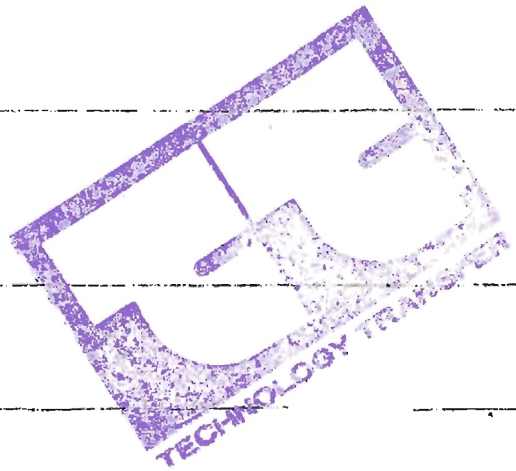
1972-9

PARTIALLY BEADED CENTERLINE MARKINGS

MUTCD Request No. M-1-71 (Experimental)



Prepared by

STATE DEPARTMENT OF HIGHWAYS
Division of Highways - State of Colorado

Planning and Research Division

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

October 1972

PARTIALLY BEADED CENTERLINE MARKINGS

I. INTRODUCTION

Several years before the publication of the 1970 MUTCD, the Colorado Division of Highways initiated field tests to investigate the relative brightness and durability of yellow and white paint stripes in the beaded and unbeaded condition and to determine the acceptability of partially-beaded centerlines. After the issuance of the 1970 edition of the Manual, the Division sought and received FHWA approval for continued testing as proposed in MUTCD Request No. M-1-71 and described in "Official Rulings on Requests," Volume 1, November 1971 issued by the U.S. Department of Transportation, Federal Highway Administration.

Approximately 100 miles of Colorado State Highways in different geographical areas were striped with half-beaded centerlines by reflectorizing only the first 7.5 feet of the normal 15-foot painted segments. Evaluation of these experimental markings was accomplished by highway engineers, maintenance men, and a research team using photometric bead detectors. The principal purpose of the experimentation was to determine if this method of reflectorization would adequately satisfy the requirements for nighttime visibility and would prove otherwise acceptable.

II. MATERIALS AND EQUIPMENT

The paint used in all sections was an alkyd type traffic paint from one manufacturer. The glass beads were treated to float on the paint and were also supplied by a single manufacturer. Specifications

for both the paint and beads are made a part of the Appendix to this report.

Daylight and nighttime types of photometers were used to ascertain the brightness of the stripes. Sketches of these instruments are shown in the Appendix. A detailed description of the photometers used may be found in the "Reflective Traffic Bead Study - Final Report, May 1970" prepared by the Research Section of the Colorado Division of Highways (copy enclosed with this report).

Unlike the nighttime photometer which records overall intensity, the daytime photometer reads reflective intensity on small 3" x 12" segments of the painted stripes. This feature enables a person to look over various stripes quite closely and actually determine the difference in brilliance between the beaded and unbeaded sections of the same stripe, although the average motorist does not see this difference at high speed.

The highway test sections were striped using the regular truck-mounted DeVilbiis spray guns and drop-on bead dispensers. Striping crews provided for a bead application rate of 4 pounds of beads per gallon of paint. Where stripes are fully beaded the overall rate usually figures out closer to 5 pounds per gallon. Broken centerlines consisted of the regular 15-foot segments with 25-foot gaps.

III. LOCATION AND TRAFFIC VOLUME OF TEST SECTIONS

Only one formal test area was established to evaluate the half-beaded stripes. Two sections totaling about 0.5 miles in length were marked on two-lane State Highway 83 approximately 25 miles south of Denver where there were 600 vehicles per day or 200,000 vehicles per lane for the two-year test period. For the sake of comparative study

these two sections were placed in conjunction with and at the same time as twelve other test sections marked to determine the relative brightness of yellow and white paint stripes in the beaded and unbeaded condition (see Summation Sheet, page 4). Additional test sections of half-beaded segments were located throughout Colorado by the Maintenance Sections to help in the evaluation. Altogether, these totaled about 100 miles.

IV. PHOTOMETER DATA

At the end of each year of service the evaluation team took readings with daytime and nighttime photometers and rated the two half-beaded sections (Nos. 13 and 14 of Summation Sheet, page 4). According to the evaluation shown on the Summation Sheet the daytime and nighttime visibility of the half-beaded stripes, both yellow and white, rated higher for each year of service than the daytime and nighttime visibility of the full-beaded stripes. Figure 1 on page 5 shows a trace of the readout of the nighttime photometer for parts of Sections 3, 4, 9, 10, 13 and 14 as an example of the relative brilliance of the different stripes. The nighttime photometer showed an average reading of 4 footlamberts for the half-beaded yellow stripes and 6 footlamberts for the half-beaded white stripes. It will be noted from Figure 2 on page 9 that these readings compare with the brilliance values of stripes that have not been exposed to deterioration from traffic wear or weathering.

The indication from the photometer tests that partially beaded stripes or segments are superior to fully beaded ones invites further analysis and explanation. It will be seen from the evaluation chart that at the beginning of the test period (1968) both partially beaded

FRANKTOWN SOUTH
(South of Denver)

EXPERIMENTAL CENTE[illegible]NE STRIPE PROJECT
FRANKTOWN - SOUTH
EVALUATION SHEET

Date 8/24/70 Time 9:30 AM

Weather Clear

Section	Mileage from Jct. SH 86	Centerline Color	Centerline Beads	No-passing stripes	EVALUATION Daytime Visibility (0-30)	Daytime Durability (0-30)	Night** Visibility (0-40)	Summation Rating* (0-100)	Section
1	0.05 - 0.18	white	no	double yellow	30 20 15%	28 20 15%	10 4 3%	68 44 33%	1
2	0.18 - 0.28	white	yes	double yellow	25 18 15%	28 20 15%	35 24 15%	88 62 45%	2
3	0.28 - 0.43	white	yes	none	25 15 12%	28 20 14%	35 21 14%	88 56 40%	3
4	0.43 - 0.51	white	no	none	30 20 13%	28 15 14%	10 5 1%	68 40 28%	4
5	0.51 - 0.62	white	no	single yellow	30 20 13%	28 20 15%	10 6 1%	68 46 29%	5
6	0.62 - 0.74	white	yes	single yellow	25 20 11%	28 20 15%	35 23 17%	88 63 43%	6
-	0.74 - 0.85	NON-TEST AREA							
7	0.85 - 0.95	yellow	yes	single yellow	20 20 10%	28 20 15%	30 21 12%	78 61 37%	7
8	0.95 - 1.08	yellow	no	single yellow	25 25 12%	28 25 15%	5 2 .4%	58 52 27%	8
9	1.08 - 1.19	yellow	no	none	25 20 16%	28 20 16%	5 2 1%	58 42 33%	9
10	1.19 - 1.28	yellow	yes	none	20 18 14%	28 20 15%	30 14 4%	78 52 33%	10
-	1.28 - 1.76	NON-TEST AREA							
11	1.76 - 1.87	yellow	no	double yellow	20 20 17%	28 20 18%	5 3 2%	53 43 37%	11
12	1.87 - 1.99	yellow	yes	double yellow	20 18 16%	28 20 17%	30 21 8%	78 59 41%	12
-	1.99 - 4.07	NON-TEST AREA							
13	4.07 - 4.26	yellow	(1/2)	none	20 22 19%	28 19 15%	30 22 17%	78 63 51%	13
14	4.26 - 4.57	white	(1/2)	none	25 18 17%	28 19 14%	32 40 32%	85 77 63%	14
					1968-69-70	1968-69-70	1968-69-70	1968-69-70	

** Photocell Evaluation

*Rating = Day Visibility + Durability + Night Visibility

Final Summation Column

Raters: Gerhardt, Safford, Baker

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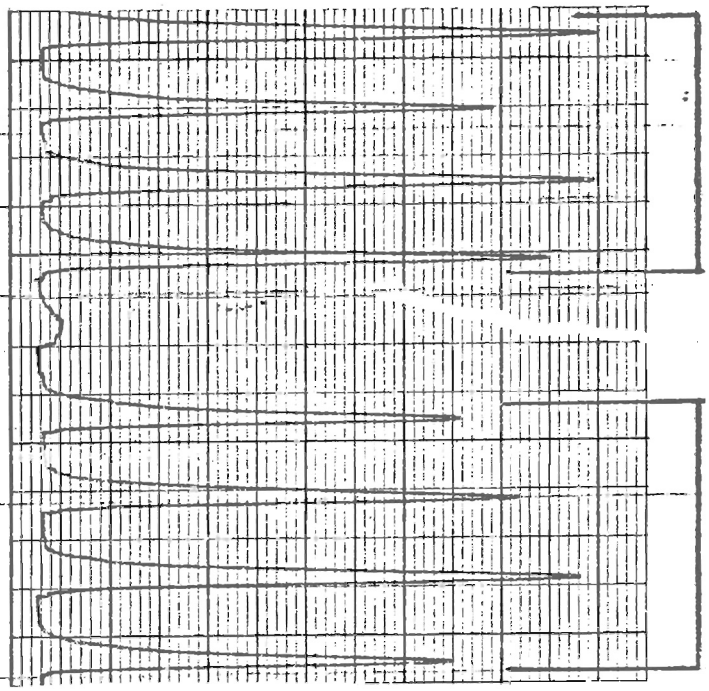
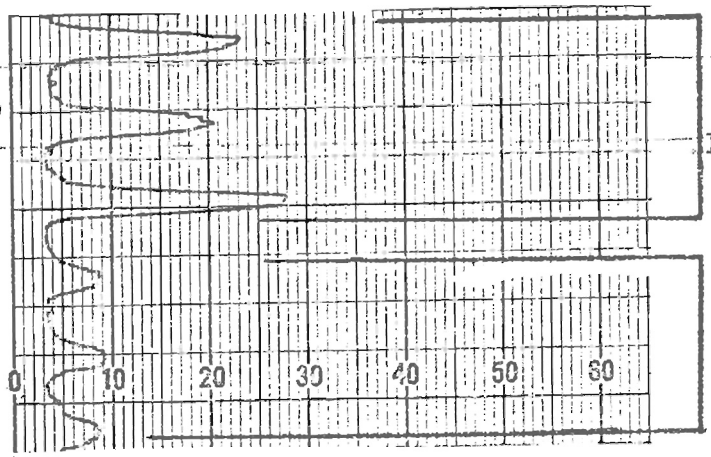
Figure 1 INTENSITY OF PAVEMENT STRIPES - From Photometer Chart



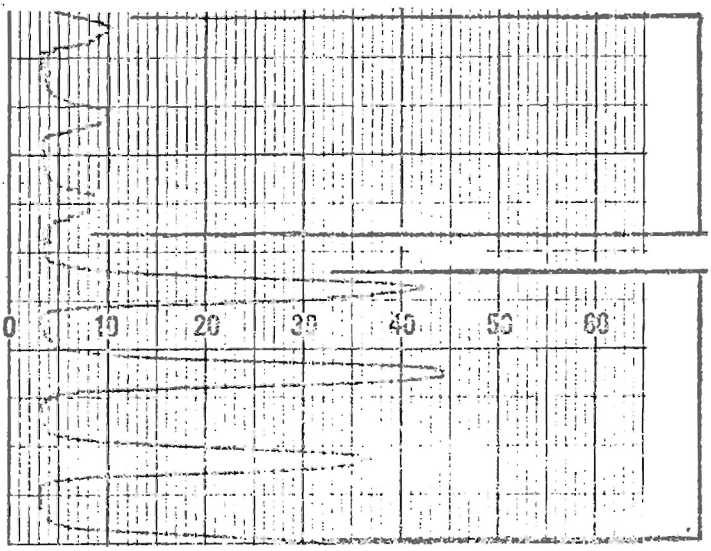
Section 14
Half beaded white centerline stripes
(In area with less traffic wear
than Sections 3 and 10 below)

Section 13
Half beaded yellow centerline stripes
(In area with less traffic wear
than Sections 3 and 10 below)



Section 10
Fully beaded yellow centerline stripes

Section 9
Yellow centerline stripes without
beads



Section 4
White centerline stripes without
beads

Section 3
Fully beaded white centerline stripes

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stripes and fully-beaded stripes had almost identical ratings. After each year of service, however, the performance of the fully-beaded stripes dropped considerably below that of the partially beaded segments; yet, durability ratings after each year of service (based on amount of paint and beads discernible) were practically the same. One explanation might be found from the fact that the half-beaded sections (Nos. 13 and 14) were situated on a hilltop or bluff away from access roads some four miles from the highway junction where traffic movements across the lines were, no doubt, less frequent than at the other locations in the area. Still another consideration to be taken into account is the action of the wind on the bluff in blowing sand and dirt off the partially-beaded sections and keeping them cleaner than the full-beaded sections. A third undetermined factor is the possibility that reflected light from the unbeaded portion of the half-beaded stripe contributed to a higher intensity of light than that produced by the fully-beaded stripes after a year or two of service. Assuming that any or all of these variables existed, it would still appear that the half-beaded stripe at the very least would compare favorably with the full-beaded one.

Despite the fact that nighttime photometer records show the half-beaded stripes to be as intense or striking as fully-beaded ones, it is significant to the motorist that the half-beaded stripe when viewed at night produces a sharp, intense flash of short duration in contrast to the relatively sustained, long-lasting glow of a fully-beaded stripe. Driver reaction to this brief, pronounced flash of light when traveling on long stretches of highway could not be determined from the limited test sections.

V. VISUAL APPEARANCE

As indicated previously, Maintenance Sections striped additional sections of centerlines with half-beaded segments primarily for visual observations. These were placed during the fall of 1971. Only a few of these partially-beaded stripes were tested with photometric equipment, but Maintenance Superintendents and Foreman were asked the following questions:

1. Is the nighttime reflectance of the partially-beaded stripe as good as the fully-beaded stripe?

   Answer: Yes - 2 No - 4

2. Is the daytime appearance of the partially-beaded stripe better than the fully-beaded stripe?

   Answer: Yes - 2 No - 2 Same - 2

Opinions were divided on the quality of daytime appearance, but the majority of those reporting observed that the nighttime reflectance and appearance of the partially-beaded stripes are not as good as the fully-beaded ones. The general consensus among the Maintenance personnel is that the nighttime appearance of partially-beaded stripes suggests that something is wrong with the paint lines and mentally compels the observer to concern himself with the condition of the line instead of its function.

VI. DURABILITY CONSIDERATIONS

The evaluation chart on page 4 shows no appreciable difference in the durability of partially-beaded stripes compared to fully-beaded ones. No observations were made of the durability of half-beaded stripes on highways where there are more than 2000 vehicles per day per lane. However, in a comparison of four different types of beads on a section

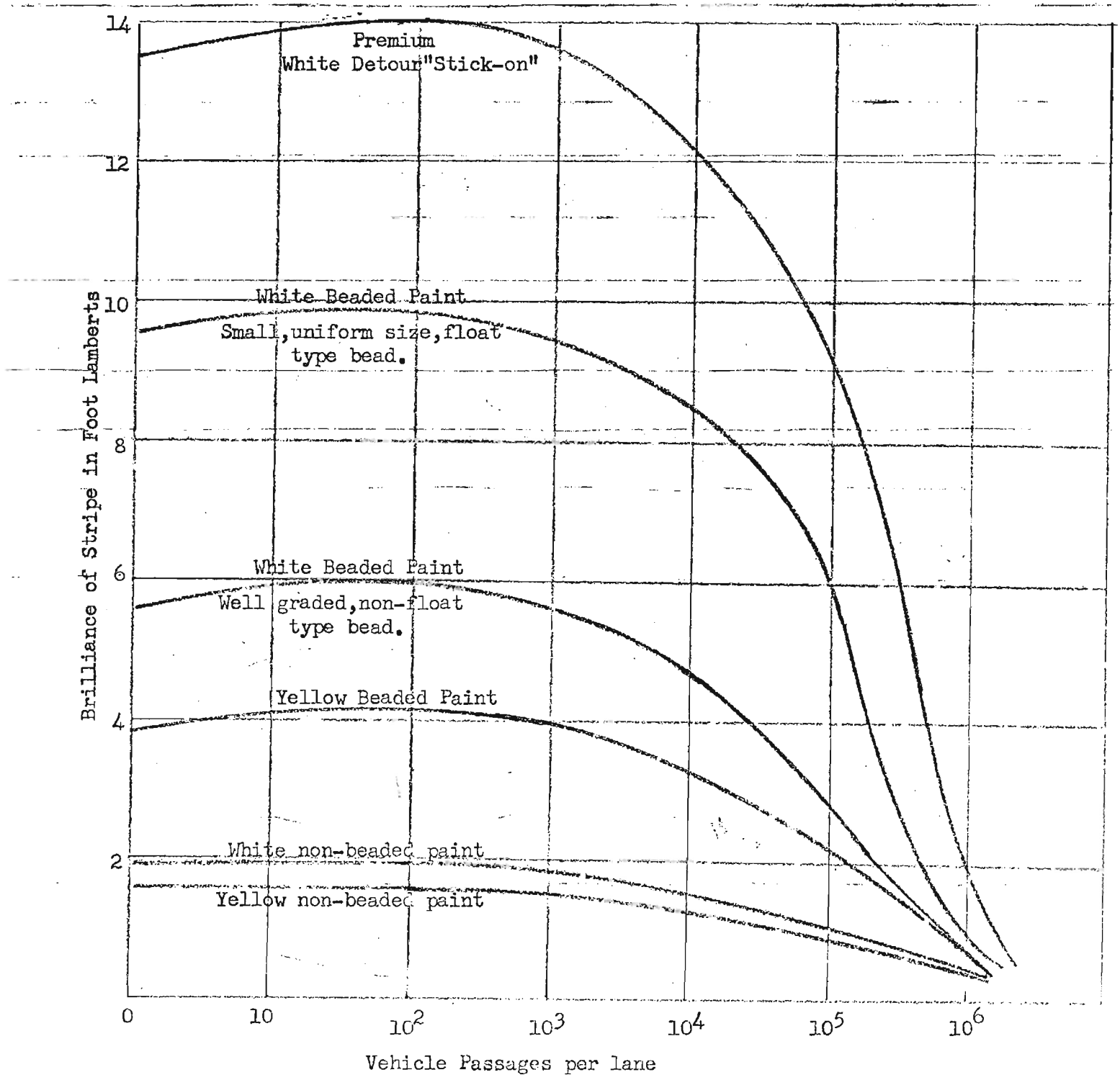
of Interstate 25 south of Denver, the performance of a few miles of partially-beaded centerline stripes was evaluated by means of the photometer. The reflectance of the partially-beaded stripe was next to the greatest of the six types being tested.

A graph of the intensity of stripe reflection based on the findings from this investigation and previous studies conducted by the Colorado Division of Highways is shown in Figure 2 on page 9. The critical area lies to the right of the 10^5 vehicle passage per lane area where the stripes become badly worn and show up poorly as lane markers. Generally, sometime before 1,000,000 vehicle passages per lane, stripes need to be repainted. When traffic is so heavy that the interval of 10^6 vehicle passages per lane occurs frequently, and the repainting must be carried out under such conditions, it is customary for many highway agencies to use plastic buttons or thick thermoplastic stripes for pavement-marking materials.

VII. COST ANALYSIS

As an item of interest bearing on the outcome of this experimentation, a cost analysis was made of the savings possible by reflectorizing one-half of the length of the broken centerline stripes on all State highways in Colorado except in the Denver metropolitan area. The potential annual reduction is 280,000 pounds of glass beads. At the current market price of $0.125 per pound, and based on the frequency at which centerlines are repainted, this would amount to a savings of $35,000 per year in materials. Even if the half-beaded stripes were confined to low volume, low speed roads the savings would be significant. Labor costs would not be affected to any appreciable extent, although the half-striping does add another complication to a duty that demands utmost concentration for proper results.

Figure 2 PAINT STRIPE DETERIORATION: -Average for Colorado Materials



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VIII. CONCLUSIONS

In summation, four basic facts were established from this experimentation:

1. Limited testing by photometers on various sections of State highways indicate that half-beaded segments of centerlines are as bright, if not brighter, at night than the fully-beaded stripes.
2. Visual observations of about 100 miles of striping indicate that partially-beaded stripes do not present a satisfying nighttime appearance to the eye of the trained observer (supervisory, maintenance personnel) and therefore leave something to be desired.
3. Half-beaded segments of centerlines, if acceptable, can produce an appreciable savings in material cost.
4. Superiority of the half-beaded stripes was definitely noticed at dusk. During this 1/2 to 1 hour period the portion of the stripe without the beads showed up much better than the beaded portion of the stripe.

Since centerlines and lane lines are vital traffic safety devices, the overall appearance of the markings to the motoring public outweighs all other considerations of acceptability. Visual observations do not support or justify further testing of partially-beaded centerline segments at this time. It is believed that the experimentation has served a useful purpose by examining the feasibility of partially-reflectorized centerlines and by developing the data presented in this report.

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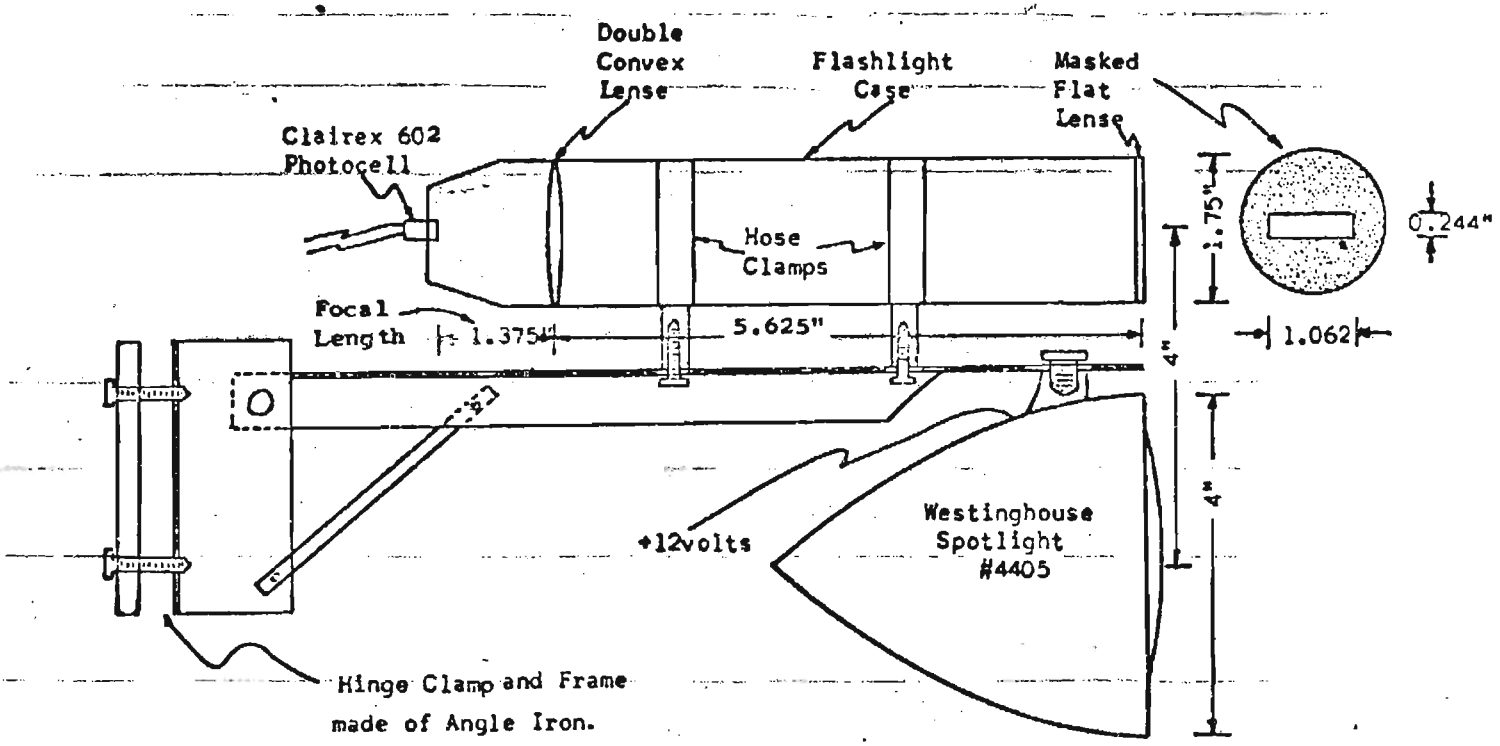
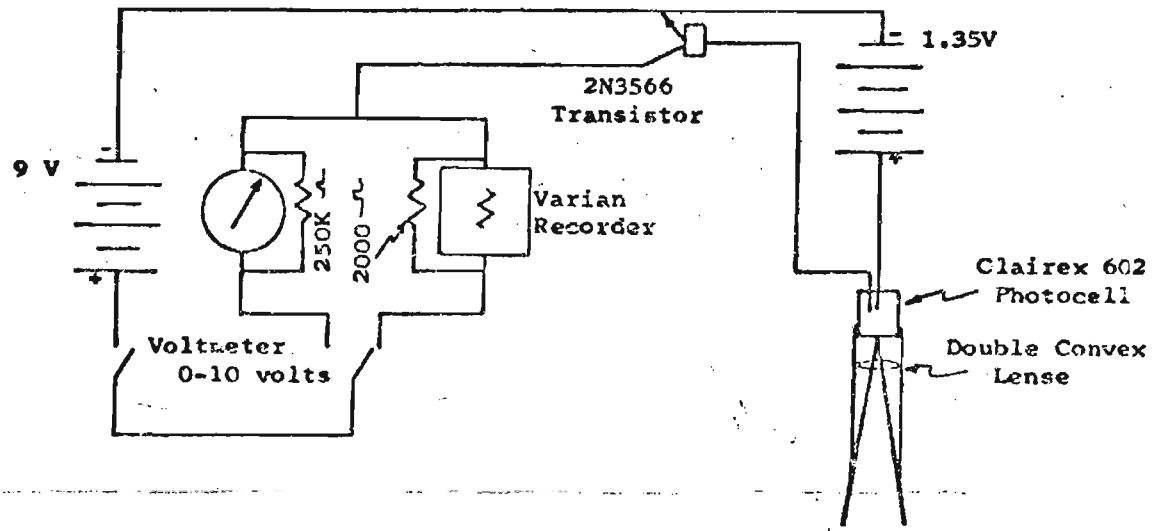
APPENDIX 1

PHOTOMETRIC BEAD DETECTOR DIAGRAM

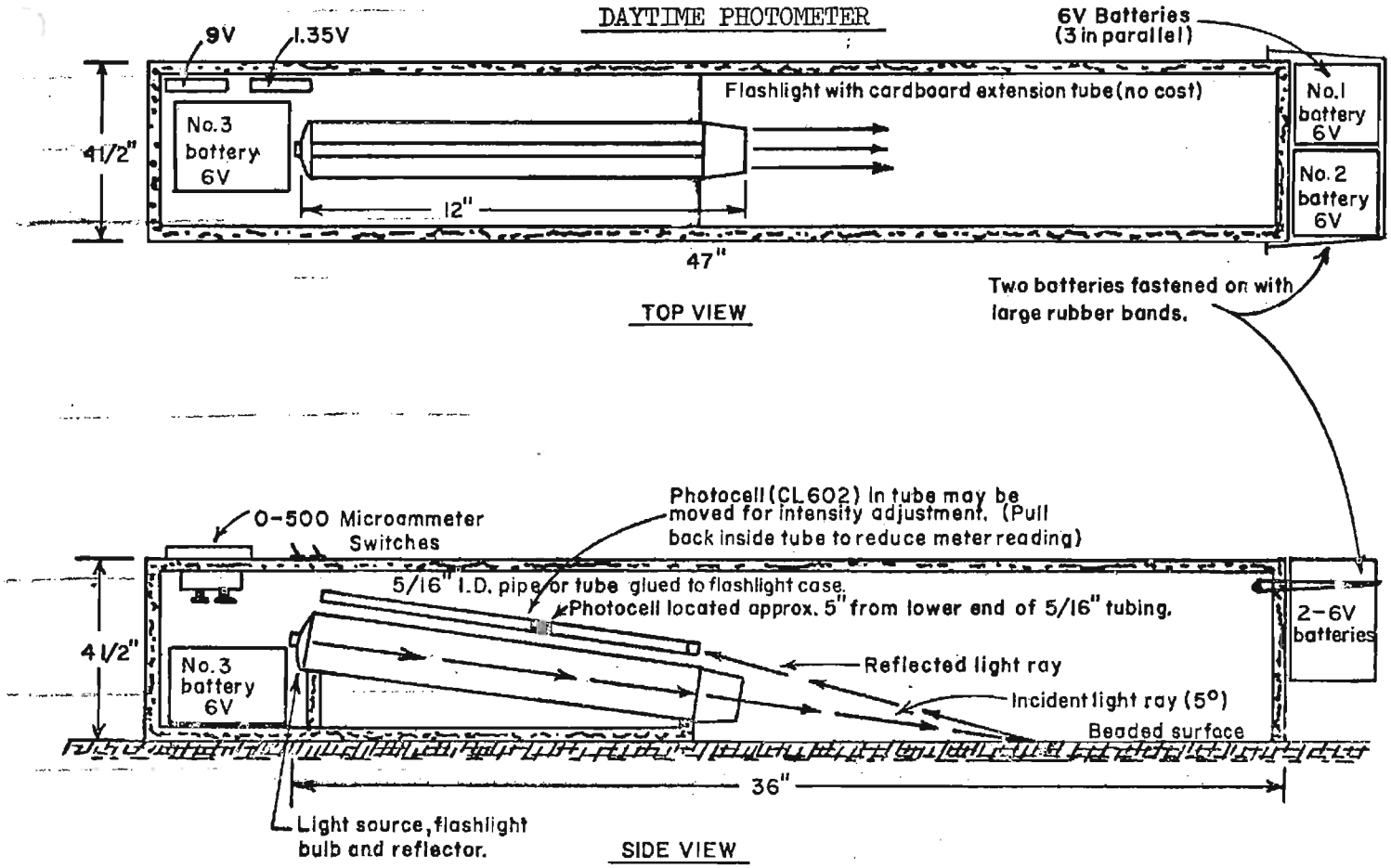


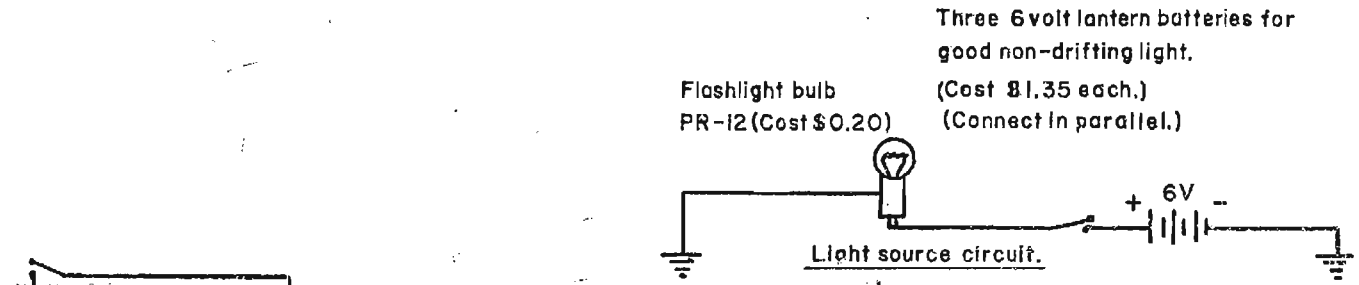
AMPLIFIER CIRCUIT

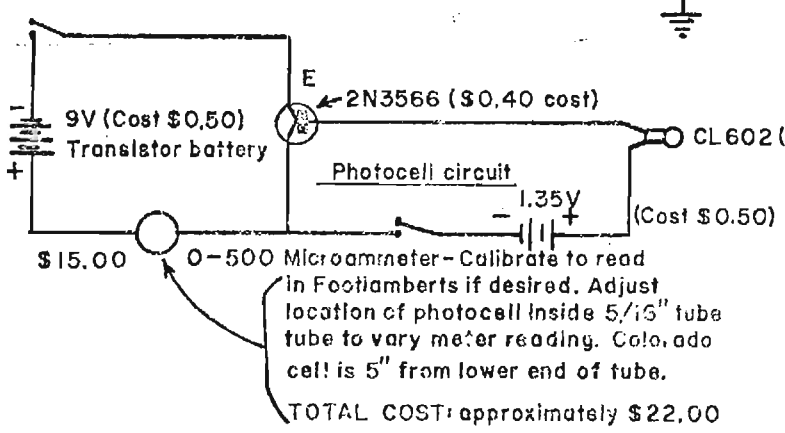


APPENDIX 2

SKETCH OF A HANDY, INEXPENSIVE DEVICE FOR DETERMINING THE RELATIVE BRILLIANCE OF BEAD PAINT STRIPES







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APPENDIX 3

STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS - STATE OF COLORADO
Staff Materials Division

TRAFFIC PAINT SPECIFICATION
Revised October 28, 1970

Scope:

This specification covers an alkyd traffic paint for lane delineation and other markings on highway pavement. It is the intent of this specification to set forth both composition and general requirements in sufficient detail that, when spray applied at a rate of 15 mils wet film thickness and reflectorized with glass spheres, the traffic paint will perform satisfactorily.

Composition Requirements:

All proportions specified are by weight. The composition of pigment and vehicle shall be from 99.0 to 101.0% of each amount specified.

Pigment (White and Yellow)	49.0 to 51.0%	
	White	Yellow
Pigment Composition:		
Titanium Calcium Pigment, ASTM D-476, Rutile	65.0%	12.5%
Titanium Dioxide, ASTM D-476, Type I	5.0%	---
Chrome Yellow, Medium, ASTM D-211, Type III	---	34.0%
Magnesium Silicate, Low Consistency, ASTM D-605 Oil Absorption of 40 max. by ASTM Method D-281	20.0%	43.5%
Mica, Dry Ground, 5% max. Residue on 325 Sieve	10.0%	10.0%
Pigment Suspending Agent (See below)		
Vehicle Composition:		
Alkyd Resin Solution (See Specs. below)	75.0%	72.0%
VM & P Naphtha, Fed. Spec. TT-N-95a, Type I; Driers, ASTM D-600, Cls. B; and Anti-skinning Agent	25.0%	20.0%
Mineral Spirits, ASTM D-235	---	8.0%

Pigment Suspending Agent - Either 3.9 lbs. of Bentone 34 with 95% ethanol, or 5.6 lbs. of M-P-A60 per 100 gallons shall be incorporated into the paint. Strict compliance with the additive manufacturer's processing recommendations for maximum paint storage stability shall be required.

Alkyd Resin Solution:

Type	Pure Drying Medium Oil Alkyd
Type of Oil	Soya and/or Linseed
Type of Solvent	VM & P Naphtha(TT-N-95a)
Viscosity (G-H)	Z - Z_2
Color (Gardner-Hellige, Disc 620 C-40)	8 max.
Non-Volatile Solids	49 - 51%
Oil Acids*	48% min.
Phthalic Anhydride*	33% min.
Acid Value*	4 - 10
Unsaponifiable Matter*	1% max.
Iodine Value of Extracted Fatty Acids	120 min.
Rosin and/or Rosin Derivatives	None

*Non-Volatile Basis

Properties of Finished Paint:

The paint at time of filling shall be free of skins, pigment agglomerates and foreign matter and shall meet the following requirements.

1. Fineness of grind, Hegman 2 min.
2. Consistency, Krebs-Stormer, K.U. @ 77°F 70 - 80
3. Drying Time - A wet film of the paint 15 mils thick shall dry to no-pick-up time of not more than 45 minutes when tested according to ASTM Method D 711-67.
4. Skinning - The paint shall not skin within 48 hrs. in a three quarters-filled tightly closed container.
5. Reflectance - The white paint shall have a daylight 45°, 0° luminous directional reflectance of not less than 80% compared to magnesium oxide.
6. Color - The color of the yellow paint shall visually match color chip No. 33538 of Fed. Std. 595. In case of dispute, the color shall be within the green and red tolerance limits when compared with the standard color chips of the "Standard Yellow for Highway Signs and Markings," U.S. Bureau of Public Roads, 1962.
7. Storage Stability - The paint shall show no curdling, gelling, hard caking or excessive skinning when stored up to 6 months from date of delivery. The paint shall be easily redispersed to a smooth homogeneous state.
8. Special Analysis - The Department reserves the right to utilize spectrographic or other instrumental methods to determine whether the specified ingredients were used or evidence of adulteration in the delivered traffic paint.

Manufacture - Packaging:

The type and capacity of manufacturing equipment as well as batching and filling procedures must be adequate for large gallonage production. Manufacture of paint shall not begin before written approval from the Department, and must proceed at a rate that will insure compliance with the delivery schedule listed in the bid proposal. An approved type strainer shall be in use at all times in the filling line.

The paint shall be furnished in either approved 5-gallon pails or 55-gallon drums as called for in the bidding schedule. Drums shall be standard open-head type with bolt or lever style closure band. The gasket for providing an airtight seal of drums shall be new Multi-Seal Brand gaskets or an approved equal. Reconditioned drums may be used provided they are clean, undamaged, and the head closure fits properly. The drums shall be painted with aluminum paint.

Each 5-gallon container shall bear an approved label having a background color of white or yellow according to the color of the paint and must show the following:

TRAFFIC MARKING PAINT - (Color)
COLO. DIV. of HIGHWAYS SPECIFICATION
Batch No. - - - - - Mfr. Date - - - - - -
(Manufacturer's Name)
(Quantity, gal.)

Drums shall have the same information stenciled on the head over a

background color corresponding to that of the contained traffic paint. Basis of payment shall be gallons of paint accepted and delivered in good condition. Filling shall be by weight equivalent to five gallons per pail or not less than 50 gallons per drum at 77°F.

Inspection and Tests:

The Department reserves the right to have an inspector present during manufacture of the paint. The manufacturer shall furnish every reasonable facility for sampling and testing the raw materials and finished paint.

The paint manufacturer shall furnish the Department with a copy of a certified analysis for each shipment of alkyd resin solution used. The analysis shall include percent solids, phthalic anhydride and oil acids along with viscosity and acid value. Paint made with alkyd resin found to be defective, by analysis of a sample taken of the tanker or car of resin at destination, shall be replaced without cost to the Department.

Test methods shall be according to ASTM or, if not covered therein, Federal Test Method Standard No. 141.

Preliminary Samples:

The bidder, upon request by the Department following opening of bids, shall furnish one quart each of white and yellow traffic paint formulated according to this specification. In addition, samples of alkyd resin solution, thinners, pigments, additives and driers shall be forwarded with information showing trade name, product code number and manufacturer. It is construed that the samples of raw materials shall represent those to be used in actual production of the paint following award of contract.

STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS - STATE OF COLORADO
Staff Materials Division
October 21, 1968

SPECIFICATIONS FOR REFLECTIVE GLASS BEADS
TYPE II SPECIAL GRADE

Scope:

This specification covers glass beads intended for use in reflectorizing traffic paint markings on pavement by the drop-on method.

General Requirements:

The glass beads shall be spherical in shape and transparent with smooth, lustrous surfaces. The beads as delivered shall be free from extraneous material and clumps of beads which cannot be broken up easily in the process of handling and distribution to the stripe.

Detail Requirements:

1. Imperfections - The glass beads shall not include more than twenty-five (25) percent irregularly shaped particles when tested according to ASTM Method D-1155. The beads shall be free of scratches, pits, milkiness, dark particles and excessive air bubbles.

2. Color - The glass beads shall be colorless to the extent that they do not impart a noticeable daytime hue to white pavement markings.

3. Index of Refraction - The glass of which the beads are composed shall have an index of refraction of not less than 1.50 by the immersion method using tungsten light.

4. Gradation - The glass beads shall meet the following gradation requirements when tested in accordance with Standard Method of Test for Sieve Analysis of Glass Spheres, ASTM Designation D-1214.

Sieve No.	Total Percent Passing
30	100
40	90-100
50	60-75
80	0-5

5. Floatation Test - A minimum of 95% by weight of the glass beads, determined on duplicate samples, shall float on xylol when tested as follows:

   A sample of approximately one gram ($\pm$ 0.005 g) of beads is evenly distributed into a clean standard 100 mm glass Petri dish previously tare weighed to $\pm$ 0.005 g. The dish is vibrated slightly to attain as near as possible a monolayer of beads. Xylene, C.P. Grade, is introduced at one side of the dish at a rate of 10 to 15 ml per minute from a burette until 30 ml has been added. The floating beads are then carefully drawn off by suction through a suitably constricted delivery tube connected to a receiving flask. Excess xylol is drawn off so that no remaining beads are lost and the dish dried in an oven at 110°C. The dish is weighed and the percentage of floating beads calculated.

Packaging and Marking:

1. Glass beads shall be furnished in bags containing fifty (50) pounds net.

2. The shipping bags shall be moistureproof, paper lined burlap bags conforming to specification ICC-36-C under Interstate Commerce Commission Regulation Section 78.234. Each bag shall be marked with name of contents, manufacturer of beads, net weight, lot number and "Colo. Type II."

Sample Requirement of Bidders:

A representative sample of two (2) pounds of the beads the bidder proposes to supply shall be furnished prior to the time of bid opening. The sample shall be forwarded to Division of Highways, State of Colorado, Materials Division, 4340 East Louisiana Avenue, Denver, Colorado 80222.