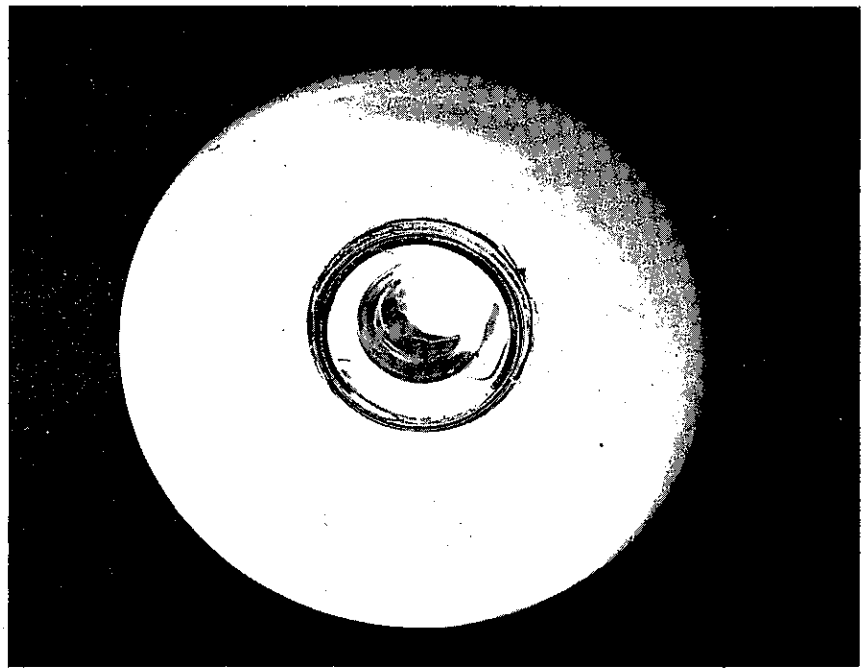

FIGURE 18

Daytime - Nighttime Combination

This marker has a "turret" shaped glass reflector in the top of a plastic marker. The "turret" is shaped and reflectorized so as to return the incident light as a point source. The result was effective but the glass cracked under traffic and became ineffective within a few months.

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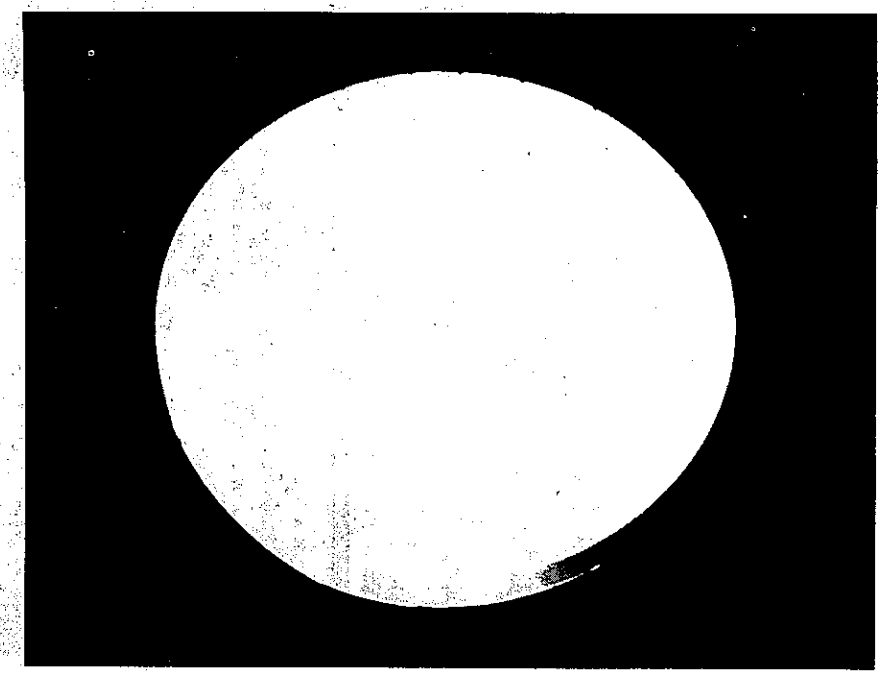
FIGURE 19

Daytime Markers (Also Furnished Beaded For Nighttime Visibility as Separate Units).



These beaded and non-beaded markers were placed alternately in groups of six in mountain snow plow areas for delineation. They were placed flush with the pavement, with epoxy adhesive in holes made with a core drill. Their durability has been good after two winters but at times they are covered with sand and water and are not effective.

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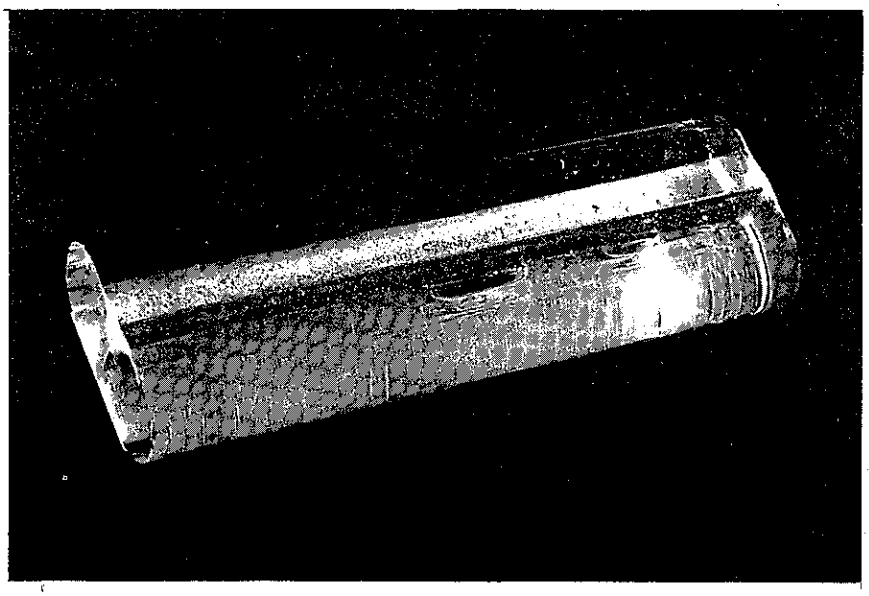

FIGURE 20

Reflective Marker

This unit consists of a highly reflective tape encased between two glass rods. It has a reflectivity approximately that of (6) and (7). Its durability is being compared with these markers.

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FIGURE 21

Nighttime View of Standard Marker Pattern on Tangent

This shows the reflective and non-reflective markers installed on a freeway. No markers have been installed in median.

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SECTION PAVEMENT MARKERS

.01 Description.—This work shall consist of furnishing and placing pavement markers at the locations shown on the plans or where directed by the Engineer.

The markers shall have the shape, dimensions and tolerances as shown on the plans.

Pavement markers will be of the type and color shown on the plans or specified in these special provisions.

.02 Type of Markers.—Pavement markers shall conform to one or more of the following types:

Type A—Non-Reflective White Markers and Type AY—Non-Reflective Yellow Markers

Class III Ceramic Type. For use on portland cement concrete and asphalt concrete road surfaces.

Class IV Ceramic Type. For use only on portland cement concrete road surfaces.

The class of non-reflective marker to be used shall be at the option of the Contractor, subject to the above limitations.

Type B—2-Way Clear Reflective Markers

Type C—Red-Clear Reflective Markers

Type D—2-Way Yellow Reflective Markers

Type G—One-Way Clear Reflective Markers

Type H—One-Way Yellow Reflective Markers

.03 Non-Reflective Pavement Markers.—Non-reflective pavement markers shall consist of a heat-fired, vitreous, ceramic base and a heat-fired, opaque, glazed surface to produce the properties required in these specifications. The glazed surface shall not be present on the bottom of the marker which will be cemented to the road surface. The markers shall be produced from any suitable combination of intimately mixed clays, shales, tales, flints, feldspars, or other inorganic material which will meet the properties herein required. The markers shall be thoroughly and evenly matured and free from defects which affect appearance or serviceability.

Non-reflective pavement markers, Class III and Class IV, shall conform to the following sampling and testing requirements:

(A) Sampling.—Twenty markers selected at random will constitute a representative sample for each batch consisting of 10,000 markers or less. Forty markers will constitute a representative sample for batches consisting of more than 10,000 markers. A resample will consist of twice as many markers as originally sampled. The batch size shall not exceed 25,000 markers.

(B) Tolerances.—

(1) At least 90 percent of the original sampling of each batch of markers shall pass all tests except as noted in (2) below. When less than 90 percent but more than 70 percent pass all tests, a resample of that batch will be allowed at the request of the Contractor. When less than 70 percent of the markers from the original sample comply with the requirements, the batch or lot represented by the samples will be rejected and no resample will be allowed. Tolerances for resamples shall be in the same ratio as specified above.

(2) Should any one of the 3 specimens selected for strength, water absorption, autoclave or bond strength testing as hereinafter specified, fail to comply with the requirements of this specification, 6 additional specimens will be tested. The failure of any one of these 6 specimens shall be cause for rejection of the entire lot or shipment represented by the sample.

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(C) Finish.—The radius of curvature of the top surface of the marker shall be between 3½ inches and 6 inches except that the curvature of the ½ inch nearest the edge may be less. Any change in curvature shall be gradual. The top and sides shall be smooth and free of mold marks, pits, indentations, air bubbles, or other objectionable marks or discolorations. The base of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05-inch) and free from gloss glaze or substances that may reduce its bond to the adhesive.

(D) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test	Requirement
(1) Bond strength to bottom surface of the marker	700 psi. Min.
(2) Glaze thickness	0.005" Min.
(3) Moh Hardness	6 Min.
(4) Directional reflectance (Type A, white markers only)	
Glazed surface	75 Min.
Body of marker	70 Min.
(5) Yellowness index (Type A, white markers only)	
Glazed surface	0.07 Max.
Body of marker	0.12 Max.
(6) Color (Type AY, yellow markers only)	
Purity	76% to 96%
Dominant wave length	579 to 585 mu
Total luminous reflectance (Y value)	.41 Min.
(7) Autoclave	Glaze shall not spall, craze or peel.
(8) Strength	
Class III markers	1,500 lbs. Min.
Class IV markers	750 lbs. Min.
(9) Water absorption	2.0% Max.

(E) Packaging.—Shipments shall be made in containers which are acceptable to common carriers and packaged in such a manner as to insure delivery in perfect condition. Any damaged shipments shall be replaced by the Contractor. Each package shall be clearly marked as to the name of the manufacturer, type, class, color, quantity enclosed, batch number, and date of manufacture.

.04 Reflective Pavement Markers.—Reflective pavement markers shall be of the prismatic reflector type consisting of a methyl methacrylate or suitably compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and contain one or two methyl methacrylate prismatic reflector faces of the color specified.

The infra-red curves of the compounded methyl methacrylate or acrylonitrile butadiene styrene shells shall match approved curves on file in the Materials and Research Department.

The base of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05-inch), rough textured and free from gloss or substances which may reduce its bond to the adhesive.

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Reflective markers shall conform to the following sampling and testing requirements:

(A) Sampling.—Fifty markers selected at random will constitute a representative sample for each shipment or lot. The number of markers in each sampled lot shall not exceed 20,000. One hundred markers will constitute a resample.

(B) Tolerances.—

(1) Unless otherwise specified, not less than 48 out of each sample consisting of 50 markers shall pass all tests. When less than 48 but more than 44 markers pass all tests, a resample will be allowed at the request of the Contractor. When less than 45 markers from the original sample pass all tests, the lot represented by the sample will be rejected and no resample will be allowed.

(2) Should any one of the 3 specimens selected for strength testing, as hereinafter specified, fail to comply with the strength requirements of this specification, 6 additional specimens will be tested. The failure of any one of these 6 specimens shall be cause for the rejection of the entire lot or shipment represented by the sample.

(C) Color.—The color of the reflectors when illuminated by an automobile headlight shall be an approved clear, yellow or red color as required. Color chips will be furnished by the Materials and Research Department. Off-color reflection shall constitute grounds for rejection.

(D) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test				Requirement
(1) Bond strength to bottom surface of the marker				
Average of 5 specimens				400 psi Min.
Minimum value				325 psi
(2) Reflectance				Specific Intensity
	Clear	Yellow	Red	
0° Incidence Angle	3.0	1.5	0.75	
20° Incidence Angle	1.2	0.60	0.30	
(3) Strength				2,000 lbs. Min.

(E) Packaging.—Shipments shall be made in containers which are acceptable to common carriers and packaged in such a manner as to insure delivery in perfect condition. Any damaged shipments shall be replaced by the Contractor. Each package shall be clearly marked as to the name of manufacturer, color, type, lot number, quantity enclosed, and date of manufacture.

.05 Installation.—Unless otherwise ordered in writing by the Engineer, markers shall be cemented to the pavement with Standard Set Type adhesive as provided under "Composition of Adhesives" of these special provisions. If approved by the Engineer, the Contractor, for his convenience, may substitute Rapid Set Type for the Standard Set Type at no additional cost to the State.

If the Contractor elects to use Rapid Set Type adhesive, he shall submit samples of all markers and Rapid Set Type adhesive proposed for use to the Engineer, for testing and approval, at least 10 days before the date of their intended use.

If Rapid Set Type adhesive is ordered by the Engineer, the difference in cost between furnishing and applying Standard Set Type and Rapid Set Type will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

The portion of the highway surface to which the marker is to be attached by the adhesive shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers and any other material which would adversely affect

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the bond of the adhesive. Cleaning shall be done by blast cleaning on portland cement concrete and old asphalt concrete pavements. Clean, newly placed asphalt concrete need not be blast cleaned unless the surface contains an abnormal amount of asphalt or the surface is contaminated with dirt, grease, oil or any other material which would adversely affect the bond of the adhesive. The adhesive shall be placed uniformly on the cleaned pavement surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker with no voids present and with a slight excess after the marker has been pressed in place. The marker shall be placed in position and pressure applied until firm contact is made with the pavement. Excess adhesive around the edge of the marker, excess adhesive on the pavement, and adhesive on the exposed surfaces of the markers shall be immediately removed. The use of thinners or solvents of any type will not be permitted for removing adhesive from reflective pavement markers. The marker shall be protected against impact until the adhesive has hardened to the degree designated by the Engineer.

The adhesive requires that the mixing operation and placing of the markers be done rapidly. When hand mixing or machine mixing the Standard Set Type adhesive, all markers shall be aligned and pressed into place within 5 minutes after mixing is started. When hand mixing Standard Set Type adhesive, not more than one quart shall be mixed at one time. Any mixed batch which becomes so viscous that the adhesive cannot be readily extruded from under the marker on application of slight pressure shall not be used.

When the Rapid Set Type adhesive is used, the components shall be mixed by a 2-component type automatic mixing and extrusion apparatus, and the markers shall be placed within 60 seconds after the adhesive has been mixed and extruded. The temperature of the Rapid Set Type adhesive shall be maintained at 60° F. to 85° F. before mixing. The Standard Set Type adhesive shall not be heated above 100° F. Any heating of epoxy adhesive shall be done by the application of indirect heat.

The mixing equipment for the epoxy adhesive shall properly meter the 2 components in a 1:1 ratio, ±5% by volume of either component. At the beginning of each day and at any other time ordered by the Engineer, the ratio shall be checked by the Contractor in the presence of the Engineer. This check shall be made by disconnecting the mixing heads, or using suitable bypass valves, and filling 2 suitable containers with the unmixed components. The mixing head shall properly mix the 2 components so that there is no trace of black or white streaks in the mixed material.

The Standard Set Type adhesive shall not be used when either the pavement or the air temperature is less than 50° F. The Rapid Set Type adhesive shall not be used when either the pavement or the air temperature is less than 30° F. No markers shall be installed if the relative humidity of the air is greater than 80 percent or if the pavement is not surface dry. The Engineer shall be the judge as to when the adhesive has set sufficiently to bear traffic. The following table may be used as a guide; however, the times shown may vary, depending upon field conditions:

TIME TO BEAR TRAFFIC

Temperature * (° F.)	Standard Set Type (Hours)	Rapid Set Type (Minutes)
100	1½	15
90	2	20
80	3	25
70	4	30
60	5	35
50	7	45
40	No application below 50° F.	65
30		85
		No application below 30° F.

* The temperature indicated is either pavement surface or air temperature, whichever is lower. The hardness of the rim of epoxy around the marker shall not be used as an indication of the degree of cure of the epoxy under the marker.

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All markers shall be installed to the line established by the Engineer. Reflective markers shall be installed in such a manner that the reflective face of the marker is perpendicular to a line parallel to the roadway centerline.

No pavement markers shall be installed over longitudinal or transverse joints of the pavement surface.

.06 Composition of Adhesives.—The adhesive shall be furnished as 2 components (State Specification 68-F-44). The adhesives are described as Standard Set Type and Rapid Set Type.

All adhesives shall have a white A epoxy component and a black B curing agent component, each packaged separately. The mixing ratio of Component A to Component B shall be one-to-one by volume. The Standard Set Type is a compositional specification, together with test requirements. The Rapid Set Type is based on laboratory test requirements only. No volatile solvents or thinners shall be present in the epoxy adhesives.

(A) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test	Requirements	
	Standard Set Type	Rapid Set Type
(1) Pot Life	7–12 minutes	5 minutes Min.
(2) Bond Strength to Concrete, Time (maximum) to reach at least 200 psi		
at 77° F., ± 1° F.	3½ hours	25 minutes
at 50° F., ± 1° F.	----	45 minutes
at 30° F., ± 1° F.	----	85 minutes
(3) Shear Strength on Concrete (Minimum)		
24 hours at 77° F., ± 3° F.	1000 psi	1000 psi
24 hours at 77° F., ± 3° F. plus water soak	700 psi	700 psi
(4) Tensile Adhesion and Cohesion		
Bond of 2″ diameter bottom of a steel rod to the following:		
(a) Class III ceramic marker bottom	1200 psi Min.	1200 psi Min.
(b) Class III ceramic marker bottom including post cure	1200 psi Min.	1200 psi Min.
(c) High strength concrete	550 psi Min.	550 psi Min.
(d) Same as in (c) plus water soak	400 psi Min.	400 psi Min.
(e) Reflective pavement marker bottom	400 psi Min.	400 psi Min.
(5) Viscosity Centipoise	T. D. Spindle	T. E. Spindle
Component A at 77° F.	1.0×10^5 to 3.0×10^5	0.80×10^5 to 1.3×10^5
Component A at 55° F.		1.3×10^5 to 5.0×10^5
Component B	As above	As above

(6) Shear Ratio Minimum		77° F.	55° F.
Component A	2.0	1.8	1.5
Component B	2.0	1.8	1.5

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Test	Requirements Standard Set Type	Rapid Set Type
(7) Lbs./Gallon or % of Air		
Component A	11.5 to 11.8	No requirement on lbs./gallon. Less than 2.5 percent air permitted.
Component B	11.7 to 12.1	Same as above.
(8) Color	Approximately that of Color Nos. 26132 to 26152 of Federal Standard No. 595.	
(9) Skinning, Components A & B	None	None
(10) Storage Stability	The components A and B shall not change in viscosity and shear index by more than ± 15 percent when stored for 2 weeks in closed containers at 115° F., ± 3° F. The adhesive shall meet all other requirements for 12 months from the date of manufacture. There shall be no hard settling of the fillers. Any settling shall be easily redispersed with a paddle.	

(B) Standard Set Type Adhesive, Composition.

STANDARD SET TYPE

Composition of Adhesive.—

PACKAGE A	Parts by Weight
Epoxy Resin [1]	100.00
Titanium Dioxide, TT-P-00442, Type IV	7.31
Resin Grade Asbestos [2]	5.00
Talc [3]	37.64
PACKAGE B	
N-Aminoethyl piperazine [4]	23.16
Nonylphenol [5]	52.00
Carbon Black, TT-P-343, Form I, Class B	0.22
Talc [3]	77.37
Resin Grade Asbestos [2]	1.00

[1] Viscosity, 5-7 poises at 25° C.; epoxide equivalent 175-205; Color (Gardner), 5 maximum; manufactured from epichlorohydrin and bisphenol A. The reactive diluent shall be butyl glycidyl ether.

[2] Specific gravity, grams per ml., 2.45; moisture content, % by weight, 2.0 maximum; surface area, square meters per gram, 60 approximately; reflectance, G.E. brightness, 72-76; nature of surface charge, electropositive (cationic); pH in water, 9.5; bulking value, gallons per 100 lbs., 4.8; oil absorption (DOP), pounds per 100 lb., 120; refractive index, n_d 25° C., 1.54-1.56; wet bulk density in water, after dispersion, 2 grams per liter, settling after 1 hr., 100 ml. clear maximum; dry bulk density, pounds per cubic foot, 4.

[3] Percent passing U.S. No. 325 sieve, 94-96; maximum particle size, 70 microns; oil absorption (Gardner-Coleman), 6-7 ml. per 20 grams fineness in oil (Hegman) 1-2; specific surface, 0.5-0.6 square meter per gram; consistency (40% suspension in linseed oil) 55-60 KU.

[4] Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

[5] Color (APHA) 50 maximum; hydroxyl number 245-255; distillation range, ° C. at 760 mm first drop 295 minimum, 5% 298 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

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.07 Packaging and Labeling of Adhesive.—Each adhesive component shall be packaged in containers not larger than 5 gallons in volume. The containers shall be new steel, not less than 24-gage and shall otherwise meet Interstate Commerce shipping standards. Each container shall be clearly labeled with the State Specification 68-F-44, designation (Component A or B), type (Standard or Rapid), manufacturer's name, date of manufacture, batch number (a batch shall consist of a single charge of all components in a mixing chamber), directions for mixing, and the following warning:

CAUTION

This material will cause severe dermatitis if it is allowed to come in contact with the skin or eyes. Use gloves and protective creams on the hands. Should this material contact the skin, wash thoroughly with soap and water. Do not attempt to remove this material from the skin with solvents. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention.

.08 Payment.—The contract unit prices paid for the types of pavement markers shown in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing and placing pavement markers, complete in place, including adhesives, as shown on the plans, and as specified in these special provisions, and as directed by the Engineer.

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(To be used only on projects in cooler coastal areas where temperatures seldom rise above 80° F.)

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SECTION PAVEMENT MARKERS

.01 Description.—This work shall consist of furnishing and placing pavement markers at the locations shown on the plans or where directed by the Engineer.

The markers shall have the shape, dimensions and tolerances as shown on the plans.

Pavement markers will be of the type and color shown on the plans or specified in these special provisions.

.02 Type of Markers.—Pavement markers shall conform to one or more of the following types:

Type A—Non-Reflective White Markers

Class II Polyester Binder Type. For use only on asphalt concrete road surfaces.

Type A—Non-Reflective White Markers and Type AY—Non-Reflective Yellow Markers

Class III Ceramic Type. For use on portland cement concrete and asphalt concrete road surfaces.

Class IV Ceramic Type. For use only on portland cement concrete road surfaces.

The class of non-reflective marker to be used shall be at the option of the Contractor, subject to the above limitations.

Type B—2-Way Clear Reflective Markers

Type C—Red-Clear Reflective Markers

Type D—2-Way Yellow Reflective Markers

Type G—One-Way Clear Reflective Markers

Type H—One-Way Yellow Reflective Markers

.03 Non-Reflective Pavement Markers.—Non-reflective pavement markers shall have the following characteristics:

Class II pavement markers shall consist of a polyester resin binder, an inert inorganic filler material and the required colorant pigments.

Class III and Class IV pavement markers shall consist of a heat-fired, vitreous, ceramic base and a heat-fired, opaque, glazed surface to produce the properties required in these specifications. The glazed surface shall not be present on the bottom of the marker which will be cemented to the road surface. The markers shall be produced from any suitable combination of intimately mixed clays, shales, talcs, flints, feldspars, or other inorganic material which will meet the properties herein required. The markers shall be thoroughly and evenly matured and free from defects which affect appearance or serviceability.

Non-reflective pavement markers shall conform to the following sampling and testing requirements:

(A) Sampling.—Twenty markers selected at random will constitute a representative sample for each batch consisting of 10,000 markers or less. Forty markers will constitute a representative sample for batches consisting of more than 10,000 markers. A resample will consist of twice as many markers as originally sampled. The batch size shall not exceed 25,000 markers.

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(B) Tolerances.—

(1) At least 90 percent of the original sampling of each batch of markers shall pass all tests except as noted in (2) below. When less than 90 percent but more than 70 percent pass all tests, a resample of that batch will be allowed at the request of the Contractor. When less than 70 percent of the markers from the original sample comply with the requirements, the batch or lot represented by the samples will be rejected and no resample will be allowed. Tolerances for resamples shall be in the same ratio as specified above.

(2) Should any one of 3 specimens randomly selected for strength, water absorption, autoclave or bond strength testing, fail to comply with the requirements of this specification, 6 additional specimens will be tested. The failure of any one of these 6 specimens shall be cause for rejection of the entire lot or shipment represented by the sample.

(C) Finish.—The radius of curvature of the top surface of the marker shall be between 3½ inches and 6 inches except that the curvature of the ½ inch nearest the edge may be less. Any change in curvature shall be gradual. The top and sides shall be smooth and free of mold marks, pits, indentations, air bubbles, or other objectionable marks or discolorations. The base of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05-inch) and free from gloss glaze or substances that may reduce its bond to the adhesive. The presence of a soft or resin-rich film on any surface of Class II markers shall be cause for rejection. The marker shall not contain any uncured polyester resin.

(D) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test	Requirement
(1) Bond strength to bottom surface of the marker using specified adhesive	
(a) Class II markers	500 psi Min.
(b) Class III and IV markers	700 psi Min.
(2) Glaze thickness (Class III and IV markers)	0.005″ Min.
(3) Hardness	
(a) Shore "D" hardness (Class II markers)	80 Min.
(b) Moh hardness (Class III and IV markers)	6 Min.
(4) Directional reflectance (Type A, white markers only)	
(a) Class II markers	75 Min.
(b) Class III and IV markers	
Glazed surface	75 Min.
Body of marker	70 Min.
(5) Yellowness index (Type A, white markers only)	
(a) Class II markers	0.07 Max.
(b) Class III and IV markers	
Glazed surface	0.07 Max.
Body of marker	0.12 Max.
(6) Color (Type AY, yellow markers only)	
Purity	76% to 96%
Dominant wave length	579 to 585 mu
Total luminous reflectance (Y value)	.41 Min.
(7) Autoclave (Class III and IV markers)	Glaze shall not spall, craze or peel.

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(8) Strength
- (a) Class II markers ..... 1,000 lbs. Min.
- (b) Class III markers ..... 1,500 lbs. Min.
- (c) Class IV markers ..... 750 lbs. Min.

(9) Water absorption (Class III and IV markers) ..... 2.0% Max.

(10) Titanium Dioxide, conforming to Federal Specification TT-P-00442, Types II, III, or IV
- (a) Class II markers ..... 10% Min.

(11) Polyester Resin Content
- (a) Class II markers ..... 31% Max.

(E) Packaging.—Shipments shall be made in containers which are acceptable to common carriers and packaged in such a manner as to insure delivery in perfect condition. Any damaged shipments shall be replaced by the Contractor. Each package shall be clearly marked as to the name of the manufacturer, type, class, color, quantity enclosed, batch number, and date of manufacture.

.04 Reflective Pavement Markers.—Reflective pavement markers shall be of the prismatic reflector type consisting of a methyl methacrylate or suitably compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and contain one or two methyl methacrylate prismatic reflector faces of the color specified.

The infra-red curves of the compounded methyl metracrylate or acrylonitrile butadiene styrene shells shall match approved curves on file in the Materials and Research Department.

The base of the marker shall be flat (the deviation from a flat surface shall not exceed 0.05-inch), rough textured and free from gloss or substances which may reduce its bond to the adhesive.

Reflective markers shall conform to the following sampling and testing requirements:

(A) Sampling.—Fifty markers selected at random will constitute a representative sample for each shipment or lot. The number of markers in each sampled lot shall not exceed 20,000. One hundred markers will constitute a resample.

(B) Tolerances.—

(1) Unless otherwise specified, not less than 48 out of each sample consisting of 50 markers shall pass all tests. When less than 48 but more than 44 markers pass all tests, a resample will be allowed at the request of the Contractor. When less than 45 markers from the original sample pass all tests, the lot represented by the sample will be rejected and no resample will be allowed.

(2) Should any one of the 3 specimens selected for strength testing, as hereinafter specified, fail to comply with the strength requirements of this specification, 6 additional specimens will be tested. The failure of any one of these 6 specimens shall be cause for the rejection of the entire lot or shipment represented by the sample.

(C) Color.—The color of the reflectors when illuminated by an automobile headlight shall be an approved clear, yellow or red color as required. Color chips will be furnished by the Materials and Research Department. Off-color reflection shall constitute grounds for rejection.

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(D) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test				Requirement
(1) Bond strength to bottom surface of the marker				
Average of 5 specimens				400 psi Min.
Minimum value				325 psi
(2) Reflectance				Specific Intensity
		Clear	Yellow	Red
0° Incidence Angle		3.0	1.5	0.75
20° Incidence Angle		1.2	0.60	0.30
(3) Strength				2,000 lbs. Min.

(E) Packaging.—Shipments shall be made in containers which are acceptable to common carriers and packaged in such a manner as to insure delivery in perfect condition. Any damaged shipments shall be replaced by the Contractor. Each package shall be clearly marked as to the name of manufacturer, color, type, lot number, quantity enclosed, and date of manufacture.

05 Installation.—Unless otherwise ordered in writing by the Engineer, markers shall be cemented to the pavement with Standard Set Type adhesive as provided under "Composition of Adhesives" of these special provisions. If approved by the Engineer, the Contractor, for his convenience, may substitute Rapid Set Type for the Standard Set Type at no additional cost to the State.

If the Contractor elects to use Rapid Set Type adhesive, he shall submit samples of all markers and Rapid Set Type adhesive proposed for use to the Engineer, for testing and approval, at least 10 days before the date of their intended use.

If Rapid Set Type adhesive is ordered by the Engineer, the difference in cost between furnishing and applying Standard Set Type and Rapid Set Type will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

The portion of the highway surface to which the marker is to be attached by the adhesive shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers and any other material which would adversely affect the bond of the adhesive. Cleaning shall be done by blast cleaning on portland cement concrete and old asphalt concrete pavements. Clean, newly placed asphalt concrete need not be blast cleaned unless the surface contains an abnormal amount of asphalt or the surface is contaminated with dirt, grease, oil or any other material which would adversely affect the bond of the adhesive. The adhesive shall be placed uniformly on the cleaned pavement surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker with no voids present and with a slight excess after the marker has been pressed in place. The marker shall be placed in position and pressure applied until firm contact is made with the pavement. Excess adhesive around the edge of the marker, excess adhesive on the pavement, and adhesive on the exposed surfaces of the markers shall be immediately removed. The use of thinners or solvents of any type will not be permitted for removing adhesive from reflective pavement markers. The marker shall be protected against impact until the adhesive has hardened to the degree designated by the Engineer.

The adhesive requires that the mixing operation and placing of the markers be done rapidly. When hand mixing or machine mixing the Standard Set Type adhesive, all markers shall be aligned and pressed into place within 5 minutes after mixing is started. When hand mixing Standard Set Type adhesive, not more than one quart shall be mixed at one time. Any mixed batch which becomes so viscous that the adhesive cannot be readily extruded from under the marker on application of slight pressure shall not be used.

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When the Rapid Set Type adhesive is used, the components shall be mixed by a 2-component type automatic mixing and extrusion apparatus, and the markers shall be placed within 60 seconds after the adhesive has been mixed and extruded. The temperature of the Rapid Set Type adhesive shall be maintained at 60° F. to 85° F. before mixing. The Standard Set Type adhesive shall not be heated above 100° F. Any heating of epoxy adhesive shall be done by the application of indirect heat.

The mixing equipment for the epoxy adhesive shall properly meter the 2 components in a 1:1 ratio, ±5% by volume of either component. At the beginning of each day and at any other time ordered by the Engineer, the ratio shall be checked by the Contractor in the presence of the Engineer. This check shall be made by disconnecting the mixing heads, or using suitable bypass valves, and filling 2 suitable containers with the unmixed components. The mixing head shall properly mix the 2 components so that there is no trace of black or white streaks in the mixed material.

The Standard Set Type adhesive shall not be used when either the pavement or the air temperature is less than 50° F. The Rapid Set Type adhesive shall not be used when either the pavement or the air temperature is less than 30° F. No markers shall be installed if the relative humidity of the air is greater than 80 percent or if the pavement is not surface dry. The Engineer shall be the judge as to when the adhesive has set sufficiently to bear traffic. The following table may be used as a guide; however, the times shown may vary, depending upon field conditions:

TIME TO BEAR TRAFFIC

Temperature * (° F.)	Standard Set Type (Hours)	Rapid Set Type (Minutes)
100	1½	15
90	2	20
80	3	25
70	4	30
60	5	35
50	7	45
40	No application below 50° F.	65
30		85
		No application below 30° F.

* The temperature indicated is either pavement surface or air temperature, whichever is lower. The hardness of the rim of epoxy around the marker shall not be used as an indication of the degree of cure of the epoxy under the marker.

All markers shall be installed to the line established by the Engineer. Reflective markers shall be installed in such a manner that the reflective face of the marker is perpendicular to a line parallel to the roadway centerline.

No pavement markers shall be installed over longitudinal or transverse joints of the pavement surface.

.06 Composition of Adhesives.—The adhesive shall be furnished as 2 components (State Specification 68-F-44). The adhesives are described as Standard Set Type and Rapid Set Type.

All adhesives shall have a white A epoxy component and a black B curing agent component, each packaged separately. The mixing ratio of Component A to Component B shall be one-to-one by volume. The Standard Set Type is a compositional specification, together with test requirements. The Rapid Set Type is based on laboratory test requirements only. No volatile solvents or thinners shall be present in the epoxy adhesives.

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(A) Tests.—All tests shall be performed in accordance with Test Method No. Calif. 425.

Test	Requirements Standard Set Type	Rapid Set Type
(1) Pot Life	7–12 minutes	5 minutes Min.
(2) Bond Strength to Concrete, Time (maximum) to reach at least 200 psi		
at 77° F., ± 1° F.	3½ hours	25 minutes
at 50° F., ± 1° F.	----	45 minutes
at 30° F., ± 1° F.	----	85 minutes
(3) Shear Strength on Concrete (Minimum)		
24 hours at 77° F., ± 3° F.	1000 psi	1000 psi
24 hours at 77° F., ± 3° F. plus water soak	700 psi	700 psi
(4) Tensile Adhesion and Cohesion		
Bond of 2" diameter bottom of a steel rod to the following:		
(a) Class III ceramic marker bottom	1200 psi Min.	1200 psi Min.
(b) Class III ceramic marker bottom including post cure	1200 psi Min.	1200 psi Min.
(c) Reflective pavement marker bottom	400 psi Min.	400 psi Min.
(d) Class II marker bottom	500 psi Min.	500 psi Min.
(e) High strength concrete	550 psi Min.	550 psi Min.
(f) Same as in (e) plus water soak	400 psi Min.	400 psi Min.
(5) Viscosity Centipoise	T. D. Spindle	T. E. Spindle
Component A at 77° F.	1.0×10^5 to 3.0×10^5	0.80×10^5 to 1.3×10^5
Component A at 55° F.		1.3×10^5 to 5.0×10^5
Component B	As above	As above
(6) Shear Ratio Minimum		77° F. 55° F.
Component A	2.0	1.8 1.5
Component B	2.0	1.8 1.5
(7) Lbs./Gallon or % of Air		
Component A	11.5 to 11.8	No requirement on lbs./gallon. Less than 2.5 percent air permitted.
Component B	11.7 to 12.1	Same as above.
(8) Color	Approximately that of Color Nos. 26132 to 26152 of Federal Standard No. 595.	
(9) Skinning, Components A & B	None	None

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Test	Requirements	
	Standard Set Type	Rapid Set Type
(10) Storage Stability	The components A and B shall not change in viscosity and shear index by more than ± 15 percent when stored for 2 weeks in closed containers at 115° F., ± 3° F. The adhesive shall meet all other requirements for 12 months from the date of manufacture. There shall be no hard settling of the fillers. Any settling shall be easily redispersed with a paddle.	

(B) Standard Set Type Adhesive, Composition.

STANDARD SET TYPE

Composition of Adhesive.—

PACKAGE A	Parts by Weight
Epoxy Resin [1]	100.00
Titanium Dioxide, TT-P-00442, Type IV	7.31
Resin Grade Asbestos [2]	5.00
Talc [3]	37.64
PACKAGE B	
N-Aminoethyl piperazine [4]	23.16
Nonylphenol [5]	52.00
Carbon Black, TT-P-343, Form I, Class B	0.22
Talc [3]	77.37
Resin Grade Asbestos [2]	1.00

[1] Viscosity, 5-7 poises at 25° C.; epoxide equivalent 175-205; Color (Gardner), 5 maximum; manufactured from epichlorohydrin and bisphenol A. The reactive diluent shall be butyl glycidyl ether.

[2] Specific gravity, grams per ml., 2.45; moisture content, % by weight, 2.0 maximum; surface area, square meters per gram, 60 approximately; reflectance, G.E. brightness, 72-76; nature of surface charge, electropositive (cationic); pH in water, 9.5; bulking value, gallons per 100 lbs., 4.8; oil absorption (DOP), pounds per 100 lb., 120; refractive index, n_d 25° C., 1.54-1.56; wet bulk density in water, after dispersion, 2 grams per liter, settling after 1 hr., 100 ml. clear maximum; dry bulk density, pounds per cubic foot, 4.

[3] Percent passing U.S. No. 325 sieve, 94-96; maximum particle size, 70 microns; oil absorption (Gardner-Coleman), 6-7 ml. per 20 grams fineness in oil (Hegman) 1-2; specific surface, 0.5-0.6 square meter per gram; consistency (40% suspension in linseed oil) 55-60 KU.

[4] Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

[5] Color (APHA) 50 maximum; hydroxyl number 245-255; distillation range, ° C. at 760 mm first drop 295 minimum, 5% 298 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

.07 Packaging and Labeling of Adhesive.—Each adhesive component shall be packaged in containers not larger than 5 gallons in volume. The containers shall be new steel, not less than 24-gage and shall otherwise meet Interstate Commerce shipping standards. Each container shall be clearly labeled with the State Specification 68-F-44, designation (Component A or B), type (Standard or Rapid), manufacturer's name, date of manufacture, batch number (a batch shall consist of a single charge of all components in a mixing chamber), directions for mixing, and the following warning:

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CAUTION

This material will cause severe dermatitis if it is allowed to come in contact with the skin or eyes. Use gloves and protective creams on the hands. Should this material contact the skin, wash thoroughly with soap and water. Do not attempt to remove this material from the skin with solvents. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention.

.08 Payment.—The contract unit prices paid for the types of pavement markers shown in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing and placing pavement markers, complete in place, including adhesives, as shown on the plans, and as specified in these special provisions, and as directed by the Engineer.

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

TEST METHOD NO. CALIF. 425-A
March, 1968

Non-Reflective Traffic Markers

1. Bond strength to bottom surface of the marker using specified adhesive.

   a. Condition test equipment, markers and specified adhesive at 77 ± 1°F for 24 hours before test. A sandblasted 2-inch diameter steel rod or pipe cap shall be used to bond the marker and adhesive.

   b. Mix adhesive on a tin plate with a trowel or spatula until mixture shows no streaks of A or B components. Place adhesive on bottom of marker and metal surface and press firmly in place. Remove excess adhesive. Allow to cure for 24 hours at 77 ± 1°F.

   c. After curing measure the bond strength using the testing machine described in No. Calif. 420 or other testing machines. The rate of loading shall be 5,000 lbs/min. Calculate the p.s.i.

2. Glaze thickness - The glaze thickness at least 1/4-inch from the edge of the marker shall be measured on a fractured piece of the marker to the nearest 0.001-inch. Measurements shall be made by a calibrated scale microscope with a minimum magnification of 25 times.

3. Hardness.

   a. Shore "D" Hardness - Test in accordance with ASTM Designation D1706-61 and record the initial maximum reading as the hardness.

   b. Moh Hardness - The Moh hardness of the glazed marker surface shall be determined relative to the mineral orthoclase, which has a hardness of 6. Using moderate hand pressure, it must not be possible to scratch the marker with orthoclase.

4. Directional Reflectance - Test in accordance with Federal Test Method Standard No. 141, Method 6121.

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5. Yellowness Index - Test in accordance with Federal Test Method Standard No. 141, Method 6131.

NOTE: For tests 4 and 5 above the test on the glazed surface of Class III and Class IV markers shall be made on the top of the convex surface of the marker. The test on the body of Class III and Class IV markers shall be made on a clean flat surface of the marker from which the glaze has been removed. Tests on Class II markers shall be made on a clean area which has been ground or sanded flat.

6. Color - Chromaticity measurements shall be made in accordance with Test Method No. Calif. 660.

7. Autoclave - Test in accordance with ASTM Designation C424 except as follows: The specimens shall be subjected to only one autoclave cycle at 50 p.s.i. for one hour.

8. Strength - The marker shall be centered, base down, over the open end of a vertically positioned hollow metal cylinder. The cylinder shall be one-inch high with an internal diameter of 3 inches and a wall thickness of 1/4-inch. A load necessary to break the marker shall be applied at a speed of 0.2-inch per minute to the top of the marker through a one-inch diameter solid metal cylinder centered on the top of the marker. Failure shall consist of a breakage of the marker at a load of less than that specified.

9. Water Absorption - Test in accordance with ASTM Designation C 373 except as follows: Specimens selected for the water absorption test shall be whole markers and the glaze shall not be removed.

10. Titanium Dioxide - Test in accordance with ASTM Designation D 1394, beginning with paragraph 7, "Total Titanium by the Jones Reductor Method". Use a 1-gram to 1.2-gram sample of the marker exclusive of any sand, glass beads, or other substance that may be adhering to or incorporated into the bottom surface of the marker.

11. Polyester Resin Content - The polyester resin content of the marker shall be determined by ignition of a portion of the marker exclusive of any sand, glass beads, or other substance that may be adhering to or incorporated into the bottom surface of the marker. Use a 10 gram to 20 gram sample of the marker weighed into a tared crucible or heat resistant beaker. Ignite at a temperature not exceeding 550°C until no carbon residue remains.

% Polyester Resin = Weight of sample - Weight of sample after ignition x 100 over Weight of Sample.

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Reflective Traffic Markers

1. Bond strength to bottom surface of the marker using specified adhesive. Test Method same as No. 1 under non-reflective traffic markers.

2. Reflectance - The markers shall be tested at a 0.2 degree angle of divergence, and a 0° and 20° angle of incidence. The marker to be tested shall be located with the center of the reflecting face at a distance of five feet from a uniformly bright light source having an effective diameter of 0.2-inch. The photocell receptor width shall be 0.05-inch and shall be shielded to eliminate stray light. The distance from the center of the light source aperture to the center of the photocell shall be 0.21-inch. If a test distance of other than five feet is used, the source and receptor shall be modified in the same proportion as the test distance. Test results shall be calculated and reported in terms of specific intensity.

   a. Angle of incidence - The angle formed by a ray from the light source to the marker, and the normal to the leading edge of the marker face.

   b. Angle of divergence - The angle formed by a ray from the light source to the marker, and the returned ray from the marker to the measuring receptor.

   c. Specific intensity - The mean candle power of the reflected light at a given incidence and divergence angle for each foot candle at the reflector on a plane perpendicular to the incident light.

$$SI = \frac{R_L}{I_L} \times D^2$$

   Where SI = Specific Intensity.
   Where R_L = Reflected Light.
   Where I_L = Incident Light
   Where D = Test Distance.

3. Strength - Refer to 8 above, except that failure shall consist of either (1) breakage or significant deformation of the marker at a load of less than 2,000 pounds; or, (2) significant delamination of the shell and the filler material regardless of the load required to break the marker.

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TEST METHOD NO. CALIF. 425-A
EPOXY ADHESIVE INTENDED FOR USE IN BONDING TRAFFIC MARKERS TO ROAD SURFACES

1. Pot Life - The pot life shall be determined at 77 ± 1°F. Mix equal volumes of Components A and B in an 8 ounce, unwaxed paper cup 2 inches ± 1/4 inch at base to give a 170 ± 10 grams total mass. Mix 60 ± 5 seconds before timing for pot life. Test with a tongue depressor with minimum stirring. Record the time the material becomes unusable as the pot life. With most materials this will be approximately the time a hard lump forms in the center.

2. Bond Strength

   a. Clean a 4" x 4" area on a flat surface of a concrete block made with a 7-sack concrete and having a tensile strength in excess of 250 p.s.i.

   b. Use the testing machine described in Test Method No. Calif. 420 or other suitable testing press. Condition test equipment, concrete, and epoxy at test temperature for 24 hours before test. Use load rate of 5,000 lbs/min. A sandblasted 2" diameter steel rod may be used in place of pipe cap.

   c. Mix adhesive on a tin plate with a trowel or spatula for 60 ± 5 seconds. Immediately start timing, place adhesive on pipe cap and concrete surface and press firmly in place. Remove excess adhesive. Just before the required test time, insert the dynamometer hook into the cap or steel rod.

3. Shear Strength - Bond 3 concrete blocks 2" x 3 1/2" x 7" of 8-sack concrete together with the 7-inch sides parallel forming 2 areas of contact 3 1/2" x 3 1/2" by overlapping the blocks. The test specimen then has a base of 2 blocks and a second surface formed by the center block. Apply the adhesive to the contact surfaces and allow to cure for 24 hours at 77°F. Cap the base and top of middle block with an approved capping compound and test at a load rate of 10,000 lbs/min. A swivel type head must be used at the top of the testing press. Computations are based on a total area of 24.5 square inches (Shear Strength = total load/24.5) Also test after 7 days water soak.

4. Tensile Adhesion and Cohesion

   Bond the bottom surface of a sandblasted 2" diameter steel rod to the surfaces listed, cure for 24 hours at 77 ± 1°F.

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4. Continued

Follow additional instructions below where applicable. Use a load rate of 5,000 lbs/min.

a. Class III ceramic marker bottom. Compute p.s.i.

b. Class III ceramic marker bottom. Post cure for 48 hours at 140°F. Condition to 77 ± 1°F and place in cold box for 24 hours at 15 ± 3°F. Allow to return to 77 ± 1°F. Test and compute p.s.i.

c. High strength concrete; 2" thick 3 1/2" wide by 7" long. Steel rod bonded to the 3 1/2" x 7" surface. Test and compute p.s.i. Any test failing in concrete below specification value shall be repeated.

d. High strength concrete specimen prepared as in 4c above. Soak in distilled water for 7 days. Remove from water and test immediately. Compute p.s.i. Any test failing in concrete below specification value shall be repeated.

5. Viscosity - The viscosity of each component shall be measured in a 3/4 filled standard round quart paint can.

Stir the components vigorously for 30 seconds with a spatula. Remove entrained air by vigorous tamping and measure viscosity within 10 minutes after stirring. Use a Brookfield viscometer, Model RVT at 5.0 RPM with a Model C Brookfield Helipath Stand and Helipath Spindle specified. Use weight included in spindle set. Component and ambient temperature is to be 77 ± .5°F at time of measurement. Readings shall be taken at approximately the center of the vertical travel of the spindle.

6. Shear Ratio - Shear Ratio = $\frac{\text{Viscosity at 0.5 RPM}}{\text{Viscosity at 2.5 RPM}}$

Readings for shear ratio shall be taken at the same time as the viscosity at 5 RPM.

7. Lbs/Gallon

Determine as in Federal Test Method Standard No. 141A Method 4184.1.

8. Percentage of Air

The entrapped air on the Rapid Set Type shall be removed by applying a high vacuum to each component heated to 175 to 180°F. The sample shall also be vibrated or tamped to facilitate air removal. Allow sample to cool to 77 ± 3°F before measurement of Lbs/gal as in 7 above. The percentage of air shall be calculated as follows:

$$\% \text{ air} = \frac{\text{Lbs/Gal (air removed)} - \text{Lbs/Gal (as received)}}{\text{Lbs/Gal as received}} \times 100$$

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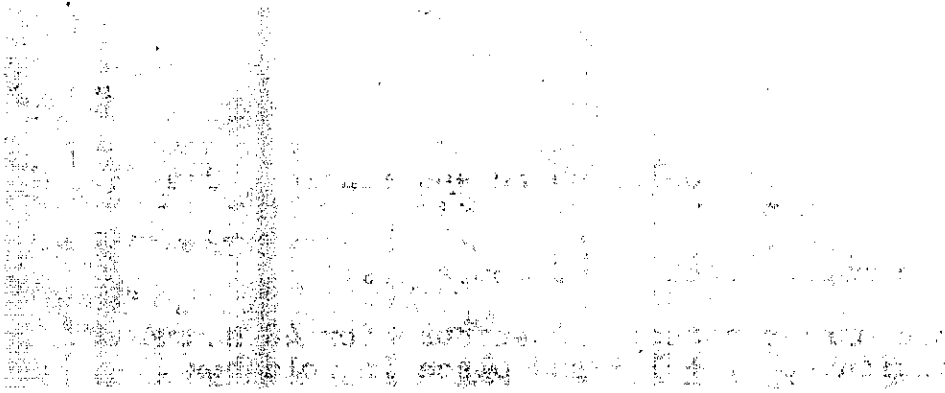

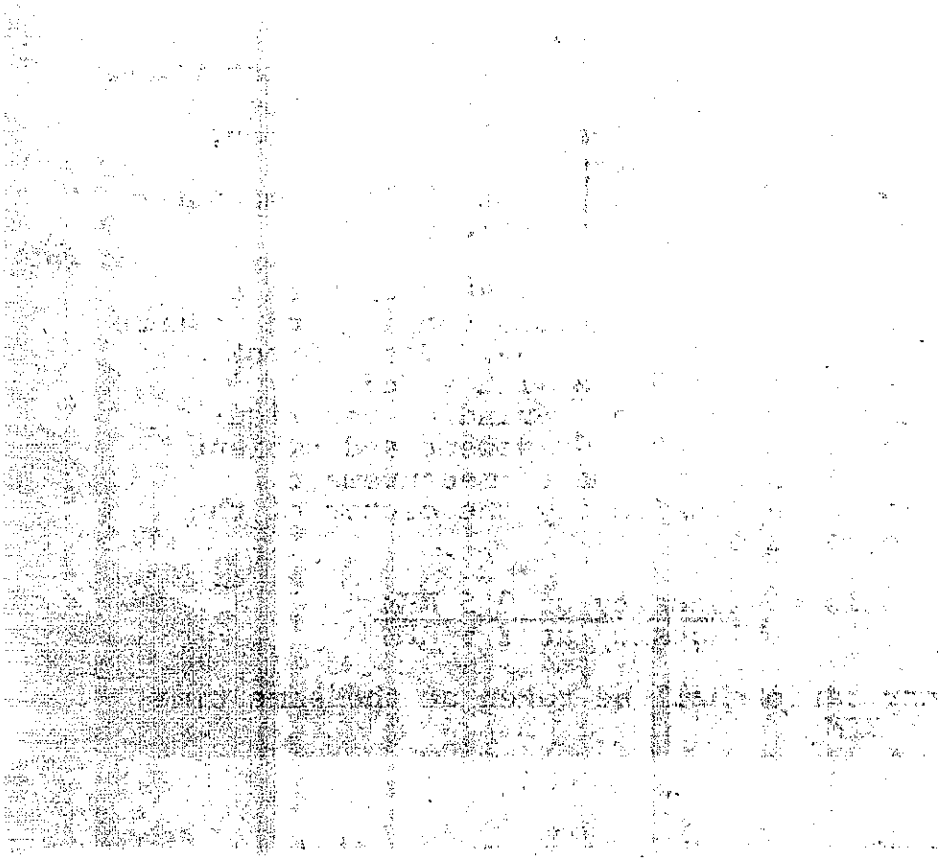

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