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Raised Reflective Markers for Highway Lane Lines

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16. ABSTRACT

Synopsis

Since 1954 the Materials and Research Department of the California Division of Highways has pioneered in the development, testing and installation of raised beaded white and yellow reflective lane line pavement markers for effective delineation during periods of inclement weather.

California has installed over 100 miles of the "wedge" and "button" shaped polyester resin markers since 1959. These markers are comprised of a flexible polyester resin binder, titanium dioxide or lead chromate pigment depending upon whether the marker is white or yellow, and reflective glass spheres. They are cemented to the pavement with an epoxy adhesive. It is anticipated their durability on concrete pavement will be at least twenty years based upon performance to date. Durability when placed on asphaltic concrete pavements in hot climatic areas is dependent upon the quality and cohesive strength of the asphaltic concrete.

In some installations, partially beaded markers were used to replace the white painted stripe as a method of permanent delineation for both day and night, and in clear and inclement weather. In other test sections, the markers were used as a supplement to the painted line for wet weather delineation when installed in the gap in the stripe.

A recent installation of a test section of a reflex reflector type marker having exceptional visibility, is now being evaluated for durability.

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

RAISED REFLECTIVE MARKERS FOR HIGHWAY LANE LINES

By
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Materials and Research Engineer
and
Herbert A. Rooney
Senior Chemical Testing Engineer

Presented at the 44th Annual Meeting
of the Highway Research Board

January - 1965

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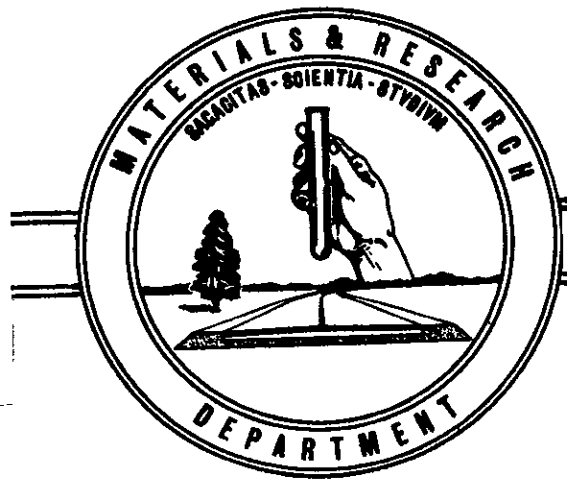

65-01

July 13, 1964

RAISED REFLECTIVE MARKERS FOR HIGHWAY LANE LINES

by

John L. Beaton* and Herbert A. Rooney**

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A recent installation of a test section of a reflex reflector type marker having exceptional visibility, is now being evaluated for durability.

RAISED REFLECTIVE MARKERS FOR HIGHWAY LANE LINES

By

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Presented at the 44th Annual Meeting
of the Highway Research Board

January, 1965

August 25, 1964

RAISED REFLECTIVE MARKERS FOR HIGHWAY LANE LINES

by

John L. Beaton* and Herbert A. Rooney**

It is California practice to use a broken (9 feet painted 15 unpainted) white stripe to delineate traffic lines. The painted portion is beaded for night visibility.

It has long been observed by motorists that during periods of inclement weather and moderate-to-heavy rainfall at night that water tends to accumulate on the pavement to a depth sufficient to cover and obscure the beaded painted center line traffic stripe. Under such conditions, light from a motor vehicle is not reflected back to the driver and he is unable to see the painted stripe. In this situation the driver often finds it difficult to remain in his traffic lane.

Beginning in 1954, the Materials and Research Department began experimentation to solve this problem with the installation of reflectorized white "buttons" or markers, made of epoxy or polyester resins, four inches in diameter and three-fourths of an inch high, the convex

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shape corresponding to the outer segment of a sphere as shown in Figure 1 and Photograph No. 8. These buttons were cemented to the highway surface with an epoxy adhesive, one each in the center of the 15-foot gap in the broken painted stripe. In theory these elevated markers "shed the water" and are not readily submerged. Such markers are considered as auxiliary devices to provide adequate delineation during periods of wet weather at night. The normal painted stripe is considered thoroughly adequate in clear weather.

Performance since 1954 indicates that these markers should have a service life of at least 20 years on portland cement concrete highways. In order to attain this durability the proper epoxy adhesive must be used and the concrete must be thoroughly cleaned by sandblasting to remove laitance, dirt, oil and grease in the area where the marker contacts the pavement surface. Useful life of the marker mounted upon asphaltic concrete pavements is dependent upon the quality of the asphaltic concrete and its cohesive strength in hot climatic areas.

Beginning in 1955 a test section was installed in which "wedge" type markers, as illustrated in Figure 3

and Photograph No. 6, were used as a complete replacement for a painted stripe on a portland cement concrete divided freeway. In this test section the distance between wedges varied, the extreme spacing being one wedge every 24 feet. All later installations had four markers, each three feet apart in the nine foot sections where the normal stripe usually occurs. Some of these installations used the beaded wedges and others the beaded buttons. Two-way wedges as shown in Figure 2 and Photograph Nos. 5 and 12, except that they were beaded, have been used on two-lane roads or as a no-passing line on non-divided freeways. In the latter case they would be yellow in color and two wedges would be cemented adjacent to one another. Photograph Nos. 1 and 2 show clear weather nighttime delineation provided by the button and one-way wedge markers respectively, and Photograph Nos. 3 and 4 illustrate nighttime visibility of these markers during a moderate rainstorm. In another photograph taken during the rain adjacent to the test area where a painted stripe was placed, the painted stripe was invisible.

The California Division of Highways has installed over 100 miles of the "wedge" and "button" shaped raised reflective white markers since 1959 in various sections

of the State on both portland cement and asphaltic concrete pavements. In some installations the markers were used as a replacement for the painted stripe and in others they were installed as a supplement to the stripe, usually two in the gap and placed six feet apart. When used as a supplement to the painted stripe the intention was to provide nighttime delineation during periods of inclement weather. The various types of "wedges" and "buttons" tried and evaluated in service, both photographically and visually, for effective delineation under the specific conditions listed below are shown in Photograph Nos. 6 to 12 inclusive.

Extensive studies made of these experimental installations reveal the following pertinent facts concerning the suitability of the white plastic markers under various conditions:

1. The fully reflectorized markers (beaded) are ineffective for daylight delineation in clear and rainy weather, particularly on portland cement concrete. The glass beads scatter the sunlight causing the markers to have a grayish cast which blends in with the portland cement concrete.

2. The fully beaded "button" marker is more effective in rainy weather at night than is the "wedge" marker. See Photograph Nos. 3 and 4.

3. On asphaltic concrete pavements, the "wedge" marker is more durable than the "button" type. Impact of traffic is less likely to cause failure in cohesion of the asphaltic concrete under the marker.

4. The glass beads used in the reflective "button" or "wedge" markers should contain about 40% of the high index of refraction variety (1.90 minimum).

5. Under overhead lighting or in the daytime the non-beaded markers are more effective than the beaded type in both clear and rainy weather.

In order to select a marker which is visible in both clear and rainy weather day and night, California has recently used a partially beaded marker. This is of necessity a compromise in order to have the virtues of the fully beaded and non-beaded types present in one marker. Being a compromise it is not as effective as the fully beaded or non-beaded types under conditions where the fully beaded or non-beaded types are the best. Copies of the California Specifications for all types of the raised white polyester reflective pavement markers currently used in this State are included in this report.

In April 1964, the Materials and Research Department installed 200 of an entirely new type raised marker on a divided freeway in Sacramento. The marker is wedge shaped and its reflectivity is based upon the same principle as reflex reflectors used on guide posts. The reflecting surface is a reflex-reflector encased in an acrylic plastic. The interior of the marker is filled

with an epoxy resin to provide rigidity. So far this type marker provides brilliant delineation in clear and rainy weather at night but is almost invisible in the daytime. Durability over an extended period of years and its effectiveness in foggy weather is yet to be determined.

This marker, as shown in Photograph No. 13, has been manufactured in three types to reflect either white, amber or red light. A nighttime picture of an installation of these markers is shown in Photograph No. 14

In order to select the proper type of a raised pavement marker for use in lane line delineation it is first necessary to determine which of the following conditions the markers are intended to serve:

1. Direction of traffic, one-way or two-way.
2. Replacement of the painted stripe.
3. Supplementation of the painted stripe.
4. Nighttime delineation only in inclement weather.

5. Delineation only under dry conditions eg. in a tunnel.

6. Day and night delineation under all weather conditions.

It is the opinion of the authors' that in clear weather the beaded painted stripe in good condition is fully adequate for delineation purposes, both day and night, and that any markers used should be intended as a supplement for delineation at night during foggy or rainy weather. When so used they should be placed in the gap between the painted dashes.

While not a part of this study, the fact that raised markers serve as a rumble warning strip to drivers changing lanes should be considered as a plus safety factor in any evaluation.

The following tables summarize uses of the various markers:

Type 1A One-way wedge, non beaded

1B One-way wedge, beaded

1C One-way wedge, half beaded

2A Two-way wedge, non beaded

2B Two-way wedge, beaded

2C Two-way wedge, half beaded

3A Button, non beaded

3B Button, beaded

3C Button, half beaded

Type	Condition						
	Replace	Supplement	Inclement Night only	Tunnel or Cont. lights	Day & Night All Weather	One Way	Two Way
1A				X		X	
1B		X	X			X	
1C	X				X	X	
2A				X			X
2B		X	X				X
2C	X				X		X
3A				X		X	X
3B		X	X			X	X
3C	X				X	X	X

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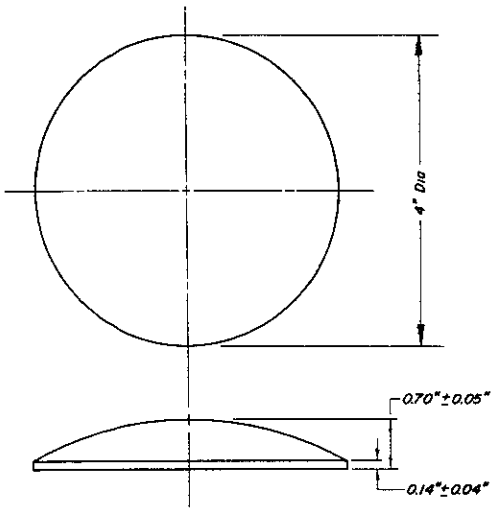
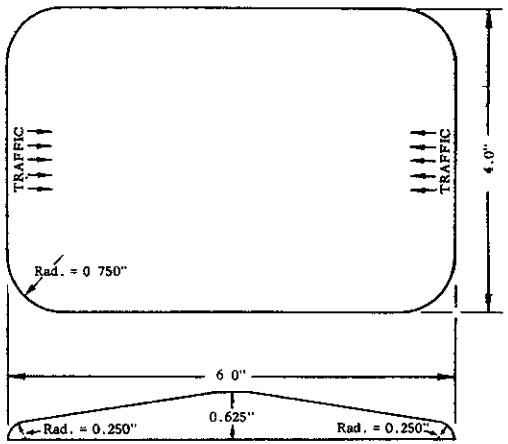
FIGURE 1



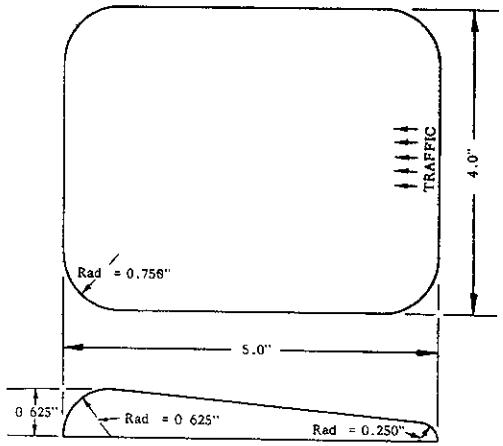
"BUTTON" TYPE

FIGURE 2



"WEDGE" TYPE
TWO WAY TRAFFIC

FIGURE 3



"WEDGE" TYPE
ONE WAY TRAFFIC

REFLECTIVE PAVEMENT MARKERS

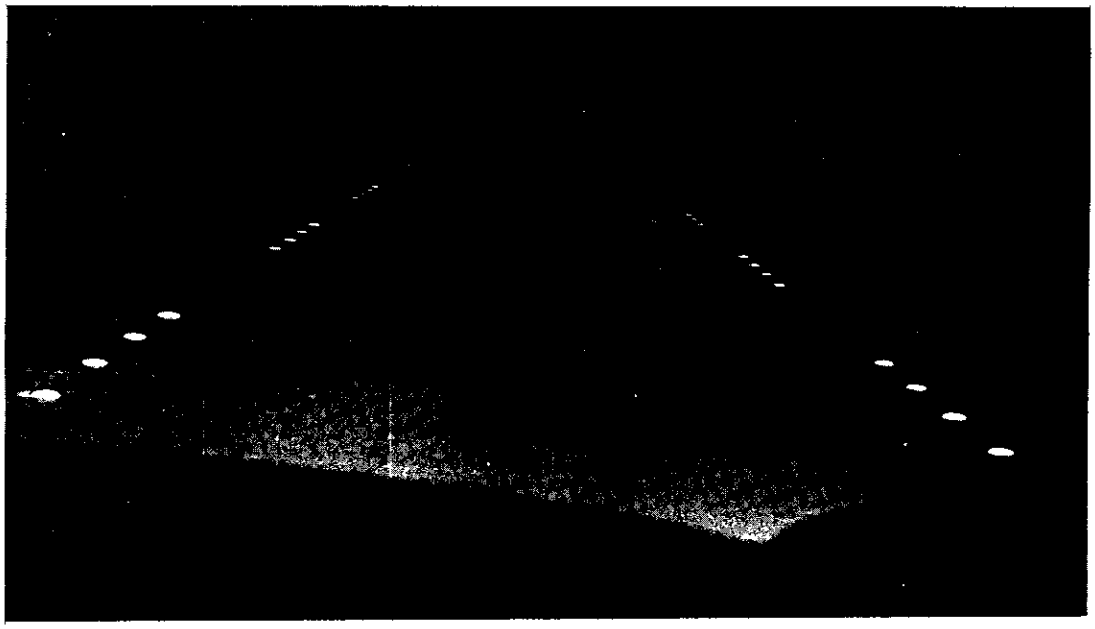


Photo No. 1. Buttons on the pavement at nighttime, clear weather.

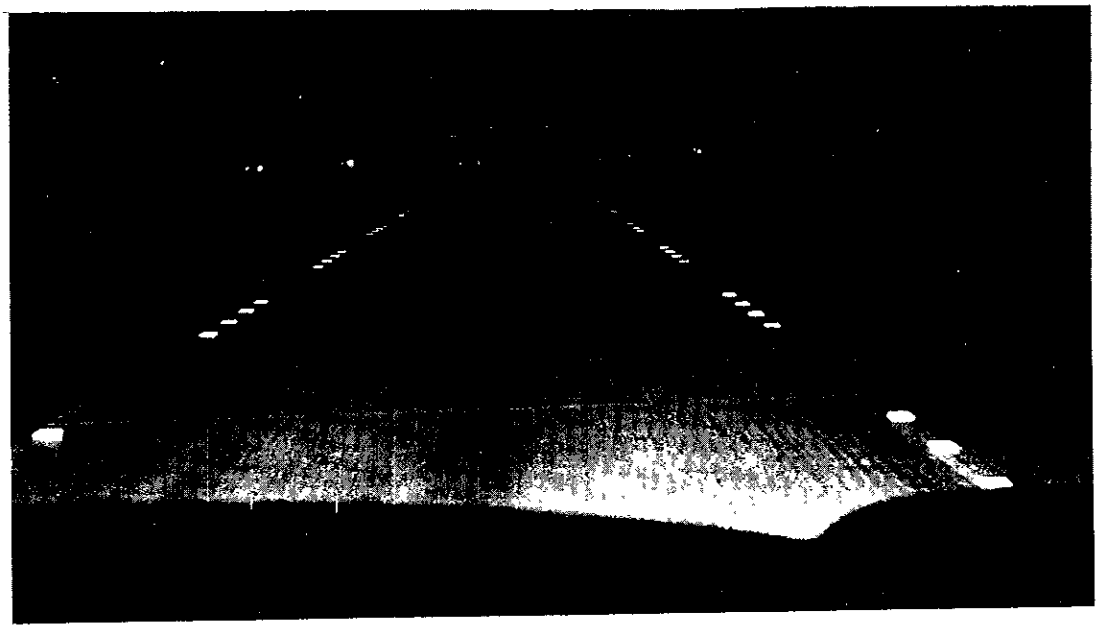


Photo No. 2. One-way wedges on the pavement at nighttime, clear weather.

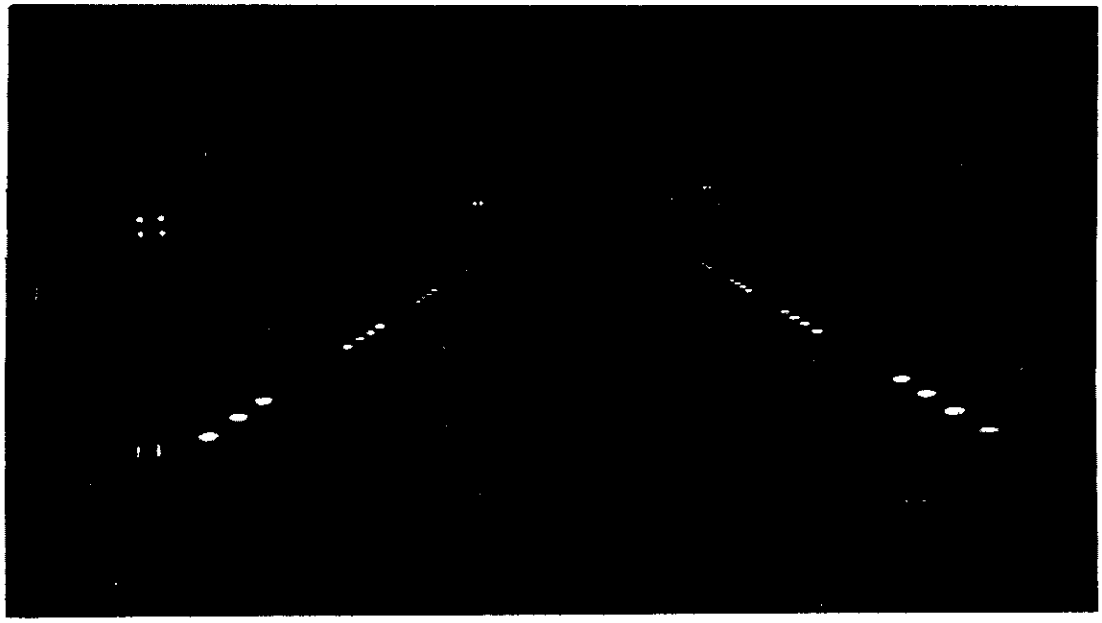


Photo No. 3. Buttons on the pavement at nighttime, moderate rain.

Photo No. 4. One-way wedges at nighttime, moderate rain.

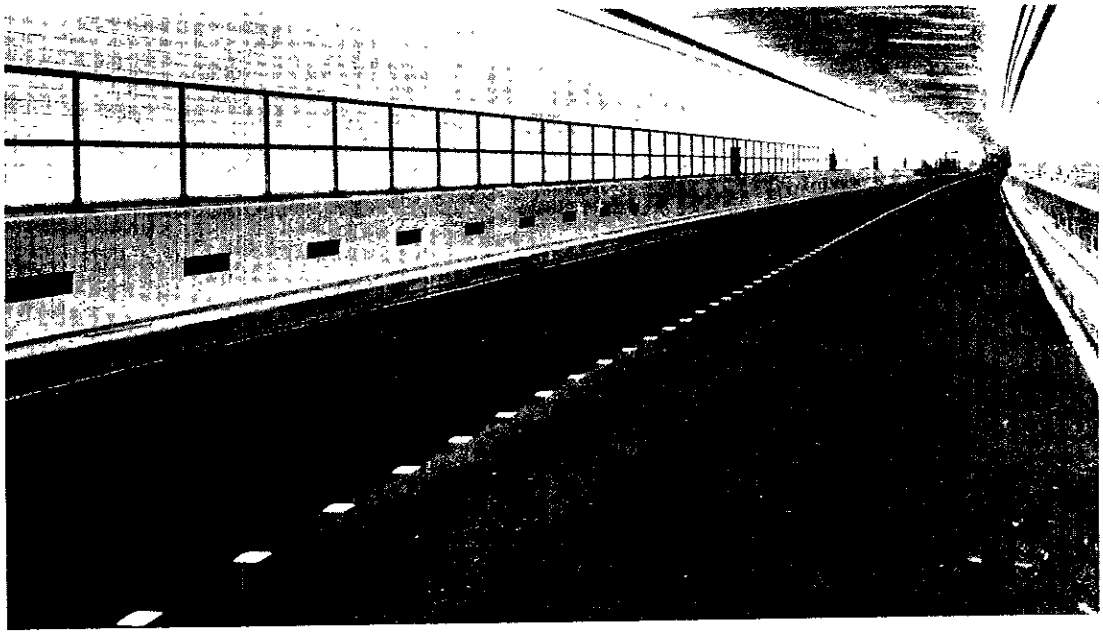


Photo No. 5. Two-way wedges, white non-beaded, on the roadway of the Webster Street Tube.

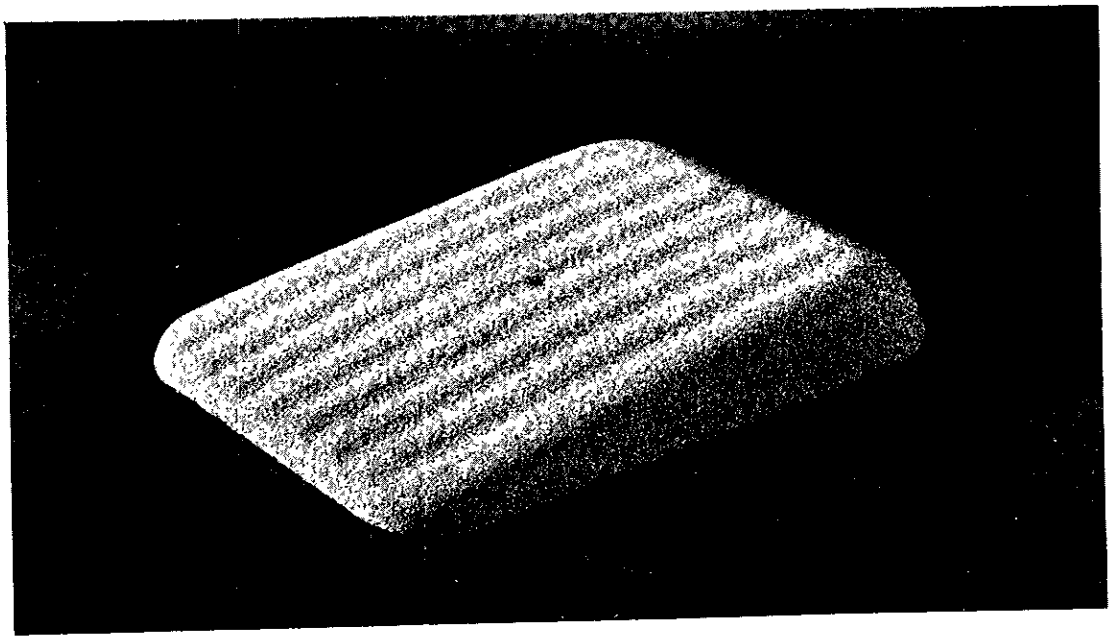


Photo No. 6. One-way glass-beaded white wedge.

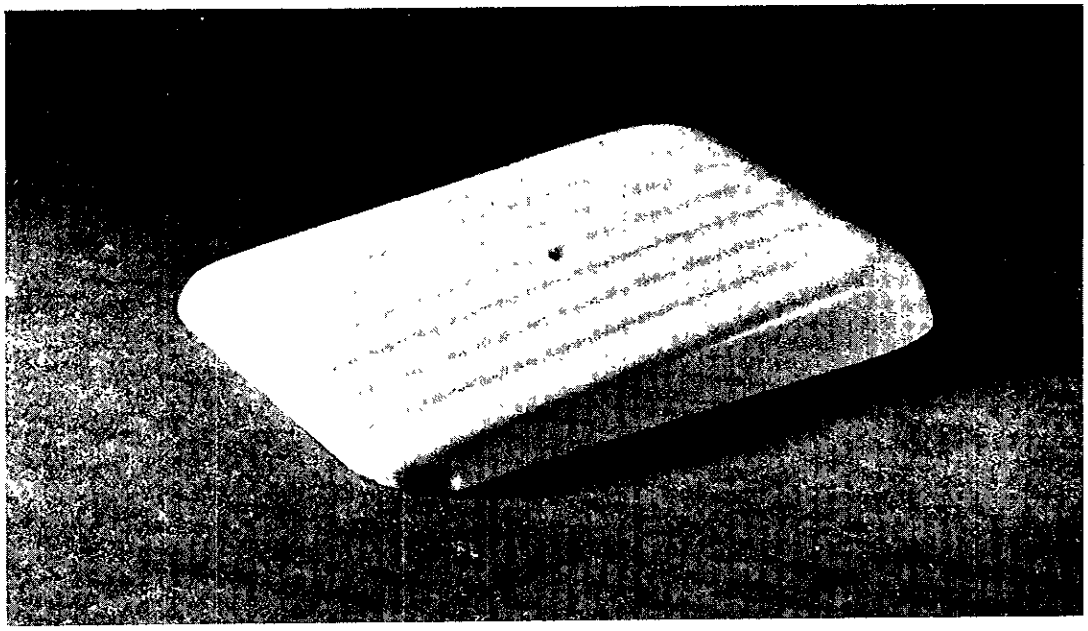


Photo No. 7. One-way plain white non-beaded wedge.

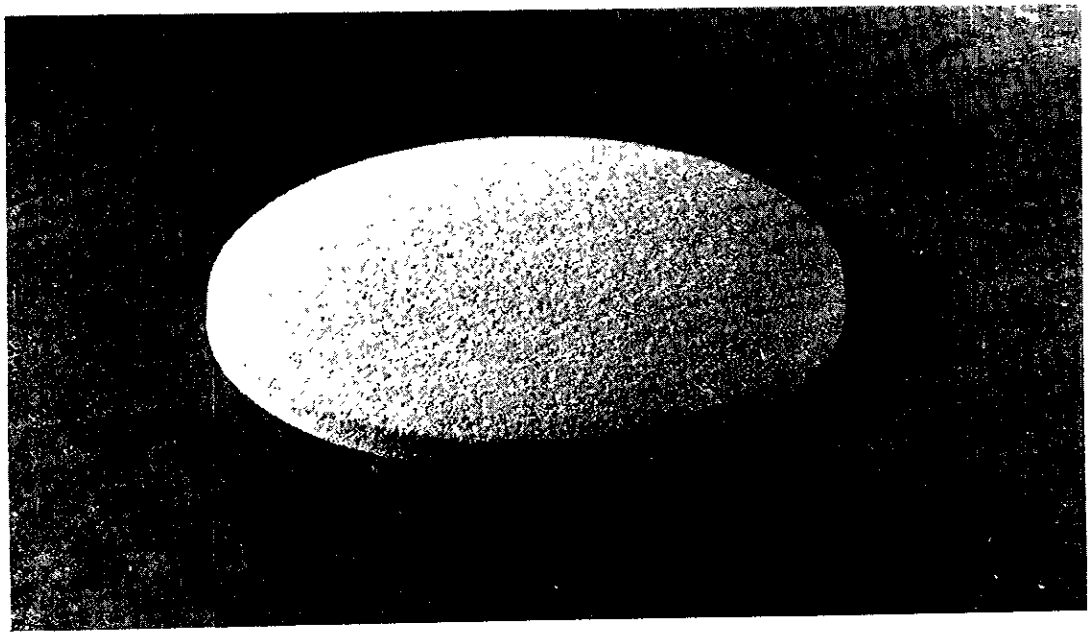


Photo No. 8. Glass-beaded white button

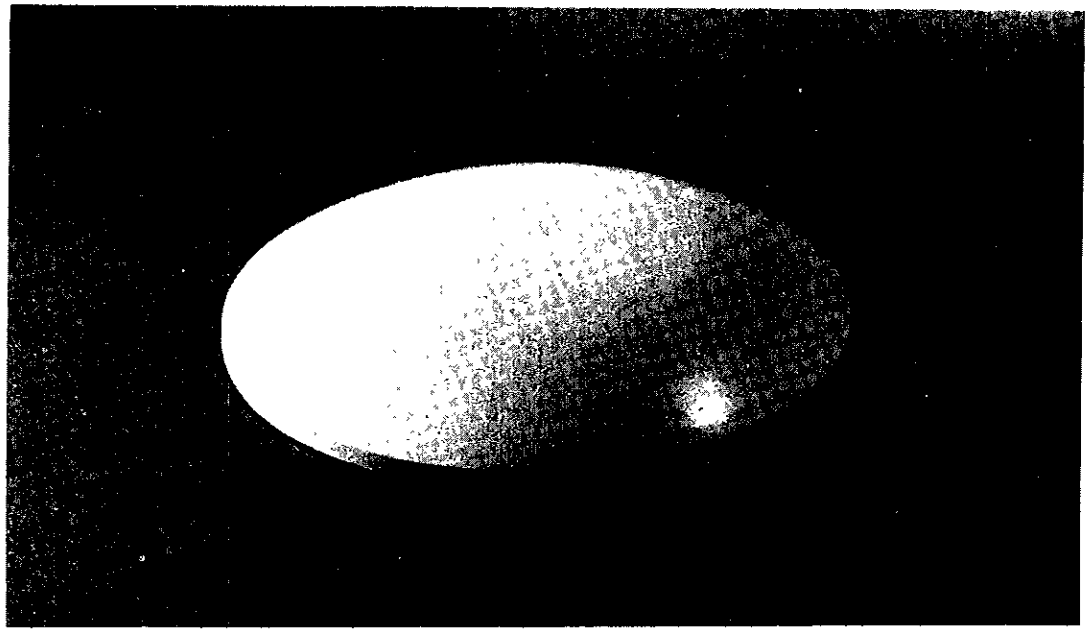


Photo No. 9. Plain white non-beaded button

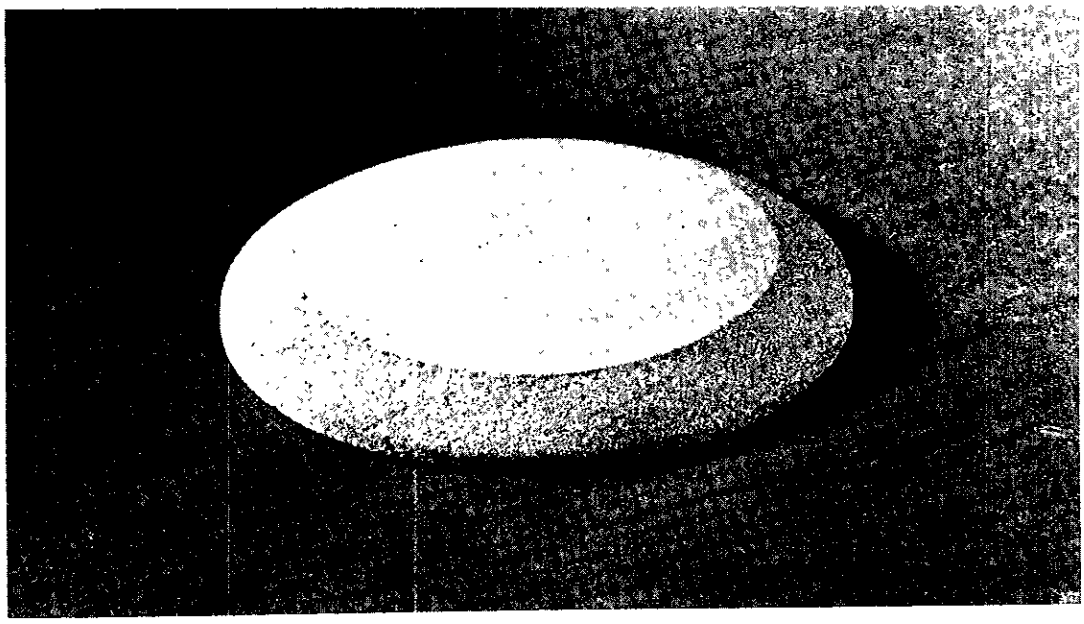


Photo No. 10. Plain white top button with glass-beaded white rim.

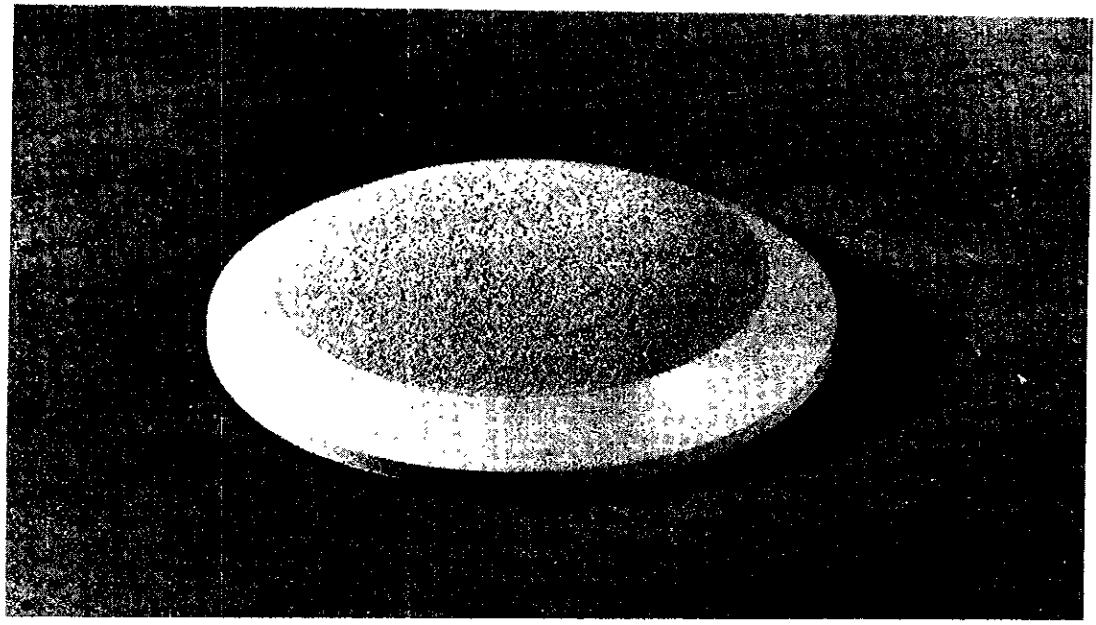


Photo No. 11. Glass-beaded white top with plain white non-beaded rim.

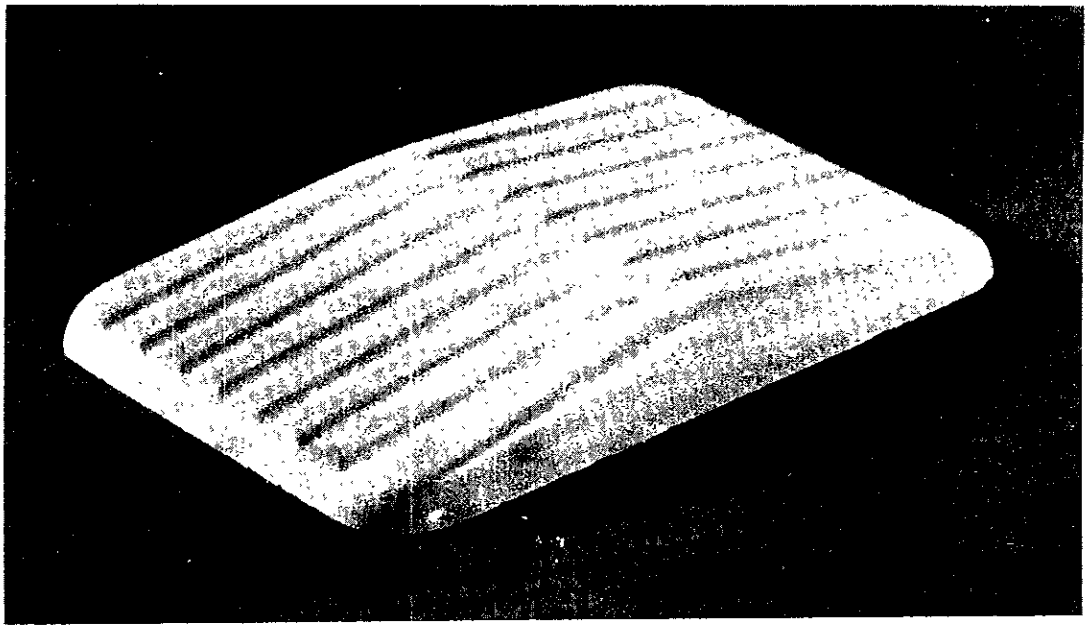


Photo No. 12. Two-way plain white non-beaded wedge.

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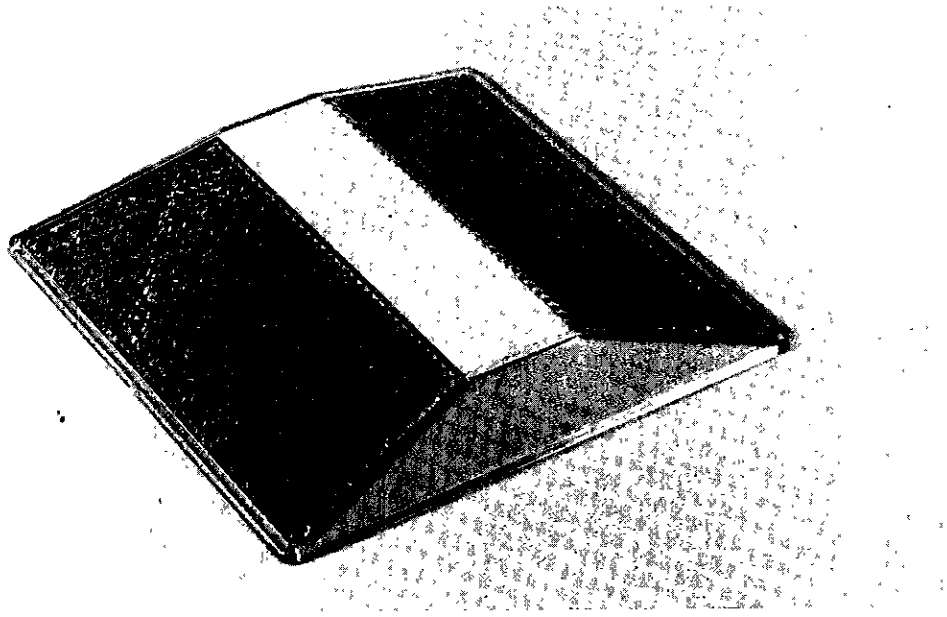


Photo No. 13. Reflex Reflector pavement marker.

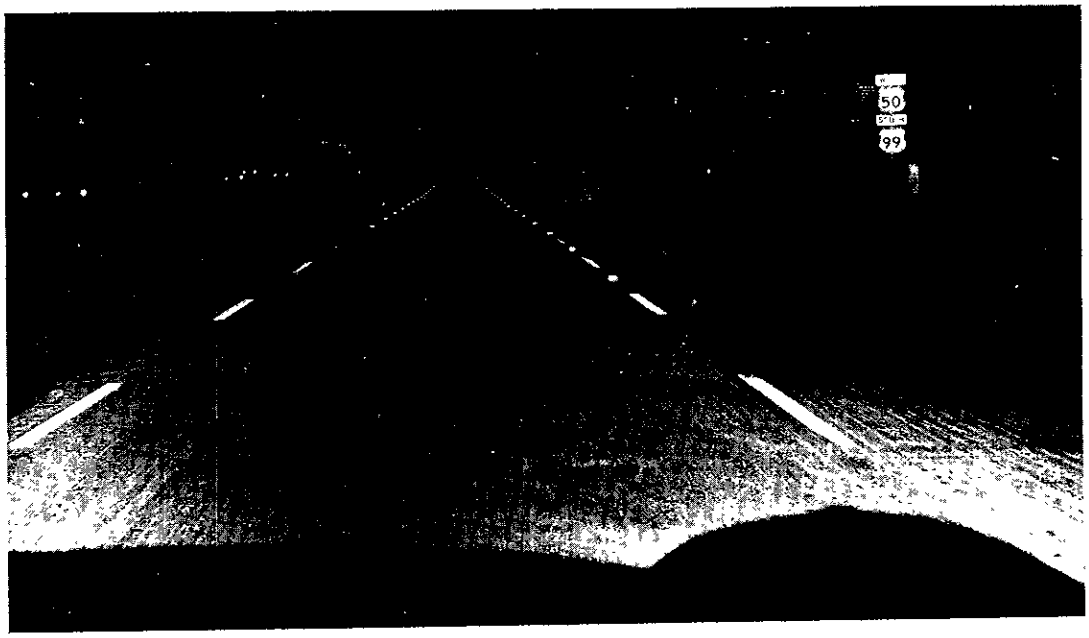


Photo No. 14. Reflex Reflectors at night.

State of California
Department of Public Works
Division of Highways

Materials and Research Department

SPECIFICATION

October 1964

PLASTIC REFLECTIVE PAVEMENT MARKERS, WEDGE TYPE, WHITE AND INTERSTATE YELLOW

FOR ONE-WAY OR TWO-WAY TRAFFIC MANUFACTURE AND INSTALLATION

Scope:

This specification is intended to cover the composition and other characteristics of the wedge type reflective pavement markers, and adhesive, together with method of installation.

Types of Markers:

Type I - Fully Beaded
Class A - For One-Way Traffic
Class B - For Two-Way Traffic

Type II - Partially Beaded
Class A - For One-Way Traffic
Class B - For Two-Way Traffic

Type I markers should be used when maximum visibility is desired at night in clear or rainy weather. This type provides poor daytime delineation. Type II markers are a compromise in that part of the surface is beaded and part is non-beaded to provide daytime and nighttime delineation.

The markers shall have the shape, construction and tolerances as shown in Figures 1, 2, 3 and 4 of the drawings attached hereto.

* Supersedes 64-F-41 dated February, 1964

Composition of Traffic Markers:

TYPE I

	White	Interstate Yellow
	Percent by Weight	Percent by Weight
Resin Content (Polyester)[1]	10 minimum	10 minimum
Glass Spheres[2, 2a]	70 minimum	70 minimum
Titanium Dioxide, TT-P-442, Type III, Class A	3 minimum	---
Chrome Yellow Medium, TT-P-346, Type III	---	3 minimum
Inert Filler	12 maximum	12 maximum

TYPE II

Retro-Reflective Section	White	Interstate Yellow
	Percent by Weight	Percent by Weight
Resin Content (Polyester)[1]	10 minimum	10 minimum
Glass Spheres [2, 2a]	70 minimum	70 minimum
Titanium Dioxide, TT-P-442, Type III, Class A	3 minimum	---
Chrome Yellow Medium, TT-P-346, Type III	---	3 minimum
Inert Filler	12 maximum	12 maximum
Non-Beaded Section		
Resin Content (Epoxy and Hardener)	35 minimum	40 minimum
Inert Fillers	40 maximum	43 maximum
Titanium Dioxide, TT-P-442, Type III, Class A	21 minimum	---
Chrome Yellow Medium, TT-P-346, Type III	---	12 minimum

The pigments shall be so dispersed in the resin to give a grind of 7 Hegman minimum.

The base of the marker shall be free from gloss and other substances that may reduce its bond to the adhesive specified below. This shall be done by sprinkling sand or glass beads on the base of the marker during molding operations and prior to curing. The presence of a soft or resin rich film on the surface of the base of the marker shall be cause for rejection.

Bond between the two sections of the Type II marker shall be structural and shall not delaminate.

The markers shall have the following minimum weights in grams:

TYPE I

	White	Yellow
Class A	369	375
Class B	488	535

TYPE II

Class A	345	340
Class B	435	444

Properties of Markers:

Impact Resistance: - The marker at a temperature of 77°F shall not break when a 1 pound steel ball falls upon it at the center of its face from a height of 30-inches. When making this test the marker shall rest upon (not cemented thereto) a flat steel plate at least 1/2-inch thick or upon flat concrete.

Reflectance: - When tested according to Test Method No. Calif. 602-C at a distance of 50-feet, the nighttime reflectance of the marker, after scrubbing with scouring powder, such as Babbitt, and a fiber brush followed by thorough rinsing and drying, shall be not less than the following values:

TYPE I

	White	Yellow
Class A		
0°	0.053	0.057
20°	0.047	0.051
Class B		
0°	0.058	0.048
20°	0.051	0.041

TYPE II

Class A		
0°	0.041	0.024
20°	0.038	0.022
Class B		
0°	0.040	0.024
20°	0.036	0.022

When a power sanded area of the surface of the white marker is tested according to Federal Test Method Standard No. 141, Method 6121, the daylight reflectance shall not be less than 70% relative to magnesium oxide.

The color of the yellow markers shall match that of the Standard on file in the Division of Highways Laboratory.

Installation:

The portion of the highway surface to which the marker is attached by the adhesive shall be free of dirt, grease, oil, loose or unsound layers and any other material which would adversely affect the bond of the adhesive. Cleaning shall be done by sandblasting on all pavement surfaces except newly placed asphaltic concrete. The adhesive specified below 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 the pavement surface with a slight excess after it has been pressed in place. Within 10 minutes after the start of mixing any batch of adhesive, the marker shall be placed in position and pressure applied until firm contact is made with the pavement and no voids are present in the adhesive. Excess adhesive around the edge of the marker shall be removed. The marker shall be protected against impact until the adhesive has hardened to the degree designated by the Engineer.

This adhesive requires that the mixing operation and placing of the markers be done rapidly and not more than one quart of adhesive shall be mixed at one time. The pot life of the adhesive may be prolonged by cooling after mixing the components or by spreading it out in a thin layer on a board before application. Any mixed batch of adhesive which becomes so viscous because of its acquiring a partial set such that the marker cannot be pressed into place with the adhesive readily extruding from the edges shall not be used.

Composition of Adhesive:

The adhesive shall be furnished as two components, each packaged separately. The components shall have the following composition:

PACKAGE A

	Lbs/3.3 Gallons
Epoxy Resin[3]	26.0
Titanium Dioxide, TT-P-442, Type III, Class A	1.9
Colloidal Silica[4]	1.3
Talc[5]	9.5

PACKAGE B

	Lbs/3.3 Gallons
Modified Aliphatic Amine Hardener[6]	6.5
Modified Aliphatic Amine Hardener[7]	13.0
Carbon Black, TT-P-343, Form I, Class B	0.06
Colloidal Silica [4]	1.2
Talc[8]	18.0

At the time of use the contents of Packages A and B shall each be thoroughly redispersed by stirring or if this is not possible the material shall be rejected. One volume from Package A shall be mixed with one volume from Package B until a uniform gray color is obtained without visible streaks of white or black.

On heavily traveled urban roads and when permitted by the Engineer an approved fast setting epoxy adhesive which sets to bear traffic within 10 minutes under all environmental conditions may be used.

Approval will be based on tests made by the Materials and Research Department. The viscosity and thixotropy of the fast setting adhesive shall be the same as that of the adhesive described above.

Labeling of Adhesive:

The package designation shall be specified on the label together with the directions for mixing and the following warning:

> This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention. Do not try to remove this material from the skin with solents.
>
> When SoCal or toluene is used for cleaning tools and equipment adequate fire fighting equipment should be maintained at all operations.

[1]The polyester resin shall be free of wax. Its properties shall be such that when compounded into the reflective marker as described under "Composition of Marker", the marker shall have the physical properties as described herein.

[2]In the white markers the clear glass beads shall be a minimum of 90 percent true spheres, index of refraction 1.90 minimum, free of dark spots, milkiness and air inclusions. The beads shall conform to the following gradation:

Sieve No.	Sieve Opening Inches	Percent Passing
25	0.028	100
30	0.023	95-100
40	0.0165	40-70
50	0.0117	10-35
70	0.0083	5-15
100	0.0059	0-5
200	0.0029	0

[2a]For yellow markers the yellow glass beads shall have the following properties:

Gradation:

Sieve No.	Percent Passing
25	100
30	95-100
40	40-80
50	10-40
70	5-25
100	0-10
200	0-2

Index of Refraction:

1.8 minimum

Specific Gravity:

4.1 maximum

Color:

Utilizing a Bausch and Lomb Spectronic No. 340 with reflective bead standardized with a magnesium carbonate block, minus 30 plus 40 beads placed about one centimeter deep in a glass cell as manufactured by American Instrument Company for this unit shall have a net reflectance after subtracting the cell value of 13 to 22 over the 565 to 585 millimicron wave length range.

Requirements 1, 2, 5, 7, 8 and 9 of the Specification for Glass Spheres, 62-F-34, shall apply to the yellow beads except that in Requirement 1 the color shall be yellow.

[3]Viscosity, 5-9 poise at 25°C; epoxide equivalent 175-205. Manufactured from epichlorohydrin and bisphenol A.

[4]SiO_2 (moisture free basis), 99% minimum; refractive index, 1.46; surface area, 175-225 square meter per gram; particle size 0.015 microns; pH (4% aqueous dispersion), 3.5-4.2; pour density, 2.3 lbs/cu.ft. maximum.

[5]Percent passing U.S. No. 325 sieve 100; specific surface 2.3-2.4 square meter per gram; maximum particle size 12 microns; oil absorption (Gardner-Coleman) 10-11 ml. per 20 grams; consistency (40 percent suspension in linseed oil) 94-97 KU; fineness in oil (Hegman) 6 minimum.

[6]Amine Value 620-630; color light amber; density 8.1 lbs/gal.; viscosity at 25°C, 2-3 poise; parts by weight used per 100 parts epoxy resin[3] 50; pot life 120 gram mass when 50 parts used per 100 parts of epoxy resin[3] 7-8 minutes.

Physical properties of epoxy resin[3] cured with this hardener when 1/8-inch thick unfilled casting post-cured 2 hours at 100°C are as follows:

Elongation	2.45% (ASTM D 638-60T at loading rate of 0.05 inches/minute)
Tensile Strength	9400 psi (Same as above)
Shore D Hardness	85

[7]Amine Value 300-325; color, light amber; density 8.15 lbs/gal; viscosity at 25°C, 34-45 poise; parts by weight used per 100 parts of epoxy resin[3] 100; pot life, 120 gram mass when 100 parts used per 100 parts of epoxy resin[3] 7-8 minutes.

Physical properties of epoxy resin[3] cured with this hardener when 1/8-inch thick unfilled casting post-cured 2 hours at 100°C.

Elongation	100% (ASTM D 638-60-T at loading rate of 0.05 inches/minute)
Tensile Strength	1800 psi (Same as above)
Shore D Hardness	52

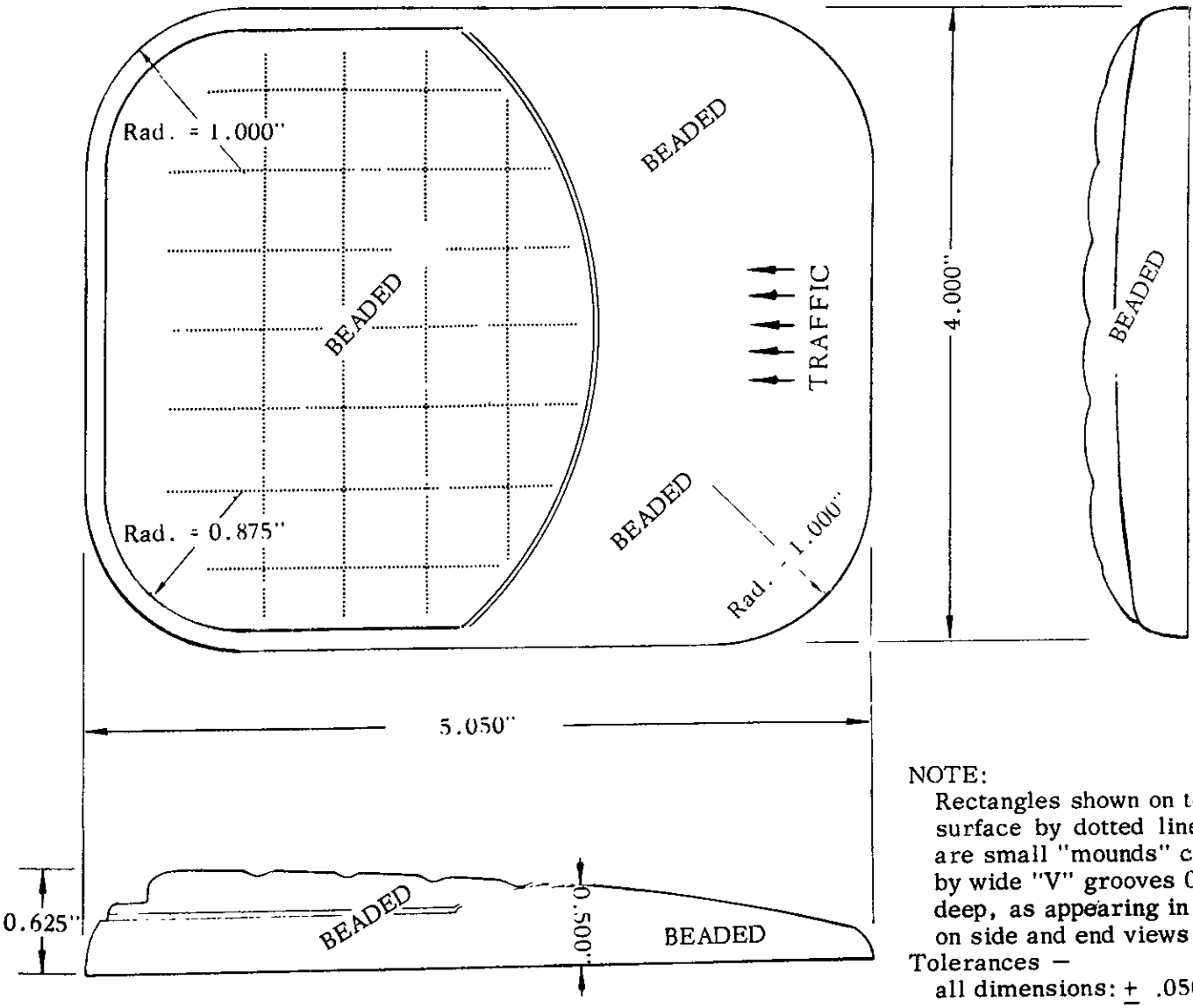
[8]Percent passing U.S. No. 325 sieve, 94-96; maximum particle size, 70 microns; oil absorption (Gardner-Coleman), 6-7 ml. per 20 grams; fineness in oil (Hegman) 1-2; specific surface, 0.5-0.6 square meters per gram; consistency (40% suspension in linseed oil), 55-60 KU.

PLASTIC PAVEMENT MARKERS

FIG. 1

TYPE I - FULLY BEADED

CLASS A - ONE WAY TRAFFIC WEDGE

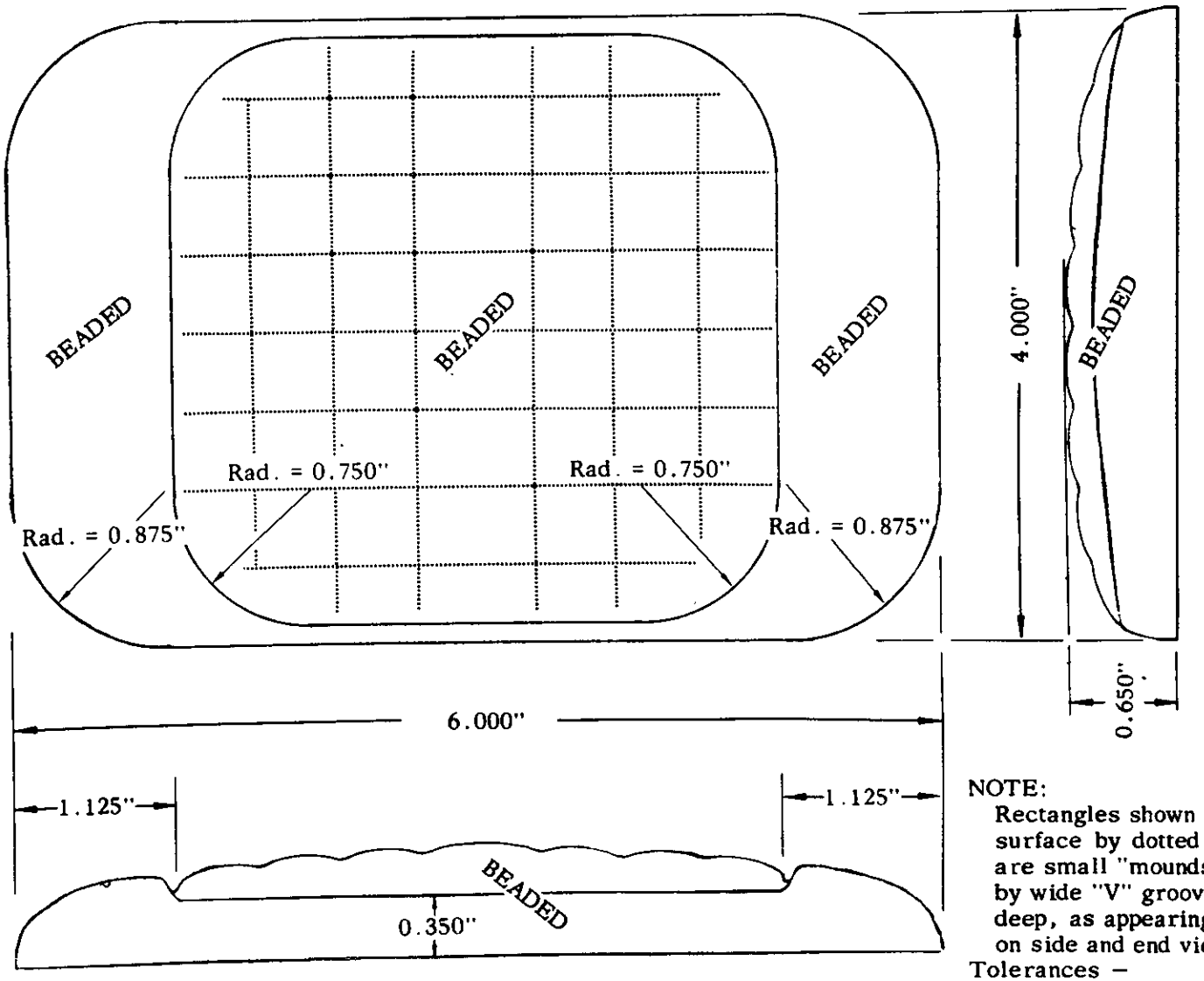


NOTE:
Rectangles shown on top surface by dotted lines are small "mounds" created by wide "V" grooves 0.030" deep, as appearing in profile on side and end views.
Tolerances –
all dimensions: ± .050"

PLASTIC PAVEMENT MARKERS

TYPE I - FULLY BEADED

CLASS B - TWO WAY TRAFFIC WEDGE



NOTE:
Rectangles shown on top surface by dotted lines are small "mounds" created by wide "V" grooves 0.030" deep, as appearing in profile on side and end views.
Tolerances –
all dimensions: ± .050"

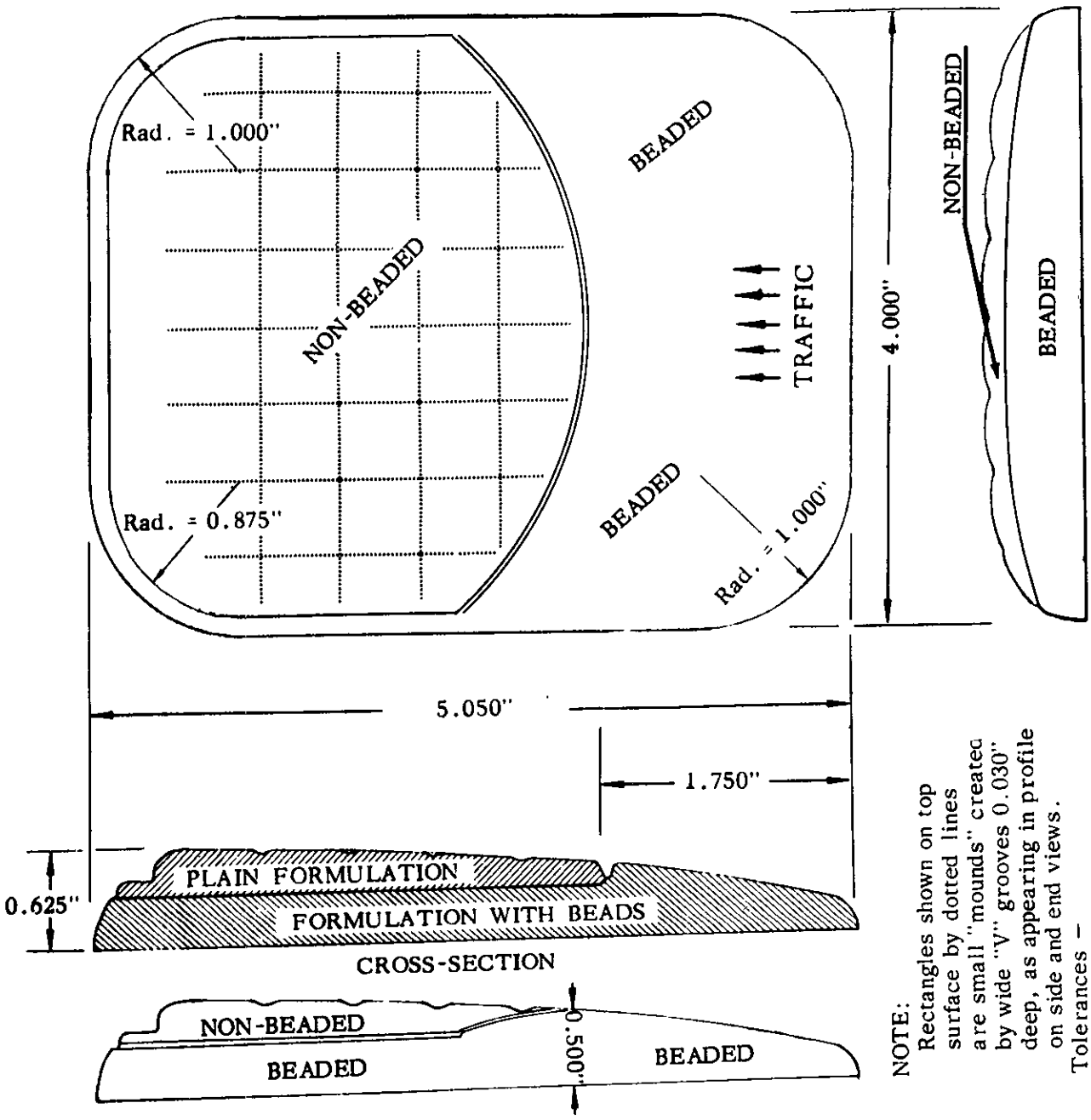
FIG. 2

FIG. 3

PLASTIC PAVEMENT MARKERS

TYPE II - PARTIALLY BEADED

CLASS A - ONE WAY TRAFFIC WEDGE

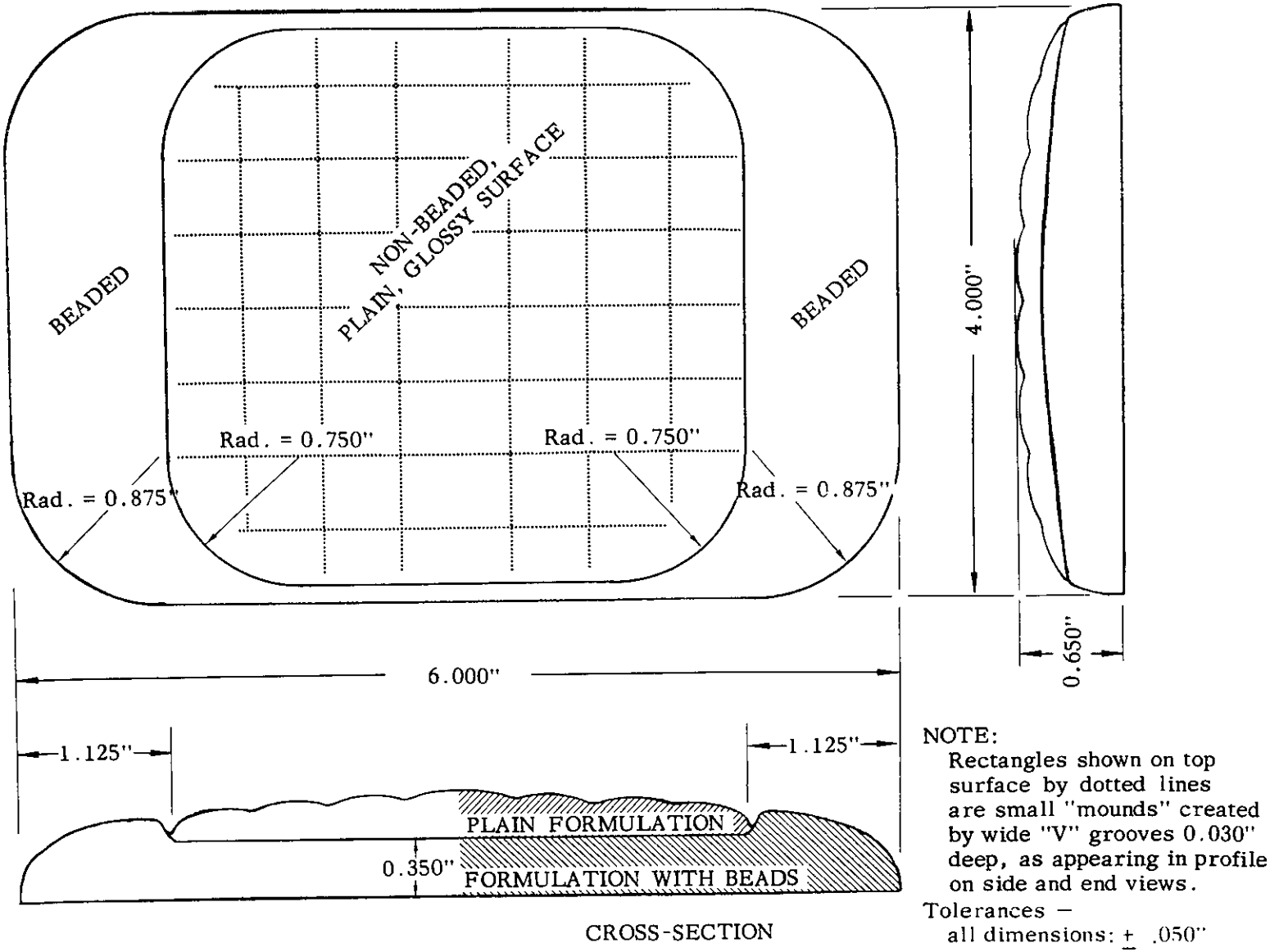


NOTE:
Rectangles shown on top surface by dotted lines are small "mounds" created by wide "V" grooves 0.030" deep, as appearing in profile on side and end views.
Tolerances – all dimensions: ± .050"

PLASTIC PAVEMENT MARKERS

TYPE II - PARTIALLY BEADED

CLASS B - TWO WAY TRAFFIC WEDGE



CROSS-SECTION

NOTE:
Rectangles shown on top surface by dotted lines are small "mounds" created by wide "V" grooves 0.030" deep, as appearing in profile on side and end views.

Tolerances —
all dimensions: ± .050"

FIG. 4

*64-F-42b

October, 1964

State of California
Department of Public Works
Division of Highways

Materials and Research Department

SPECIFICATION

October, 1964

REFLECTIVE PAVEMENT MARKERS, PLASTIC BUTTON TYPE, WHITE AND INTERSTATE YELLOW, MANUFACTURE AND INSTALLATION

Scope:

This specification is intended to cover the composition and other characteristics of the button type reflective pavement markers, and adhesive, together with method of installation.

Type of Markers:

Type I - Fully Beaded

Type II - Partially Beaded

Type III - Non-Beaded

The markers shall have the shape of the outer segment of a spheroid and shall conform to the dimensions and tolerances given in Figures 1, 2 and 3.

Type I markers should be used where maximum visibility is desired at night in clear or rainy weather. This type provides poor daytime delineation. Type II markers are a compromise in that part of the surface is beaded and part is non-beaded to provide daytime and nighttime delineation. Type III markers are designed for daytime visibility and nighttime visibility under strong overhead lighting. They are of no value under automobile headlight illumination at night.

* Supersedes 64-F-42 dated February, 1964.

Composition of Markers:

TYPE I

	White Percent by Weight	Yellow Percent by Weight
Polyester Resin[1]	10 minimum	10 minimum
Glass Spheres 2,2a	70 minimum	70 minimum
Titanium Dioxide, TT-P-442, Type III, Class A	3 minimum	---
Chrome Yellow, Medium TT-P-346, Type III	---	3 minimum
Inert Filler	12 maximum	12 maximum

TYPE II

Retro-Reflective Section	White Percent by Weight	Yellow Percent by Weight
Resin Content (Polyester)[1]	10 minimum	10 minimum
Glass Spheres 2,2a	70 minimum	70 minimum
Titanium Dioxide, TT-P-442, Type III, Class A	3 minimum	---
Chrome Yellow, Medium TT-P-346, Type III	---	3 minimum
Inert Filler	12 maximum	12 maximum
Non-Beaded Section		
Resin Content (Epoxy and Hardener)	35 minimum	40 minimum
Titanium Dioxide, TT-P-442, Type III, Class A	21 minimum	---
Chrome Yellow, Medium TT-P-346, Type III	---	12 minimum
Inert Filler	40 maximum	43 maximum

TYPE III

	White Percent by Weight
Resin Content (Epoxy and Hardener)	30 minimum
Inert Filler	45 maximum
Titanium Dioxide, TT-P-442, Type III, Class A	21 minimum

The pigments shall be dispersed in the resin to give a grind of 7 Hegman minimum.

The base of the marker shall be free from gloss and other substances that may reduce its bond to the adhesive specified below. This shall be done by sprinkling sand or glass beads on the base of the marker during molding operations and prior to curing. The presence of a soft or resin rich film on the surface of the base of the marker shall be cause for rejection.

Bond between the two sections of the Type II marker shall be structural and shall not delaminate.
The markers shall have the following minimum weights in grams:

	White	Yellow
Type I	248	239
Type II	232	229
Type III	164	-

Properties of Markers:

Impact Resistance: - The marker at a temperature of 75°F shall not break or crack when subjected to the impact of a steel ball 1-7/8-inch in diameter falling freely from a height of 30-inches. In performing the test, the marker shall be placed convex side up on a steel plate not less than 1/2-inch in thickness. The steel ball shall strike the marker approximately at its center.

Reflectance: - When tested according to Test Method No. Calif. 602-C at a distance of 50-feet, the nighttime reflectance of the marker, after scrubbing with scouring powder, such as Babbitt, and a fiber brush followed by thorough rinsing and drying shall be not less than the following values:

	Type I		Type II	
	White	Yellow	White	Yellow
0°	0.053	0.024	0.012	0.005
20°	0.049	0.022	0.010	0.004

When a power sanded area of the surface of the white marker is tested according to Federal Test Method Standard No. 141, Method 6121, the daylight reflectance shall not be less than 70% relative to magnesium oxide.

Installation:

The marker shall be cemented to the pavement with the adhesive specified below.

The portion of the highway surface to which the marker is attached by the adhesive shall be free of dirt, grease, oil, loose or unsound layers and any other material which would adversely affect the bond of the adhesive. Cleaning shall be done by sandblasting on all pavement surfaces except newly placed asphaltic concrete. The adhesive specified below 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 the pavement surface with a slight excess after it has been pressed in place. Within 10 minutes after the start of mixing any batch of adhesive, the marker shall be placed in position and pressure applied until firm contact is made with the pavement and no voids are present in the adhesive. Excess adhesive around the edge of the marker shall be removed. The marker shall be protected against impact until the adhesive has hardened to the degree designated by the Engineer.

This adhesive requires that the mixing operation and placing of the markers be done rapidly and not more than one quart of adhesive shall be mixed at one time. The pot life of the adhesive may be prolonged by cooling after mixing the components or by spreading it out in a thin layer on a board before application. Any mixed batch of adhesive which becomes so viscous because of its acquiring a partial set such that the marker cannot be pressed into placed with the adhesive readily extruding from the edges shall not be used.

Composition of Adhesive:

PACKAGE A

	Lbs/3.3 Gallons
Epoxy Resin[3]	26.0
Titanium Dioxide, TT-P-442, Type III, Class A	1.9
Colloidal Silica[4]	1.3
Talc[5]	9.5

PACKAGE B

	Lbs/3.3 Gallons
Modified Aliphatic Amine Hardener[6]	6.5
Modified Aliphatic Amine Hardener[7]	13.0
Carbon Black, TT-P-343, Form I, Class B	0.06
Talc[8]	18.0
Colloidal Silica[4]	1.2

At the time of use the contents of Packages A and B shall each be thoroughly redispersed by stirring or if this is not possible the material shall be rejected. One volume from Package A shall be mixed with one volume from Package B until a uniform gray color is obtained without visible streaks of white or black.

On heavily traveled urban roads and when permitted by the Engineer an approved fast setting epoxy adhesive which sets to bear traffic within 10 minutes under all environmental conditions may be used.

Approval will be based on tests made by the Materials and Reseach Department. The viscosity and thixotropy of the fast setting adhesive shall be the same as that of the adhesive described above.

Labeling of Adhesive:

The package designation shall be specified on the label together with directions for mixing and the following warning:

> This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any gets in the eyes flush for 10 minutes with water and secure immediate medical attention. Do not try to remove this material from the skin with solvents. When SoCal or toluene is used for cleaning tools and equipment adequate fire fighting equipment should be maintained at all operations.

[1]The polyester resin shall be free of wax. Its properties shall be such that when compounded into the reflective marker as described under "Composition of Marker", the marker shall have the physical properties as described herein.

[2]In the white markers the clear glass beads shall be a minimum of 90 percent true spheres, index of refraction 1.90 minimum, free of dark spots, milkiness and air inclusions. The beads shall conform to the following gradation:

Sieve No.	Sieve Opening Inches	Percent Passing
25	0.028	100
30	0.023	95-100

Sieve No.	Sieve Opening Inches	Percent Passing
40	0.0165	40-70
50	0.0117	10-35
70	0.0083	5-15
100	0.0059	0-5
200	0.0029	0

2a For yellow markers the yellow glass beads shall have the following properties:

Gradation:

Sieve No.	Percent Passing
25	100
30	95-100
40	40-80
50	10-40
70	5-25
100	0-10
200	0-2

Index of Refraction:

1.8 minimum

Specific Gravity:

4.1 maximum

Color:

Utilizing a Bausch and Lomb Spectronic No. 340 with reflective bead standardized with a magnesium carbonate block, minus 30 plus 40 beads placed about one centimeter deep in a glass cell as manufactured by American Instrument Company for this unit shall have a net reflectance after subtracting the cell value of 13 to 22 over the 565 to 585 millimicron wave length range.

Requirements 1, 2, 5, 7, 8 and 9 of the Specification for Glass Spheres, 62-F-34, shall apply to the yellow beads except that in Requirement 1 the color shall be yellow.

[3]Viscosity, 5-9 poise at 25°C, epoxide equivalent 175-205. Manufactured from epichlorohydrin and bisphenol A.

[4]SiO_2(moisture free basis), 99% minimum; refractive index, 1.46; surface area, 175-225 square meter per gram; particle size 0.015 microns; pH (4% aqueous dispersion), 3.5-4.2; pour density, 2.3 lbs/cu.ft. maximum.

[5]Percent passing U.S. No. 325 sieve, 100; specific surface, 2.3-2.4 square meter per gram; maximum particle size, 12 microns; oil absorption (Gardner-Coleman), 10-11 ml. per 20 grams; consistency (40 percent suspension in linseed oil), 94-97 KU; fineness in oil (Hegman), 6 minimum.

[6]Amine value 620-630; color, light amber; density, 8.1 lbs/gal; viscosity at 25°C, 2-3 poises; parts by weight used per 100 parts of epoxy resin[3], 50; pot life, 120 gram mass when 50 parts used per 100 parts of epoxy resin[3], 7-8 minutes.

Physical properties of epoxy resin[3] cured with this hardener when 1/8-inch thick unfilled casting post-cured 2 hours at 100°C.

Elongation	2.45% (ASTM D 638-60T at loading rate of 0.05 inches/minute)
Tensile Strength	9400 psi (Same as above)
Shore D Hardness	85

[7]Amine value 300-325; color, light amber; density, 8.15 lbs/gal; viscosity at 25°C, 34-45 poises; parts by weight used per 100 parts of epoxy resin[3], 100; pot life, 120 gram mass when 100 parts used per 100 parts of epoxy resin[3], 7-8 minutes.

Physical properties of epoxy resin[3] cured with this hardener when 1/8-inch thick unfilled casting post-cured 2 hours at 100°C.

Elongation	100% (ASTM D 638-60T at loading rate of 0.05 inches/minute)
Tensile Strength	1800 psi (Same as above)
Shore D Hardness	52

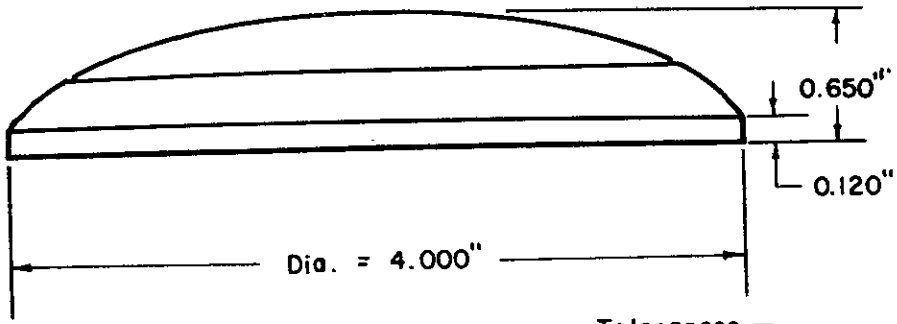
[8]Percent passing U.S. No. 325 sieve, 94-96; maximum particle size, 70 microns; oil absorption (Gardner-Coleman), 6-7 ml. per 20 grams; fineness in oil (Hegman) 1-2; specific surface, 0.5-0.6 square meters per gram; consistency (40% suspension in linseed oil), 55-60 KU.

PLASTIC PAVEMENT MARKERS

ROUND TRAFFIC BUTTON

TYPE I

FULLY BEADED



Tolerances –
all dimensions: ± .050

FIG. 1

ROUND TRAFFIC BUTTON

TYPE III

NON-BEADED

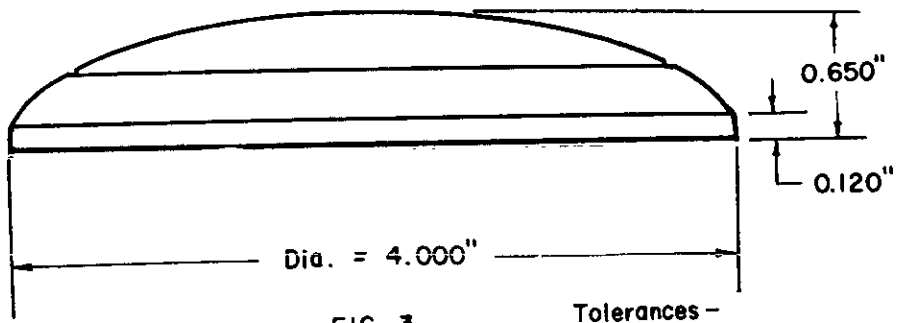


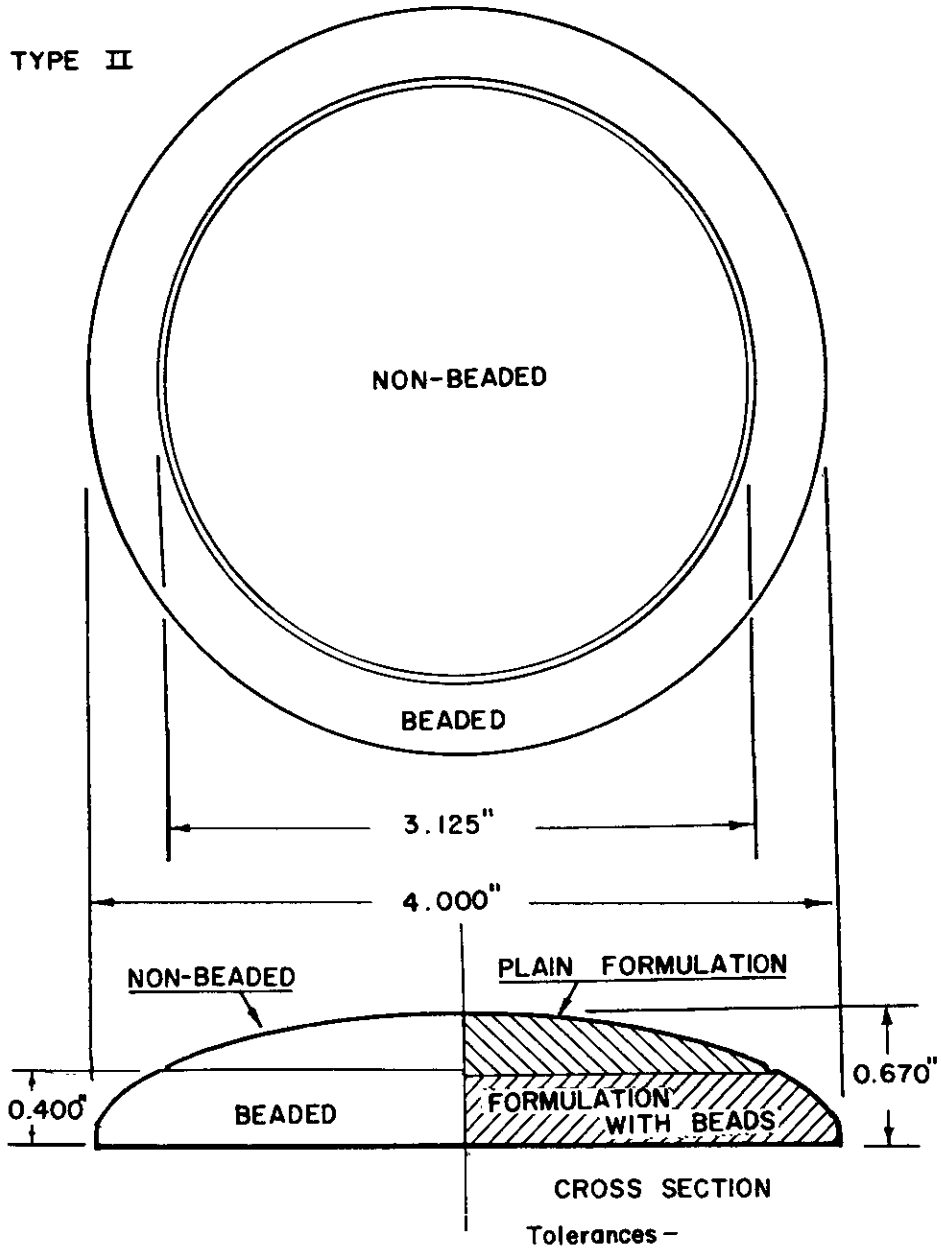
FIG. 3

Tolerances –
all dimensions: ± .050

ROUND TRAFFIC BUTTON

PARTIALLY BEADED

TYPE II



Tolerances –
all dimensions: ± .050

FIG. 2