Technical Report Documentation Page

1. REPORT No.

646224

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

A Report on (1) The Use of Portable Photometric Equipment For the Field & Laboratory Evaluation of Reflective Signing Materials (2) The Use of Clear Coat to Restore Reflective

5. REPORT DATE

July 1967

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

Field, R.N. and R.A. Pelkey

8. PERFORMING ORGANIZATION REPORT No.

646224

9. PERFORMING ORGANIZATION NAME AND ADDRESS

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

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

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Conclusions reached are that (1) field evaluations based on reflectance is not always an accurate measure of a reflective sign's serviceability, (2) the equipment investigated (Esna Reflex Photometer) was not suitable as a portable field instrument nor as an alternate to the standard light tunnel for the control testing of reflective materials in the laboratory, and (3) clear coat can partially restore a weathered reflective sheeting sign. However, it may not be economically desirable.

17. KEYWORDS

Testing equipment, signs, reflective signs, reflectance, maintenance, coatings, meters, serviceability

18. No. OF PAGES:

52

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1966-1967/67-14.pdf

20. FILE NAME

67-14.pdf

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

A REPORT ON

(1) THE USE OF PORTABLE PHOTOMETRIC EQUIPMENT FOR THE FIELD & LABORATORY EVALUATION OF REFLECTIVE SIGNING MATERIALS.

(2) THE USE OF CLEAR COAT TO RESTORE REFLECTIVE SHEETING SIGNS.

67-14

State of California
Highway Transportation Agency
Department of Public Works
Division of Highways
Materials and Research Department

July 1967

Laboratory Project
Auth. W. O. 646224

Mr. John A. Legarra
State Highway Engineer
California Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT ON

(1) THE USE OF PORTABLE PHOTOMETRIC EQUIPMENT FOR THE FIELD AND LABORATORY EVALUATION OF REFLECTIVE SIGNING MATERIALS.

(2) THE USE OF CLEAR COAT TO RESTORE REFLECTIVE SHEETING SIGNS.

Study made by . . . . Structural Materials Section
Under general direction of . . . . E. F. Nordlin
Work supervised by . . . . R. N. Field
Report prepared by . . . . R. A. Pelkey

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

RAP/RNF:mw

ABSTRACT

REFERENCE: Field, R. N., and R. A. Pelkey, A Report on (1) The Use of Portable Photometric Equipment for the Field and Laboratory Evaluation of Reflective Signing Materials, and (2) The Use of Clear Coat to Restore Reflective Sheeting Signs", State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report No. 646224, July 1967.

ABSTRACT: The development of a reflectance meter for field use in measuring the efficiency of reflective signs and criteria for sign surface maintenance is reported. Concurrently, the effectiveness of a restorative clear coat is included. The investigation was conducted on standard 3M flat top reflective sheeting.

Conclusions reached are that (1) field evaluations based on reflectance is not always an accurate measure of a reflective sign's serviceability, (2) the equipment investigated (Esna Reflex Photometer) was not suitable as a portable field instrument nor as an alternate to the standard light tunnel for the control testing of reflective materials in the laboratory, and (3) clear coat can partially restore a weathered reflective sheeting sign. However, it may not be economically desirable.

KEY WORDS: Testing equipment, signs, reflective signs, reflectance, maintenance, coatings, meters, serviceability.

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I. BACKGROUND AND INTRODUCTION

A Laboratory Project Authorization for "The Development of a Reflectance Meter to Evaluate Glass Bead Type Signs in the Field" was requested in a memo from Mr. J. E. Barton to Mr. J. L. Beaton dated July 1960. The project proposed the development of a portable reflectance meter capable of producing test results in the field comparable to those obtained in the laboratory. Following an initial investigation by the Electrical and Electronics Subsection, an Esna Reflex Photometer was purchased and correlation studies were conducted on reflector button reflectance. Reflectance measurements obtained with the Esna photometer and with the standard light tunnel equipment (Test Method No. Calif. 602-C, Exhibit 1) were compared. No correlation was established between the two test procedures.

In January 1964 the project was assigned to the Commodities and Signing Unit for further study. Research was conducted on the possibility of adapting the Esna equipment for measuring the reflectance of both unweathered and weathered reflective sheeting. Reflectance measurements obtained with the Esna photometer and with the standard light tunnel equipment (Test Method No. Calif. 642-A, Exhibit 2) were compared. No correlation was established on weathered reflective sheeting samples. However, correlation on unweathered silver and yellow reflective sheeting was possible.

In February 1965 additional funds were obtained to extend the investigation to cover screened colors on reflective sheeting, clear coating of reflective sheeting, and further study on reflector buttons. Following an extensive study, it was determined that the Esna equipment was not suitable for use as a field test instrument or as a bench test instrument for the control testing of reflective sheeting.

With the advent of the new prismatic reflective pavement markers, the decision was made to modify the Esno photometer to permit its use as a bench test instrument in the control testing of this product. Specifications written for the control testing of these markers require a specific intensity reading at a 1/5 degree divergence angle (representing a viewing distance of 500 feet on the highway) and at 0 and 20 degree incidence angle. To achieve the 20 degree incidence angle, it was necessary to modify the sample platform to enable it to pivot 20 degrees right and left. This required a slot in the tube of the Esna for clearance at the 20 degree left position. With these modifications, it appears the Esna equipment will be of practical use in this capacity.

We were subsequently informed by the Elastic Stop Nut Corp., Stimsonite Division, that a new and improved version of the Esna photometer for use in the field evaluation of reflective sheeting had been developed. It was therefore felt that further investigation by the Materials and Research Department into the development of an instrument for this purpose was not warranted. Future investigation into the capabilities of the new Esna photometer and further study of clear-coating may be justified when definite conclusions can be reached regarding the weathering characteristics of the new 3M type "Z" Scotchlite and other newly developed reflective signing materials.

II. OBJECTIVES

The primary objectives of this investigation were as follows:

1. To investigate the value of developing a portable instrument for measuring the reflectance of in-service reflective sheeting signs in the field.

2. To evaluate the use of a reflex photometer as an alternate laboratory method for control testing of reflector buttons.

3. To investigate the effectiveness of clear coating in restoring the reflectance of weathered reflective sheeting.

4. To evaluate the weathering characteristics of reflective sheeting and the feasibility of establishing a reflectance control point for the application of clear coat.

III. CONCLUSIONS

The following conclusions are based on an analysis of the results of 345 separate readings on 65 different samples of reflective sheeting in field and laboratory investigations:

1. The modified Esna photometer evaluated in this study proved to be of questionable value as a portable instrument for measuring the reflectance of in-service reflective sheeting signs. This instrument was found to be unwieldy and awkward to operate when making measurements on the 7 ft. high ground mounted signs.

2. When testing reflector buttons or reflective sheeting for compliance with the existing specifications, the Esna photometer evaluated in this study was not as suitable as the standard light tunnel photometer. With a few exceptions specifications could not be established for the laboratory use of the Esna photometer because a satisfactory correlation of reflectance readings between the light tunnel and the Esna photometer could not be obtained. However, with minor modifications the Esna photometer has been found to be of value as a routine test instrument for reflective prismatic pavement markers.

3. All current reflective sheeting signs are manufactured using 3M type "Z" reflective sheeting. An evaluation as to the effectiveness of clear coating in restoring reflectance to the type "Z" reflective sheeting could not be made at this date as we have had less than four years' exposure experience with this material, and it has not yet shown any signs of deterioration. When these signs show some deterioration from weathering, the economic value of clear coating should be determined.

   Laboratory reflectance tests indicate that reflective sheeting signs produced prior to 1963 (not 3M type "Z" material) can be partially restored by an application of clear-coat, provided the coating is applied properly and the surface has not deteriorated excessively. However, clear-coating may not be economically desirable.

4. Because the reflectance of a weathered reflective sheeting sign is dependent upon many factors such as type, severity and extent of surface deterioration and color, a control point for clear coat application could not be determined.

IV. INTRODUCTION TO REFLECTIVE SHEETING

On today's modern highways, vehicular guidance and driver information are of prime importance in the safe and orderly movement of traffic. Highway signs in the warning and regulatory series should provide the motorist with clear messages, distinctive shapes, and a logical color system. On the national average, one third of all traffic moves during the hours of darkness; therefore, nighttime visibility is of prime importance. Flat-top reflective sheeting is the only reflective material which presently meets these prerequisites, both by day and by night, and under most weather conditions.

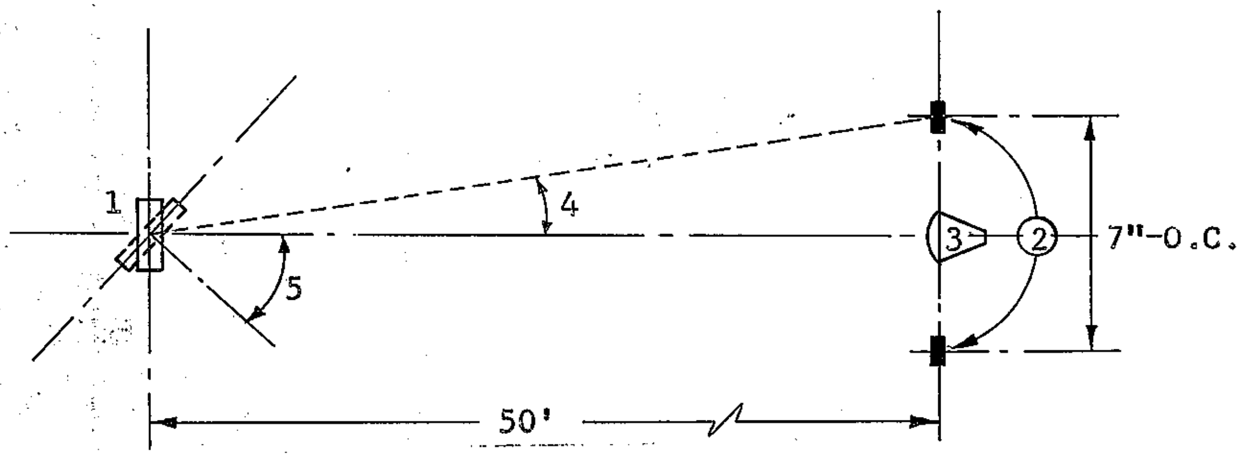
This material is a reflective lens system consisting of spherical lens elements of micron size partially embedded in a binder film on a pre-coated adhesive backing and encased by an outer transluscent resin space coat having a refractive index compatible to that of the encased beads. Due to the spherical shape of the beads, the entrance and exit angle of the light is limited only by the depth of bead encapsulation which produces a wide angle reflex material. The color in the system is attained by pigmenting the space coat. This space coat is smooth, with a flat outer surface which minimizes the adherence of surface dirt and also is hydrophyllic. The space coat permits light to enter and be reflected, by the encased beads, back to its source.

However, with time and exposure the space coat deteriorates to such a degree that reflected light cannot return through it to the source. Because of this deficiency, the manufacturer recommends that, after a period of time as deterioration develops, the surface be coated with clear finish to (1) assist in restoring nighttime reflectance to an acceptable level, (2) to improve the daytime appearance, and (3) to extend the service life of the sign.

"Scotchlite", a proprietary material produced by the 3M Corp., is the only reflective sheeting manufactured that currently meets California Division of Highways specifications. Therefore, all research conducted on reflective sheeting for this study was with the 3M material.

The nighttime visibility of a reflective material when viewed at any distance depends on the reflectance at the divergence angle formed at that distance. For reflective sheeting, performance is measured in terms of specific brightness, which is a measure of reflected light at a specific incidence and divergence angle per unit area of reflective surface for each foot candle of illumination incident on the reflective surface. This is expressed as candlepower per foot candle per square foot ($cp/fc/ft^2$).

On the average passenger vehicle, the vertical distance between the headlights and the driver's eye is 1.746 feet[5]. As the vehicle approaches a reflective sign, a constantly changing angle is formed between a line from the vehicle headlights to the reflective material and back to the driver's eyes. This angle, termed the "divergence angle", is inversely proportional to the distance between the vehicle and the reflective material and is equal to the angle whose tangent is 1.746 divided by this distance. For example, at a distance of 300 feet the divergence angle is approximately 1/3°. Because of the physical limitations of the light tunnel test equipment, this 1/3° divergence angle is obtained at a 50 foot distance by proportionally reducing the vertical distance between the light source (vehicle headlights) and the photocell receptors (driver's eye) from 1.746 feet to 0.291 feet (Figure 1). This test parameter is specified in Test Method No. Calif. 642-A.



1. Reflective Sheeting Sample
2. Photocell Receptors
3. Light Source
4. Divergence Angle (angle formed by a ray from the light source to the reflector and the ray from the reflector to the receptor).
5. Incidence Angle (angle formed by a ray from the light source to the reflector and the normal to the reflector surface).

FIGURE 1 - LIGHT TUNNEL GEOMETRY

All reflectance measurements on reflective sheeting recorded for this investigation were taken at an incidence angle of 0 degrees. Because of the reduced area of the Esna photometer test specimen size (19 sq. in.) as compared to the light tunnel specimen size (64 sq. in.) reflectance measurements taken with the Esna photometer at other incidence angles were not of sufficient intensity to accurately measure.

Minimum specific brightness values at the 0° incidence angle as specified in the current California Division of Highways Specifications for Reflective Sheeting are listed in Table I below:

Table I

Minimum Specific Brightness Values for Reflective Sheeting

Sheeting Color	Specific Brightness CP/FC/Ft.^{2}
Silver	54.0
Yellow	20.0
Red	8.2
Blue	4.2
Green	3.4

V. REFLECTIVE SHEETING INVESTIGATION AND TESTS

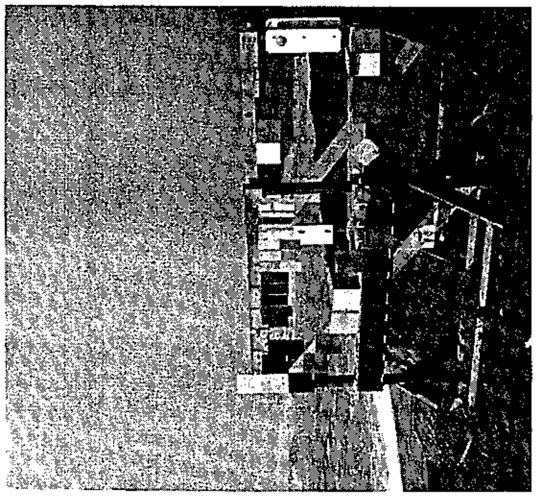
The samples of reflective sheeting used in this investigation were selected from (1) unweathered laboratory control samples, (2) weathered samples with up to seven years of test rack exposure at five locations (Cambria, Fortuna, Truckee, Sacramento, and Palm Springs), and (3) surveys of in-service signs in the Sacramento-Elk Grove-Roseville area (Figure 2).

A preliminary comparison check was made of the color temperature characteristics of the Esna tungsten-carbide filament lamp and the sealed beam lamp used in the light tunnel. There was no significant difference in reflectance level readings due to the difference in color temperature of the two types of filaments.

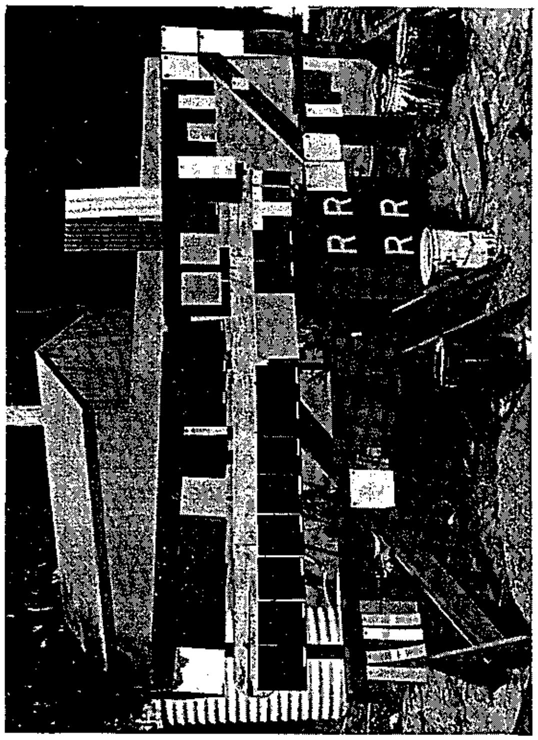
The next step in the investigation was an attempt to establish a correlation of reflectance readings between the Esna photometer and the light tunnel photometer.

After many comparative readings in the laboratory, both with the Esna equipment and the light tunnel photometer, an average ratio of specific brightness between the two systems was developed for unweathered silver and yellow samples of the older flat-top type reflective sheeting. This specific brightness ratio also appeared to be the same for unweathered samples of the newer "Z" type reflective sheeting. Efforts were concentrated mainly on silver and yellow sheeting because the greater majority of our highway signs are made up of these two colors with other colors screened on for legend or background delineation.

Ratios of specific brightness reflectance readings between the light tunnel photometer and the Esna photometer on unweathered samples of yellow and silver reflective sheeting are listed in Table II on page 10.



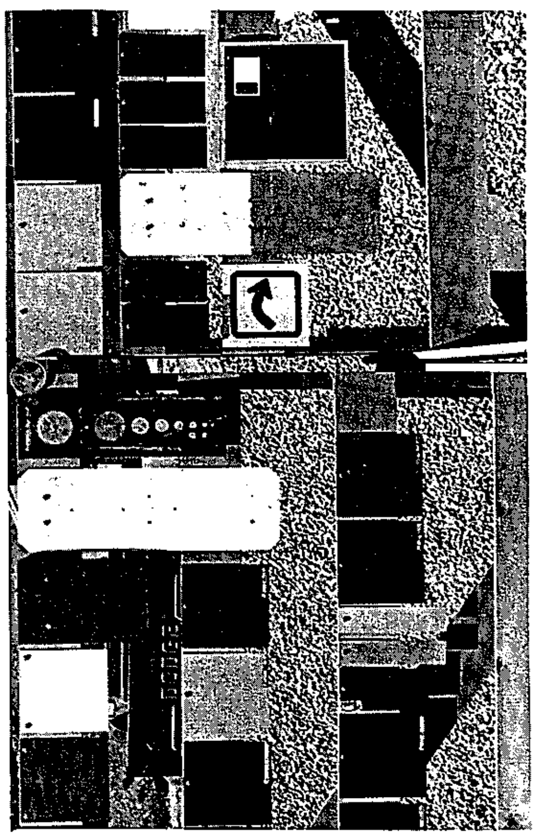
Cambria



Palm Springs

Fortuna

Sacramento



Truckee

FIGURE 2

Table II

Typical Specific Brightness Readings

Color and Sample	Esna SB	Light Tunnel SB		Ratio-Esna/Lt. Tunnel
Silver #1	54.0	81.0		0.67
Silver #2	50.0	77.4		0.65
Silver #3	61.2	90.0		0.68
Silver #4	53.2	84.5		0.63
Silver #5	50.0	75.7		0.65
Silver #6	59.0	84.5		0.70
			Average	0.67
Yellow #1	47.1	45.8		1.03
Yellow #2	40.1	42.2		0.95
Yellow #3	41.8	38.7		1.08
Yellow #4	39.4	42.2		0.93
Yellow #5	45.6	44.0		1.01
Yellow #6	42.4	44.0		0.96
			Average	1.00

SB - Specific Brightness

Additional reflectance measurements obtained with the Esna photometer and the light tunnel photometer on red, blue, and green reflective sheeting were compared. From these comparisons it was possible to establish a correlation ratio for the particular samples tested. Average specific brightness reading obtained by both methods on all colors of unweathered reflective sheeting and the ratios derived are contained in Table III below:

Table III

Average Specific Brightness Readings

Reflective Sheeting Color	Specific Brightness Esna	Specific Brightness Light Tunnel	Ratio Esna/Lt. Tunnel
Silver	54.09	84.33	0.64
Yellow	42.77	42.53	0.94
Green	8.42	13.20	0.64
Blue	6.22	7.00	0.89
Red	37.00	7.90	4.7

With these ratios for unweathered material, it was possible to establish specification values for the Esna photometer in relation to the standard Division of Highways specifications which are based on light tunnel photometric readings. The readings were made at a zero degree incidence angle only. (This is the only angle at which readings can be accurately measured on reflective sheeting with the standard Esna equipment.) Control specifications established for the Esna photometer as the minimum acceptable specific brightness reading for each color reflective sheeting are shown in Table IV below:

Table IV

Minimum Specific Brightness Values

Color	Specific Brightness Div. of Hwys. Specs.	Ratio Esna/Lt. Tunnel	Calculated Specific Brightness Esna Specs.
Silver	54.0	0.64	35.0
Yellow	20.0	0.94	19.0
Green	3.4	0.64	2.2
Blue	4.2	0.89	3.7
Red	8.2	4.7	39.0

It was noted when calculating the specific brightness readings that the ratios derived were reasonably close to 1.0 for all colors except red (see Table III). As color correction by means of a filter is required with the Esna photometer when testing colored acrylic reflector buttons, it appears that this requirement also holds true when testing colored reflective sheeting. The photometer manufacturer's specifications establish the filter thickness at twice the thickness of the acrylic lens element being tested. However, signing manufacturers using reflective sheeting apply their own pigmentation formula and thickness of screening paste to obtain the screened-on colors required. The thickness and shade would thus be difficult to establish.

When making readings with the Esna photometer, the extreme sensitivity of the photocell to red produces particularly erroneous results when comparing the many different shades, formulations, and thicknesses of screened red reflective sheeting that are normally produced by the various sign manufacturers. Furthermore, as weathering causes indeterminant changes in the color, shade, and thickness of the screened coating, readings on a weathered surface could not be correlated with those obtained when the material was new. The effect weathering had on the correlation of readings became more apparent as the investigation progressed. However, at this point in the investigation it already appeared that consistent accurate brightness readings on colored reflective sheeting were not possible with the Esna photometer unless accurately colored and dimensioned corrective lenses could be developed and employed. This did not appear practical for reflective sheeting material.

In attempting to apply the calculated Esna specification established for unweathered reflective sheeting (Table IV) to weathered material, it was found that the Esna equipment and the light tunnel did not record specific brightness readings of weathered material in any consistent ratio. The ratios between Esna readings and light tunnel readings tended to vary considerably depending on the severity and type of weathering of the material. No correlation between the two methods was obtained for weathered samples. There was no consistency in the specific brightness deterioration recorded on the Esna photometer as compared to light tunnel measurements on the same samples. It was concluded that added variances of color, shade, thickness, etc. in weathered reflective sheeting samples made the lack of an accurate filter lens for the Esna unit even more critical than for unweathered material. It should be noted here that the light tunnel photometer photocells are color corrected and measurements obtained with this equipment are reasonably close to the color sensitivity of the human eye.

The weathered samples used in this phase of the investigation were obtained from the Materials and Research Department statewide exposure racks. A description of these weathered samples varies from glossy to etched, and from smooth to crazed. Reflectance readings were made on the weathered samples before and after clear-coating with both the Esna photometer and in the light tunnel. Reflectance readings on weathered silver reflective sheeting illustrating the variance in the ratios obtained are contained in Table V below. The material is listed in order of the severity of the weathering for ease of comparison.

Table V

Weathered Silver Reflective Sheeting

Sample		Condition	Specific Brightness Esna	Specific Brightness Lt. Tunnel	Ratio Esna/Lt. Tunnel
2003	UC	Good - No Craze	36.1	52.8	0.68
	CC	" " "	32.2	42.2	0.76
2022	UC	Good - Slight Craze	35.6	51.1	0.70
	CC	" " "	30.1	37.0	0.81
2011	UC	Fair, Light Craze	31.8	38.7	0.82
	CC	" " "	27.6	31.7	0.87
2020	UC	Poor, Moderate Craze	27.0	38.7	0.70
	CC	" " "	25.5	31.7	0.80
2003	UC	Poor, Heavy Craze	20.0	24.6	0.81
	CC	" " "	27.6	33.4	0.83
2008	UC	Bad, Crackle Finish	4.8	7.0	0.69
	CC	" " "	11.7	14.1	0.83
2016	UC	Bad, Crackle Finish	4.5	7.0	0.64
	CC	" " "	9.7	12.1	0.80
2009	UC	Bad, Heavily Etched	3.1	3.5	0.88
	CC	" " "	17.2	17.6	0.98
2018	UC	Bad, Heavily Etched	2.8	3.5	0.80
	CC	" " "	16.6	17.2	0.96

UC - Uncoated weathered sample. CC - Weathered sample after clear-coating.

The reflectance reading ratios obtained from the uncoated samples as shown in Table V range from a low of 0.64 to a high of 0.88, with an average of 0.75. On the clear coated samples, the range is from a low of 0.76 to a high of 0.98, with an average of 0.85. Neither average approaches the 0.64 average shown in Table III for unweathered silver sheeting.

It should be noted that the ratios do not consistently vary as the severity of deterioration due to weathering increases nor is there any clear correlation of the ratios between the uncoated and the clear-coated portions of the same sample, except that the ratio is always lower for the uncoated portion. Due to this variance in ratios, any specifications developed for use with the Esna photometer would have to provide values for both uncoated and clear-coated material. Additional consideration would have to be given to these values dependent on color and severity of weathering. It is obvious that an objective rating of the performance of a weathered sign with the Esna photometer would be impossible.

The decision as to when a sign should be clear coated based on length of exposure only is subjective due to the variable weather conditions that prevail throughout the state. This weathering factor varies considerably, dependent on the geographical location and directional exposure of the sign. In an attempt to establish specifications for clear-coating, reflective readings were taken on weathered samples in the uncoated condition following the standard method for control testing reflective sheeting (Test Method No. Calif. 642-A). Portions of each sample were then clear-coated and reflectance readings were taken on the clear-coated portion. Figure 3-a shows samples of weathered material with the top end of each panel clear-coated. Figure 3-b shows a weathered sample under reflected light. The right half of this sample was clear-coated.

The effect of clear-coating on the specific brightness of weathered material is illustrated in Table VI on page 15.

Clear coating can either increase or decrease the reflectance of a weathered sign panel, depending on the surface condition. Where there was little or no gloss apparent, reflectance was generally increased by clear-coating. If any gloss exists, clear-coating generally reduced the reflectance. As shown in the readings in Tables V and VI, the reflectance of slightly weathered reflective sheeting is reduced after clear-coating whereas the reflectance of more severely weathered material is increased.

It was observed that surface blemishes and cracking such as found on heavily crazed signs are accentuated when viewed under reflected light. Clear coating would be of little value in these cases as the day and particularly the night appearance would not be considered acceptable. If the surface is only lightly crazed, the greater increase in reflectance produced by clear-coating then minimizes the blemishes. This is illustrated in Figure 4 in which two weathered reflective sheeting signs are compared under reflected light and normal daylight. Figure 4-a is a sign heavily crazed after 5 years' south exposure and Figure 4-b is a sign moderately

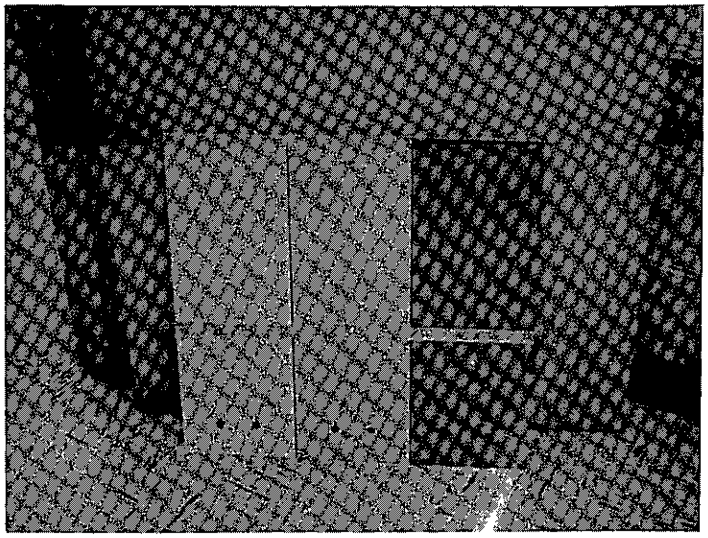


Fig. 3-a

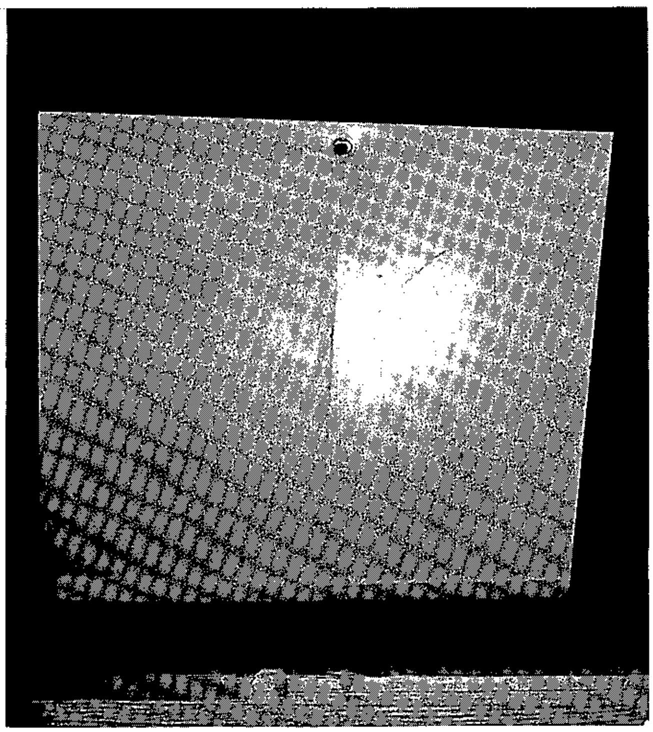


Fig. 3-b

FIGURE 3

crazed after 5 years' north exposure. It was concluded that crazing is a surface deterioration that accompanies the general weathering of the sheeting, and in itself has little effect on the reflective ability of the sign until it reaches extensive proportions. However, on a heavily crazed sign, the daytime and nighttime appearance can become objectionable before the reflectance is reduced to an unacceptable level and the sign should be replaced. On the moderately crazed samples observed in this investigation, the reflectance and daylight appearance were improved by clear-coating.

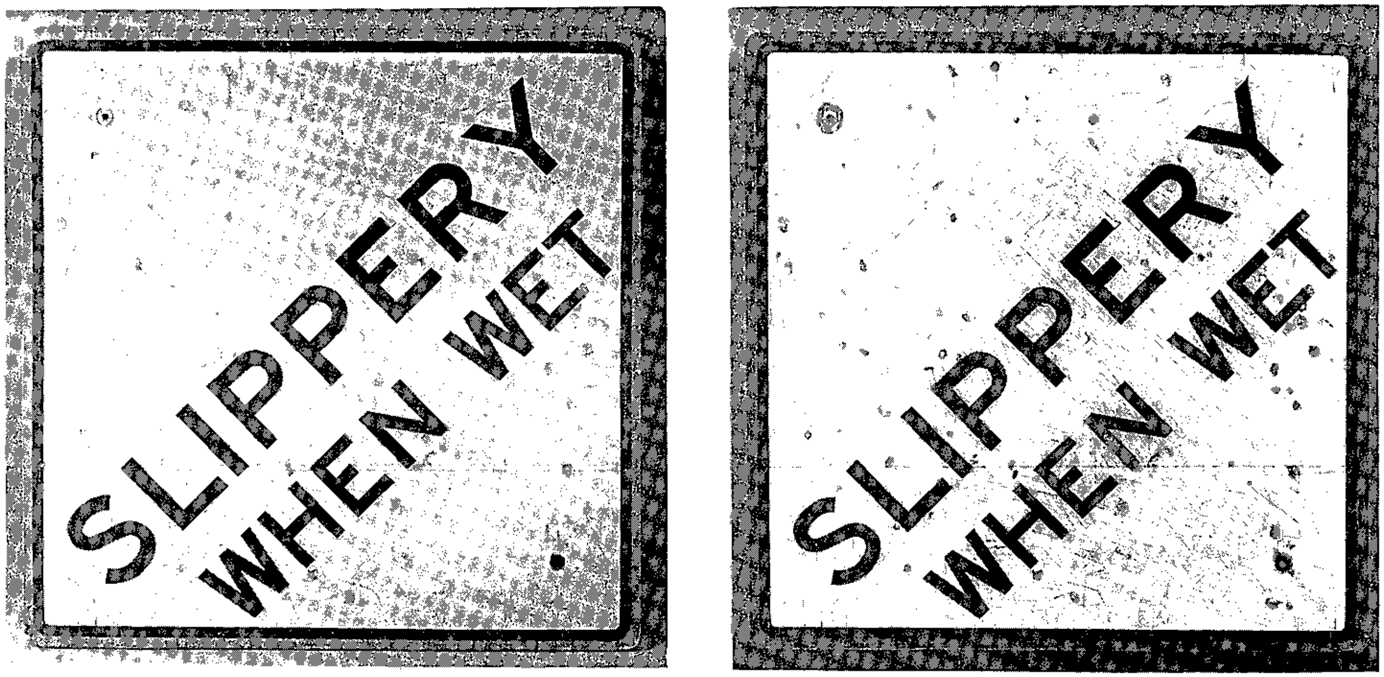
Examples of surface deterioration with no evidence of crazing were noted on etched signs found in areas of windblown sand. Two severely etched panels of silver reflective sheeting removed from the Palm Springs sign rack after 5½ years of exposure were completely free from craze and had a good daytime appearance. However, the specific brightness was only 3.5 cp/fc/ft^2. An application of clear-coat, 1.5 mils in thickness, increased the specific brightness to 17.6 cp/fc/ft^2.

Table VI

Effect of Clear-Coating on Specific Brightness

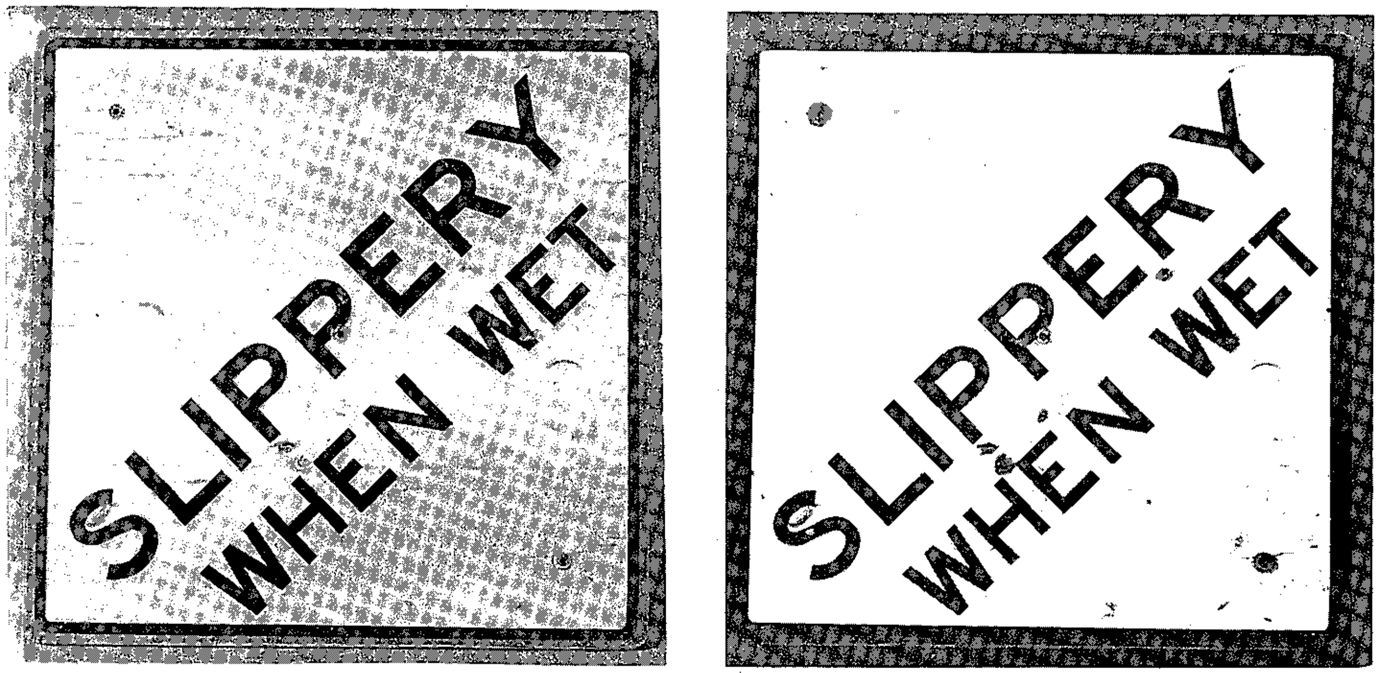
Location and Exposure	Surface Condition	Specific Brightness Uncoated	Specific Brightness Clear Coated
Palm Springs			
Silver #2009 South	Sandblasted and etched	3.5	17.6
#2018 South	Sandblasted and etched	3.3	17.1
Sacramento			
Silver #2062 South	Fair	29.7	35.9
#2008 South	Bad, crazed	7.0	14.7
#2016 South	Bad, crazed	7.0	14.1
Yellow #1301D South	Bad, crackled	1.6	21.7
Fortuna			
Silver #2011 South	Good, no craze	52.8	42.2
#2002 South	Good, slight craze	51.1	37.0
#2022 South	Fair, light craze	38.7	31.7
Yellow #2000 North	Good, slight craze	18.7	14.4
Cambria			
Silver #2020 South	Fair, mod. craze	38.7	31.4
#2003 South	Poor, heavy craze	24.6	33.4
Control Samples			
Silver 63-8 S2 & S3	Unweathered	84.0	81.0
Yellow 63-8 Y2 & Y3	Unweathered	34.3	32.6
Green 63-8 G2 & G3	Unweathered	14.0	12.3
Blue 63-8 B2 & B3	Unweathered	7.9	7.0

Signs which require a background color other than silver or yellow, such as guide signs (blue and green route shields) and some regulatory signs (red stop signs and wrong-way signs) are generally



Daylight　　　　Reflected Light

Fig. 4-a　　South Facing



Daylight　　　　Reflected Light

Fig. 4-b　North Facing

FIGURE 4

fabricated by the reverse silk screen process. This is accomplished by using silver sheeting as the base color for the legend and reverse screening the background on with translucent pigmented screening paste. This produces the desired background color and delineates the silver message. The characteristics of this screening paste are similar to that of the old clear-coated silver Scotchlite (pre- "Z" type) in that it is affected by weathering to the same degree and responds to clear-coat in the same manner.

In Figure 5, a reverse screened blue interstate shield is shown under reflected light. The right half of this slightly weathered sign has been clear coated, and although the color is rejuvenated, the reflectance has been reduced.

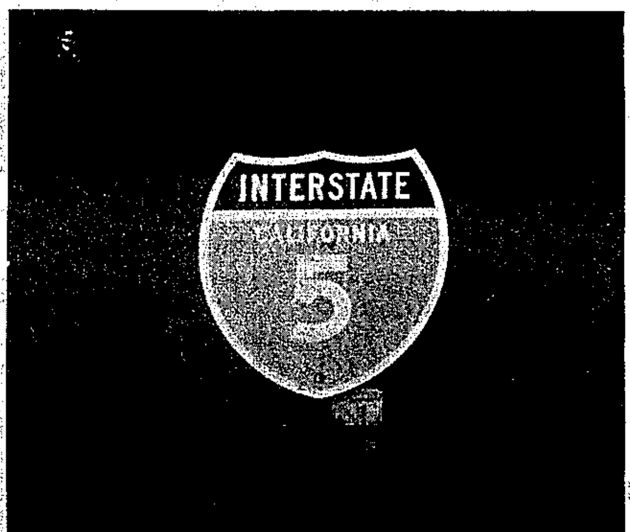


FIGURE 5

One factor often overlooked in evaluating the condition of a reflective sheeting sign is that the surface does not necessarily deteriorate in an even, over-all pattern. In many cases a sign will have an acceptable over-all daylight appearance, with only small moderately crazed areas where the surface has started to deteriorate. However, under nighttime reflectance these crazed areas usually appear dull, and in the presence of dew are completely nonreflective, presenting an objectionable, mottled appearance. If a sign in this condition were to be clear-coated, it is possible that while the crazed portions could be restored to an adequate nighttime reflectance, the reflectance of the "good" glossy portion would be reduced. "Spot" clear-coating is not recommended as it is too time consuming and generally results in a poor, splotchy appearing sign. "Spot" deterioration is illustrated in Table VII on the following page.

Table VII

"Spot" Deterioration

Sign and Color	Condition and Exposure	Specific Brightness Readings Area #1	Area #2	Area #3	Area #4
Stop - Red	3 years - surface good bad cracks	24.5	23.2	24.5	22.2
Stop - Red	4 years - surface crazed severe to slight	25.9	27.5	20.8	14.9
Int. Shield Blue	Very slight craze	8.9	8.3	7.5	7.2
Int. Shield Blue	Heavy craze	4.4	4.4	3.9	3.3
Int. Shield Blue	No craze	8.9	8.9	9.5	9.7
Int. Shield Blue	Surface streaked	4.7	5.9	4.0	3.9

The clear-coating resin often weathers in an irregular manner, producing a mottled appearing sign. In many instances this type of deterioration is more objectionable than the crazing which might have occurred in a nonclear-coated sign. Figure 6 illustrates the effect of clear-coat weathering on reverse screened blue (Figure 6-a) and on silver sheeting (Figure 6-b) under daylight conditions.

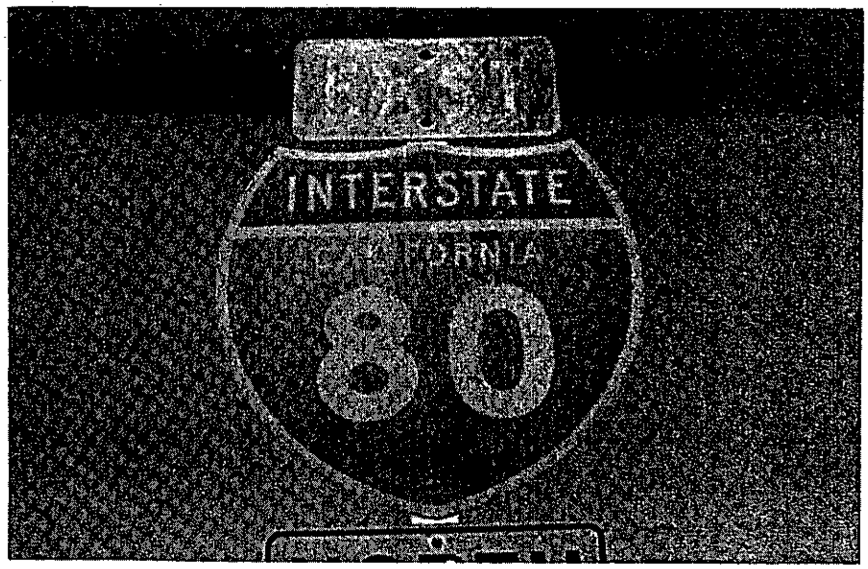


Fig. 6-a

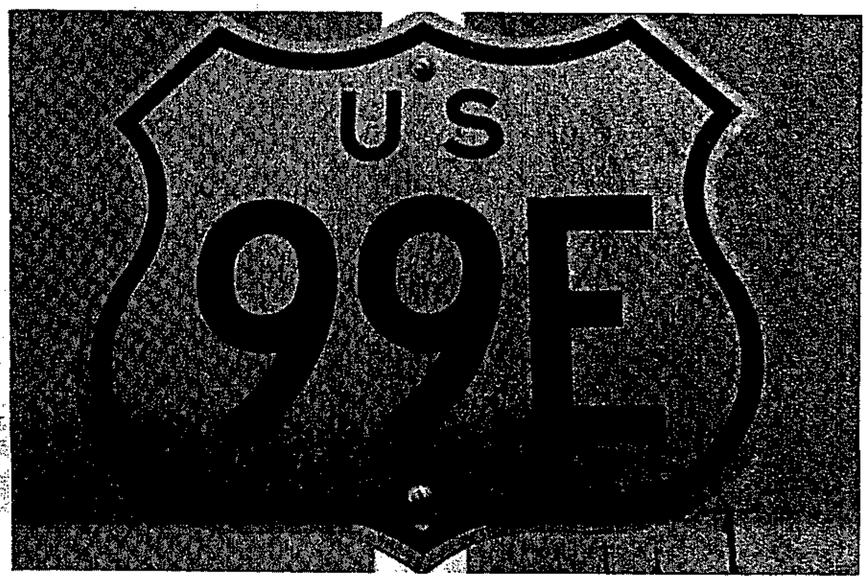


Fig. 6-b

FIGURE 6

VI. CLEAR-COAT APPLICATION ON REFLECTIVE SHEETING

Successful field clear-coating is dependent upon many controlling factors. Sign location and accessibility are of primary importance. In some cases it may be more advantageous to remove the sign to the shop for clear-coating. The superior coating obtainable with shop application over field application tends to make this the more practical method even though it is more costly.

Prior to clear coating, the sign must be clean of all dirt, road film, etc. A reflective sheeting sign should never be wiped clean with a dry cloth as the abrasive action of the dirt particles can scratch the relatively soft plastic surface. Tar, oil, diesel smut, and bituminous materials should be removed with kerosene or mineral spirits prior to washing. No aromatic hydrocarbons such as acetone should be used in cleaning a reflective sheeting surface.

Washing should be done with a soft brush or cloth, a mild detergent and cool water followed by a clear water rinse. Washing or clear-coating should never be performed during extremely warm weather. The face of a sign exposed to the sun may reach temperatures in excess of 150 degrees, and moisture penetration from washing with the resulting high vapor pressures from evaporation can severely blister the reflective sheeting film and loosen it from the adhesive.

Clear-coat applied on a hot surface sets up too rapidly, and the desired flow-out necessary for a smooth, evenly distributed coating cannot be obtained. Clear-coat should be applied in an even, wet, glossy coat, as heavy as possible without causing sag. Spraying is the most satisfactory method of application in the shop. Field spraying of clear-coat has not been found to be satisfactory due to the difficulty in obtaining uniform coverage and film thickness without runs on the vertical sign face, particularly when windy. Application by brush is unsatisfactory because of the inability for other than an experienced workman to obtain a uniform film thickness. In addition, the brush strokes and overlaps existing in brush applied clear-coat are visible under reflected light. Application by roller has been found to be a relatively satisfactory method in obtaining uniform coverage and film of the desired thickness without runs or sags.

It is extremely difficult in field clear-coating, regardless of the application method employed, to obtain uniform coverage without "holidays" in the clear-coat. These "holidays" show up as dull areas under reflected light and, as the sign weathers, also become more apparent in daylight. Uneven film thickness also produces a splotchy sign appearance under reflected light as weathering progresses. Areas of thin coatings generally craze and weather to a greater degree than those areas where the clear-coat was applied in a thick coating.

Figure 7 shows a south exposed reflective sheeting sign on Interstate 80. Figure 7-a shows the poor daytime appearance. Note the difference between the small center panel and the larger outer panels. The center panel had a thick, roller applied clear-coating while the outer panels had a thinner, sprayed-on coating. Figure 7-b shows the same sign under reflected light. Note the holidays in the clear-coating. Those areas which missed being coated and areas of varying coating thickness give the sign a mottled, textured appearance.

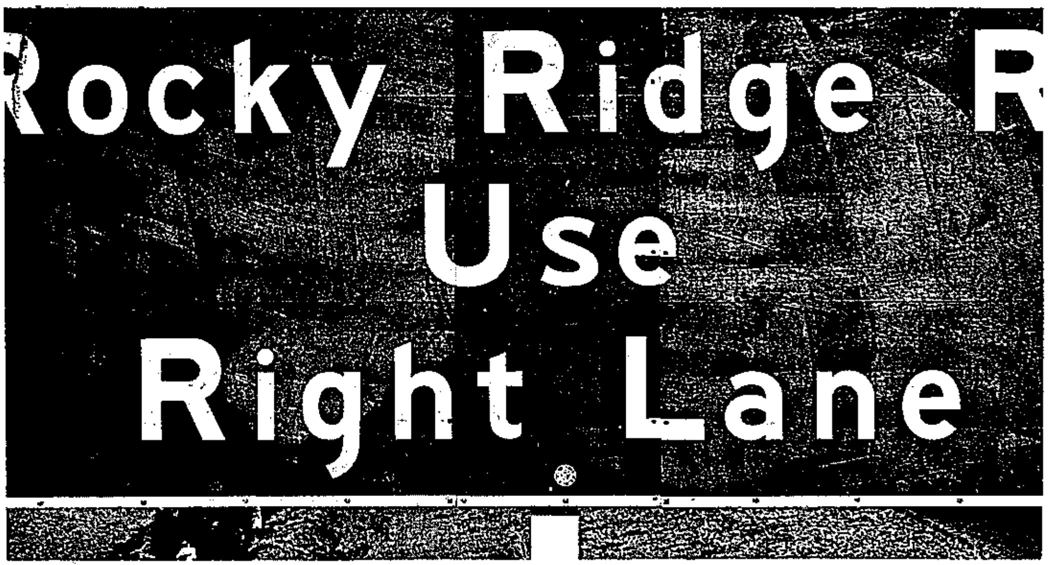


FIGURE 7-a

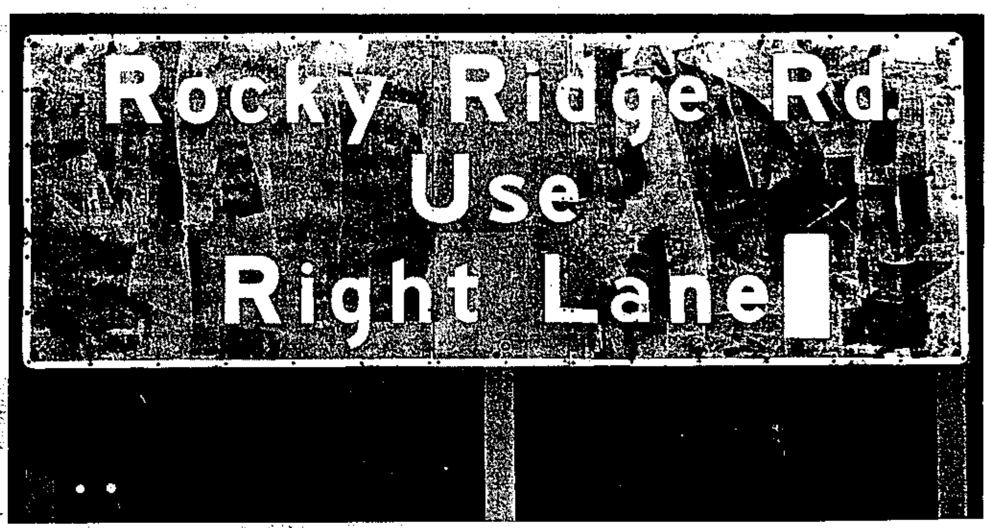


FIGURE 7-b

FIGURE 7

VII. ECONOMICS OF CLEAR-COATING

In addition to the fact that determining when to clear-coat is subjective and that clear-coating is sometimes of questionable value, the problem of economics must be considered. Older signs produced and erected prior to 1963 are at or nearing the clear-coating stage. Should a program of clear-coating the newer "Z" type signs be initiated as they approach failure (as recommended by the sheeting manufacturer), considerable weight must be given to the economics involved as this would be an extensive undertaking.

Field experience has indicated that clear-coating can extend the service life of a south facing sign 1 - 2 years and a north facing sign 2 - 3 years. On this basis, it appears that the cost per square foot per year for clear-coating a south facing sign is slightly in excess of the replacement/erection cost for a new sign; and the cost per square foot per year for clear-coating a north facing sign is almost 3/4 the replacement/erection cost of a new sign. If these figures are found to be applicable to all reflective sheeting signs ("Z" type as well as the older type reflective sheeting), serious consideration must be given to the over-all effectiveness and advisability of clear-coating.

It should be mentioned, however, that the life expectancy of new "Z" type reflective sheeting signs has not yet been established, and the effectiveness of clear-coat in extending the service life of these signs may be greater than for the older type reflective sheeting.

[illegible]

VIII. REFLECTOR BUTTON THEORY AND TESTING

The reflector button, used for improved nighttime visibility of highway delineators and for legend delineation, is a compound prismatic lens system of the corner-cube type (Figures 8-a, 8-b). It possesses the ability to accept light and reflect it back to the emanating source in a limited cone, the axis of which is a line between the source and the reflector. The lens consists of a piece of homogeneous transparent acrylic plastic bounded by a spherical surface on one side and a seal on the back to exclude moisture and soils. The spherical front surface is designed to return the light in a slightly diverging beam and can be pigmented to any desired color. The inner surface of the spherical face is composed of sets of cube corners formed of three plane faces meeting mutually perpendicular to form part of the surface of a cube. The long diagonal that passes through the intersection of these faces is approximately perpendicular to the front surface (Figures 8-c, 8-d).

This system operates on the principal of total internal reflectance. In a corner-cube reflector, a ray of light enters through the front surface, is totally internally reflected once at each of the three internally perpendicular faces of one corner cube, and leaves the front surface approximately in a line parallel to the incident ray. Generally, the cube corners of a commercial reflector button are less than perfect[1]. Therefore, there is a loss of reflectance through some of the light being scattered, reflected in a blur and disbursed into wide angles outside the cone of reflectance. Occasionally a cube corner of more exact form is retained through the manufacturing process which results in a greater amount of light being reflected than the over-all average. This is referred to as a "sport" by the industry.

Two conditions must be satisfied in order that a ray of light be usefully reflected. First its direction must be such that it will satisfy the condition for total internal reflectance at each of the three faces, and second it must meet every one of these faces. Rays that strike the reflector at certain angles will not be reflected because total internal reflection fails. Normally this occurs only at incidence angles greater than 20 degrees[1]. For this reason reflector buttons are efficient only at incidence angles less than 20° in contrast to reflective sheeting which is efficient at incidence angles up to 40°.

The California Division of Highways measures the performance of reflector buttons in terms of percent reflectance. This is a simple ratio of reflected light to incident light. However, for ease of comparison in this investigation reflectance was measured as specific intensity which is expressed in terms of candle power per foot candle (cp/fc).

As with reflective sheeting, the physical limitations of the light tunnel test equipment prohibit the testing of reflector buttons at actual highway viewing distances. However, because of their greater efficiency, reflector buttons are tested at 100 feet

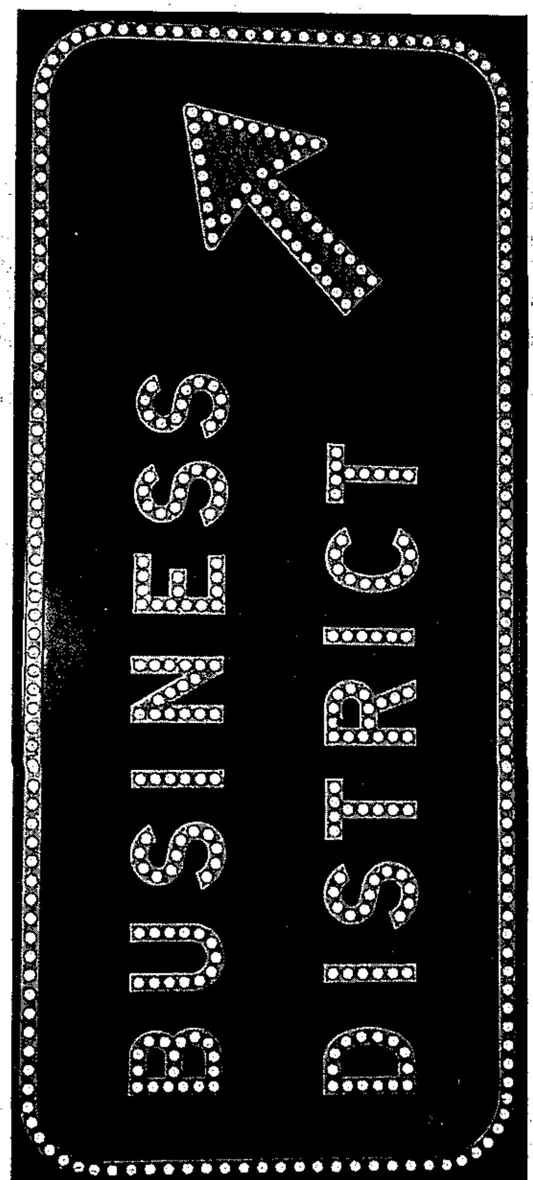


Fig. 8-a

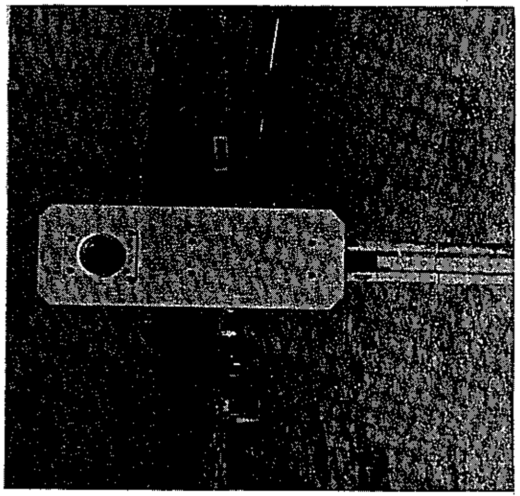


Fig. 8-b

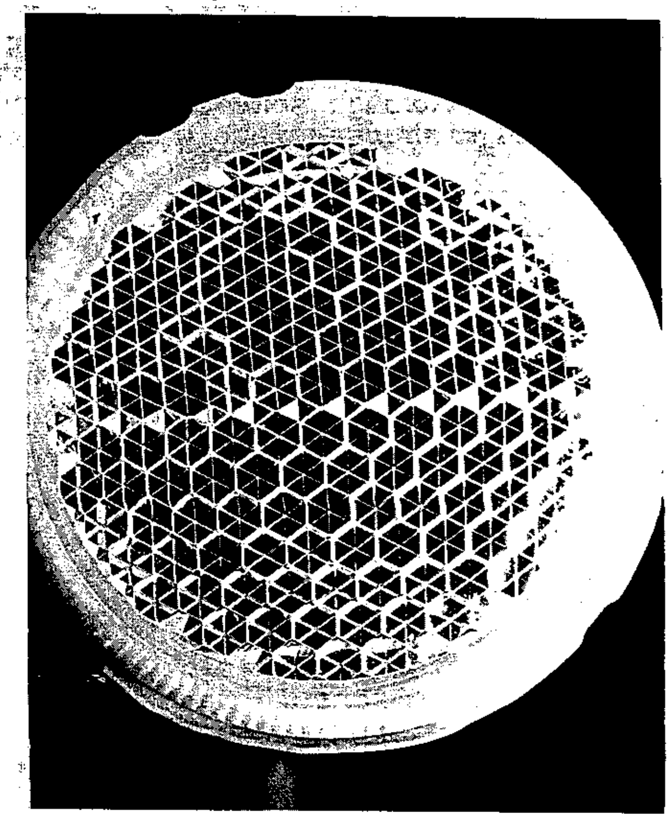


Fig. 8-c

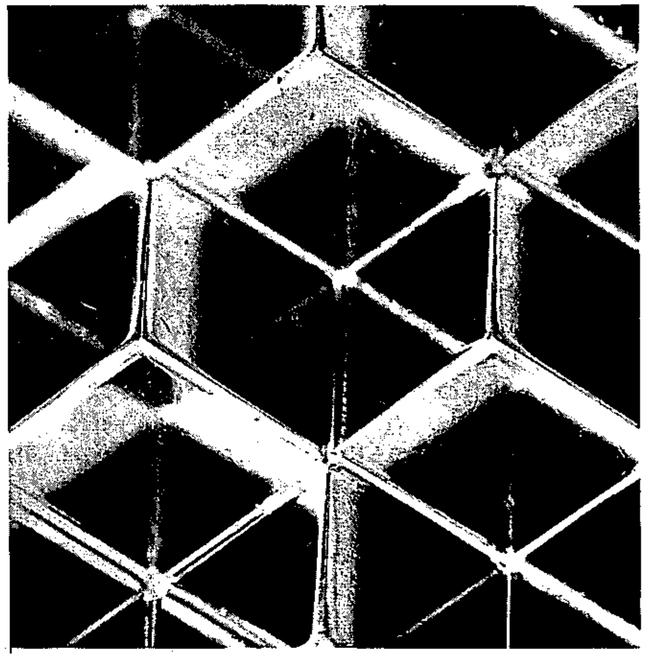


Fig. 8-d

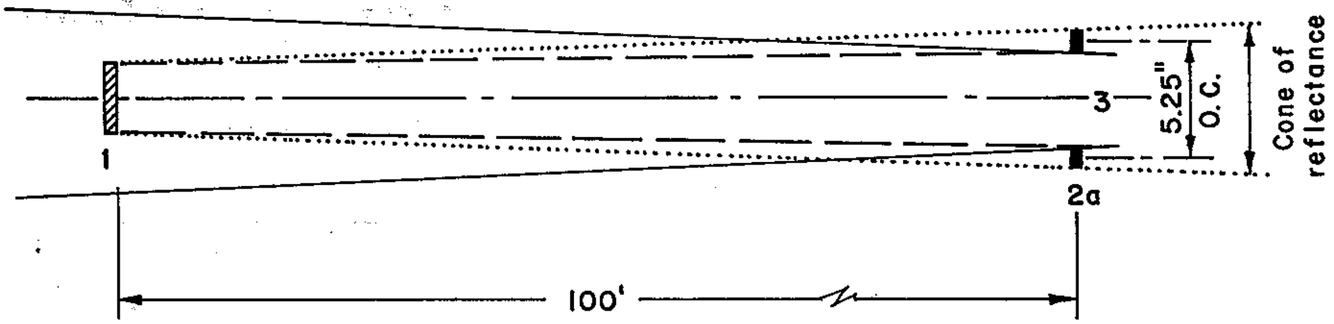
FIGURE 8

in the light tunnel which establishes a divergence angle of 1/8° and is representative of a highway viewing distance of 800 feet. This 1/8° divergence angle is obtained at the 100 ft. distance by proportionally reducing the vertical distance between the light source (vehicle headlights) and the photocell receptors (driver's eye) from 1.746 feet to 0.218 feet (Figure 9). As described elsewhere in this report (Section IV, Paragraph 6), the divergence angle is that angle formed between a line from the vehicle headlights to the reflective material and back to the driver's eye. This test parameter is specified in Test Method No. California 602-C.

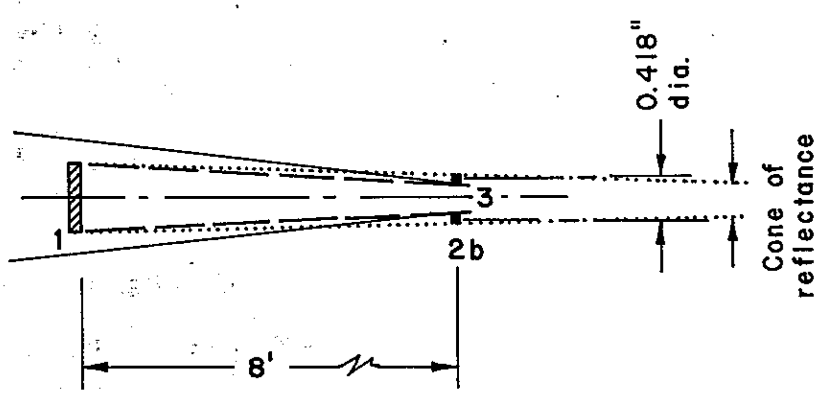
When measuring the reflectance of a reflector button, the entire button surface is illuminated. For most commercial reflectors, the return beam is concentrated within a cone of a 2° half angle. The manner in which the light is distributed within this cone directly affects the specific intensity at any one point. The photocells in the light tunnel and the Esna photometer measure only a portion of the light within this cone. A "sport" or cluster of "sports" can directly affect the intensity of this measured light.

To eliminate the effect of orientation, the Esna photometer manufacturer recommends rotating the reflector about its axis when taking reflective measurements. This is accomplished by spinning the reflector at 300 rpm, thus averaging any high or low reflective areas within the reflector. Although we found very little variance in reflectance within any single reflector, either in the Esna photometer or the light tunnel, we were still unable to correlate the reflectance readings between the photometer and the light tunnel. Although the geometry of the reflectance measurement components of the photometer and the light tunnel are in proportion (Figure 9), the photometer measures a disproportionately larger cube surface in comparison to the surface measured in the light tunnel. It appears that any light scattering effects from the cube corners significantly altered the reflective readings to the extent that no correlation was possible. Examples of this lack of correlation are apparent in the reflective readings taken on 25 representative reflector buttons. Table VIII compares the reflective readings obtained in the Esna photometer and the light tunnel and lists the variance between these readings in cp/fc. This variance ranged from +3 to +58 cp/fc. The Esna photometer indicated a higher reading than the light tunnel in all instances. There appears to be a correlation between reflectors with the same intensity. However, no correlation was apparent between the groups of reflectors. For example, reflectors No. 3, 4, 12, and 21 each read in the vicinity of 151 cp/fc in the photometer and 123 cp/fc in the light tunnel. The difference averaged +28 cp/fc. Reflectors No. 6, 10, 16, and 19 each read in the vicinity of 155 cp/fc in the photometer and 133 cp/fc in the light tunnel. The difference averaged +21 cp/fc. Reflectors No. 8, 11, 14, and 20 each read in the vicinity of 156 cp/fc in the photometer and 143 cp/fc in the light tunnel. The difference averaged +13 cp/fc. There is no numerically in-ratio correlation for the photometer except that as the cp/fc reading increased, the difference decreased.

It might be possible, with further research, to establish relative specifications applicable to the Esna photometer. However, it is not felt that the efficiency presently obtained with the light tunnel method could be realized.



LIGHT TUNNEL



PHOTOMETER

1. Sample Reflector Button.
2. Photocells.
   a. Light Tunnel - Four 594-RR-OV Weston Photocells 5 1/4" o.c.
   b. Photometer - Photocell Receptor Ring 0.418" dia.
3. Light Source.

Figure 9

Table VIII

Correlation Readings, 3¼" Clear Reflector Buttons

Sample No.	Specific Intensity Light Tunnel	Specific Intensity Photometer	Difference in cp/fc
1	135	156	+21
2	130	153	+23
3	123	151	+28
4	123	151	+28
5	135	155	+20
6	133	155	+22
7	145	158	+11
8	143	156	+13
9	138	155	+17
10	133	155	+22
11	143	156	+13
12	123	151	+28
13	150	158	+ 8
14	143	157	+14
15	133	154	+21
16	135	155	+20
17	100	143	+43
18	113	148	+35
19	133	154	+21
20	143	156	+13
21	123	151	+28
22	153	156	+ 3
23	128	153	+25
24	138	154	+16
25	78	136	+58

IX. TESTING PARAMETERS WITH THE ESNA PHOTOMETER

The Esna Reflex Photometer is a self contained photo-electric reflectance reading instrument. The housing of this instrument consists basically of a rigid aluminum tube 5½ inches in diameter and 10½ feet long (Figure 10).

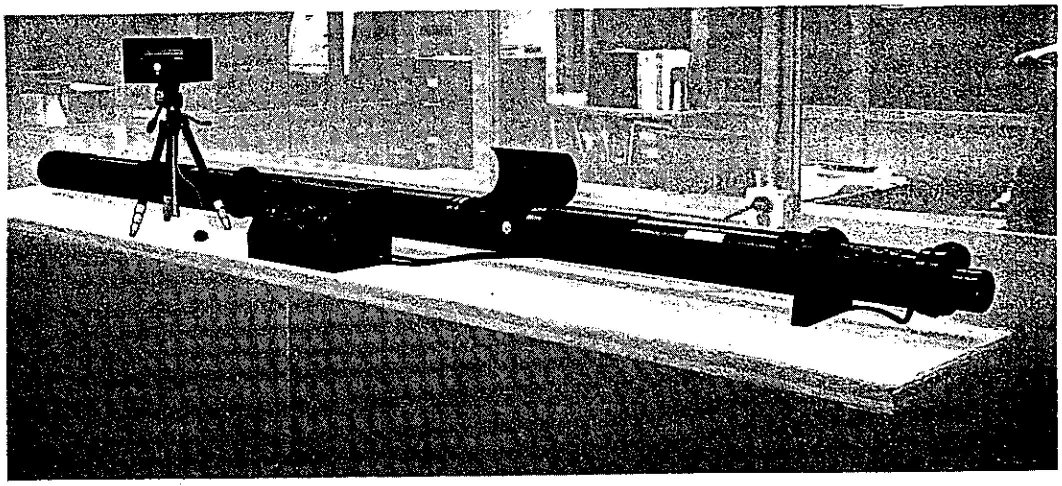


FIGURE 10

The inside of the housing is painted with optical flat black enamel which, along with internal baffles, shield the system from specularly reflected light. It is made up in sections which can easily be assembled and dismantled. Seven openings along the length of the tube provide easy access to the seven test stations. These stations permit measurements at seven different photometric distances, which establish divergence angles ranging from 0.5° to 0.1°. All access openings are equipped with hinged covers to exclude ambient light. Data on the seven test stations are listed in Table IX below:

Table IX

Test Station Data

Divergence Angle	Photometric Distance Feet	Equivalent Highway Distance, Feet
1/2	2.0	200
1/3	3.0	300
1/4	4.0	400
1/5	5.0	500
1/6	6.0	600
1/8	8.0	800
1/10	10.0	1000

For the purpose of the reflective sheeting portion of this investigation the housing tube was cut off at the second station, establishing a photometric distance of 3 feet, thus providing a divergence angle of 1/3 degree (equivalent to a viewing distance of 300 feet on the highway), which is standard for reflective sheeting control testing (Test Method Calif. No. 642-A). In the reflector button portion of this investigation the material to be measured was inserted at the sixth station, establishing a divergence angle of 1/8 degree (representing a viewing distance of 800 feet on the highway) at a photometric distance of 8 feet.

Figure 11 shows the principal on which the Esna photometer operates. The light output from lamp (A) is directed through a collimating and focusing lens system (B), then through a small aperture to the reflective material (C) being tested. The light is then reflected to a photocell (D) built in the form of a very narrow ring surrounding the aperture. The current output of the photocell is fed into a sensitive microammeter (E), the deflection of which is proportional to the light incident upon the photocell and therefore to the brightness of the reflective material.

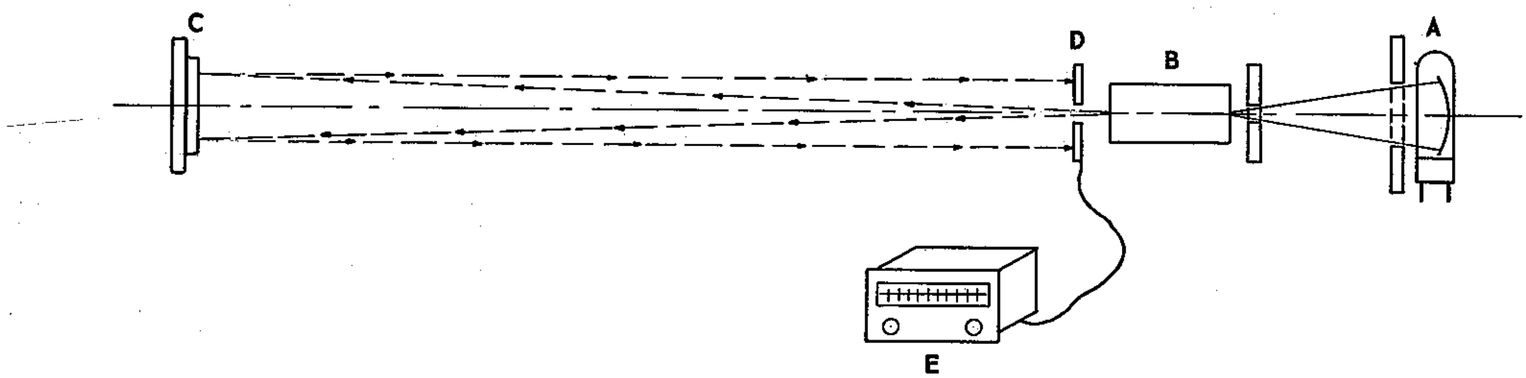


FIGURE 11

The lamp is a standard 150 watt, 20 volt projector lamp, GE Type DEF. No other type is recommended. It is equipped with a built-in dichroic, condensing mirror which reflects light but passes radiant heat, thus minimizing temperatures in the optical system. The power unit contains a 150 watt voltage regulator for maintaining a constant voltage input to the photometer, a transformer for supplying current at 20 volts to the projector lamp, a small transformer for supplying current to the meter lamp, the on-off motor switches and receptacles for the various leads.

The operating procedure consists of the following steps:

1. Plug the male connector on the end of the lamp and fan cable into the octal receptacle on the power unit.

2. Connect the cable marked "Meter" to the appropriate terminals on the back of the microammeter.

3. Connect the lamp cord from the power unit to the remaining terminals which supply current to the lamp in the meter.

4. Turn scale indicator on the microammeter to the "short" position.

5. Plug the three wire cable into a 120 volt, 60 cycle, single phase A.C. outlet.

6. "Spin" switch to off position.

7. "Lamp" switch to normal position.

8. Throw the on-off switch to "ON" position.

The testing procedure used in taking reflective readings is as follows:

1. Set iris and beam divergence levers to the full open position.

2. After 15 minute warm-up period, remove photocell and cover. With photocell covered, zero instrument by turning adjusting screw on face of microammeter.

3. Place photocell in holder at end of tube and switch scale multiplier to 10. Record reading as IL (Initial brightness of lamp in foot candles of illumination).

4. Switch scale multiplier switch to "short" position and replace photocell to original position in tube.

5. Place end of tube tightly against sample of reflective sheeting and select appropriate scale multiplier which gives a convenient large scale deflection.

6. a. Compute specific brightness (for reflective sheeting) using the following formula:

$$SB = \frac{RL}{IL} \times \frac{D^2}{A}$$

Where SB = Specific brightness
RL = Reading of reflective sample
IL = Initial brightness of lamp
D = Photometric distance in feet (3 feet)
A = Area of reflective sample in Ft^2 ($0.132\ ft^2$)

b. Compute the specific intensity (for reflector buttons) using the following formula:

$$SI = \frac{RL}{IL} \times D^2$$

Where SI = Specific intensity
RL = Reading of reflective sample
IL = Initial brightness of lamp
D = Photometric distance (8 feet)

X. REFERENCES

1. Reflex Reflectors, Chandler, K. N. and J. A. Reid.

2. Reflex Reflector Phometry, Nagel, R. I.

3. A Progress Report on the Service Life of Various Highway Signing Materials, Ledbetter, C. R.

4. Esna Reflex Photometer, Stimsonite Signal Division, Elastic Stop Nut Corp.

5. An Instrument for Precision Photometry of Reflex Reflective Materials, Nagel, R. I. and A. M. Troccoli.

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 602-C
July, 1963
(2 pages)

METHOD OF TEST FOR REFLECTANCE OF HIGHWAY REFLECTOR BUTTONS (OPTICAL REQUIREMENTS)

Scope

This method covers the procedure for determining the reflectance of highway reflector buttons measured in percentage of incident light reflected by the button under standardized test conditions.

Procedure

A. Apparatus

1. Leeds and Northrup 9835-B stabilized D.C. indicating amplifier.
2. D.C. microammeter, G.E. DP-9.
3. Button mounting plate and Goniometer with a horizontal scale of 0° to 70° right and left.
4. Four photocells, Weston Model 594 RR-OV and mounting plate that will slide snugly into the mounting bracket on the Goniometer.
5. 117 V.-6.3 volt transformer, 10 amp., 60 cycle.
6. Black opaque cloth, one square yard.
7. Sealed beam spotlamp, G.E. 4515, and a portable assembly for mounting spotlamp, transformer, and photocell assembly.
8. Sorensen voltage regulator, 115 V. A.C., Model No. 500-S.
9. 20,000 ohm resistor.
10. Leeds and Northrup resistance decade box, 0 to 1000 ohm range.
11. 100 ohm Helipot potentiometer.
12. 1.34 volt mercury cell, or equivalent cell of stable voltage.
13. Three 33″ high steel stands made of 6″ pipe with ⅜″ end plates, 12″ square.

B. Control Factors

1. A corridor or "light tunnel" of 110 feet minimum length shall be employed for this test and the entire area of the light tunnel and all objects or equipment in the area shall be painted a flat, nonreflective black.
2. The three stands shall be spaced at 50 ft. intervals with at least 8 ft. of instrument and operating space provided to the rear of the end stand which supports the test button assembly.
3. New sealed beam spotlamps shall be seasoned under normal operating voltage for 20 hours prior to employment in the performance of reflectance tests.
4. The equipment is arranged and connected as shown in Figure 1.
5. The four photocells shall be centrally placed on the mounting plate with their centers spaced at 90° intervals on the circumference of a 5¼ inch diameter circle. A 4⅞ inch diameter opening concentric with the above 5¼ inch diameter circle shall be provided in this mounting plate to permit the entrance of the light beam from the spotlamp. The positioning on the 5¼ inch diameter circle provides a divergence angle of ¼° at 50 ft. and ⅛° at 100 ft. intervals between reflector button and photocells.
6. The 0° reading on the Goniometer shall designate the 0° incident light position as measured on a horizontal plane.
7. The centers of the spotlamp, the photocell array and the reflector button shall be placed in a straight line and on the same horizontal plane. The photocell assembly shall be mounted perpendicular to the axis of the light beam in both the horizontal and vertical planes. The reflector button mounting plate shall be placed perpendicular to the light beam in the vertical plane and at 0° incident light shall be 90° to the light beam in the horizontal plane.
8. The spotlamp, after being centrally focused on the reflector button, shall not be moved throughout the test.
9. To avoid saturation of the amplifier, the output current should be limited to a maximum of 100 microamperes by the selection of a suitable shunt resistor to the input of the amplifier as designated below.
10. Reflector buttons, 1⅝ inches and larger, shall be tested at a distance of 100 feet. In obtaining the incident light and the reflective light readings, shunt 50 ohms or 100 ohms resistors, respectively, across the input of the Leeds and Northrup amplifier.
11. For reflector buttons smaller than 1⅝ inches, a test distance of 50 feet shall be employed. In obtaining the incident light and reflected light readings, shunt 20 ohms or 100 ohms resistors, respectively, across the input of the amplifier.
12. The reflectance value for all buttons shall be taken with a single button for the 0° angle reading. The same applies to the 20° angle readings with the exception of the ½ inch diameter buttons. In this instance the sample is divided into groups of 19 buttons each. These 19 buttons, in a cluster arrangement of six and twelve buttons set symmetrically around a central button at respective radii of ¾ inch and 1½ inch from center to center, shall be employed for the 20° angle readings. The readings for each cluster, 20° right and left, shall constitute the entire light reflectance of all 19 buttons.
13. Check buttons, a selected series of reflector buttons of various sizes, 3 inch, 1⅝ inch, etc., are employed to test consistency of operations during the testing period.

C. Preparation of Specimen

Wipe the button clean and free from smudges. Exercise care to prevent scratching the button in sampling or handling.

D. Test Procedure

1. Arrange the apparatus as shown in Figure 1 and select the proper test distance.
2. Turn on the power to the equipment and confirm that the spotlamp is connected into the regulated power supply and at the proper voltage. Place the photocell assembly into the Goniometer's mounting bracket normally occupied by the reflector button as-

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July, 1963

sembly. Focus the spotlamp onto the center of the photocells. Allow the test equipment a 15 minute warm up period; if, after this initial warm up time the incident light reading is constant over a 5 minute test interval, the equipment is assumed to be stabilized and ready to use for the testing.

3. Obtain the incident light value from the spotlamp by the following method:

a. The photocell assembly remains in the Goniometer's mounting bracket. Rotate the mounting bracket. Rotate the mounting bracket assembly to the 0° position. Select the proper shunt resistance as indicated in B-10 or B-11.

b. To avoid damaging the microammeter, set the microammeter on the 1000 microampere scale until a suitable lower scale is determined. Set the scale multiplier selector on the Leeds and Northrup amplifier on 40. Close the switch to the microammeter and select a suitable meter scale.

c. Cover the photocells with a black opaque cloth to exclude all light and adjust the microammeter to zero with the bucking current potentiometer. Remove the black opaque cloth and record the microammeter reading.

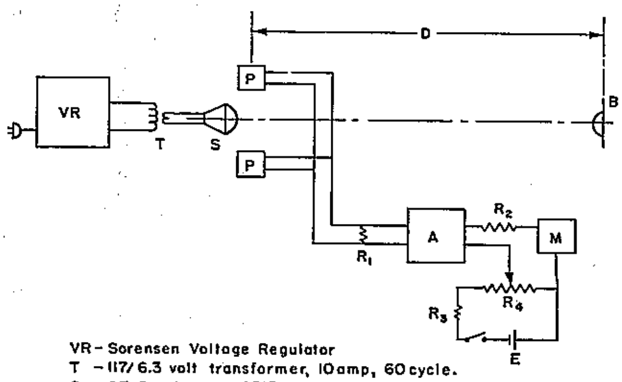
d. Move the photocell unit to its normal position adjacent to the spotlamp.

e. Incident light readings should be repeated every 50 buttons.

4. Place the button mounting plate in the Goniometer's mounting bracket and insert the check button. Select the proper shunt resistance as indicated in B-10 or B-11. Set the scale multiplier selector on the Leeds and Northrup amplifier on 1. Close the switch to the microammeter and select a suitable operating scale. Cover the button with a black opaque cloth to exclude reflected light from the button, and zero the microammeter with the bucking current potentiometer. Remove the black opaque cloth and read the microammeter. Record the reading of the check button and repeat this test every 25 buttons to assure stability of the equipment.

5. Remove the check button from the mounting plate and replace it with the button to be tested.

6. Close the switch to the microammeter and select a suitable scale. Cover the test button with a black opaque cloth; zero the microammeter; remove the cloth and record the microammeter readings for the 0° and the 20° right and 20° left positions as indicated on the Goniometer.



VR – Sorensen Voltage Regulator
T – 117/6.3 volt transformer, 10amp, 60cycle.
S – GE Spotlamp # 4515
P – Two Weston Photo cells # 594-RR-OV. (Total of four employed in test)
B – Reflective Material.
D – Test Distance
A – Leeds and Northrup 9835-B Stabilized D.C. indicating amplifier.
M – D.C. Microammeter, G.E. DP-9.
E – 1.34 Volt mercury cell.
R_1 – Leeds and Northrup resistance decade box, 0 to 1000 ohm range.
R_2 – 20,000 ohm resistor.
R_3 – 150 ohm resistor.
R_4 – 100 ohm Helipot potentiometer.

FIGURE 1

E. Calculations

From the readings obtained, calculate the percent reflectance as follows:

R.L. = Microammeter reading of reflector button × scale multiplier

I.L. = Microammeter reading of photocells × scale multiplier × $\frac{S.R.}{S.I.}$

Where

R.L. = Reflected light of the reflector button under test, determined as described in D-4 above.

I.L. = Incident light determined as described in D-3 above.

S.R. = Value in ohms of the shunt resistance in the decade box employed for the reflector button microammeter reading.

S.I. = Value in ohms of the shunt resistance in the decade box employed for the incident light microammeter reading.

Scale Multiplier: Reading on amplifier output select switch.

Then

$$\text{Percent Reflectance} = \frac{R.L.}{I.L.} \times 100$$

F. Precautions

Adhere strictly to the procedure as outlined to obtain consistent and comparable results.

Reporting of Results

Report results on Form T-610.

REFERENCE

A California Method

End of Text on Calif. 602-C

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 642-A
July, 1963
(2 pages)

METHOD OF TEST FOR REFLECTANCE OF REFLECTIVE SHEETING FOR HIGHWAY SIGNS

Scope

This method covers the procedure for measuring the reflectance of reflective sheeting in units of "candle-power per foot candle per square foot" under standardized test conditions.

Procedure

A. Apparatus

1. Leeds and Northrup 9835-B stabilized D.C. indicating amplifier.
2. D.C. microammeter, G.E. DP-9.
3. Reflective sheeting mounting plate and Goniometer with a horizontal scale of 0° to 70° right and left.
4. Four photocells, Weston Model 594 RR-OV, and mounting plate that will slide snugly into the mounting bracket on the Goniometer.
5. 117 V. – 6.3 V. transformer, 10 amp., 60 cycle.
6. Black opaque cloth, one square yard.
7. Sealed beam spotlamp, G.E. 4515, and a portable assembly for mounting the spotlamp, transformer, and photocell assembly.
8. Sorensen voltage regulator, 115 V.A.C., Model No. 500-S.
9. 20,000 ohm resistor.
10. Leeds and Northrup resistance decade box, 0 to 1000 ohm range.
11. 100 ohm Helipot potentiometer.
12. 1.34 volt mercury cell, or equivalent cell of stable voltage.
13. Two 33″ high steel stands made of 6″ pipe with ⅜″ end plates, 12″ square.

B. Control Factors

1. A corridor or "light tunnel" of 60 feet minimum length shall be employed for this test and the entire area of the light tunnel and all objects or equipment in the area shall be painted a flat, nonreflective black.
2. The test distance between the reflective sheeting stand and the combination sealed beam spotlamp and photocell stand shall be 50 feet.
3. New sealed beam spotlamps shall be seasoned under normal operating voltage for 20 hours prior to employment in the performance of reflectance tests.
4. The equipment is arranged and connected as shown in Figure I.
5. The four photocells shall be centrally placed on the mounting plate with their centers spaced at 90° intervals on the circumference of a 7 inch diameter circle. This arrangement provides a divergence angle of ⅓° at a test distance of 50 feet. A 4½ inch diameter opening concentric with the above 7 inch diameter circle shall be provided in this mounting plate to permit the entrance of the light beam from the spotlamp.
6. The 0° reading on the Goniometer shall designate the 0° incident light position as measured on a horizontal plane.
7. The centers of the spotlamp, the photocell array and the reflective sheeting panel shall be placed in a straight line and on the same horizontal plane. The photocell assembly shall be positioned perpendicular to the axis of the light beam in both the horizontal and vertical planes. The reflective sheeting shall be placed perpendicular to the light beam in the vertical plane and at 0° incident light shall be 90° to the light beam in the horizontal plane.
8. To avoid saturation of the amplifier, the output current should be limited to a maximum of 100 microamperes by the selection of a suitable shunt resistor to the input of the amplifier.
9. A 3″ reflector button, mounted on a plate that will slide snugly into the mounting bracket on the Goniometer and position the reflector button in accordance with the positioning described in B-7, is employed as a stability check on the operation of the equipment.
10. The spotlamp, after being centrally focused on the reflective sheeting in the test position, shall not be moved throughout the test.

C. Preparation of Samples

1. The test is performed on reflective sheeting applied to the intended sign-backing material. To obtain comparable test results, the sheeting must be free from letters, edgings, insignia, holes, and scratches. Remove foreign substances such as smudges or dust from the reflective sheeting.

D. Test Procedure

1. Arrange the apparatus as shown in Figure I.
2. Turn on the power to the equipment and confirm that the spotlamp is connected into the regulated power supply and at the proper voltage. Place the photocell assembly into the Goniometer mounting bracket normally occupied by the reflective sheeting assembly. Focus the spotlamp onto the center of the photocells. Allow the test equipment a 15 minute warm up period; if, after this initial warm up time the incident light reading is constant over a 5 minute test interval, the equipment is assumed to be stabilized and ready to use for the testing.
3. Obtain the incident light value from the spotlamp by the following method:
   a. The photocell assembly remains in the Goniometer's mounting bracket.
   b. To avoid damaging the microammeter, set the microammeter on the 1000 microampere scale until a suitable lower scale is determined. Set the scale multiplier selector on the Leeds and Northrup amplifier on 40. Select the 20 ohm resistor in the decade box. Expose the photocells to the 0° incident light rays, close the switch and select a suitable meter scale.
   c. Cover the photocells with a black opaque cloth to exclude all light; zero the meter with the bucking current potentiometer.
   d. Remove the black opaque cloth and record the microammeter reading.

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e. Move the photocell assembly to the normal position adjacent to the spotlamp.

4. Slide the stability checking reflector button with mounting plate into the Goniometer's mounting bracket set in the 0° position. In general, set the resistance between 20 to 100 ohms on the decade box; set the scale multiplier switch on 1. Close the switch to the microammeter and select a suitable meter scale; cover the reflector button with a black opaque cloth; zero the microammeter with the bucking current potentiometer; remove the black opaque cloth and record the microammeter reading.

5. Remove the check button assembly from the Goniometer's mounting bracket and insert the reflective sheeting assembly. In general, set the resistance on the decade box between 20 and 100 ohms, the scale multiplier switch is retained at 1. Place the reflective sheeting on the mounting plate. Close the switch to the microammeter and select a suitable scale. Cover the reflective sheeting with a black opaque cloth and zero the meter with the bucking current potentiometer. Remove the black opaque cloth. The reflective sheeting is rotated about the vertical axis and the reflected light readings shall be recorded for 0° and 10°, 20°, 30°, 40° and 45° right and left.

6. Repeat test procedure D-4 after measuring each reflective sheeting to ensure that the incident light reading remains unchanged.

E. Calculations

From the readings obtained calculate the reflectance in candlepower per foot candle per square foot of reflective area as follows:

R.L. = Microammeter reading of reflective sheeting × scale multiplier.

I.L. = Microammeter reading of photocells × scale multiplier × $\frac{S.R.}{S.I.}$

Where

R.L. = Reflected light of reflective sheeting under test, determined as described in D-5 above.

I.L. = Incident light determined as described in D-3 above.

S.R. = Value in ohms of the shunt resistance in the decade box employed for the reflective sheeting microammeter reading.

S.I. = Value in ohms of the shunt resistance in the decade box employed for the incident light microammeter reading.

Scale Multiplier: Reading on amplifier output select switch.

Then

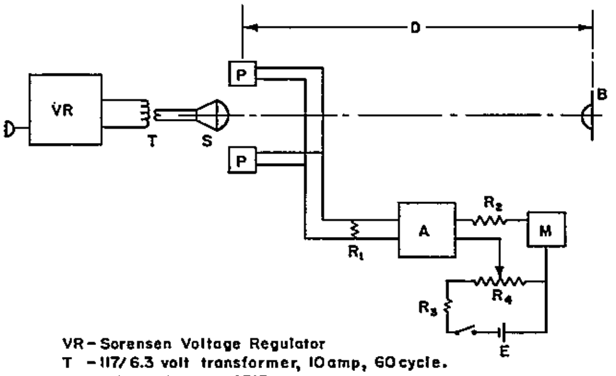
The candlepower per foot candle per square foot

$$= \frac{R.L. \times D^2}{I.L. \times A}$$

Where

D = Distance in feet from photocells and spotlight to reflective sheeting. (50 feet)

A = Area in square feet of the panel of reflective sheeting used. (Usually 8" x 8" panel)



VR – Sorensen Voltage Regulator
T – 117/6.3 volt transformer, 10 amp, 60 cycle.
S – GE Spotlamp # 4515
P – Two Weston Photo cells # 594-RR-OV. (Total of four employed in test)
B – Reflective Material.
D – Test Distance
A – Leeds and Northrup 9835-B Stabilized D.C. indicating amplifier.
M – D.C. Microammeter, G.E. DP-9.
E – 1.34 Volt mercury cell.
R_1 – Leeds and Northrup resistance decade box, 0 to 1000 ohm range.
R_2 – 20,000 ohm resistor.
R_3 – 150 ohm resistor.
R_4 – 100 ohm Helipot potentiometer.

FIGURE 1

F. Precautions

Adhere strictly to the procedure as outlined to obtain consistent and reliable results.

Reporting of Results

Report results on Form T-610.

REFERENCE

A California Method

End of Text on Calif. 642-A