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16. ABSTRACT

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HIGHWAY RESEARCH REPORT

DEVELOPMENT AND EVALUATION OF RAISED TRAFFIC LANE MARKERS 1968 TO 1971

INTERIM REPORT

71-20

STATE OF CALIFORNIA	MATERIALS AND RESEARCH DEPARTMENT
BUSINESS AND TRANSPORTATION AGENCY	RESEARCH REPORT
DEPARTMENT OF PUBLIC WORKS	NO. M & R 635152
DIVISION OF HIGHWAYS	

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration October, 1971

STATE OF CALIFORNIA--BUSINESS AND TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

5900 FOLSOM BLVD., SACRAMENTO 95819

Research Report
M&R No. 635152

October, 1971

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

DEVELOPMENT AND EVALUATION
OF RAISED TRAFFIC
LANE MARKERS
1968 TO 1971

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Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCES

Shelly, T. L., Rooney, H. A., and Beede, B. K. "Development and Evaluation of Raised Traffic Lane Markers, 1968 to 1971," State of California, Department of Public Works, Division of Highways, Materials and Research Department, June 1968, Research Report No. 635152.

ABSTRACT

The State of California has continued evaluation of the marker system adopted in December 1965. The reflective markers drop considerably in reflectance under traffic but are good at night especially in the rain when they are needed most. The ceramic markers are good when clean but during hot dry weather darken considerably. Many new markers have been evaluated but none have been found which are superior to the ceramic and reflective markers being specified. Current research on a 1.90 index of refraction beaded white portland cement-limestone-titantium dioxide marker, will be given a one year trial in a test installation on a freeway in Sacramento.

KEY WORDS

Traffic markings, reflective markers, reflector buttons, lanes, traffic marking materials.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the many individuals who have participated in the continued development and evaluation of pavement markers.

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 Mr. Harry C. Ammon for his work in developing a marker washing machine and to Mr. James A. Cechetini for his development of the white portland cement wedge marker.

This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration, 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 Federal Highway Administration.

INTRODUCTION

This is a continuing project on the development and evaluation of raised traffic lane markers. The first report was issued in 1968 and covered all work done since 1953. Since 1968, a constant evaluation of the marker system now specified by the California Division of Highways has been made, including the durability of both the reflective markers and ceramic daytime markers. Other markers submitted by industry or developed by the laboratory have also been evaluated. These include six types of reflective markers, five types of non-reflective markers, and nine types of combination reflective, non-reflective markers evaluated since 1968.

CONCLUSIONS

The reflectance of the State adopted cube corner reflective marker is reduced to about 1/20 to 1/50 of its original value within a few months due to surface abrasion. This reflectance however is adequate and remains relatively constant except when covered with tire stain, or when the marker is seriously damaged. During the summer or early fall, which are usually very dry in California, the markers are badly stained by traffic. In this condition the reflective markers may not be as good at night as a good beaded paint line. During wet weather, when the markers are clean and covered with a film of moisture, visibility is excellent, often approaching 1/4 to 1/3 the reflective value of the systems when new. Thus, the system is at its best when it is needed most.

Expected service life for reflective markers varies from 1-1/2 years under the most severe conditions to three to eight years for most freeway locations and to over 10 years for rural roads with low traffic density.

The ceramic marker system gives good daytime visibility when clean, and when wet it supplements the cube corner reflective marker in providing good night time delineation. During late summer and early fall in the drier parts of the State, considerable road film accumulates on the ceramic markers and the visual delineation is less than desired in the daytime and almost nonexistent at night. A markerwashing machine has been developed to clean the markers in critical areas. The ceramic markers are expected to last in excess of 10 years, although in some areas they will become severely pitted. This pitting is occurring more rapidly in some areas than was indicated at the time the first report was published in 1968. The white ceramic markers have very little nighttime delineation in dry weather.

Marker retention is being investigated. Investigation to date has shown the reasons for loss are:

1. Poor installation technique. This included poor mixing of the epoxy components, poor preparation of the road surface and placing the marker when the epoxy adhesive has already taken a partial set. This latter problem is more common for the rapid set epoxy.

2. Unsound road surface.

3. Use of a rapid set epoxy adhesive which has some physical properties which are unsatisfactory and which is difficult to handle in the field.

Although many types of new markers, both reflective and nonreflective, have been evaluated none of these are equal to the system adopted by the State of California. Many of these new markers have been experimental and the evaluation of their performance has assisted in the development of other markers which may be successful. This evaluation program has provided encouragement for the development of a reflective marker with a replaceable lens and the research on a white beaded inorganic button or wedge as a possible replacement for the ceramic marker.

IMPLEMENTATION

Reference is made to the "Background Summary of 1953-68 Report" (Page 1 of this report) wherein implementation of pavement markers for delineation, adopted as Statewide Standard in 1965, is discussed. No significant changes have been made in the standard adopted; therefore there is no new raised pavement marker implementation to report at this time. As discussed herein, other markers are being tried on an experimental basis and it is hoped that improvements can be implemented in the near future that will improve maintenance of visibility of markers (less blackening from tire marks and a possible replacement of the nonreflective ceramic marker with a beaded reflective type).

In conjunction with the study of pavement markers, a new specification for a rapid set epoxy adhesive has been developed which will be used on all future contracts requiring this type of adhesive. This adhesive has been formulated to overcome most of the problems which were observed during the laboratory and field observations made of failures between the ceramic marker and the rapid set adhesive. The adhesive has approximately one fiftieth the curing shrinkage of the present rapid set epoxy adhesive.

TABLE OF CONTENTS

I Background Summary of 1953-68 Report

This is a continuing project on the development and evaluation of raised traffic lane markers. The first report was issued in 1968 and covered all the work done since 1953. In that report all the preliminary work was discussed leading to the statewide adoption of a raised marker system in December 1965 in lieu of a painted stripe. This consisted of polyester or epoxy daytime markers and acrylic cube corner reflective nighttime markers. (See Appendix I) Field performance of early installations of the adopted system was discussed and comments on other experimental markers which had been evaluated were also included.

The first experimental installations starting in 1953 were of raised white reflectorized markers made with white pigmented epoxy resins filled with glass beads. These were intended to be a supplement to the painted stripe for nighttime wet weather visibility. Various other markers with both beaded and nonbeaded segments were tested: The nonbeaded section was intended to improve daytime visibility. These beaded or partially beaded markers were fairly adequate for nighttime wet weather visibility but were unsatisfactory for daytime visibility. One installation consisted of wedge shaped, white, beaded portland cement markers. These gave good nighttime wet and dry weather visibility and good daytime visibility but were not suitable over asphaltic concrete due to their low strength. The beaded and nonbeaded epoxy and polyester markers were severely stained by tires in the dry months of the year. The nighttime reflectance of the beaded epoxy and polyester type was poor because the polyester and epoxy resins tenaciously adhered to the glass beads and also provided a surface that did not wear away rapidly enough so as to expose a fresh surface to the traffic. They were, however, strong enough to resist cracking when placed over asphaltic concrete pavement.

Staining of polyester and epoxy markers from tires during the hot summer months was noted when markers were placed throughout the State, especially in the drier areas. Investigation showed that tire action during even a very light rain had a scrubbing effect that almost entirely removed this tire stain and other road film that had accumulated on the raised markers. Ceramic markers had the greatest resistance to tire staining and were specified in lieu of polyester or epoxy markers in September 1966 for most of the State. The initial "standard strength" ceramic markers were not satisfactory for use on asphaltic concrete due to cracking. "High strength" ceramic markers, with twice the required strength of "standard strength" ceramic markers, were far less susceptible to breakage and were specified for asphaltic concrete pavements.

Various types of reflectorized markers were presented by industry and trial installations made by the laboratory in the interval 1953-68. The first cube corner type with a reflective face perpendicular to the road surface was installed in 1963 and in 1964 the first extensive installation of slanting acrylic cube corner reflectors was installed and evaluated. The latter system was adopted in December 1965 when the marker program was initiated statewide. This marker provided excellent initial nighttime reflectance in both wet and dry weather when new and clean but was only moderately durable as compared to a beaded epoxy or polyester marker. Other reflective markers tested either had poor durability under traffic or insufficient nighttime visibility.

II. Investigations 1968-71

A. Durability of Cube Corner Reflective Markers

Two to three years after the first cube corner reflective markers were installed experimentally, it was noted that the lens surfaces were being badly damaged by traffic. In some locations the reflective surfaces were completely destroyed. In order to evaluate this damage, reflectance readings were taken of markers removed from the roadway. Areas were selected which have different traffic densities. The results showed that under fairly heavy freeway traffic, the original markers which had a specific intensity of 3.0 to 6.0 candle power/ft. candle, were reduced to a specific intensity of 0.1 to 0.2 within about six months. During the dry hot summer weather, an accumulation of road film further reduces the specific intensity to 0.05 to 0.10. The readings were made with an Esna photometer, placing the marker upside down in the instrument. The error in reading the markers this way was about ± 10%. This was adequate for this type of study. However, the instrument was not as sensitive as would be desirable for testing used markers which have a very low reflectance.

This original loss in reflection before structural damage occurs is due to numerous small scratches on the surface of the lens. These scratches can be partly removed with a fine abrasive so that much of the original reflectance is restored. However, since this original large drop in reflectance occurs so quickly, polishing would have to be done frequently to be effective and is not generally recommended. When markers reach a specific intensity of about .05, nighttime dry weather visibility is not as good as conventional traffic stripe. In wet weather, the road film is very quickly removed. When damp the markers provide very good visibility, especially in the rain, when they are needed most for delineation.

This good performance in wet weather was confirmed in the Laboratory by comparing the reflectance of both wet and dry markers. Usually a wet marker has 5 to 10 times the reflectance of a dry marker, and often reaches a specific intensity of 0.5 to 1.5.

There is some polishing action on acrylic lens as well as scratching from tire action. If a marker is lightly sandblasted to a specific intensity of 0.0 and placed on a roadway where there is considerable lane changing it will give a value of 0.02 to 0.05 within about 6 months, due to road polishing by traffic.

The surfaces of the reflective markers are often eventually damaged so there is no reflectance even when wet. This is probably due to a series of impacts from tire rims or from rocks lodged in tire treads. The estimated life for the reflective marker would vary from about 1-1/2 years in areas where there is considerable lane changing to 3 to 8 years under most freeway traffic and up to 10 years or more on many rural roads.

Areas Selected for Evaluation of Cube Corner Reflective Markers

Area (1) Interstate 80 near Vacaville and Fairfield where the average daily traffic count for 1969 was 26,000 (one way for 3 lanes). In this area there are relatively few on and off ramps. This decreases the amount of lane changing and reduces the average number of impacts per marker.

Area (2) South Sacramento Freeway, 47th Avenue area. The average daily traffic during 1969 was 35,000 (one way for 3 lanes). In this area there are many on and off ramps. This increases lane changing and increases the number of marker impacts. The markers in the high speed lane had considerably less impact.

Area (3) Highway 16, a 2 lane roadway, adjacent to the Sacramento River. In this area the average daily traffic for both lanes during 1969 was 7,200. This is a levee road, traffic speed is relatively slow and the number of marker impacts is low.

Area (4) Pioneer Bridge over Sacramento River. This is on I-80 just west of Sacramento and is heavily traveled.

Area (5) Interstate 80 between Arden Way and El Camino Avenue. This is a heavily traveled area of freeway with an average daily traffic count of about 95,000 (one way for four lanes).

Area (6) South Sacramento Freeway 1-2 miles south of Florin Road. The average daily traffic count for this area is 28,000 (one way for two lanes).

Observations on Removed Markers

Reflectance readings of reflective markers before and after cleaning with a mild ammonia and soap solution in the Laboratory are tabulated below. This cleaning approximates the actual cleaning action during moderate rains.

Area (1) Twenty Stimsonite 88 markers* were removed after being in service 3-1/2 years near Fairfield.

Area (2) Twenty Stimsonite 88 markers on adjacent lanes of the South Sacramento Freeway at 47th Avenue. These markers had been in service three years.

Area (3) Ten Stimsonite 88 markers from Highway 16 between Bryte and Woodland after being in service two years.

Area (4) Thirteen Stimsonite 88 markers were removed from the Pioneer Bridge. Five of these Stimsonite 88 markers removed near an off ramp showed the most damage of any removed to date.

MARKER REFLECTANCES

Area		Between** Lanes	Reflectance as removed (specific intensity)	After Cleaning (specific intensity)
1	I-80 Freeway	1 & 2	0.06	0.12
1	I-80 Freeway	2 & 3	0.07	0.14
2	So. Sacto. Freeway	1 & 2	0.18	
2	"	2 & 3	0.06	
3	Highway 16 (2 lanes)	Two Way (center)	0.08	0.27
4	Pioneer Bridge near off ramp	Westbound 3 & 4	0.01	0.01
4	Pioneer Bridge	Eastbound 2 & 3	0.05	0.12
5	I-80 Between Arden & El Camino	2 & 3 3 & 4	0.08***	
6	So. Sacto Freeway South of Florin Rd.	1 & 2	0.18	

*The four areas studied all had Stimsonite markers. Other areas surveyed but not included in this report show the Ray-O-Lite Marker to be equivalent in durability.

**Lanes are numbered starting from the median on Freeways.

***No pictures available.

Selected Areas and Photographs of Removed Markers

INTERSTATE 80 NEAR VACAVILLE BETWEEN LANES #1 & #2

AREA I

The markers in the photograph on the facing page were removed from Interstate 80 near Vacaville where the average daily traffic count for 1969 was 26,000 (one way, three lanes). In this area there are relatively few ON and OFF ramps. This decreases the amount of lane changing and therefore reduces the average number of impacts per marker.

The average reflectance of these markers after 3-1/2 years of road service was 0.07. All markers had only very slight damage to the lens area. Most of the damage consisted of small pits which were most likely caused by rocks in the treads of tires. Only a very small percentage (10%) of the markers had any significant erosion of the marker casing.

These markers were removed in June, 1969 and were moderately covered with tire stain. This tire stain was removed in the laboratory with a mild ammonia soap solution which approximates tire wiping action during rain. The average reflectance was then increased to 0.14.

It is expected that these markers would continue to be efficient as nighttime delineators for another five years.

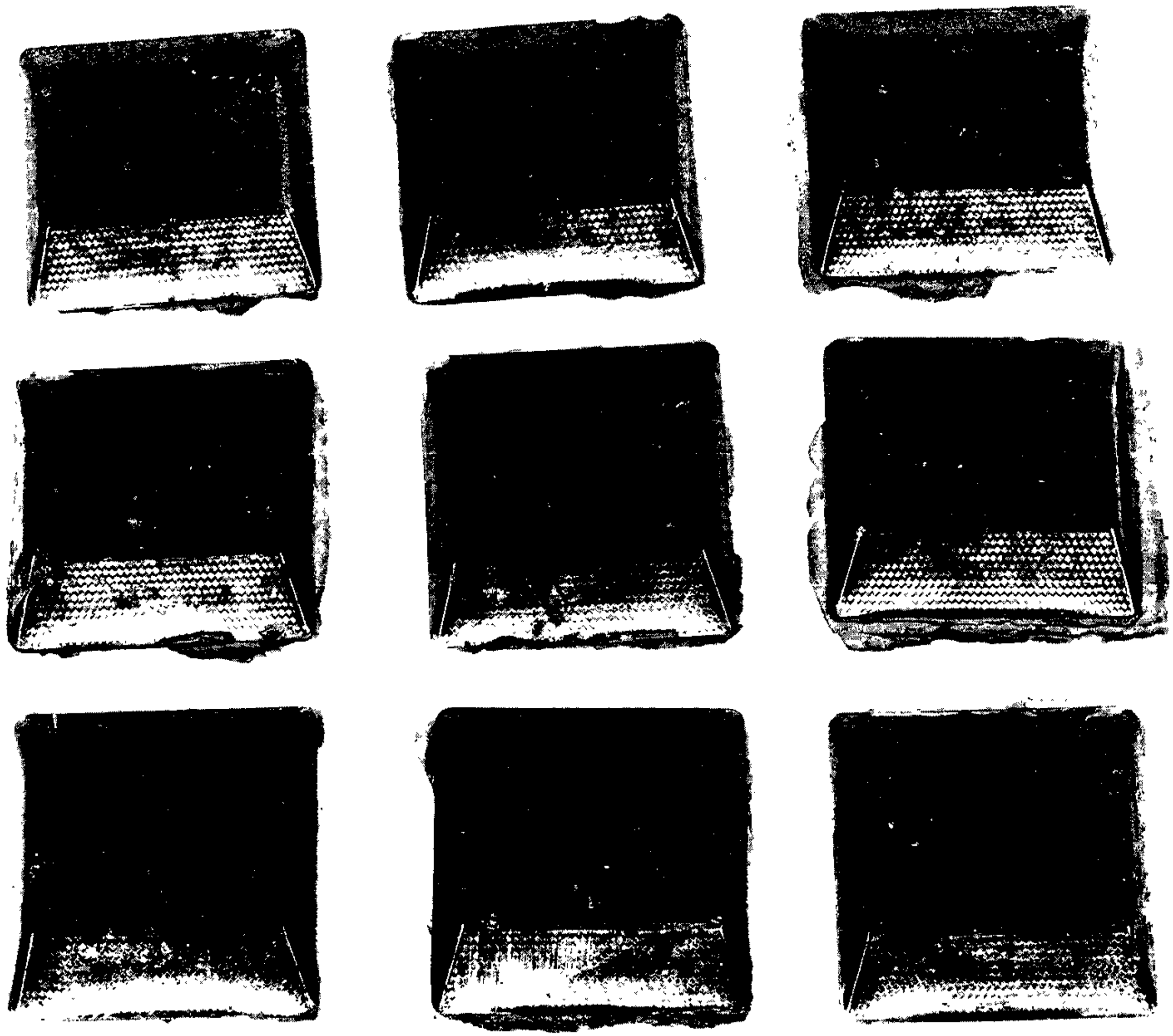


FIGURE 1

Test Area I I-80 Near Vacaville Between Lanes 1 and 2.

INTERSTATE 80 - NEAR VACAVILLE
BETWEEN LANES #2 & #3

These standard acrylic cube corner nighttime markers were removed from the same area as the markers on the previous page except adjacently between Lanes #2 and #3. These markers had also been in service for 3-1/2 years.

In spite of the fact these markers had a slightly higher average reflective (0.07) than the ones between Lanes #1 & #2, these markers showed slightly greater damage to the casings and lens area. As with most locations inspected, the markers in the low speed traffic lanes show greater deterioration than markers between lanes #1 and #2. Trucks and the heavier highway vehicles usually use #2 and #3 lanes of the roadway.

After these markers were cleaned in the laboratory, the average specific intensity increased to 0.14.

It is expected that these markers would also continue to be effective as nighttime delineators for another three to five years.

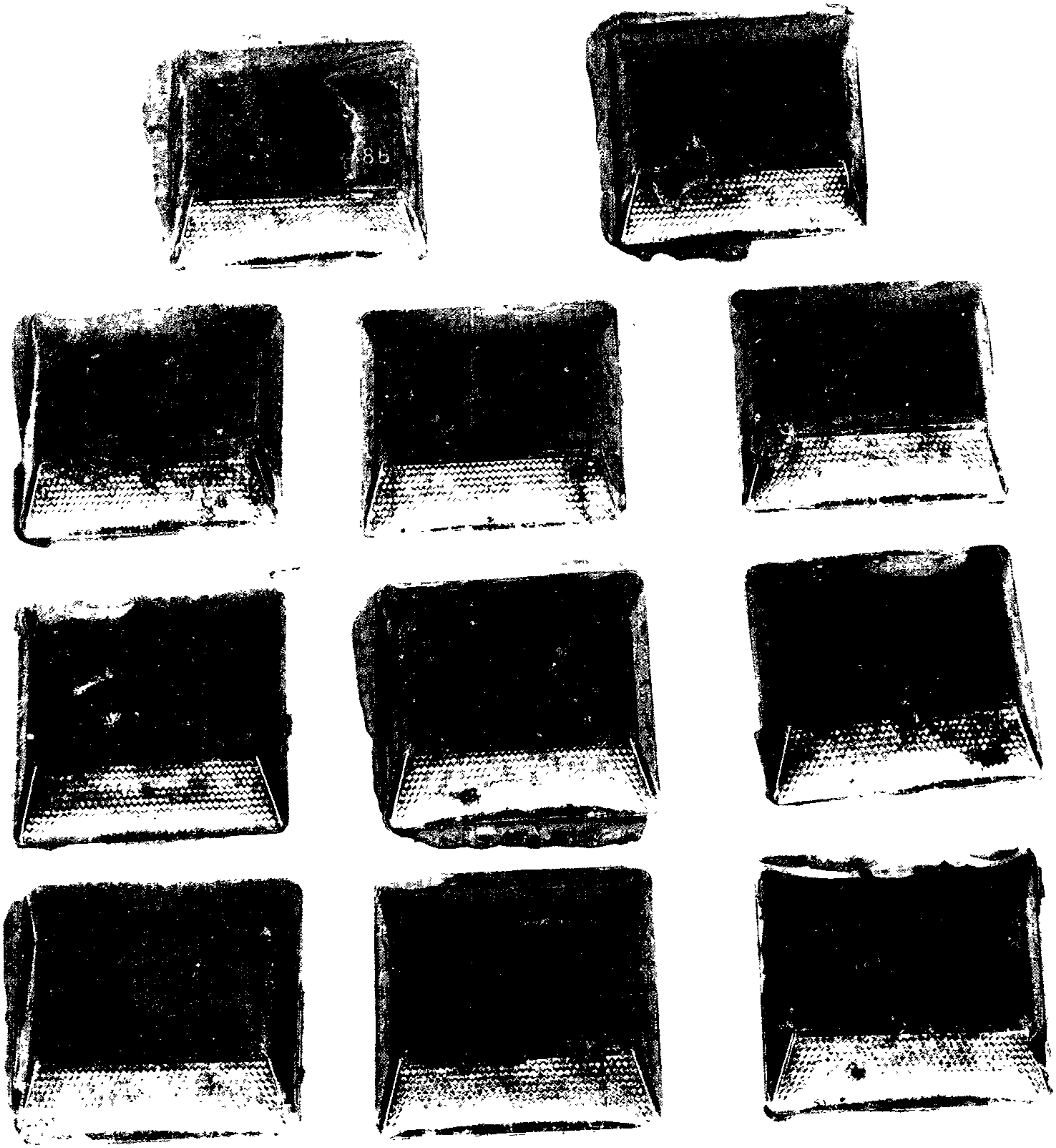


FIGURE 2

Test Area I I-80 Near Vacacille Between Lanes 2 and 3.

SOUTH SACRAMENTO FREEWAY - 47TH AVENUE AREA BETWEEN LANES #1 AND #2

AREA 2

These standard acrylic cube corner nighttime markers were placed on the South Sacramento Freeway approximately adjacent to the 47th Avenue On-Ramp, between northbound lanes #1 and #2. The average daily traffic during 1969 was recorded as 35,000 (one way for three lanes). In this particular area of the freeway, there is one moderately used on-ramp and one moderately used off ramp; however, most traffic in the high speed (#1) lane is through traffic. Therefore, these markers were subjected to a relatively low frequency of tire impacts.

The photograph shows the condition of the markers after three years of road service. As can be seen, the lens damage was slight to moderate enabling the markers to remain effective nighttime delineators.

The average reflectance of these markers as measured in the laboratory, when new, had a specific intensity of 6.0. After three years service, the average value was 0.18.

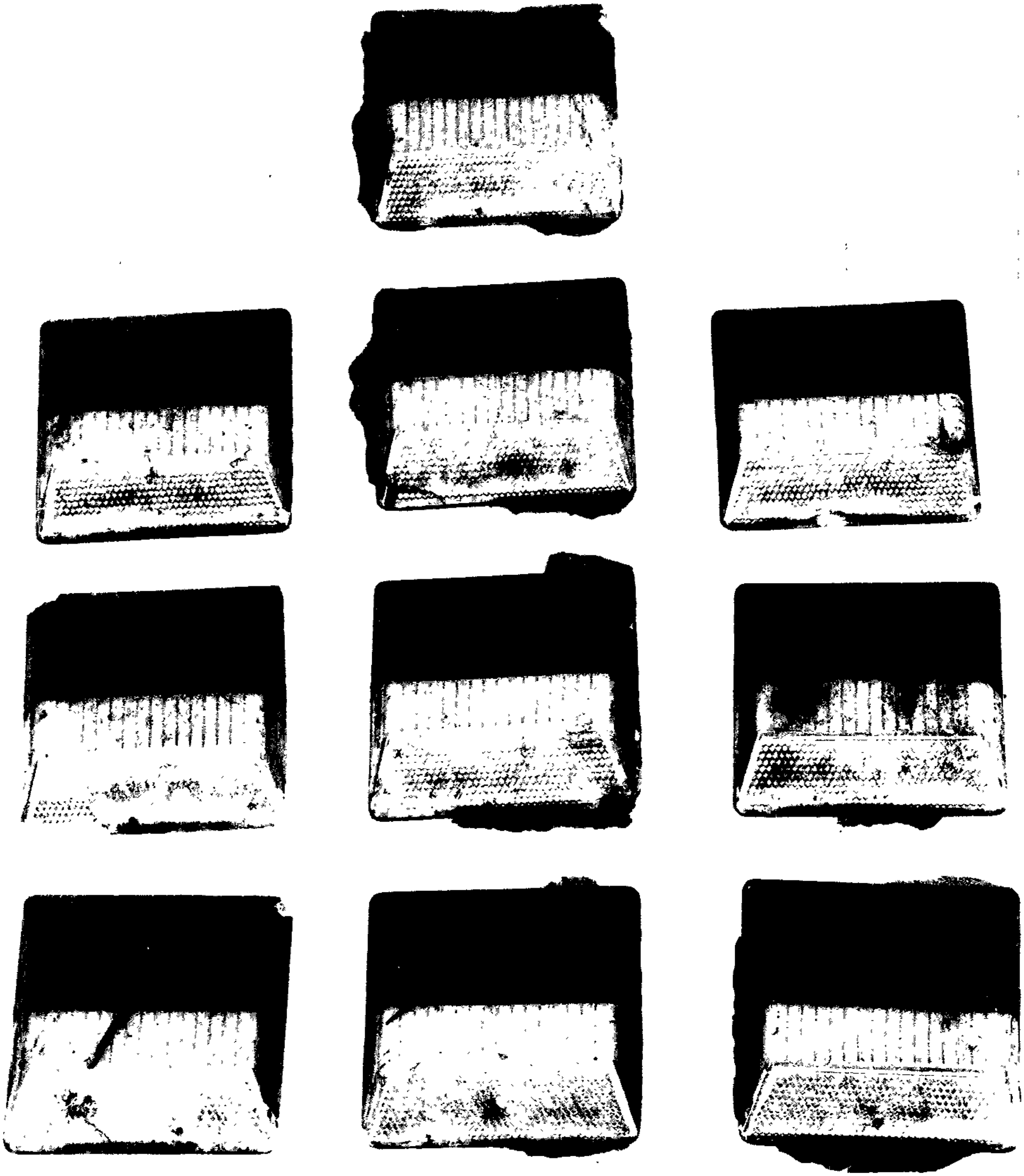


FIGURE 3

Test Area 2 South Sacramento Freeway Between Lanes 1 and 2.

SOUTH SACRAMENTO FREEWAY - 47TH AVENUE AREA BETWEEN LANES #2 AND #3

AREA 2

These standard acrylic cube corner nighttime markers were placed in the same area as the markers on the previous page except that they were placed between lanes #2 and #3. Because of the proximity of the on and off ramps, these markers were subjected to a much greater frequency of tire impacts than the markers between lanes #1 and #2. (Average daily traffic - 35,000.)

The average reflectance of the markers when removed after three years of service was 0.06. Two of the markers had zero reflectance and were invisible at night. These two markers had their entire lens area destroyed by tire impacts.

An important feature of this group of markers is the various degrees of damage. Marker (#7) had the least damage with marker #2 having the greatest damage. The following table lists the markers and their respective reflectance.

Marker #	Reflectance
1	0.07
2	0.00
3	0.01
4	0.09
5	0.10
6	0.10
7	0.17
8	0.02
9	0.00

This group of markers shows the type of damage usually seen under heavy traffic. Some markers may be nearly destroyed while adjacent markers will be in fair to good condition.

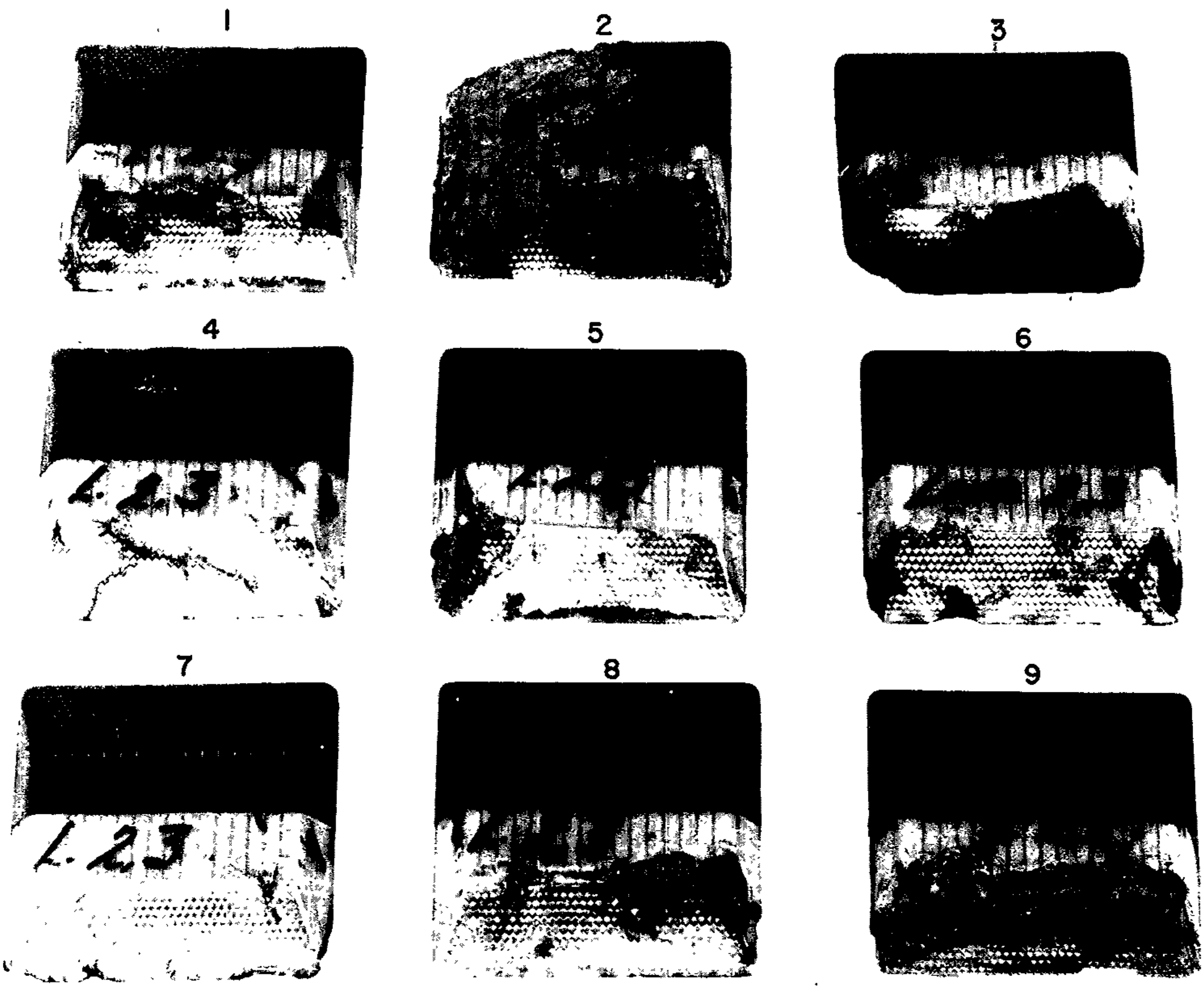


FIGURE 4

Test Area 2 South Sacramento Freeway Between Lanes 2 and 3.

MARKER EVALUATION - HIGHWAY 16 NEAR SACRAMENTO

AREA 3

Highway 16 is a two-lane roadway adjacent to the Sacramento River. In this area the average daily traffic for both lanes was 7,200 for the year 1969. This is a levee road, vehicle speeds are relatively slow and lane changes rather infrequent.

These markers were removed after two years service. After two years, the average specific intensity was 0.08 as measured in the laboratory. This low reflectance is caused by numerous small scratches in the lens surface.

As can be seen in the adjacent photograph, only one marker showed evidence of major case damage. All other lens areas are entirely intact.

It would be expected that these markers would continue to provide adequate nighttime delineation for an estimated service life of up to 10 years or more.

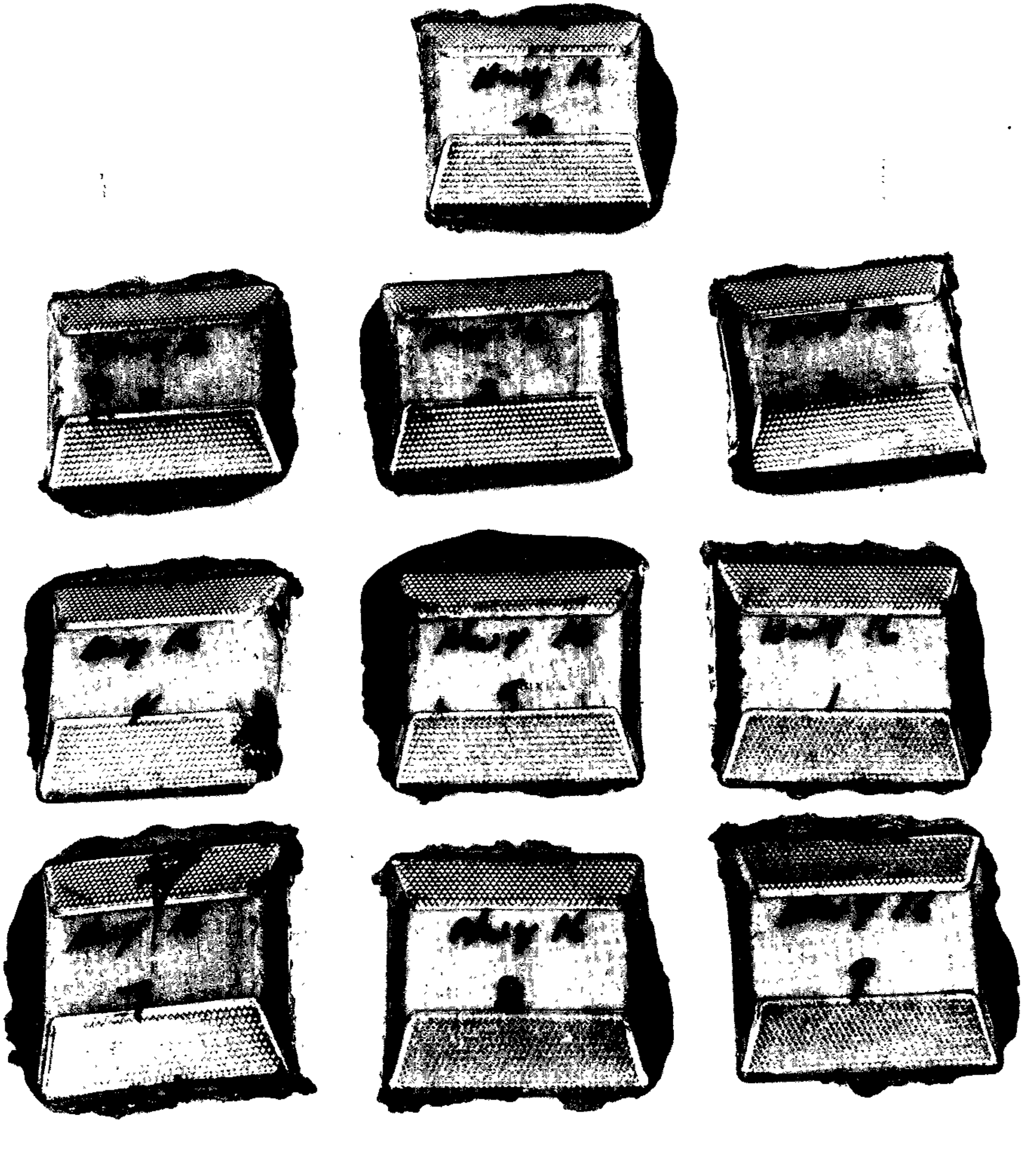


FIGURE 5

Test Area 3, Highway 16, 2-Lane 2-Way Road.

INTERSTATE 80 - PIONEER BRIDGE - WESTBOUND
BETWEEN LANES #3 AND #4

AREA 4

During nighttime observations in October 1969 it was observed that several markers in the westbound approach area of the Pioneer Bridge, in the outside lane, had lost most of their reflectance. It was decided to remove some of these acrylic cube corner markers for laboratory inspection.

Five adjacent markers are shown in the photo on the left. Four of the markers had a reflectance of 0.00 as measured in the laboratory. The marker at top center had a reflectance of 0.01.

This group of markers had been on the road approximately 2-1/2 years and showed the greatest wear and damage of any area under observation for such a period of time. These markers were removed from an area where the frequency of tire impacts is high. There is one off ramp near the area where the badly damaged markers were removed. The damage was severe enough to suggest that other factors, such as impact from a rim on a flat tire may have been responsible for part of the damage.

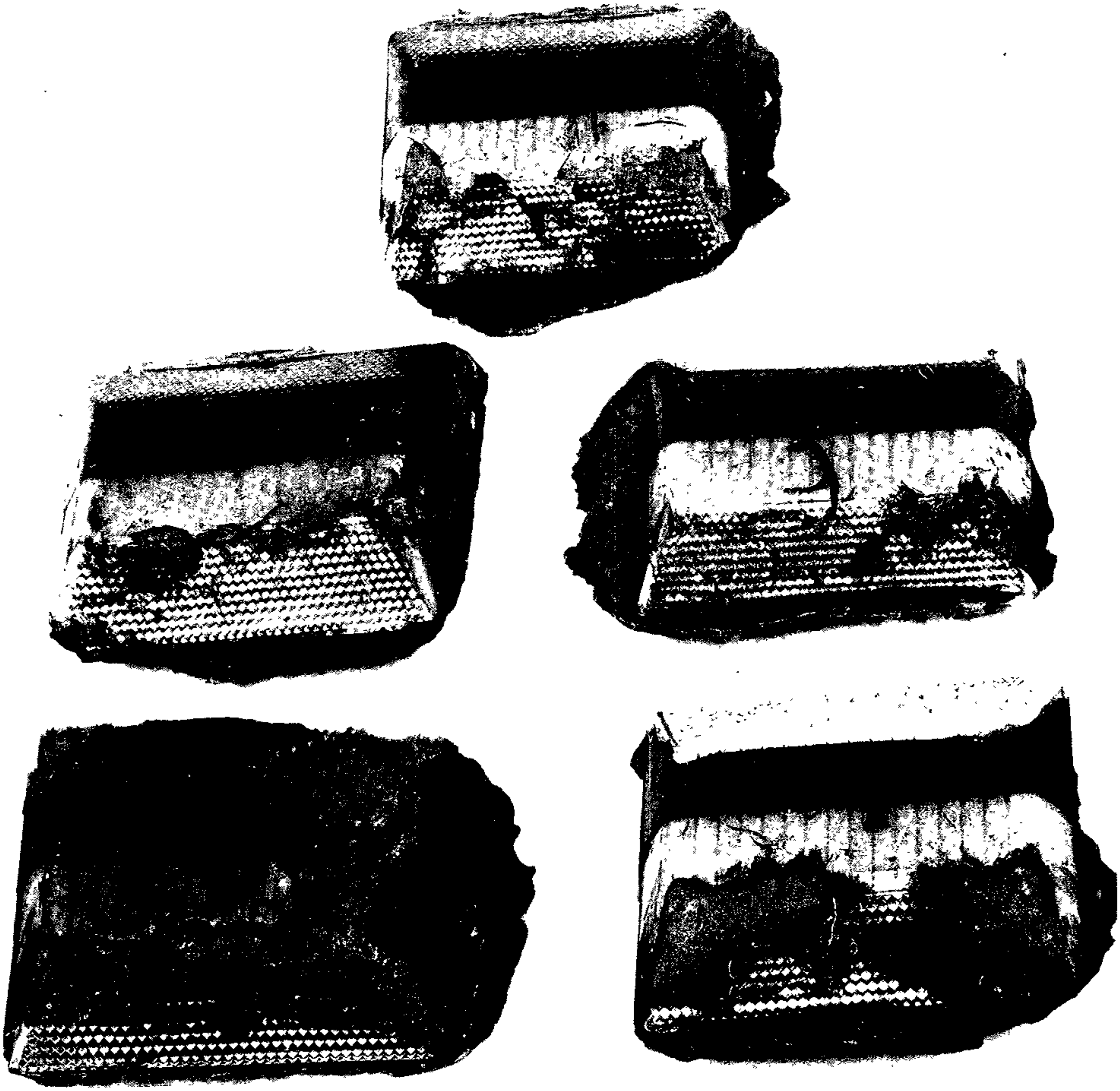


FIGURE 6

Pioneer Bridge West Bound Between Lanes 3 and 4.

INTERSTATE 80 - PIONEER BRIDGE - EASTBOUND BETWEEN LANES #2 AND #3

AREA 4

Eight standard acrylic cube corner, red and clear, nighttime reflective markers were removed at random from between the eastbound #2 and #3 lanes of the Pioneer Bridge just east of the middle of the bridge. These markers were removed because they were giving poor nighttime delineation at the time and it was not obvious whether tire stain or break up of marker was responsible. The markers were removed in October 1969, and all were heavily covered with tire stain. Only one of the eight markers had moderate lens erosion. The remaining seven had only slight damage due to pitting and small cracks. The average specific intensity of the removed markers was 0.05. After cleaning with mild ammonia and soap solution, the value increased to 0.12.

These markers had been in service approximately 2-1/2 years and they are expected to last three to four years more in this area.

Most of the reflective markers available locally for inspection were Stimsonite markers.

The Ray-O-Lite marker is, similar to the Stimsonite, composed of two acrylic lenses for each direction and has an A.B.S. shell as compared to the Stimsonite acrylic shell. The initial specific intensity of a Ray-O-Lite marker is comparable to a Stimsonite marker.

The first fair sized installation of Ray-O-Lite Markers (area 5) was made prior to their adoption by the State of California. Fifty-five Ray-O-Lite and fifty-five Stimsonite markers were installed at the junction of the North Sacramento and Elvas Freeways where there is considerable lane changing. After 27 months the average specific intensity of the Ray-O-Lites was 0.08 and the average of the Stimsonites was 0.10. This data substantiated our earlier decision that the two types of reflective markers were essentially equivalent.

The second installation (area 6) inspected which was installed under contract after the adoption of the Ray-O-Lite marker was on the South Sacramento freeway approximately two miles south of area 2. After 23 months of service the average specific intensity of the Ray-O-Lites was 0.14. The markers in Figure 18b were photographed just after being removed from the roadway and have not been cleaned.

The Ray-O-Lite markers appear darker than the comparable Stimsonites of area (2) for two reasons:

I. The ABS shell Stains more under traffic then the acrylic shell of Stimsonite.

II. The angle of light for the picture caused the markers to appear darker.

The following lists the markers and their respective specific intensity:

Marker No.	Specific Intensity
1	0.18
2	0.11
3	0.20
4	0.12
5	0.16
6	0.09
7	0.11
8	0.08
9	0.19
10	0.15
Average	0.14

Figure 7a

Test Area 6, South of Florin Road, South Sacramento Freeway, between lanes #1 & 2.

B. Ceramic Markers

In the last marker report published in 1968 it was estimated that 5 to 8% of the surface of the ceramic marker would be pitted within 10 years. It was also predicted that the glaze would become frosted. This prediction has generally been valid although in some areas pitting has been more severe than expected. Under one-way traffic the pitting has occurred mostly on the leading edge of the marker. The body of the marker is white which provides adequate visibility in the daytime when clean. However, the pits rapidly collect dirt or tire stain which detracts from their visibility during daytime dry weather, and whether clean or dirty, delineates poorly in nighttime clear weather.

It was noted in the 1968 report that during very long, hot, dry weather periods, even new ceramic markers stained badly. This has been a continuing problem which is discussed in the following section C.

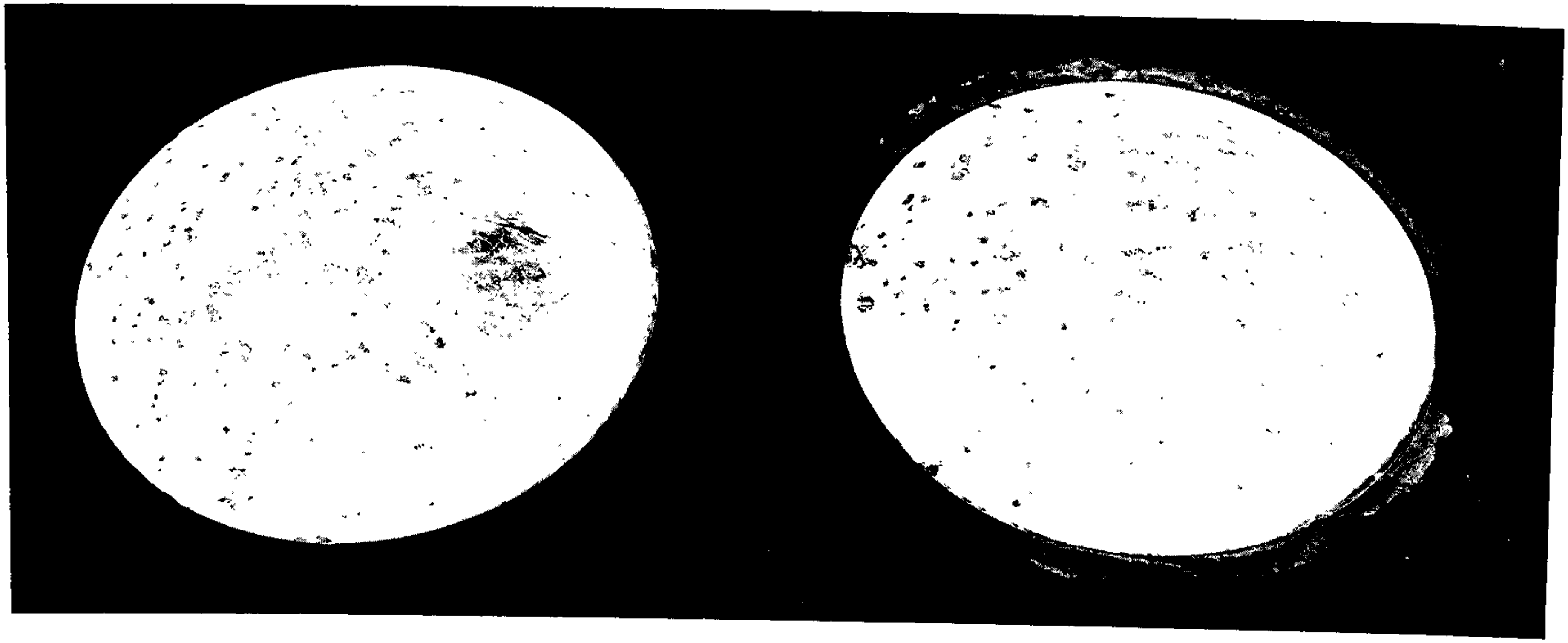


Figure 8

Ceramic Marker

These markers were removed from US 99 a few miles south of the 47th Avenue test section on the South Sacramento Freeway. This is a 4 lane freeway with a traffic density of about 30,000. The damage to these markers is the most severe observed to date. The left marker was removed from a curve, the right marker from a tangent section. The pitting generally extends below the glaze and covers an estimated 12% of the total surface for the left marker and 6% of the right marker. One possible explanation for this damage is the use of studded tires which have been permitted since our initial evaluation of ceramic markers. This roadway probably carried a moderate amount of traffic which might be expected to use snow tires. Some imprints were observed on reflective markers in this area that looked like an imprint of a stud typically used in tires.

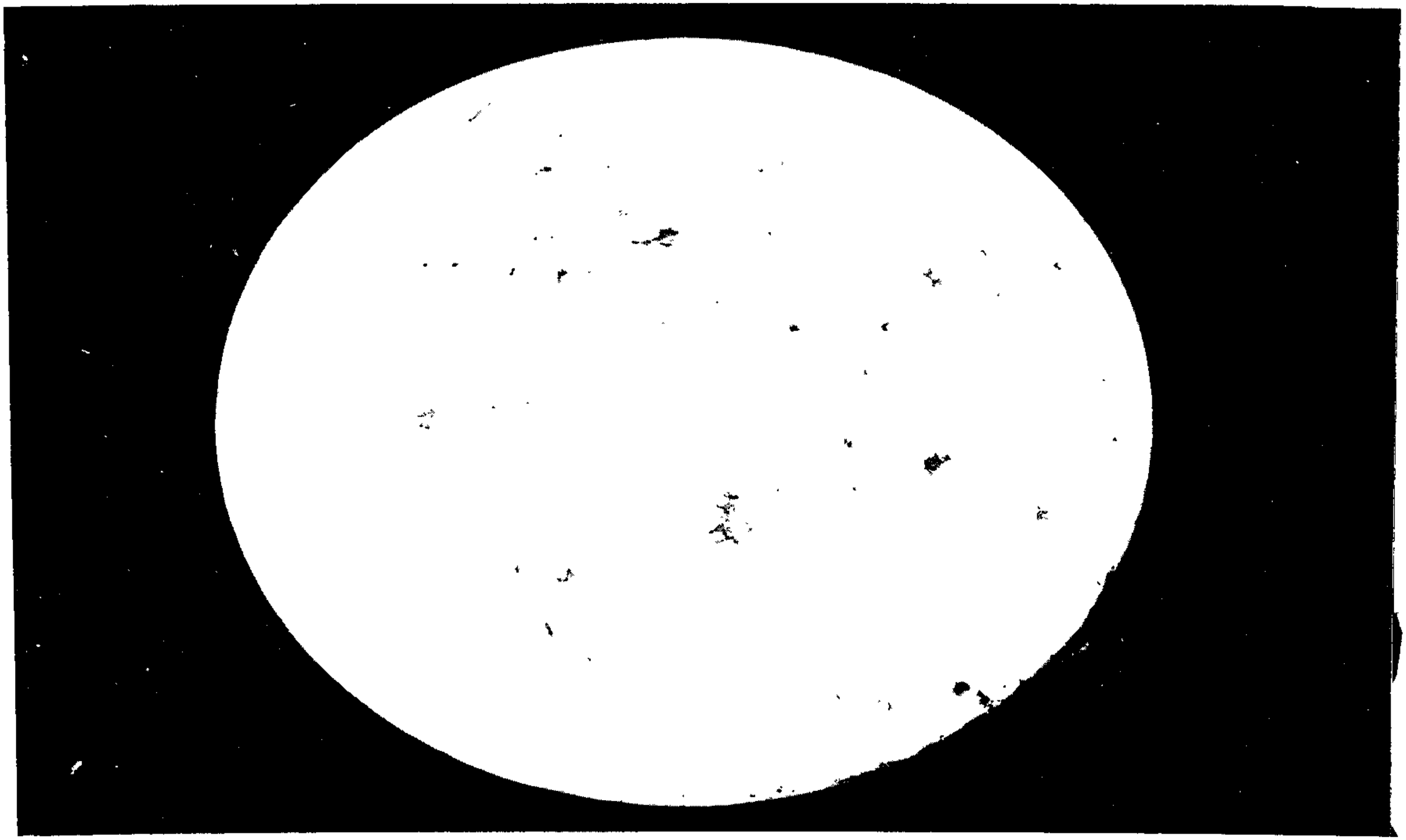


Figure 9

Ceramic Marker

This marker was removed from Route 16 (test area 3). Markers in this area show about 1-2% pitting and the pattern is uniform over the face of the marker as would be expected on a two lane road. These markers are about 3 years old.

C. Road Film

Raised markers are especially susceptible to an accumulation of a dark film during periods of hot dry weather. This film on the markers is not easily soluble in any of the common organic solvents but is easily removed with a cleanser containing a fine abrasive. From this it is concluded that the film is primarily rubber from tires. The temperature of the marker appears to be a factor in determining the amount of staining since markers shaded by an overpass were stained less than adjacent markers in the direct sunlight. Staining of markers during the long, hot, dry summers in California has continued to be a problem. The use of ceramic markers, adopted in 1966 for use in the drier areas of the state, delays the formation of this film. However, during late summer and fall these day-time markers sometimes blend with the road surface or in some cases are actually darker than the roadway. Traffic paint over the nine foot gap occupied by the daytime markers improves daytime visibility, but has only been applied experimentally and in special locations.

A traffic marker washer has been developed by the State of California Equipment Shops, see Figures 10 and 11. This consists of a brush 14" wide by 18' long with 4" nylon bristles which have been impregnated with an abrasive. This unit is mounted beside a 2 ton truck and a detergent water solution is supplied to the brush. Effective cleaning is obtained at speeds of 45 mph. This machine has been used in five districts.

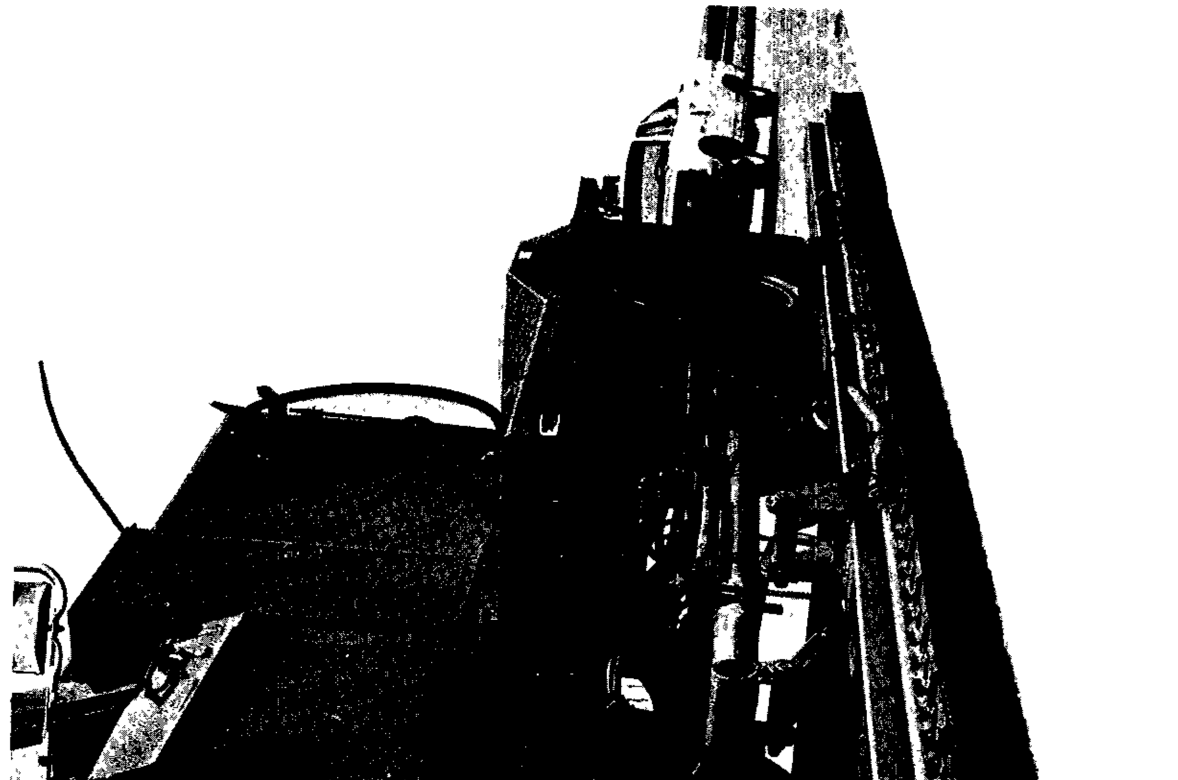


FIGURE 10

Marker Washing Device

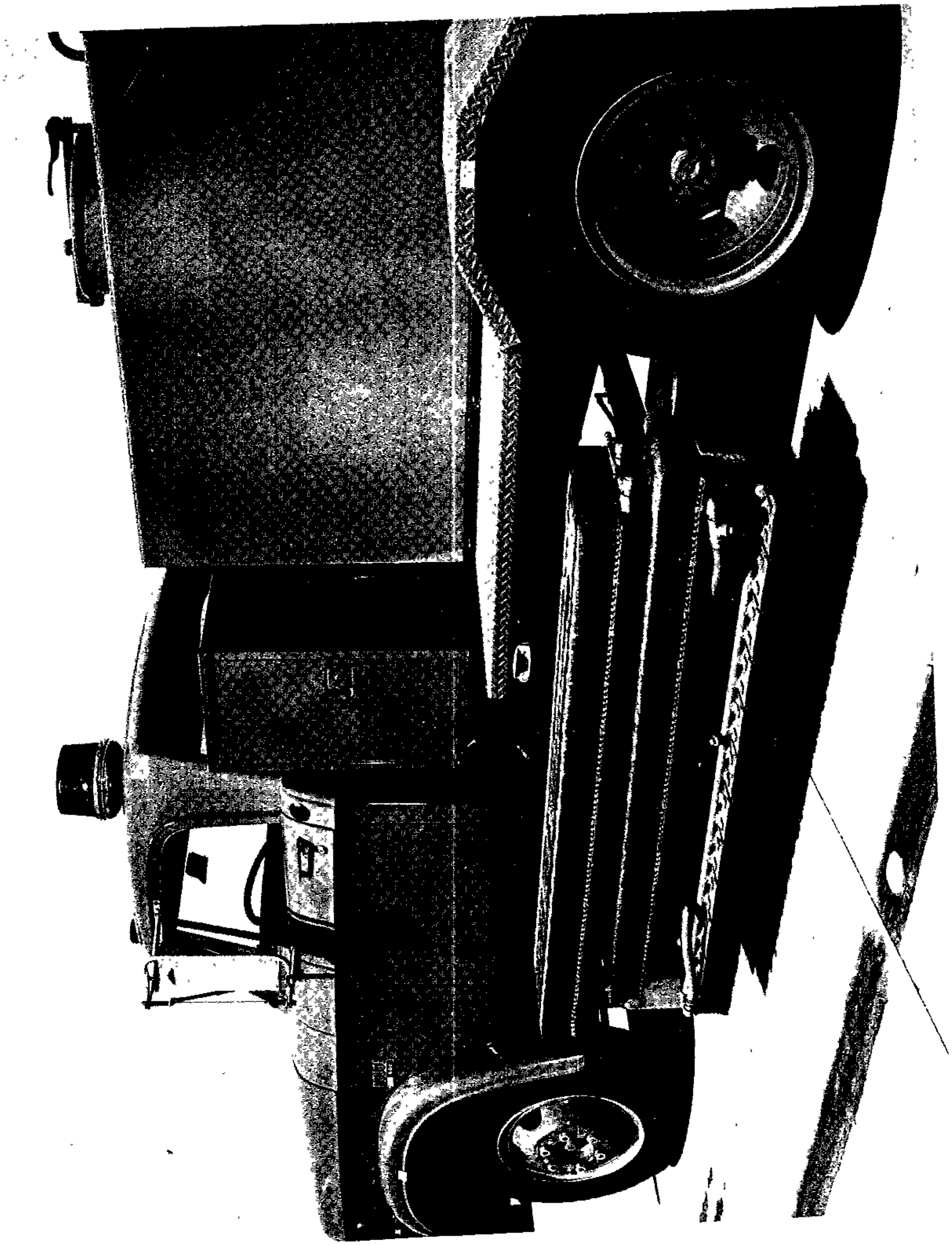


FIGURE 11

Marker Washing Device
(Folded for Transporting)

D. Further Evaluation of Raised White Portland Cement Mortar Reflective Markers

In the spring of 1955, raised wedge shaped white portland cement mortar markers, designed by James A. Cechetini of the Materials and Research Department, were installed experimentally on the then new Elvas Freeway near Sacramento as traffic lane delineators in lieu of a conventional painted stripe on the eastbound lanes. This portland cement concrete freeway was initially two lanes in each direction and was widened to three lanes over most of its length in 1965 at which time it became a part of Interstate 80. The markers were removed on the widened portion at the time the additional lanes were added in 1965 and missing markers did not exceed five percent. As of January 1971, on the remaining two lane portion, these markers, after 16 years of heavy traffic, had no loss and are essentially undamaged.

The wedge shaped markers were made of a white portland cement binder, a small amount of titanium dioxide and glass beads in lieu of aggregate to provide nighttime visibility. These markers were self cleansing and retained their whiteness and reflectivity day and night because of continuous slow chalking or sloughing of the top surface exposing new glass beads and a fresh underlying surface.

The markers were cemented to the road surface by laboratory personnel utilizing a laboratory formulated epoxy -- polysulfide adhesive. Even though shortly after installation small hairline shrinkage cracks developed in the markers, this did not affect their durability.

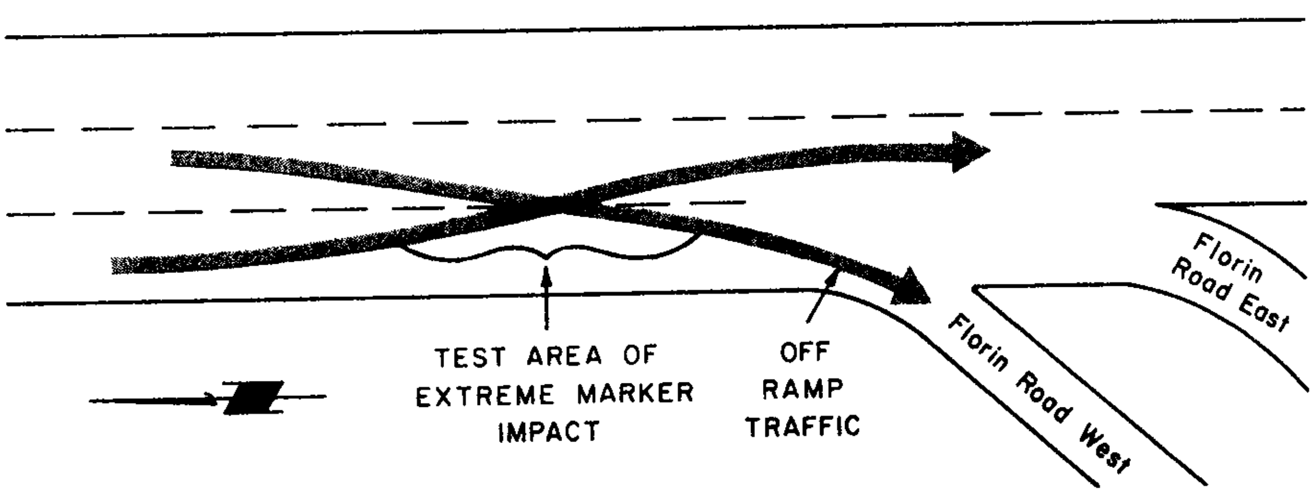
Plastic matrix markers, and to a lesser extent, ceramic markers, darken by tire staining during the long dry summer months of the Sacramento Valley. This was not true of the white portland cement matrix type because of constant renewal of the surface through chalking. This surface renewal occurs because portland cement is a weaker binder than polyester or epoxy resins.

The markers, as constructed, were brittle and therefore suitable for installation only on portland cement concrete roads where there is little flexural movement. When firmly bonded to the PCC surface with epoxy adhesive, brittleness was no longer a limiting factor. However, life of the markers on asphaltic concrete may be limited because of flexural movement of the asphaltic concrete surface during the warm summer months. This limitation of brittleness may be overcome by research in the redesign of the shape and the use of polymer additives and reinforcement to the white portland cement matrix.

E. Testing of New Markers

Since the 1968 report, a continued evaluation of other markers has been made. Test sections have been relatively short varying from a few markers up to a 1/2 mile section. Controls of our specification markers are included in trial installations for comparison. Most areas selected for test are subject to heavy traffic. A total of six types of nonreflective, five types of reflective markers and 10 combination markers have been evaluated. Some cast-in-place glass beaded markers of latex modified white portland cement installed flush with the road surface are under evaluation for use in snowplow areas.

Most of the markers to be evaluated are placed on the South Sacramento Freeway. This is a six lane freeway carrying about 35,000 vehicles daily in each direction. One particular area has been of value in providing a test section which duplicates all except the most severe traffic conditions. This area is in the vicinity of the Florin Road off ramps where a three lane section narrows to two lanes forcing most trucks to make a lane change. See diagram.



This situation forces the through traffic in the #3 lane to cross over toward the #2 lane, and any traffic in the #2 lane that desires either off ramp access must cross over toward the #3 lane. Therefore, markers located within about 1000 feet of the Florin Road West off ramp are subjected to vehicles changing lanes in both directions, left to right and right to left.

Several of the 4" glass and plastic rods along with the standard 2 inch clear acrylic cube corner control units have been placed in this area. After four to six months, most of the glass and plastic units were damaged to such an extent that they did not continue to serve as effective nighttime delineators. The standard acrylic cube corner captive units did, however, continue to give good nighttime delineation for two years and are expected to continue for one to two more years unless removed for further test installations. Hence, even though this location is severe, it is not as bad as some areas in the larger metropolitan areas where the reflective markers may be largely destroyed within 18 months.

The following are pictures and a discussion of most of the new markers under evaluation.

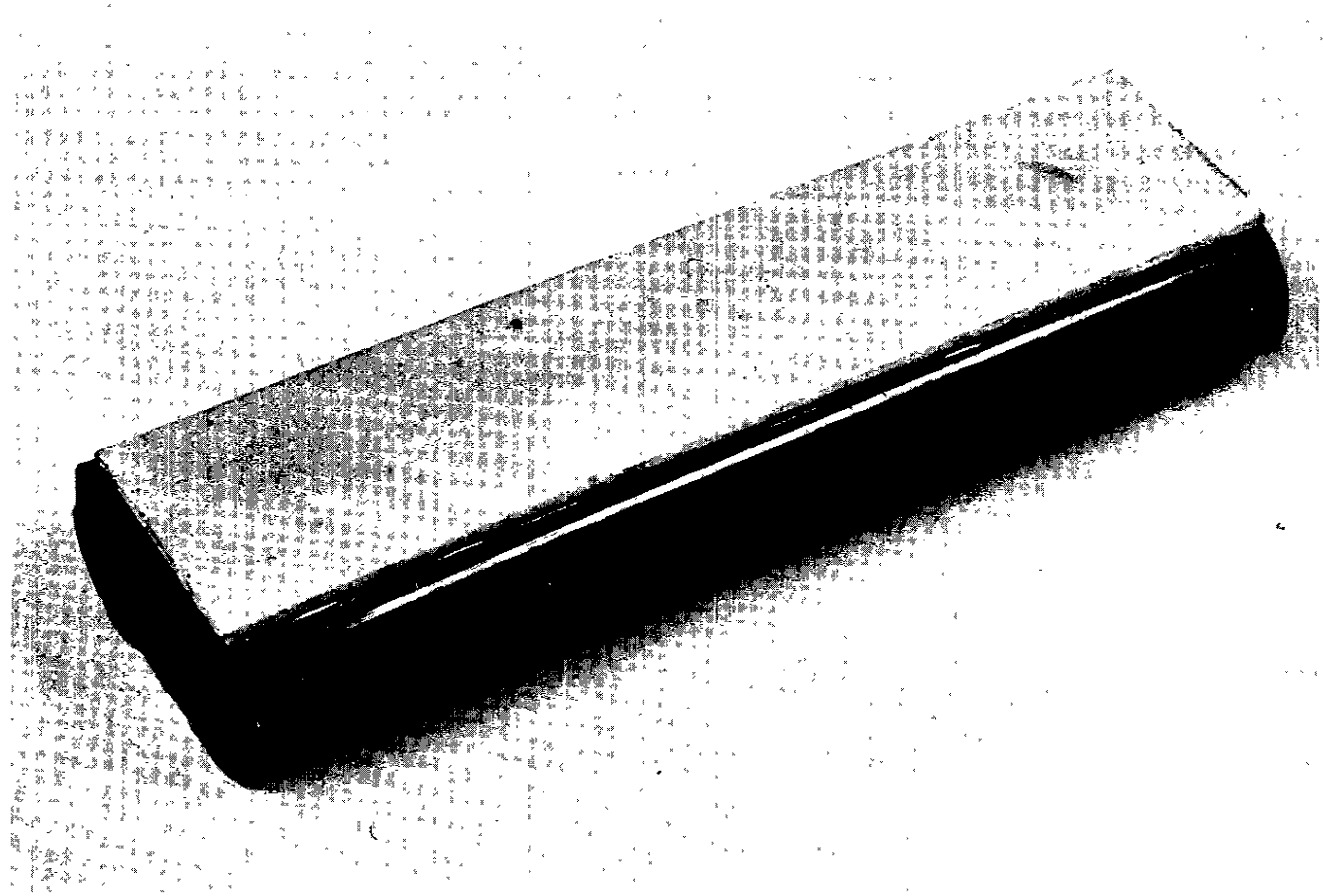


FIGURE 12

REFLECTORIZED TAPE ENCASED BETWEEN TWO
4 INCH GLASS BARS

This unit consists of a highly reflective tape encased between two glass rods. The top covering is a fibre glass strip to improve impact resistance. It has good initial nighttime visibility with an approximate specific intensity of 4. Several of these markers were placed on freeway areas ranging from light to severe traffic conditions. Markers that were subjected to minimal lane changing showed good nighttime delineation for three years. However, markers that were subjected to continuous heavy lane changing and truck traffic showed a very limited durability of approximately six months. Marker failure was due to the glass rods breaking or severely chipping and total bond failure between the marker and epoxy adhesive.

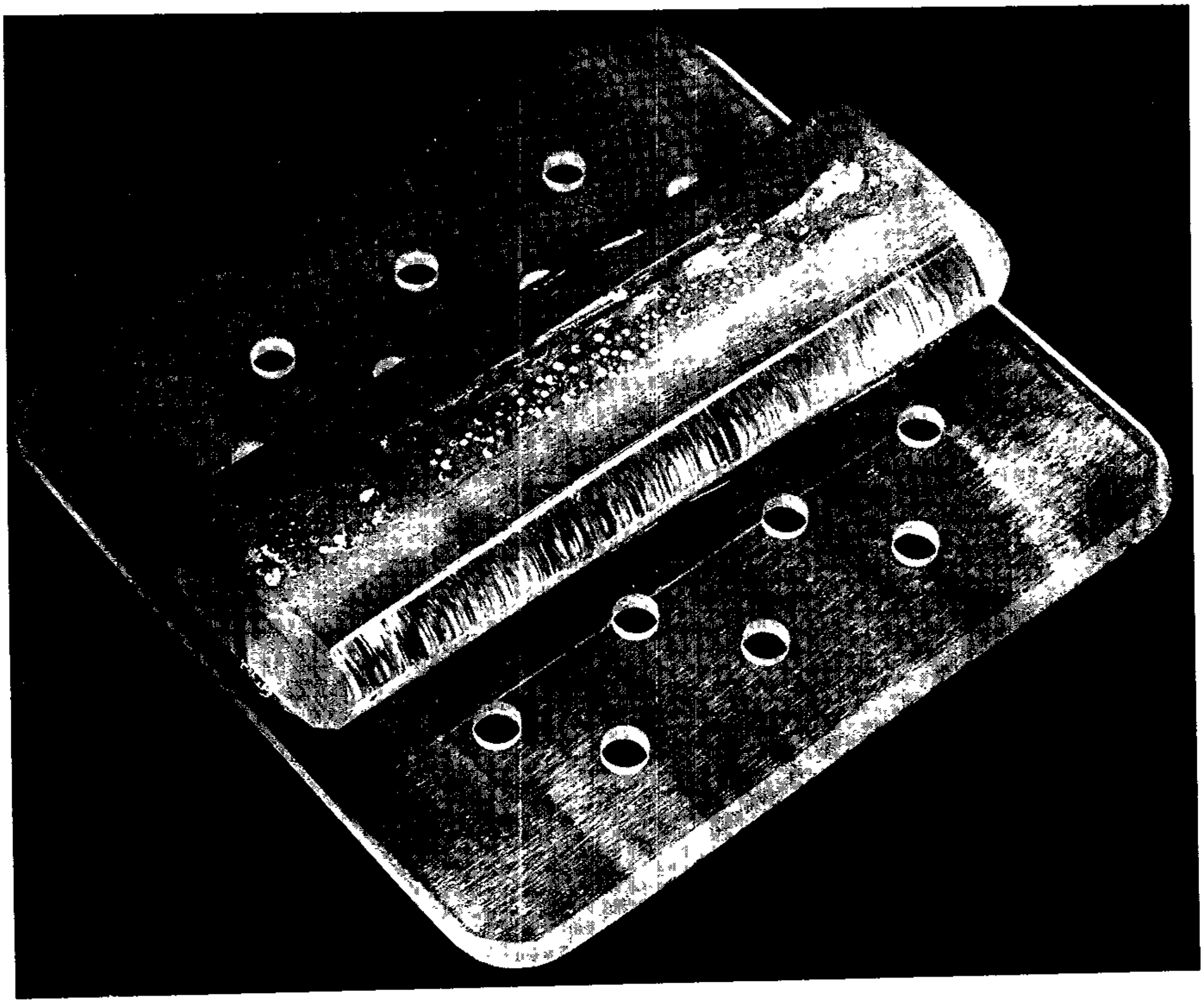


FIGURE 13

REFLECTORIZED TAPE ENCASED BETWEEN TWO 4 INCH PLASTIC BARS

This unit consists of a highly reflectorized tape encased between two 4" plastic rods with a large plastic base to assist in adhesion to the road. The approximate specific intensity of this unit is 4-1/2. Eight of these markers were placed on the highway in an area of heavy lane changing and truck travel. Observations indicate marker durability of approximately six months under these conditions. Type of marker failure was similar to the four-inch glass rod unit, except about 90% of the failure was due to the marker breaking off the plastic base.

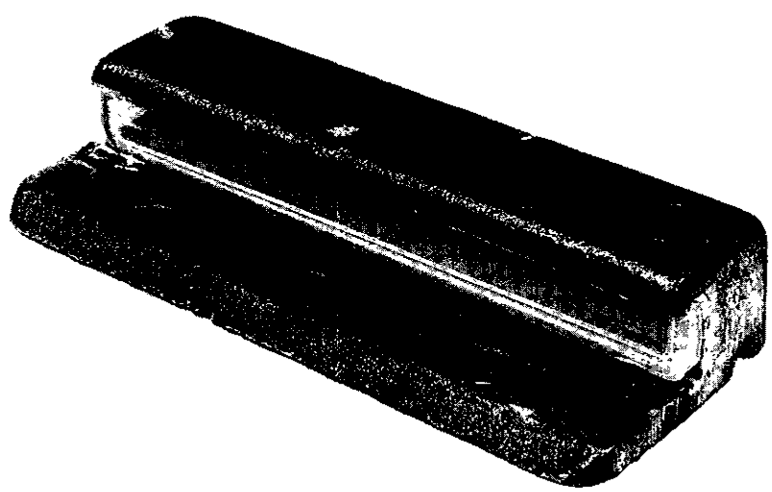


FIGURE 14

METAL CASE WITH REPLACEABLE REFLECTORIZED ELEMENT

The body of this marker is made of either cast iron or aluminum and is designed so that the reflective element can be replaced. Observations of a test installation showed that the markers provided good initial nighttime delineation (approximate specific intensity of 2,) but became invisible after only a few months because of accumulated dirt on the surface of the lens area. Because of the recessed lens, tire scrubbing action during rain is ineffective in cleaning the marker. Thus after field exposure, dirt accumulation remained on the lens area, and the marker became ineffective.

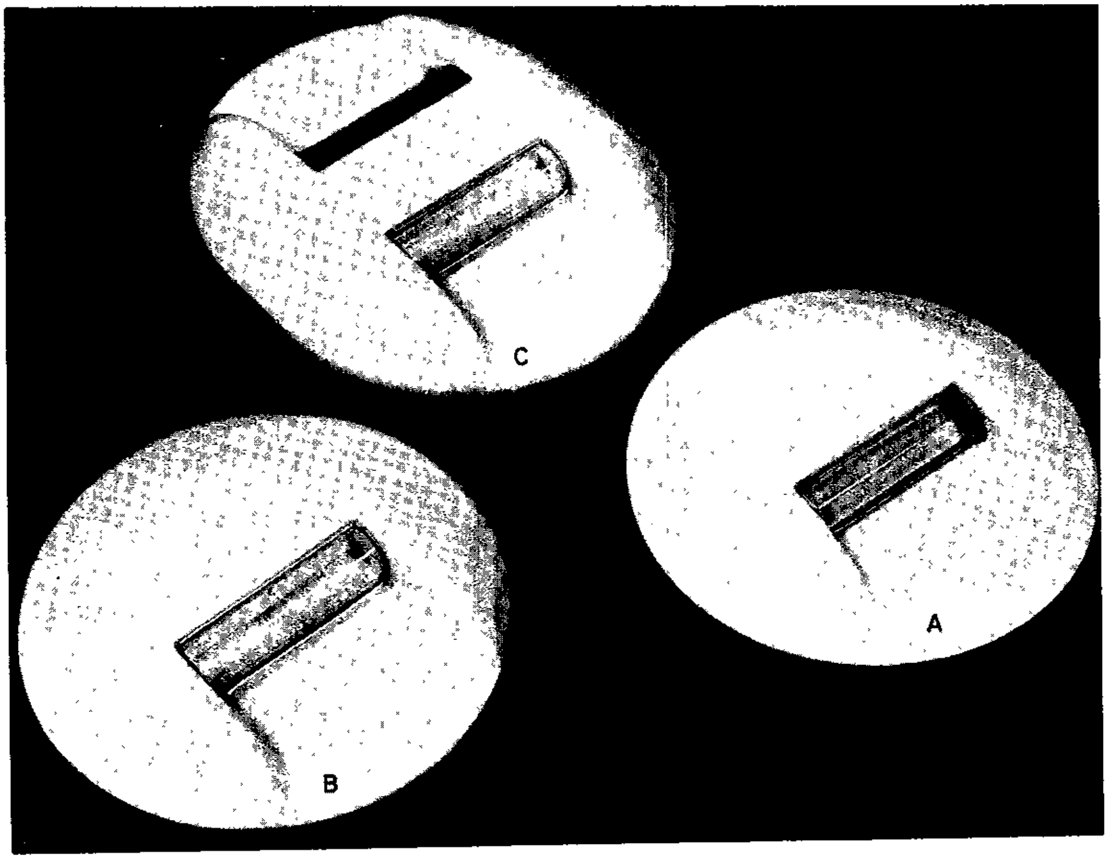


FIGURE 15

CERAMIC DAYTIME MARKERS WITH A REFLECTIVE ELEMENT CONSISTING OF AN ENCASED REFLECTIVE TAPE

These markers are all designed to give continuous daytime and nighttime delineation. The specific intensity of these markers is approximately 1.0 (clear side). Four types have been installed in test sections for evaluation. The first unit (Picture A) had either a full round glass or quarter-round acrylic rod. Later units tested (Picture B) consisted of a single quarter-round glass rod with improved base design. The last unit installed (Picture C) is a two-way marker with both rods being quarter-round acrylic.

All four types of units have been placed in test installations on the highway. The unit in Picture A was not satisfactory for nighttime visibility due to breakage of the glass rods which occurred after several month of service. The model with the quarter-round acrylic rod is still under test. The daytime visibility of all types is about that of a regular ceramic marker. There has been some cracking of the ceramic marker due to the configuration needed to hold the reflective elements but this is not as serious as with a similar unit previously tested.

Units (B) and (C) have been recently installed and evaluation is not complete at this time.

FIGURE 16

GLASS-DOMED UNIT ENCASED IN RUBBER BASE

These markers consist of a glass dome encased in rubber. A similar unit with a plastic base has been tested by the laboratory and was unsatisfactory. It was thought that the rubber base might possibly have given more impact resistance to the glass dome and increased its life. However, highway test installation indicated breakage of the glass domes after a service life of a few months. The resulting marker was ineffective for nighttime delineation. Initial nighttime reflectance of this marker was considerably less than the standard acrylic cube corner reflective marker now in use. Rubber materials stain considerably during the hot dry summer months.

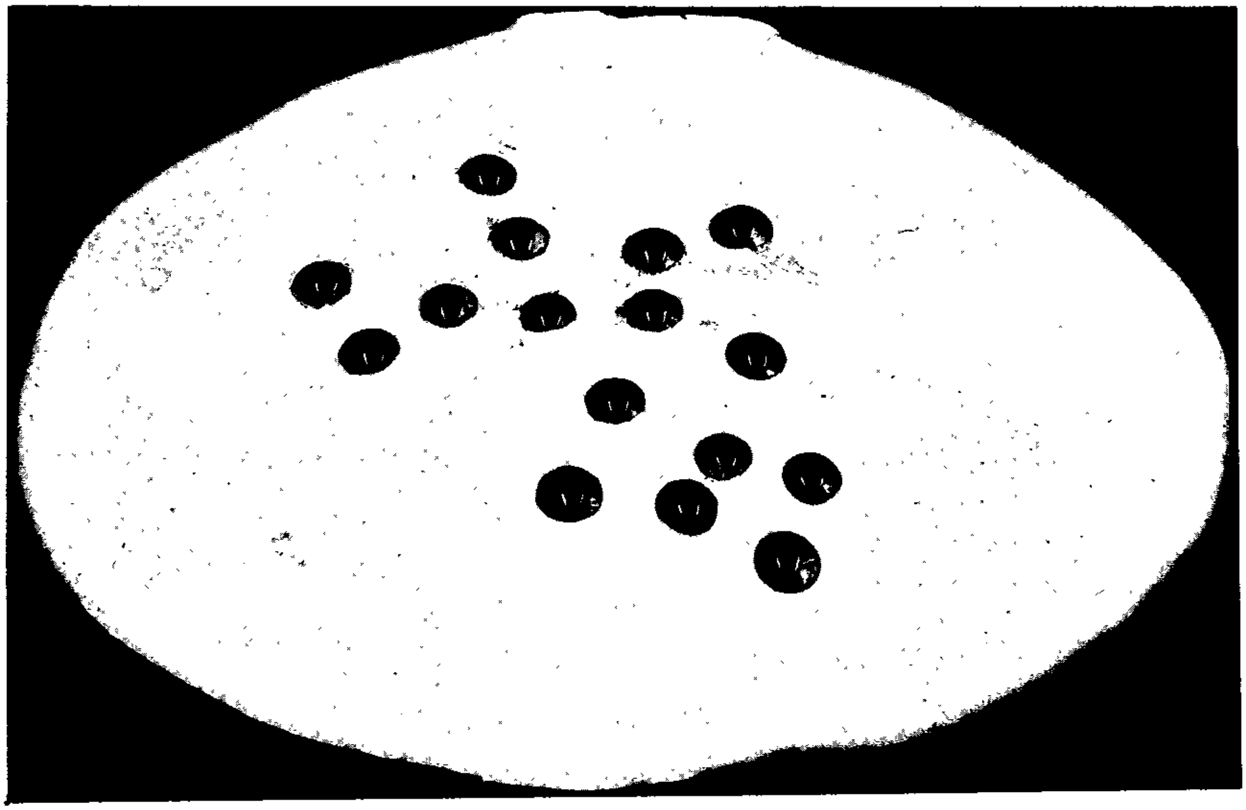


FIGURE 17

EPOXY MARKERS WITH GLASS BEADS
(Cast in Place)

About 1/2 mile of these cast in place beaded epoxy markers were placed on the South Sacramento Freeway in 1966. The markers were formed by first extruding a 1/8" x 4" diameter pad of white epoxy adhesive on the roadway. Fifteen to twenty 1/4" coated glass beads were then dropped into the adhesive. The coating on the imbedded portion of the beads was intended to improve the reflectance of the bead. Before the beads are visible, the coating on the exposed surface must first be worn off by traffic.

Reflection of the unit was extremely low when new and the delineation of the markers were essentially nil immediately after installation. After three years service, beads were cracked or etched by traffic so that the markers were barely visible at night. Daytime visibility was poor due to tire stains on the epoxy surface.

FIGURE 18

"LOW PROFILE" DAYTIME CERAMIC MARKER

This ceramic marker is 1/2" in height and is designed to minimize tire impact noise caused by lane changing. It is approximately 65% the height of the standard ceramic marker now in use. Preliminary evaluation of a test installation indicates these markers do not have the strength of a high-strength ceramic marker. Hence, they may not be suitable for use over AC. After five months of service in a test installation, one-third of the markers broke when applied over a 1/16" pad of butyl-rubber adhesive. None of the standard high-strength ceramic control markers broke.

This type of test was used to compare the high-strength ceramic markers with the standard strength ceramic marker for use over flexible pavements. In a previous test installation, all standard strength ceramic markers broke when placed over butyl rubber while no high strength ceramic marker broke when placed over butyl rubber.

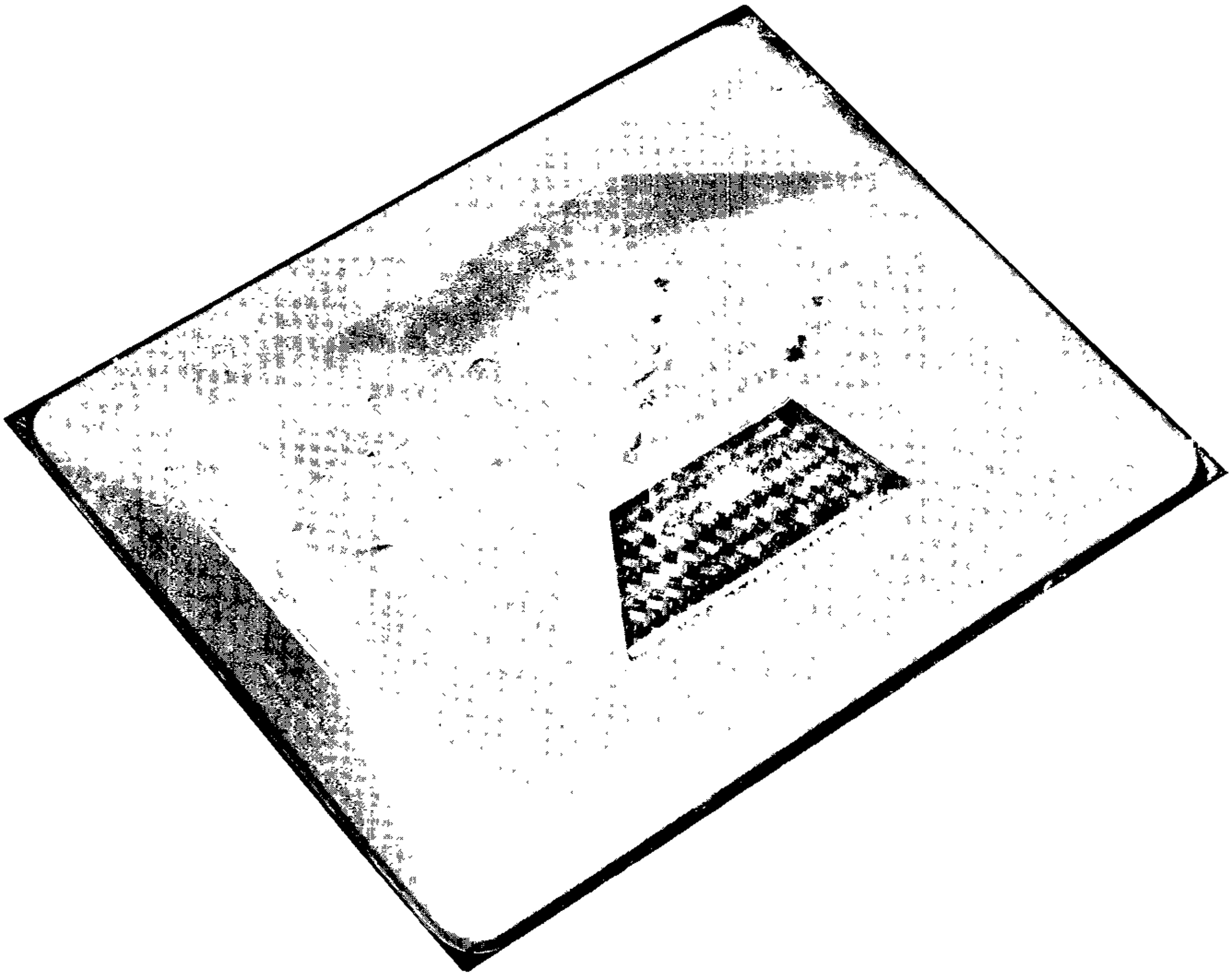


FIGURE 19

REFLECTORIZED UNIT CONSISTING OF AN EPOXY FILLED ACRYLIC SHELL

A test installation of these markers was placed on the South Sacramento Freeway in June 1967. (Area 1). These markers provided good delineation for two years after which time the plastic casings began to separate from the epoxy filler. Approximately 50% of the markers installed experienced loss of the casing. In many instances, the reflectorized unit remained attached to the filler, still providing nighttime delineation. However, without the casing they began to deteriorate rapidly.

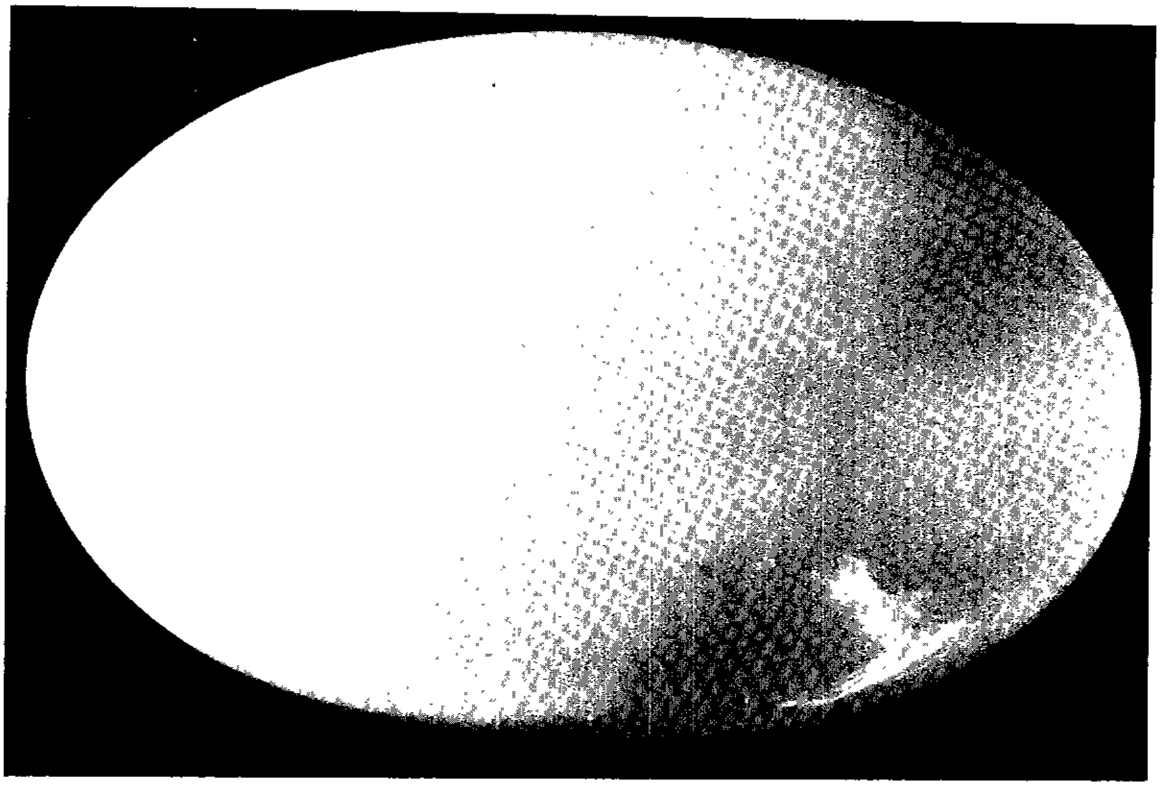


FIGURE 20

GLASS DAYTIME MARKER

This marker should have about the same resistance to tire stains as ceramic markers in areas where there are periods of long hot weather. It has the same size and shape as a standard ceramic marker; however, the glass marker has a low reflectance which gives the markers a "milky" appearance. It does not have the high white opaqueness of a ceramic marker. This is especially noticeable when the sun is behind the driver. Evaluation to date shows that tire wiping action combined with light rain or heavy moisture does clean the marker but the improvement is not as evident as with the ceramic marker. These markers are more brittle and break into sharper pieces than the ceramic markers.

Several of these markers were installed in a test installation and evaluation indicated severe cracking of the marker possibly caused by poor bond to adhesive. A similar marker but with a rougher bottom has been received and installed by the laboratory for evaluation.

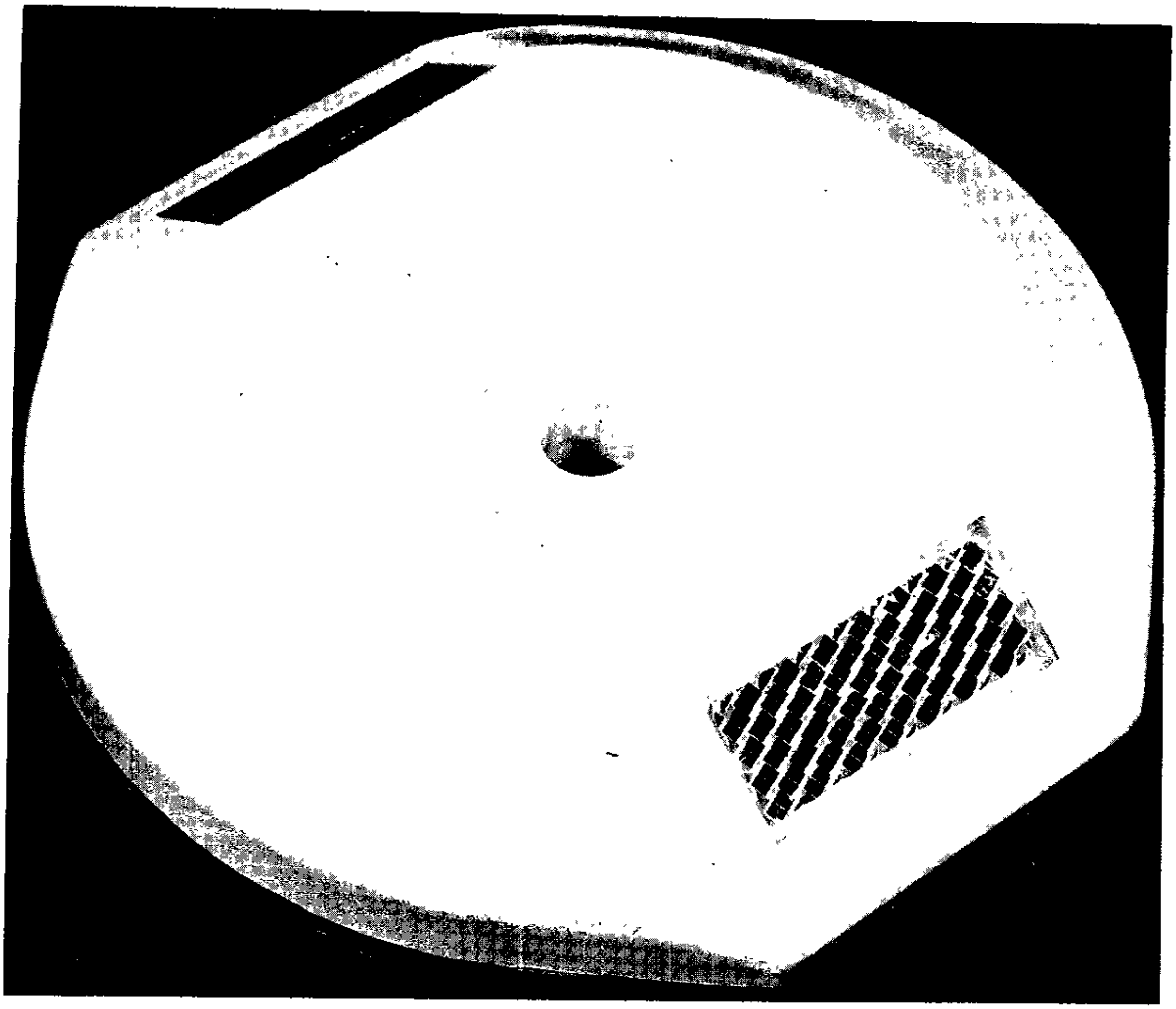


FIGURE 21

PLASTIC MARKER WITH REPLACEABLE REFLECTIVE
ELEMENTS AND CONTAINING NO FILLER

This unit has replaceable reflective elements; however, the marker has to be removed from the roadway due to the elements being replaced through the bottom of the marker. These markers were each supplied with their own adhesive pad on the bottom. Several markers were placed in a test installation and within 48 hours all markers were either displaced or missing from their original positions, due to failure of the adhesive pad.

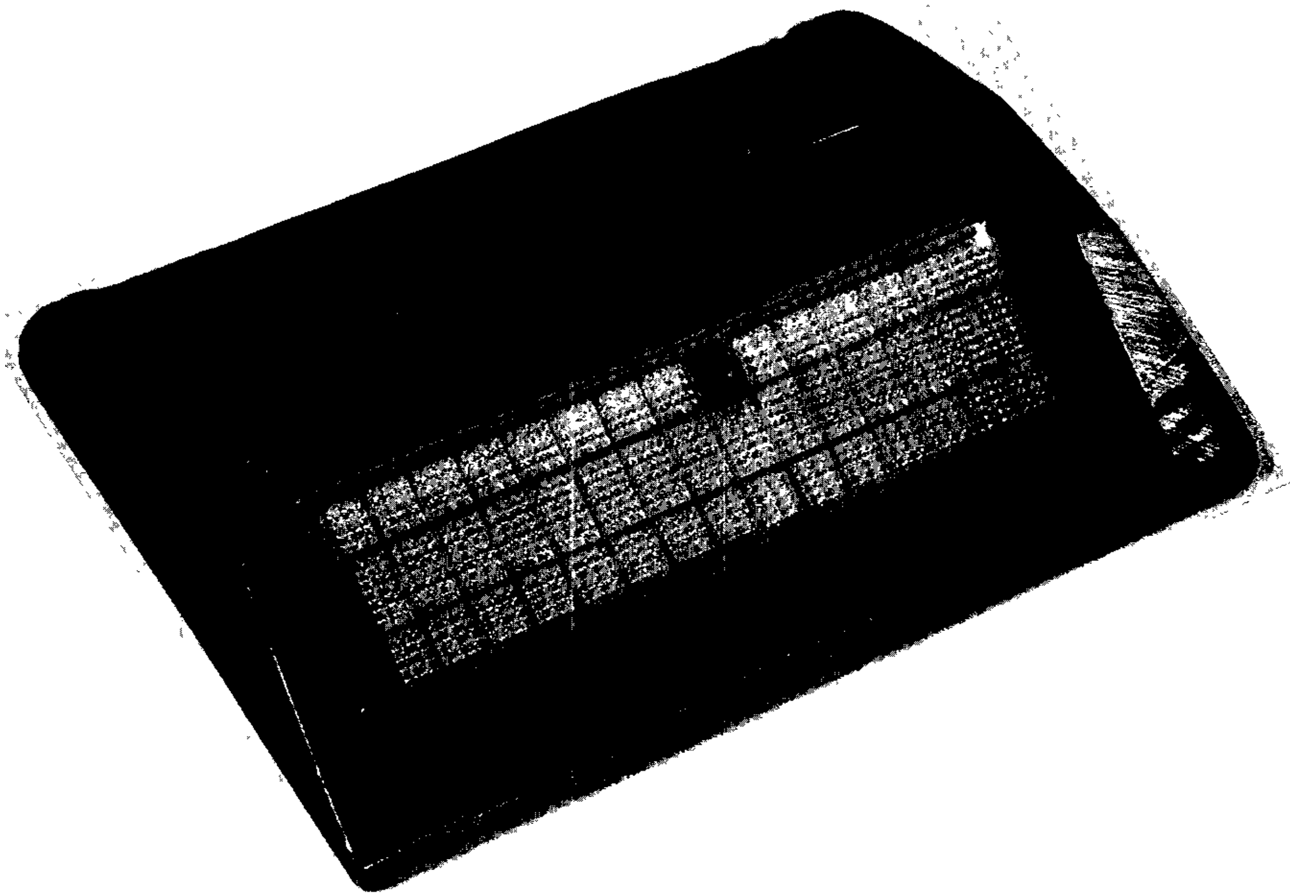


FIGURE 22

MODIFIED SNOWPLOW MARKER FOR USE IN SNOW FREE AREAS

A snowplow marker, as in Figure 24, was modified for use on the South Sacramento Freeway. The runners of the marker were cut off so that they could be installed on the roadway without the necessity of cutting slots in the PCC. Five Modified Snow-Plow Markers were installed to test this design for feasibility of replaceable elements. After one year of service with the original elements, nighttime observations indicate fair to good delineation. Lens damage to these units after one year is moderate to severe. No reflective readings have been taken on these markers. This design needs some improvement to provide a good nighttime marker with a replaceable lens.

MARKERS FOR SNOWPLOW AREAS

In the fall of 1966 a trial section of polyester beaded and non-beaded markers was placed in shallow core holes so as to be flush with the road surface. This section was at an elevation of 6,000 ft. on I-80. After about two years, a considerable number of markers were missing. Close inspection showed that about five non-reflective markers were missing for every one missing reflective marker. The rate of wear of the non-beaded marker was slower than that of the adjacent PCC. See Figure 23. Eventually, the marker projected enough above the road surface so that a snowplow blade would catch on the edge and dislodge it. The beaded marker wore at about the same rate as the adjacent PCC. On removing some beaded and non-beaded markers which were apparently intact, it appeared that marker loss was being accelerated by a gradual fracturing of the PCC under the marker-adhesive unit, probably because of differences in the coefficient of expansion of the PCC and the thick layers of epoxy adhesive.

A later installation of PVA modified white portland cement markers is under evaluation. The coefficient of expansion problem is eliminated, but the wear rate may be greater than the adjacent PCC. See Appendix II. The visibility of these flush markers is marginal at best, largely due to the excess of sand and salt on the roadway during the winter months. This concept is being pursued largely because there appears to be no other method for delineation in these areas. Grooved stripes have been tried and were largely ineffective due to the wear and the amount of sand that often remains in the grooves.

The attached pictures summarize the experience with the Stimsonite 99 snowplow markers. Figure 25 shows two of seven markers placed February 27, 1969, and photographed after 24 hours service. All markers had been removed by a motor grader. The markers were installed in cold weather and considerable heating of the pavement and the markers was necessary to dry the surfaces and to cure the adhesive. The top of one marker was sheared off leaving the runners still embedded in the concrete.

A second installation of Stimsonite 99 markers, without reflective elements, was made on the South Sacramento Freeway September 30, 1969, and tested October 3, 1969. A front mounted plow on a four ton truck chassis and a motor grader weighing about 14 tons were used for testing the markers. Figures 26, 27 and 28 were taken in the field and in the laboratory of the markers and grader blade.

The conditions of test and the findings of the second installation are outlined below:

1. Three markers were installed between the wheel tracks and five markers just to the right of the right wheel track.

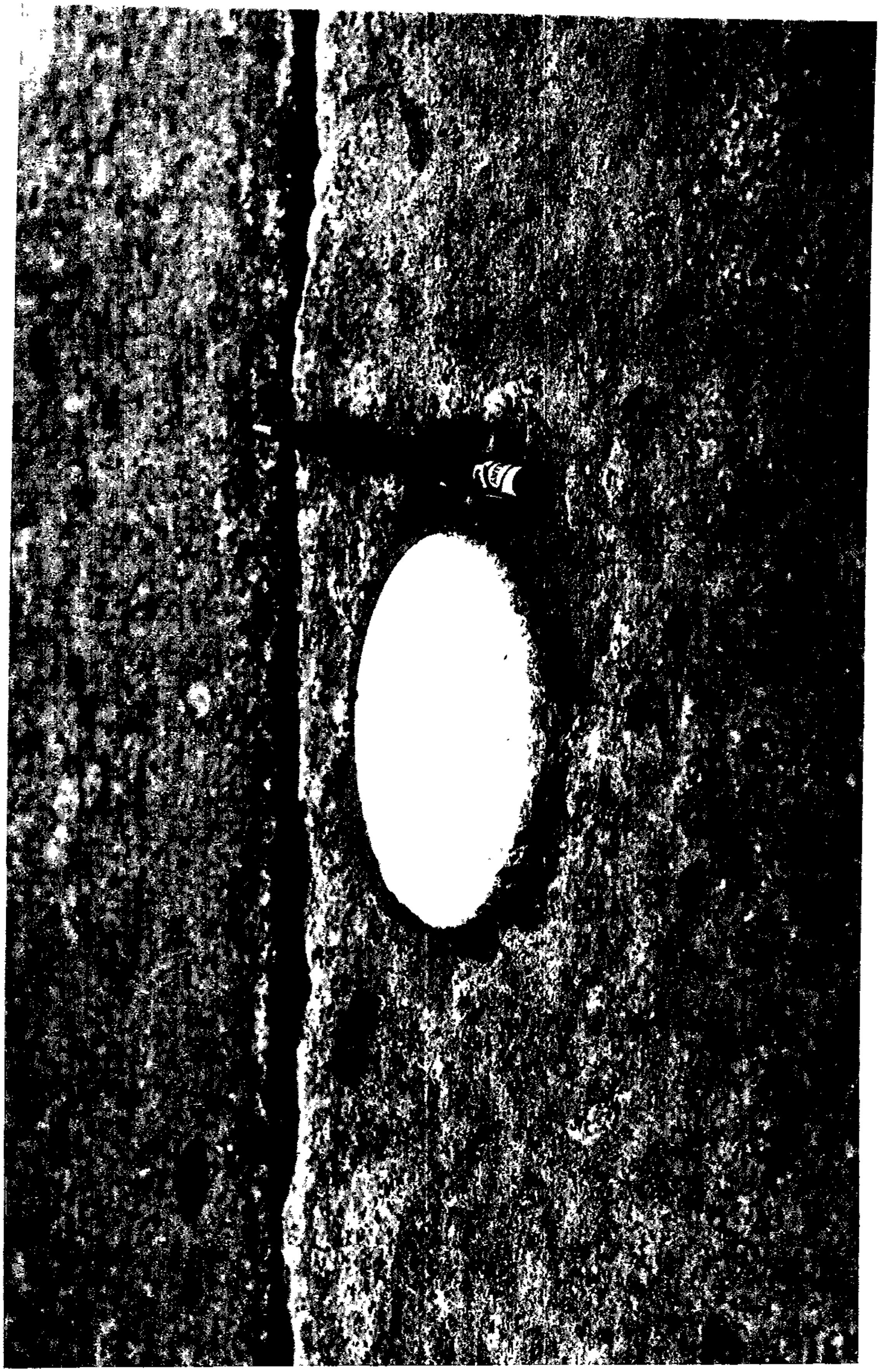


FIGURE 23

POLYESTER MARKER INSTALLED FLUSH WITH PAVEMENT.

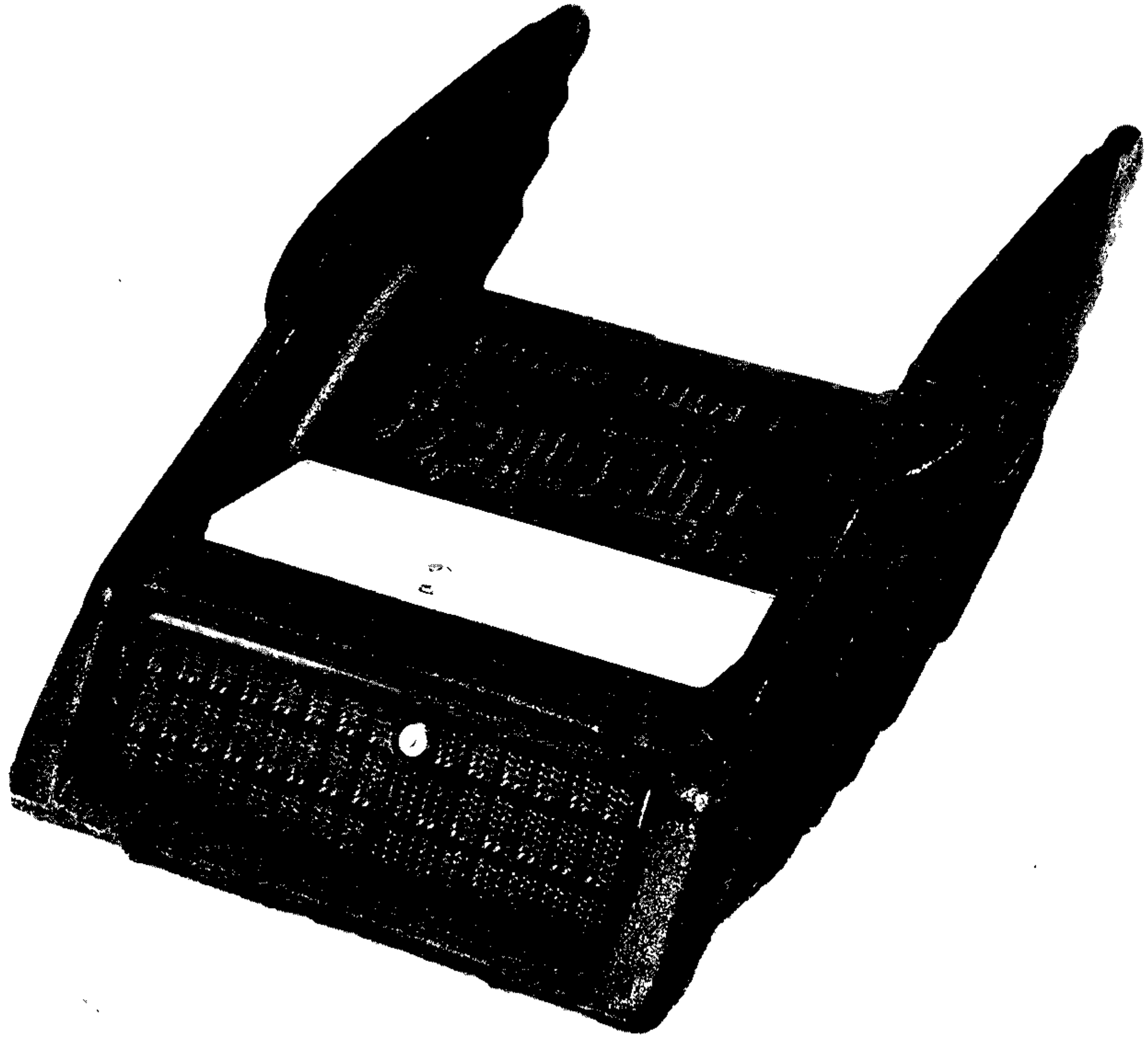


FIGURE 24

SNOWPLOW MARKER WITH REPLACEABLE REFLECTIVE ELEMENTS.

2. The truck mounted blade caused no appreciable damage after six passes at speeds up to 25-30 mph.

3. The first pass of the grader blade damaged the markers between the wheel track and damaged the grader blade. It caused no appreciable damage to the markers near the right wheel track.

4. Three passes were made over the markers at increasing speeds, all with a blade angle of about 40°. The markers and the blade were damaged with each successive plowing. High blade pressure was used to accelerate the test.

5. The fourth pass was made with the blade at right angles to the pavement. This was done, however, after the markers and the blade were damaged, so no comparisons could be made as to the relative amount of damage with the plow at different angles.

6. No markers were torn from the pavement.

These tests indicated that the Stimsonite 99 markers will not withstand the type of plow action used which was intended to duplicate the most severe conditions that would be encountered when trying to remove packed ice on high elevation California mountain passes. The damage to the grader blade was excessive.

One hundred and twenty Stimsonite 99 markers were installed at an elevation of about 2500 feet on I-80 north of Colfax in the fall of 1969. The winter of 1969-70 was unusually mild at the lower elevations with little or no snow fall. The marker casings were intact after this winter but the visibility at night was reported to be poor. An inspection during the summer of 1970 showed that most of the elements were intact but that there was considerable damage to the lens. It could be assumed that this was caused by a very small amount of chain action. During the winter of 1970-71 there was considerable snowplow operations, the markers damaged the blades of three plows so that they had to be removed from service for repairs. The markers were removed to avoid further damage to plows. This would indicate that the previous test described above on the South Sacramento Freeway was indicative of the conditions that exist under heavy snow removal conditions.

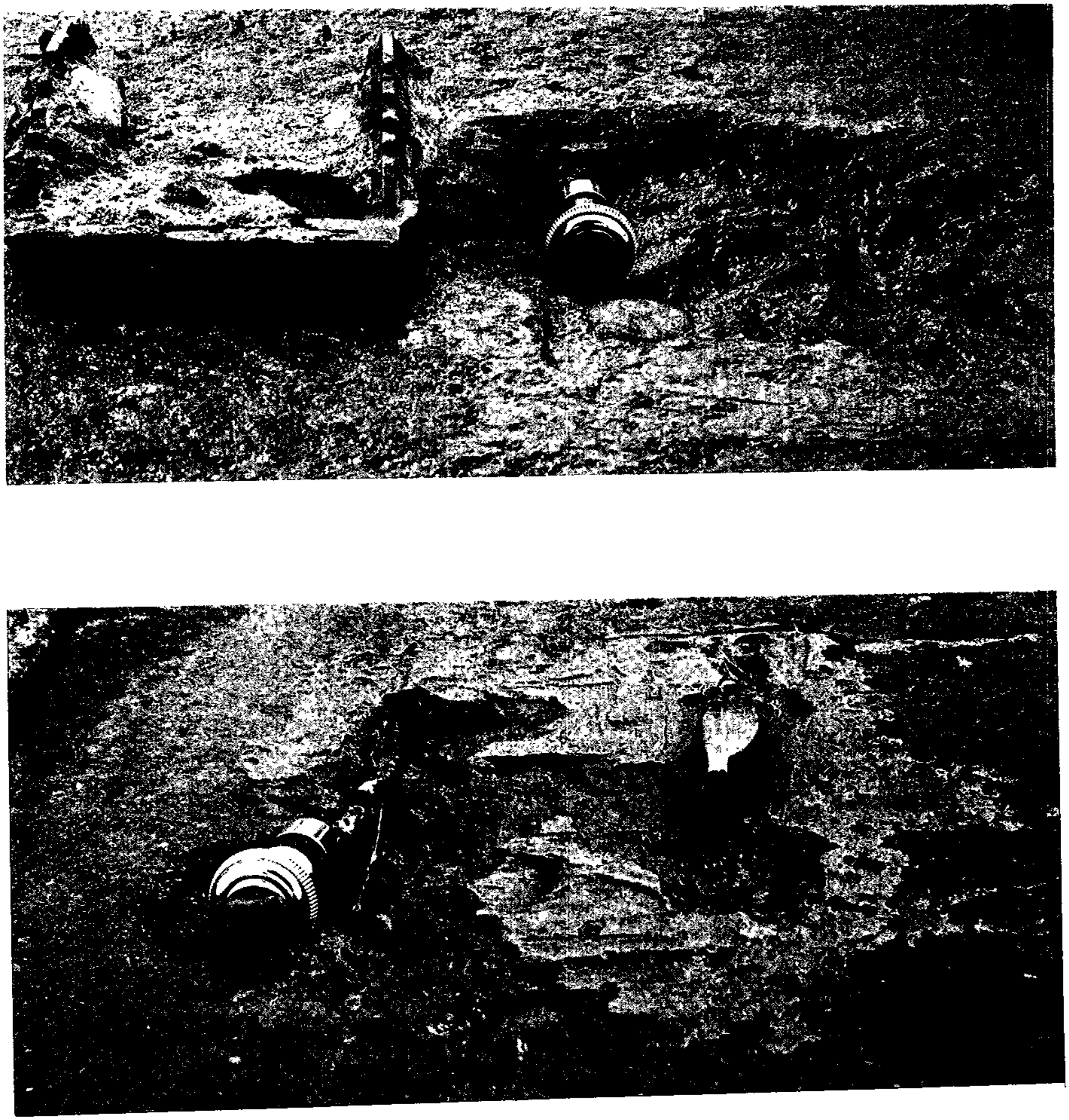


FIGURE 25

These snowplow markers were installed on Interstate 80 near Soda Springs. They were subject to snowplow action within 6 hours after placement and after 24 hours all were missing mostly by failure of road surface. (see text)

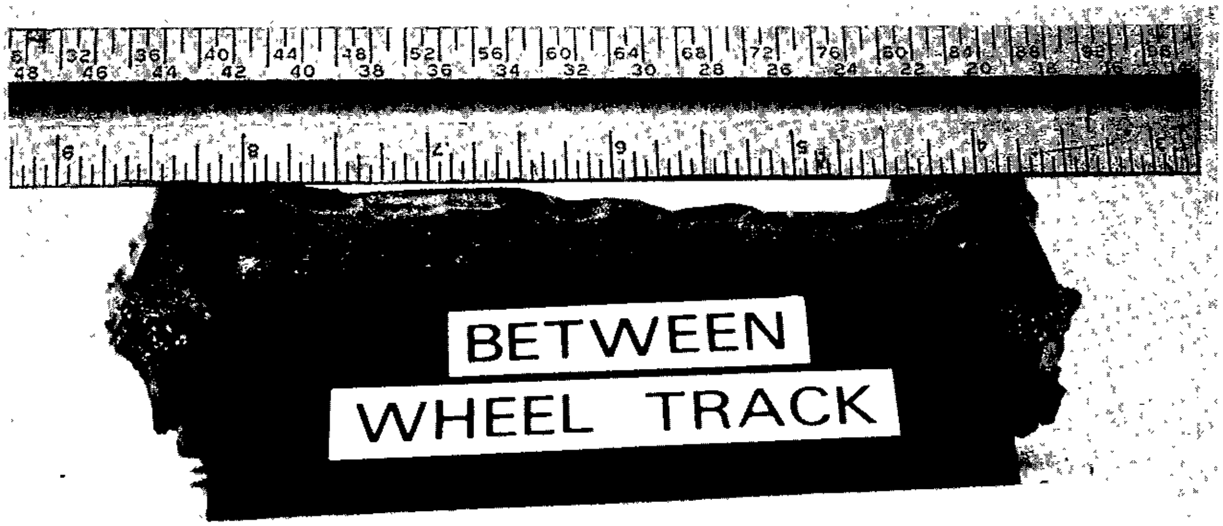


FIGURE 26

Snowplow marker placed between the wheel track of lane #3 of the South Sacramento Freeway. This marker was subjected to 4 to 5 passes with the motor grader and suffered severe damage to the top surface. (No reflective elements were used for this test.)

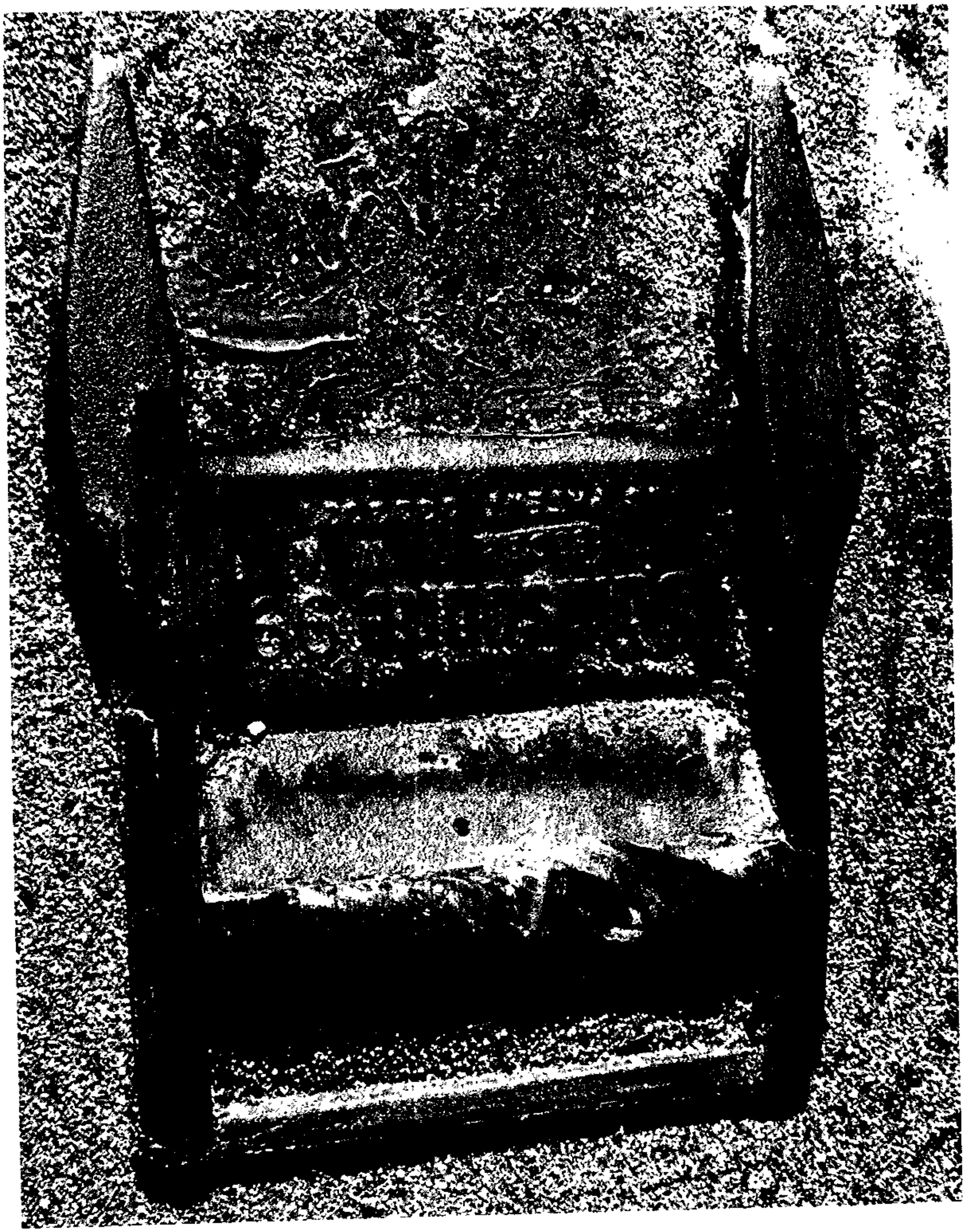


FIGURE 27

Snowplow marker placed on the South Sacramento Freeway showing the condition after 4 to 5 passes with a motor grader. Note cracked casing. (No reflective elements were used during this test.)

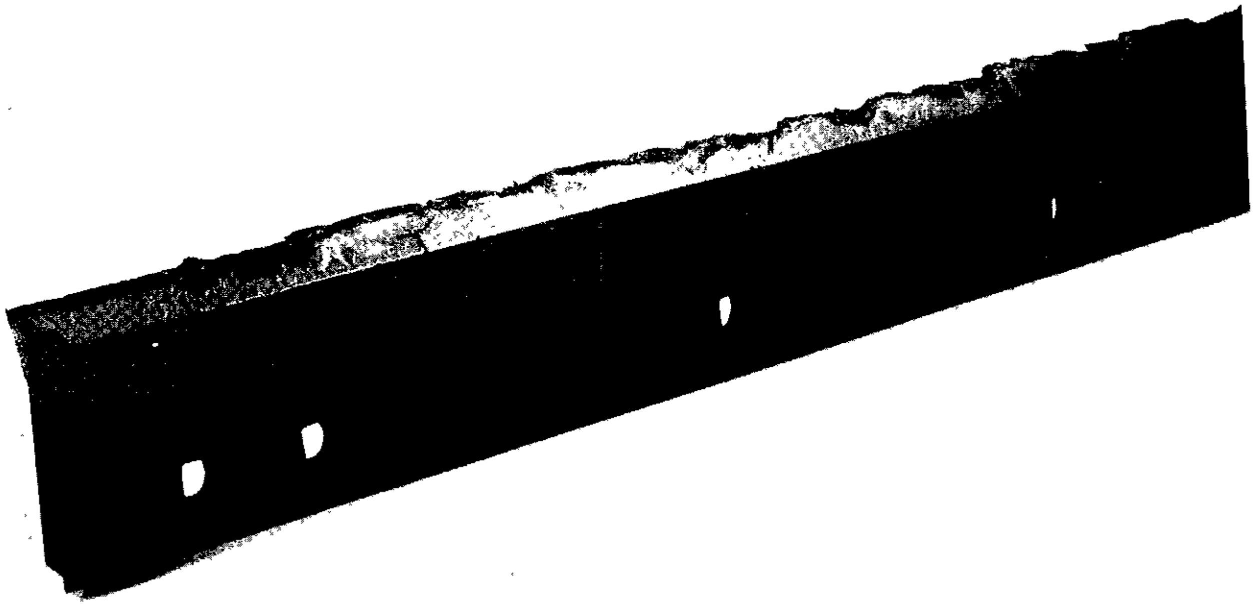


FIGURE 28

Snowplow blade used in testing of snowplow markers. This picture shows the condition of the blade after only 5 passes over the test installation which consisted of approximately 6 markers.

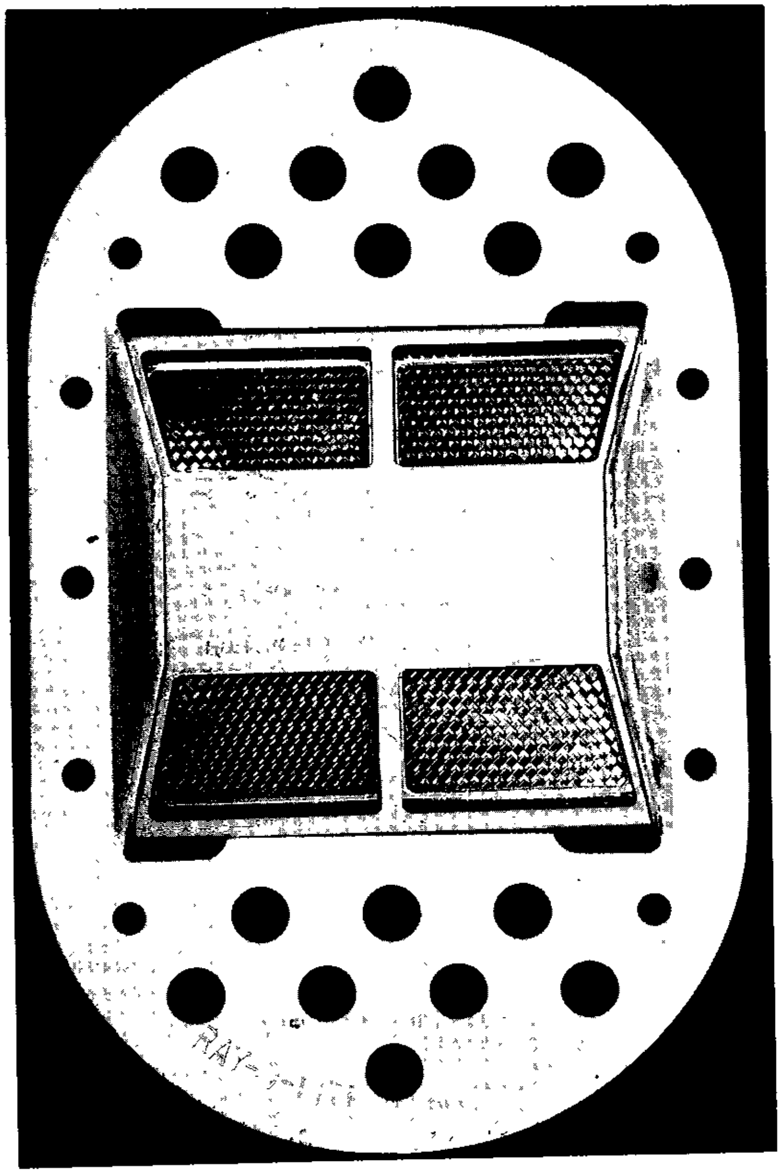


FIGURE 29

MARKER FOR SEVERE TRAFFIC AND LIGHT SNOW AREAS

This unit is a standard type acrylic cube corner marker encased within a protective metal shell. The marker is designed for use in areas where traffic is severe or in light snow areas where rubber tipped snowplow blades are used or the blade does not reach the surface of the road.

Some markers of this design were placed in snow areas; however, they were removed by snowplows or with jack hammers when it was found that raised markers generally were a hazard to snowplows operating under conditions of heavy snow fall.

E. Failure of Markers to Remain in Place on Roadway

Observation of markers placed under contract during the last five years has shown that it is necessary that the road surface be sound, the adhesive be properly metered, mixed and applied; and that the marker be immediately placed in firm contact with the roadway.

Factors which cause marker failures are as follows:

1. Poor Installation

    A. Improper proportioning of the adhesive. The two components must be mixed as specified, within a 5% tolerance, to give optimum performance.

    B. Inadequate mixing of the two components. Mixing heads often channel unmixed or poorly mixed material out the nozzle. This is often not evident on the outside of the "shot" of epoxy. It is necessary to cure the epoxy and fracture the shot to detect improper mixing. The markers, at times have not been forced into contact with the roadway before a partial set of the adhesive has occurred.

2. Unsound Road Surface (resulting in the marker pulling out some road surface).

The problems with Portland Cement Concrete are due to insufficient sand blasting of the surface so as to remove all laitance, old traffic paint, and unsound mortar which is often formed by excess working of the surface during finishing operations. All attempts to use other cleaning methods such as grinding have given a weak surface. The failures have occurred about evenly with the reflective and non-reflective markers.

With asphaltic concrete, failure in the road surface may occur when the surface layer lacks cohesive strength, such as may occur with a fresh mix in a warm climate; or an old roadway where the asphalt is brittle and is often showing excessive cracking. The loss with this type of failure has been predominately with the reflective markers.

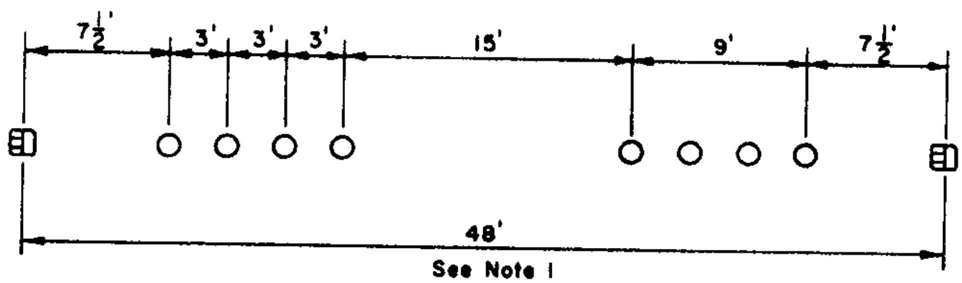
3. Lack of Bond Between the Ceramic Marker and the Epoxy Adhesive. This type of failure has been serious on some contracts, most failures occurring with the specified rapid set adhesive. Quality of workmanship as outlined above is probably responsible for many of the failures. However, the specified rapid set adhesive is more difficult to handle, is more brittle, has higher water sensitivity and has more shrinkage during cure than the specified standard set adhesive. The reflective markers in the problem areas have

not failed in bond. This would indicate that the stress between the ceramic marker and the adhesive due to the different coefficient of expansion and shrinkage of the epoxy during curing was enough to cause failure in a critical situation. The reflective marker has about the same coefficient of expansion as the epoxy and no trouble is observed here.

As indicated previously in this report, a new rapid set epoxy adhesive specification is being written which will reduce the curing shrinkage to one fiftieth of its former value.

Appendix I

California Freeway Marking Pattern



LANE LINE ON FREEWAYS

LEGEND

○ 4" Plain White

Red - Clear

NOTES:

1. Place reflective markers at 48' intervals on tangents and on curves of 1000' radius or greater, and at 24' intervals on curves with less than 1000' radius, unless otherwise shown.

Appendix II

Composition of Markers Placed on Westbound Lanes
of I-80, West of Kingvale
September 22-24, 1970

Formulation Number	No. of Markers	Component	% by Wt.	Water Cement Ratio	% TiO_2
M3	14	Glass beads (1)	45.2	0.61	7.18
		White cement (2)	22.6		
		PVA emulsion (3)	28.7		
		Water (4)			
M3a	28	Glass beads	51.3	0.49	4.08
		White cement	25.6		
		PVA emulsion	16.3		
		Water	6.8		
M5	70	Glass beads	59.6	0.44	2.10
		White cement	23.6		
		PVA emulsion	8.4		
		Water	8.4		
M6	42	Glass beads	28.9	0.43	2.02
		Ottawa sand (5)	28.9		
		White cement	25.8		
		PVA emulsion	8.1		
		Water	8.3		
M7a	28	Glass beads	28.6	0.45	2.25
		Fair Oaks sand:			
		Coarse (6)	21.0		
		Fine (7)	7.5		
		White cement	25.6		
		PVA emulsion	9.0		
		Water	8.3		
M7b	70	Glass beads	28.8	0.43	2.02
		Fair Oaks sand:			
		Coarse	28.8		
		White cement	25.8		
		PVA emulsion	8.1		
		Water	8.5		

Appendix II - Composition of Markers Placed on Westbound Lanes I-80, West of Kingvale

Formulation Number	No. of Markers	Component	% by Wt.	Water Cement Ratio	% TiO_2
M8	42	Glass beads	48.4	0.43	2.05
		Silicon Carbide (8)	9.4		
		White cement	25.4		
		PVA emulsion	8.2		
		Water	8.6		
M9	21	Glass beads	64.4	0.41	0
		White cement	25.3		
		Water	10.3		

(1) Glass spheres, State Specification No. 601-80-34.

(2) Riverside white cement, Type I.

(3) A dispersion of rutile titanium dioxide in a polyvinyl acetate emulsion (Reichhold Plyamul 9155). TiO_2 content 25.0%; total solids 64.1%; 10.9 lbs./gal. Sub PO No. 196558; Frank W. Dunne Company.

(4) Quantity of water which gave the best workability for a given formulation. Preliminary batches containing somewhat less water were also installed. This does not include water content of PVA emulsion.

(5) ASTM Designation C-109.

(6) Passing No. 16 sieve, retained on No. 30 sieve.

(7) Passing No. 50 sieve.

(8) Silicon carbide grit, passing No. 8 sieve, retained on No. 16 sieve. PO No. 197692, Barker Industrial and Foundry Supply.

(9) Water-cement ratio includes water contained in the PVA emulsion.

Appendix III

95-2.04 EPOXY ADHESIVE FOR PAVEMENT MARKERS
(State Specification 702-80-44)

CLASSIFICATION:

The adhesives described are a Standard Set Type and a Rapid Set Type (State Specification 702-80-44), each of which is a 2 component system. The 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 and Rapid Set Type specifications have compositional requirements together with test specification limits. 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	Requirements Rapid Set Type
(1) Pot Life	8-13 minutes	6 minutes min.
(2) Bond Strength to Concrete, Time (maximum) to reach not less than 200 psi		
at 77° F., ± 2° F.	3 1/2 hours	25 minutes
at 50° F., ± 2° F.	---	45 minutes
at 30° F., ± 2° F.	---	85 minutes
(3) Slant Shear Strength on Concrete (base area)		
24 hours at 77° F., ± 2° F.	2200 psi min	2200 psi min.
24 hours at 77° F., ± 2° F. plus water soak	1500 psi min.	2200 psi min.

(4) Tensile Adhesion and Cohesion		
Bond of 2" diameter bottom of a steel rod to the following:		
(a) Class II polyester marker bottom	475 psi min.	475 psi min.
(b) Class III and IV ceramic marker bottom	700 psi min.	700 psi min.
(c) Class III and IV ceramic marker bottom including post cure	700 psi min.	700 psi min.
(d) Reflective pavement marker bottom	500 psi min.	500 psi min.
(5) Viscosity Centipoise Component A and Component B at 77° F.	T.D. Spindle 1.0×10^5 to 3.0×10^5	T.E. Spindle 1.8×10^5 to 4.0×10^5
(6) Shear Ratio Minimum at 77° F. Component A and Component B	2.0	1.8
(7) Lbs./Gallon Component A Component B	 11.5 to 11.8 11.7 to 12.1	 9.50 to 9.85 11.50 to 11.85
(8) Color of Mixed Components	Approximately that of Color Nos. 26132 to 26152 of Federal Standard No. 595.	
(9) Skinning, Components A & B (original container)	None	A none, B slight
(10) Infrared Curves Components A & B	Shall match curves in Test Method No. Calif. 425	
(11) 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 date of manufacture. There shall be no settling of the fillers that cannot be easily redispersed with a paddle.	

STANDARD SET TYPE

COMPOSITION:

Component A	Parts by Weight
Epoxy Resin[1]	100.0
Titanium Dioxide, TT-P-442, Type III or IV	7.31
Resin Grade Asbestos[2]	5.00
Talc[3]	37.64
Component 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 175-195; 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 lbs., 120; refractive index, Nd 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.

RAPID SET TYPE ***

COMPOSITION:

Component A	Parts by Weight
Epoxy Resin[1]	100.00
Hydrogenated Castor Oil[2]	4.80*
Titanium Dioxide TT-P-442, Type III or IV	3.00
Silicone Anti-Foam Type Q	0.01

*4.6 to 5.2 parts by weight permitted to achieve proper viscosity

Component B	
High Functionality Polymercaptan Hardener[3]	60.00
2,4, 6-Tri (dimethylaminomethyl) phenol[4]	7.00
Alkyl Substituted Polynuclear Aromatic Oil[5]	14.65
2-Ethyl Hexanoic Acid[6]	0.15
Carbon Black TT-P-343, Form 1, Class B	0.05
Hydrogenated Castor Oil[2]	1.25**
Talc[7]	46.88
Silicone Anti-Foam Type Q	0.01

**1.15 to 1.30 parts by weight permitted to achieve proper viscosity

[1]Di glycidyl ether of bisphenol A, viscosity, 100-160 poise at 25° C.; epoxide equivalent 180-200. Color, Gardner 1933, 3 max. No reactive diluent shall be used.

[2]Chemically modified hydroxy ester of glycerol tris hydroxy stearate.

Acid value	3 maximum
Melting point	127° C. - 137° C.
Iodine value (Wijs)	5 maximum
Hydroxyl value	150 - 165
Particle size, % passing U.S. No. 200 sieve	99 - 100

[3]Liquid polymercaptan resin, viscosity 100-130 poise at 25° C.; specific gravity 1.14-1.16; mercaptan value, 3.6 meq/gram. Color, Gardner 1933, 1. Infrared curve shall match the curve on file in the Materials and Research Department of the Division of Highways.

*** Rapid Set Adhesive is not latest specification referred to on pages VI and 49.

[4]Formula weight 265; specific gravity at 25° C./25° C., 0.973; refractive index 1.514 at 25° C.; distillation range 96% at 130° C. to 160° C. (0.5 - 1.5 mm.); flash point, Tag open cup, 300! F. minimum; water content 0.06% maximum.

[5]High boiling, alkyl substituted polynuclear aromatic oil. Weight per gallon at 77° F., 9.00-9.15; flash point, °F., Pensky Martens closed cup (ASTM E 134), 350-390; viscosity SU at 100° F., 90-120; mixed aniline point (ASTM D 1012), °F., 72 maximum; color, Gardner, 1933, 12 maximum; viscosity, Gardner-Holdt at 77° F., A-C. Percent aromatic 95 minimum.

Distillation Range

Percent Distilled	°F.
IBP	580 min.
5	610-640
10	620-660
50	650-700
90	680-740

[6]Practical Grade, B. P., 112-114° C., 8 mm.

[7]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.

NOTES ON FORMULATING RAPID SET TYPE:

1. Due to the variable density of the aromatic oil in item 5, the weight of oil used in Component B must bulk no more than 1.65 gallons per 60 pounds of polymercaptan hardener.

2. Hydrogenated castor oil in Item 2 of Components A and B requires a temperature of at least 160° F. for maximum effectiveness.

3. Components A and B will produce low pounds per gallon due to entrapped air, unless they are de-aerated with high vacuum at a temperature of about 160° F.

DIRECTIONS FOR USE:

Any settling of fillers or pigments in Components A or B shall be completely redispersed to provide a homogeneous mix before the components are used. Just before use, Components A and B shall be mixed in a one-to-one ratio by volume.

When the Rapid Set Type Adhesive is used, the components shall be mixed by a 2-component type automatic mixing and extrusion apparatus. The temperature of the Rapid Set Type Adhesive shall be maintained at 65° F. to 85° F. before mixing. The temperature of the Standard Set Type Adhesive shall be maintained at 60° F. to 100° F. before mixing. Any heating of epoxy adhesive shall be done by the application of indirect heat.