Research Report
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HIGH-INTENSITY REFLECTIVE MATERIALS FOR SIGNS

by

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ABSTRACT

Field observations and laboratory tests and evaluations were conducted on High-Intensity and Engineering Grade materials (Scotchlite), manufactured by the Minnesota Mining and Manufacturing Company, and were compared in regard to reflectivity, durability, and cost.

The High-Intensity Grade materials were found to have outstanding performance characteristics in comparison to Engineering Grade materials. The material significantly enhances sign legibility under low-beam illumination, and accelerated weathering tests showed superior durability.

INTRODUCTION

The intuitive need for improved sign legibility has increased through the years as traffic volumes, speeds, and roadway designs have advanced. Because of increased traffic volumes, low-beam headlight illumination at night has become more imperative. Signs are being located farther from the travelled lanes; higher speeds are requiring messages to be legible at greater distances (for driver decision and response). Recent studies have indicated that even Engineering Grade Scotchlite, materials designated as Type I, Class A in Kentucky Special Provision, No. 89-B (APPENDIX A) may be inadequate for many signing situations. Signs may be made larger and(or) incorporate materials which are brighter. Thus far, neither brightness nor sign size has exceeded optimum under low-beam headlight illumination. Obviously, economics and other considerations come into issue.

A 1970 report *(1)* issued by the Division of Research encompassed all materials available commercially at that time. Luminance calculations were performed then for a typical sign installation on interstate highways using selected Type I, Class A (Engineering Grade Scotchlite) and Class B (High-Intensity Grade Scotchlite) and Type II-B (button inserts, Stimsonite W-900 Series and Stratolite) legend materials. Similar computations were made using proposed reflectivity levels of the same materials and were shown in Table XIII of that report. A copy of that table is included here (Table I). On high-beam illumination, all of the materials (silver-white) were shown to perform quite adequately. In fact, the brightness of Class B material, as well as Type II-B, was found to exceed the needed luminance (10 to 20 foot-Lamberts) for 100 percent of optimum legibility. The luminance of any sign legend above 20 foot-Lamberts tends to diminish the distance to the sign at which the message becomes legible. Sign legibility, of course, is also related to the contrast provided between the legend and the material used for the background. On low beam, the minimum specified reflectivity for Class A materials was shown to be 65 percent of optimum legibility, while for Class B materials it was 80 percent. Specifications for various materials were proposed, and S.P. No. 89-A was subsequently adopted by the Department. Reflectivity requirements specified for sign surfaces properly included concerns for adequate sign legibility under existing traffic, headlight illumination, and roadway geometrics and were based on the available Class A materials in all colors and Class B materials in silver-white and green. It was clearly evident then, as now, that Class A materials did not fully satisfy brightness requirements for signs under low-beam illumination and that the Department may need to consider the use of brighter (Class B) materials whenever possible.

The above-cited findings and opinions on sign legibility are in general agreement with the investigative efforts of others. Youngblood and Woltman *(2)* measured sign brightness in several states. Adler and Straub *(3)* examined sign design from the standpoint of legibility and brightness and concluded that: "In general, to account for night legibility, signs must be made larger and(or) brighter." Their study considered only Engineering Grade Scotchlite (equivalent to Class A in S.P. No. 89-B). Comments offered by Woltman *(4)* puts the overall problem in a good perspective. However, uncertainties concerning needed brightness of

TABLE I *

SIGN LUMINANCE
(at 600 feet)

SILVER-WHITE MATERIAL	LUMINANCE (FOOT-LAMBERTS)		APPROXIMATE PERCENT OF OPTIMUM LEGIBILITY	
	HIGH BEAM	LOW BEAM	HIGH BEAM	LOW BEAM
SELECTED MATERIAL SAMPLES				
Type I, Class A	12.3	0.8	100	75
Type I, Class B	24.6	1.6	95	85
Type II-B	58.0	3.9	90	90
MINIMUM SPECIFIED REFLECTIVITY OF MATERIALS				
Type I, Class A	6.1	0.4	95	65
Type I, Class B	17.9	1.2	100	80
Type II-B	47.5	3.2	90	90

*Table XIII, Ref. 1, corrected for typographical errors

signs (legend and background) remain. The National Cooperative Highway Research Program recently initiated Project No. 3-24 entitled "Determine the Luminous Requirements for Retroreflective Highway Signing." The project is designed to deal with the effect of reflectivity on sign legibility and the range of reflective values that will satisfy motorist needs. Hopefully, the range of acceptable legend and(or) background luminosity will be established as a function of sign characteristics, road geometry, environmental conditions, etc.

No evidence has been found to indicate that materials in the reflectivity level of Class B (S.P. No. 89-B) are excessively bright under high-beam illumination or significantly reduce sign legibility. Fortunately, brighter materials (Class B), now offered in all colors except brown, were found to be extremely durable and, therefore, offer significant long-term savings. These findings are presented here.

NIGHTTIME INSPECTION OF SIGNS

A team of observers made a night tour of I 65 between Elizabethtown and Nashville, Tennessee, for the explicit purpose of viewing and photographing signs reflectorized with several types of materials. Signs in Tennessee were surfaced with High-Intensity Grade Scotchlite whereas those in Kentucky consisted of Engineering Grade Scotchlite -- but some with Type II-B (button inserts) legends. Signs were viewed from traffic and passing lanes under low- and high-beam illumination. The brightness and legibility of signs constructed with the High-Intensity Grade Scotchlite (Kentucky Class B) were adjudged to be significantly superior under all viewing conditions. The relative brightness of the various signs were not apparent in the photos. A more direct illustration of the two Scotchlite materials is shown in Figure 1. There the upper half of the sign consists of High-Intensity Grade materials; the lower half is Engineering Grade. Five demonstration signs with **TEST** legends were erected as shown in Figure 2. The sign faces incorporated various combinations of materials used in the legend (silver white) and background (green). The two signs with High-Intensity Grade background and legend in High-Intensity Grade and Type II-B were the brightest. Also, several other signs were installed and photographed. Each set of signs here contrasted the brightness between High-Intensity Grade materials and those with Engineering Grade materials in orange (construction sign -- arrow, Figure 3), in yellow (warning sign -- curve arrow, Figure 4), and in red (**YIELD** and **STOP** signs, Figure 5). The High-Intensity Grade signs were significantly superior.

DURABILITY

Durability or life expectancy of sign surfaces is an important criterion in specifying and purchasing these materials. Reflective materials deteriorate from natural causes -- as do paints and many other organic coatings. The point of failure of a sign, however, is difficult to define because it may depend upon the minimum level of reflectivity chosen for the particular type of sign. Engineering Grade Scotchlite may retain "adequate" level of reflectivity for about six years -- depending somewhat on the position of the sign with respect to exposure to the sun. In daylight, a sign may show visible evidences of deterioration (surface cracking, etc.) and be considered failing even though the intensity remains "adequate". Either replacement or clear-coating the sign face must then be considered.

Introduction of 3M's front-window, air-cavity-type materials (High-Intensity Grade Scotchlite) has generated considerable interest in its performance characteristics. Reflectivity of this material is relatively unaffected by dew, fog, and rain. Only impacting snow or sleet causes blackout. Accelerated weathering tests were conducted on specimens of silver-white, green, yellow, red, and orange sheeting according to the method outline in S.P. No. 89-B and contrasted with Engineering Grade materials of the same colors. Results are shown in Figures 6 through 10. Graphs for reflectivity of Engineering Grade sheeting in colors of blue and brown are also presented (Figures 11 and 12) for informational purposes.

Most of the Engineering Grade materials deteriorated rapidly after 1,200 hours in the weatherometer; whereas, the High-Intensity materials in colors of silver-white and green remained relatively unaffected for about 4,500 hours, yellow for about 3,200 hours, and red (transparent red on silver-white sheeting) for about 2,400 hours. Accelerated weathering tests, therefore, showed the material to be extremely durable. The materials, of course, may be considered as performing satisfactorily beyond the cited weatherometer hours. Time of failure of the materials is indicated on the graphs and were derived from suggested reflectivity levels, when related to equivalent Kentucky photometer values, by the 3M Company in their specifications.

The orange material is unique in its intended use and requires judgements which will be discussed later. It is apparent that the orange High-Intensity Grade material is sufficiently durable and outstandingly bright to recommend its use for maintenance and construction signing.

ORANGE MAINTENANCE SIGNS

With the issuance of the revised "Manual on Uniform Traffic Control Devices" in 1971, construction and maintenance warning signs were changed from yellow to orange. The intent, of course, was to differentiate between these signs and other warning signs and, therefore, to improve the attention value of signs used in construction and maintenance areas. A recent report by Seymour *(5)* asserted that "orange signs produced a slight improvement over yellow signs in reducing traffic conflicts and merges near the barricade." The study, however, dealt with daylight viewing conditions only. While no formal studies have been conducted on the effectiveness of orange signs at night, inspections under headlight illumination have shown reduced attention value of the orange signs in contrast to yellow signs. The problem here is not related to differences in colors but rather to the reduced brightness or retro-reflective efficiencies of the orange material (Engineering Grade). Yellow and orange materials qualify under the following specific reflectivity requirements (S.P. No. 89-B):

CLASS A MATERIALS

COLOR / Incidence Angle	0.5° Divergence 4°	0.5° Divergence 15°	0.5° Divergence 30°	0.2° Divergence 4°	0.2° Divergence 15°
Yellow	30	25	15	50	40
Orange	12.5	11	5	21	17

As evident above, the change from yellow to orange has resulted in reduced brightness of maintenance signs and surely affects advantages gained in change of color. Equivalent, conventional tunnel-photometer values which are comparable to those obtained by the test procedure and the minimum values specified in S.P. 89-B are presented in Table A-1 for Class A materials and Table A-2 for Class B materials (in APPENDIX A).

High-Intensity orange sheeting is considerably brighter than the Engineering Grade (Class A) and qualifies as Class B (reflectivity) with the following specific reflectivities:

ORANGE – CLASS B					
	0.5° Divergence			0.2° Divergence	
Incidence Angle	4°	15°	30°	4°	15°
	23	20	15	50	45

Reflectivity of this material may be considered comparable to the reflectivity of yellow signs used previously and would, therefore, greatly enhance the effectiveness of orange signs. Inasmuch as construction and maintenance signs are expected to survive only for a limited time, 1,000 hours of accelerated weathering would be more than an ample test for durability.

YELLOW WARNING SIGNS

Improved durability and brightness of the yellow High-Intensity Grade material (Class B) in contrast with the Engineering Grade (Class A) is evident (Figure 8). The highway user and the Department would benefit from the use of High-Intensity Grade sheeting. Unfortunately, the material does not conform to the Color Tolerance Chart (PR Color No. 1), issued by the U.S. Department of Commerce, when the chart is used for comparison with the material as prescribed on the chart. The material appears darker than the dark limit when viewed at 45° for 90° illumination called for in the instructions. Yet, the material appears Highway Yellow on signs outdoors when viewed under directional lighting (nighttime) and under clear sky conditions with the sign oriented away from direct sunlight. With the sun shining on the sign, the material does exceed the dark limit prescribed by the Color Tolerance Chart. The overall color performance of the material was judged to be acceptable, or at least tolerable, when the judgement was coupled with the consideration of the outstanding attributes of the material in regard to reflectivity (brightness) and durability (life expectancy). Therefore, an alternate method for comparing the Color Tolerance Chart with the material was incorporated in the S.P. 89-B.

On February 26, 1973, the FHWA issued an Instructional Memorandum (IM 21-1-73) on Color Specifications of Sign Materials which superseded a previous IM 21-11-71, dated December 9, 1971. The FHWA will now allow the use of any 45°-0° geometry instruments to measure color (previously disallowed) if the chromaticity coordinate limits established do not exclude any commercially available reflective sheeting. Visual testing based on the Color Tolerance Charts remains an alternate method for acceptance of materials.

Chromaticity coordinate limits were developed earlier *(1)* for reflectivity Class A materials (silver-white, green, yellow, blue, and red) but not for Class B materials. Acceptance by FHWA of the color limits proposed earlier, and subsequently disallowed, is not assured by IM 21-1-73. Considerable efforts would be involved in developing appropriate chromaticity limits to encompass all materials contemplated for use by the Department. The effort, and the attendant uncertainty of acceptance of such specifications, may not be worthwhile. A visual test using the Color Tolerance Charts, therefore, remains the most implementable means of specifying color requirements for reflective sheeting at this time.

COST CONSIDERATIONS

The weathering tests have been sufficiently conclusive to justify the use of the high-intensity, super-grade materials. These materials may be expected to last two to three times longer than the best grade of material available heretofore. The cost of the material is 84 percent greater ($0.90 per square foot compared to $1.65). The net savings to the Department may amount to more than $0.65 per square foot of applied material alone. Additionally, significant savings in labor and equipment costs would be realized from less frequent replacement of sign faces. The Louisiana Department of Highways *(6)* cited labor and equipment rental for rework of deteriorated large signs to cost about $1.00 per square foot. Vandalism and damage from accidents, of course, would diminish the cited savings.

IMPLEMENTATION

An implementation package on retro-reflective materials began with issuance of Report No. 298 *(1)*, October 1970 (revised and re-issued March 1972). The report covered geometric relationships between the driver, headlamps, and traffic signs; investigation of reflectivity, color, durability, and other properties of available reflective materials; adoption of a testing apparatus to measure material properties; and development of test procedures. A revised specification for retro-reflective materials was prepared. The document was deliberately designed as a general specification and included only those features which were judged most essential from the standpoint of material identification, classification, and features to insure adequate in-service performance of materials used in highway signs, reflectors used in traffic delineations, and coating compounds applied to structures for safety purposes. Special Provision No. 89 was approved December 10, 1970.

The implementation package advanced through Report No. 330, "High-Intensity Reflective Materials for Signs", June 1972 *(7)*, and Report No. 368 (revised report, same title), May 1973 *(8)*. The reports cited field observations, laboratory tests, and evaluations on High-Intensity and Engineering Grade materials (Scotchlite) manufactured by the Minnesota Mining and Manufacturing Company. Reflectivity, durability, and costs were compared. High-Intensity Grade materials (Kentucky Class B) were found to have outstanding performance characteristics in every respect when compared to Engineering Grade materials (Kentucky Class A). In view of these findings, the report cited recommended revisions to Special Provision No. 89-A and advocated usage of materials meeting S.P. No. 89-A as Type I, Class B on grounds of economy and improved safety of highways. To date, the following actions were taken by the Department:

1. the sequel specification (S.P. No. 89-B) (APPENDIX A) was approved April 26, 1973,

2. effective July 1, 1973, available materials meeting Class B requirements (S.P. No. 89-B) were required in construction contracts and price contracts (in-house use), and

3. construction and maintenance warning signs (orange) were required to meet Class B reflectivity after April 1, 1974. The effective date was posponed from July 1, 1973, to permit contractors to liquidate signs on hand and to acquire necessary equipment.

On February 26, 1974, the Federal Highway Administration accepted the Departments' public interest statement and issued final approval for the use of high-intensity materials (Kentucky Class B reflectivity) in sign reflectorization.

General recommendations in the use of reflective materials were prepared (APPENDIX B) to aid the traffic engineer in the selection of appropriate materials, or combination of materials, for various signs; these are based on considerations for roadway geometrics, illumination, and traffic conditions.

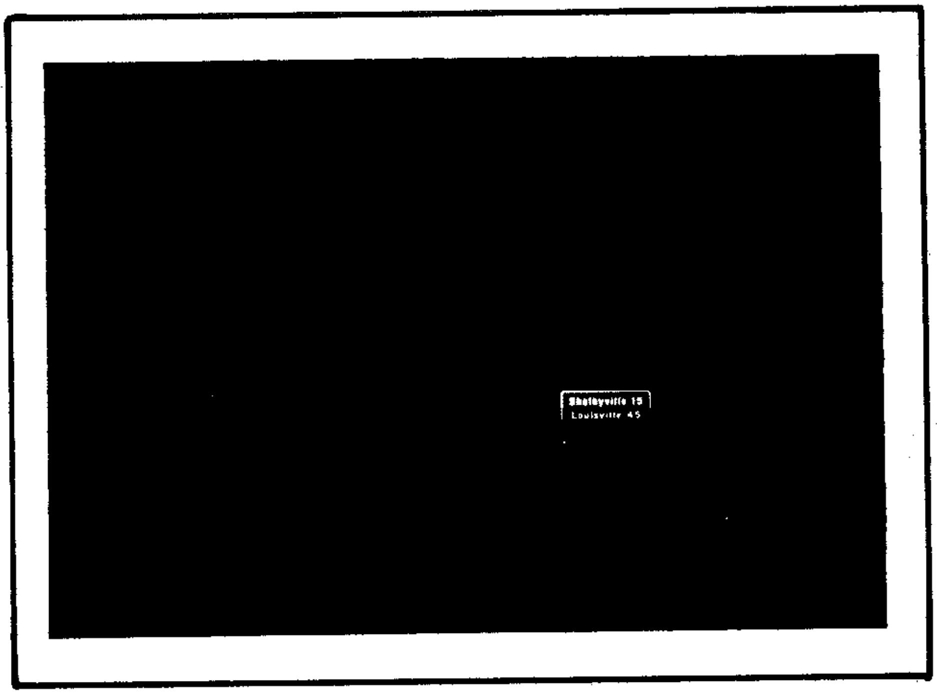
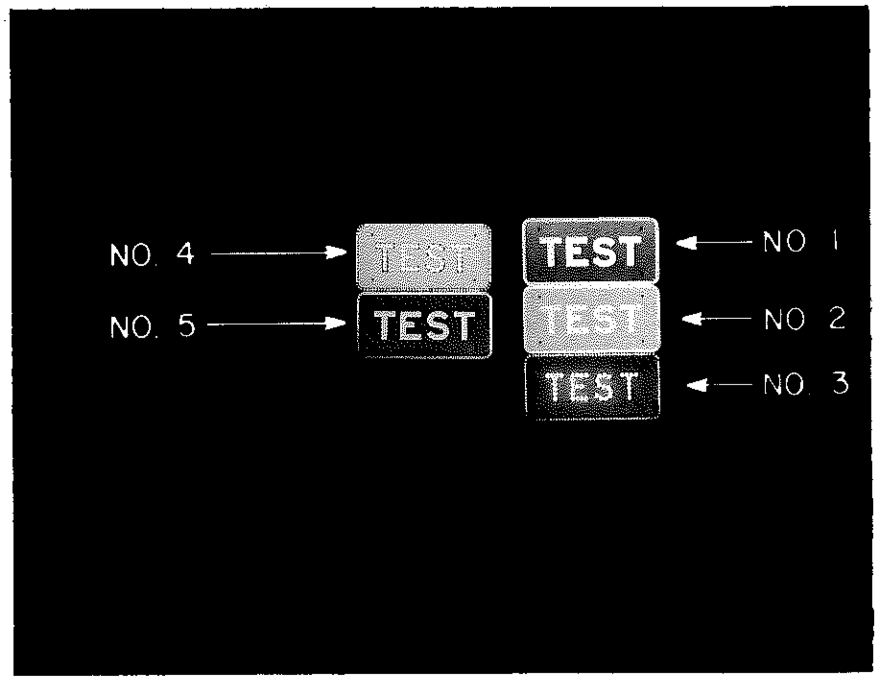


Figure 1. High-Intensity Grade on Upper Half of Sign and Engineering Grade on Lower Half; I 64, Kentucky.

Figure 2. Test Installation on I 64 near Frankfort, Kentucky.



SIGN NO.	MESSAGE AND BORDER	BACKGROUND
1	High-Intensity Grade	Engineering Grade
2	High-Intensity Grade	High-Intensity Grade
3	Bottom Inserts	Engineering Grade
4	Bottom Inserts	High-Intensity Grade
5	Engineering Grade	Engineering Grade

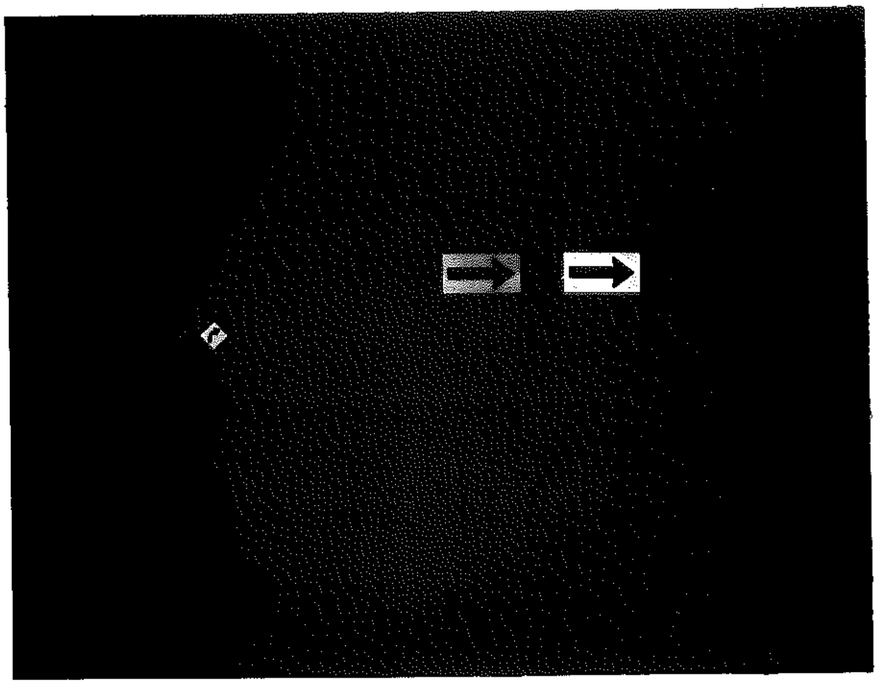


Figure 3. Orange Construction Signs -- High-Intensity Grade at Right and Engineering Grade at Left; Yellow Warning Signs at a Distance -- High-Intensity Grade at Right and Engineering Grade at Left.

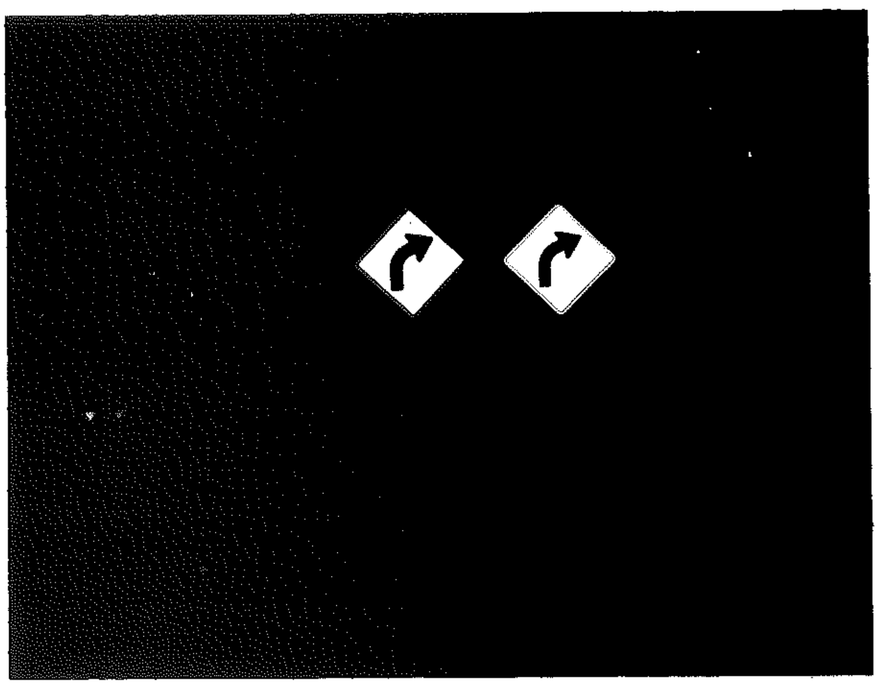


Figure 4. Yellow Warning Signs -- High-Intensity Grade at Right and Engineering Grade at Left; Red Yield Signs at a Distance -- Engineering Grade at Right and High-Intensity at Left.

Figure 5. Red Yield Signs -- Engineering Grade at Right and High-Intensity at Left; Stop Signs at a Distance -- High-Intensity Grade at Right and Engineering Grade at Left.

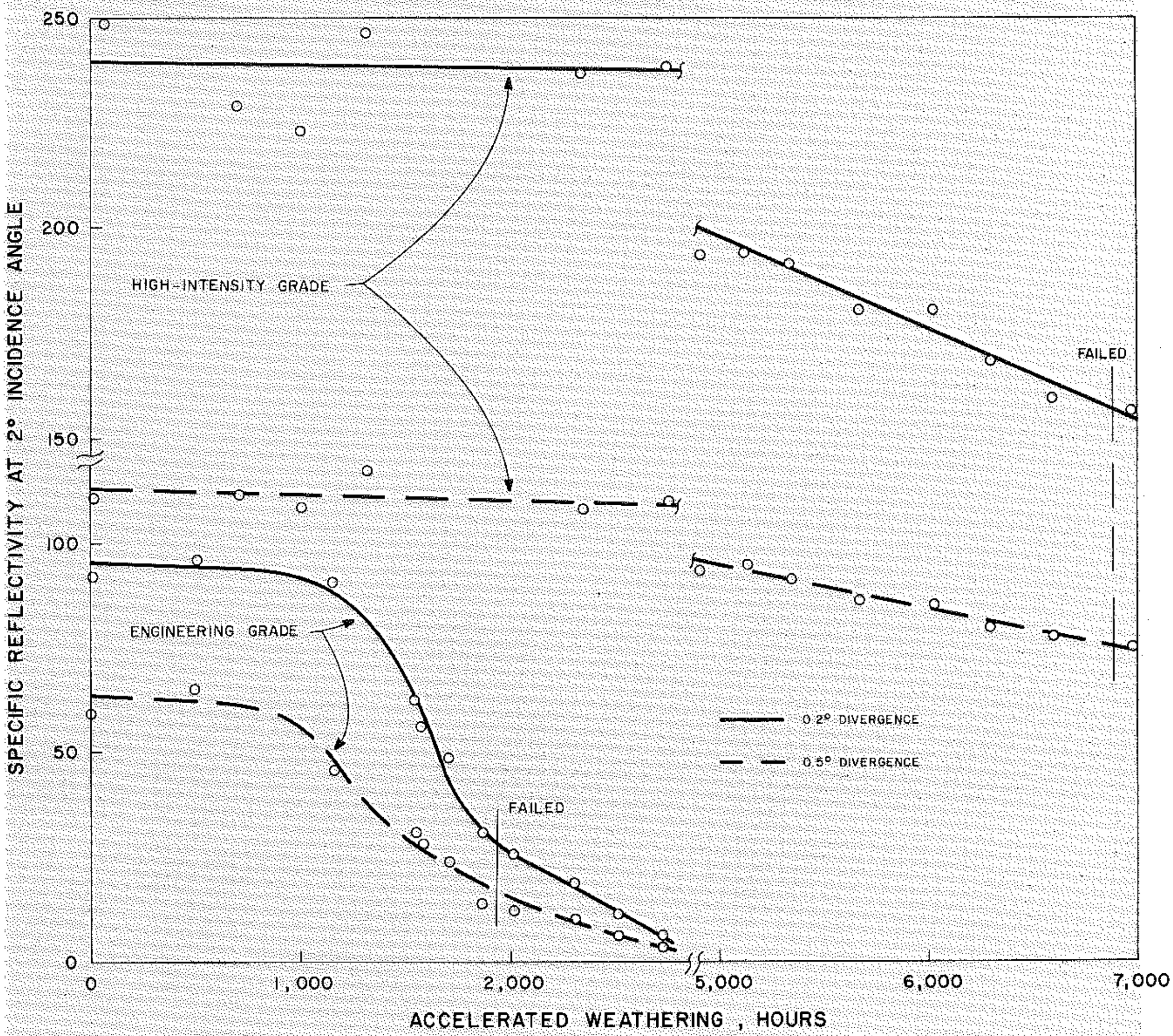


Figure 6. Accelerated Weathering of Silver-White Scotchlite Sheeting.

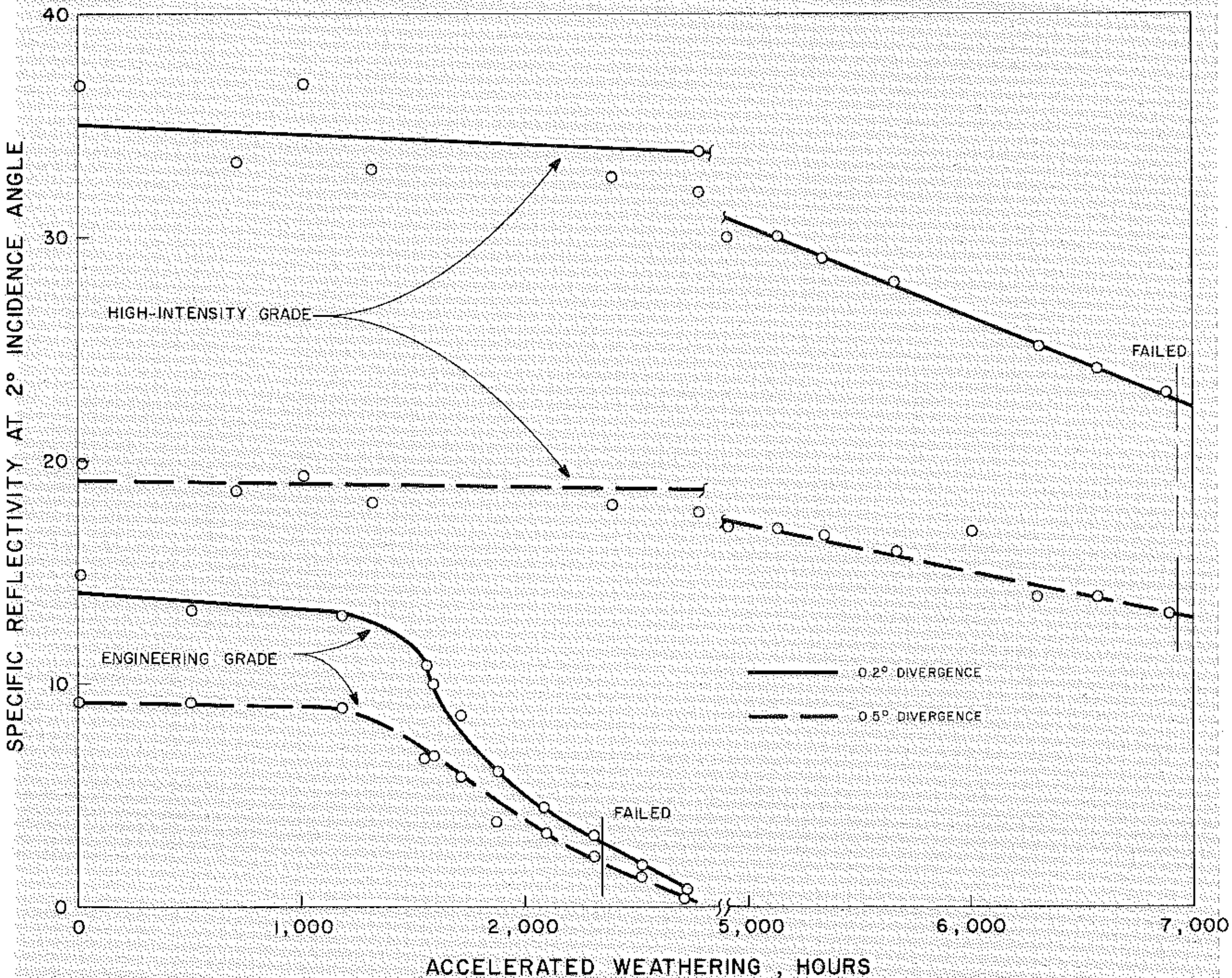


Figure 7. Accelerated Weathering of Green Scotchlite Sheeting.

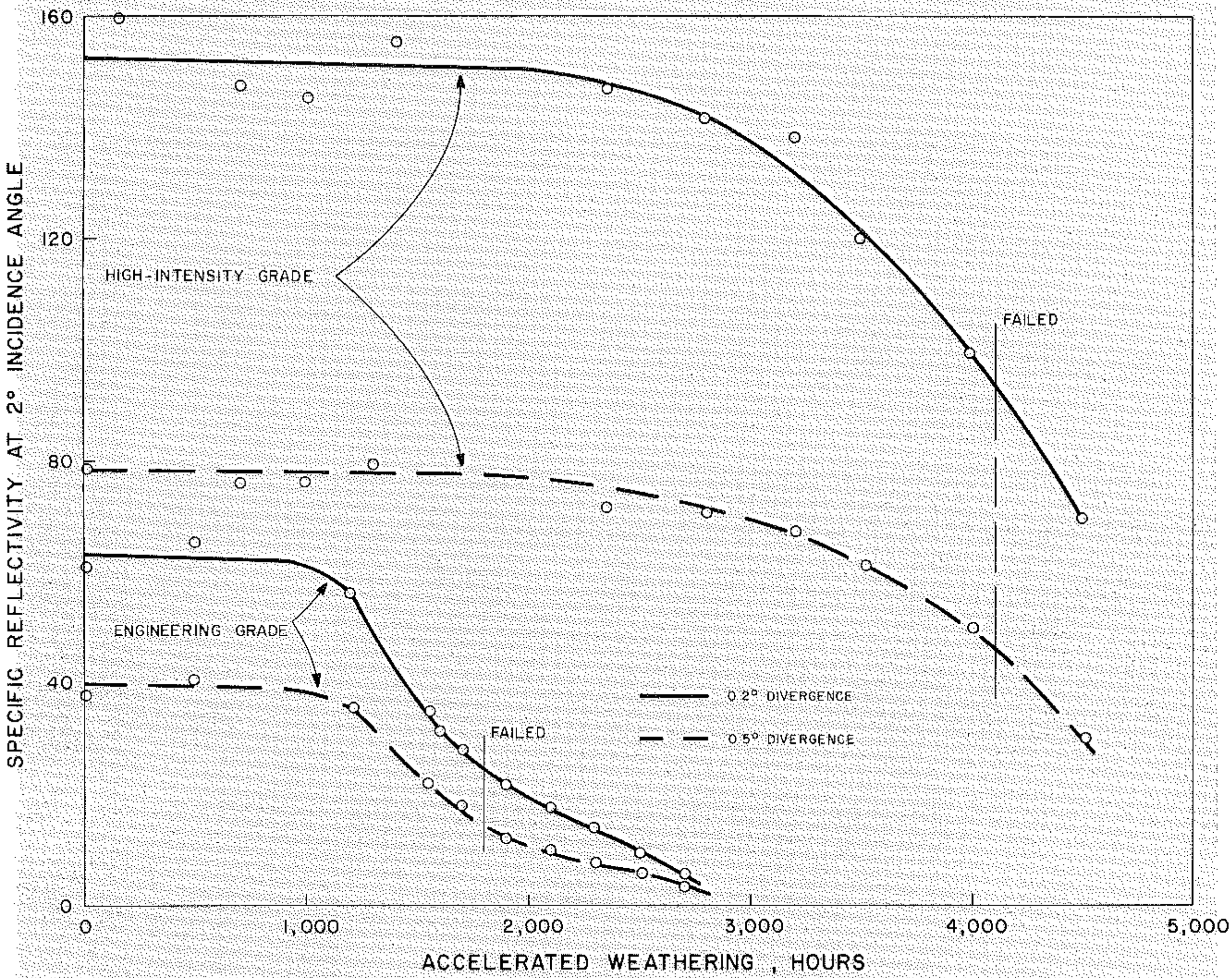


Figure 8. Accelerated Weathering of Yellow Scotchlite Sheeting.

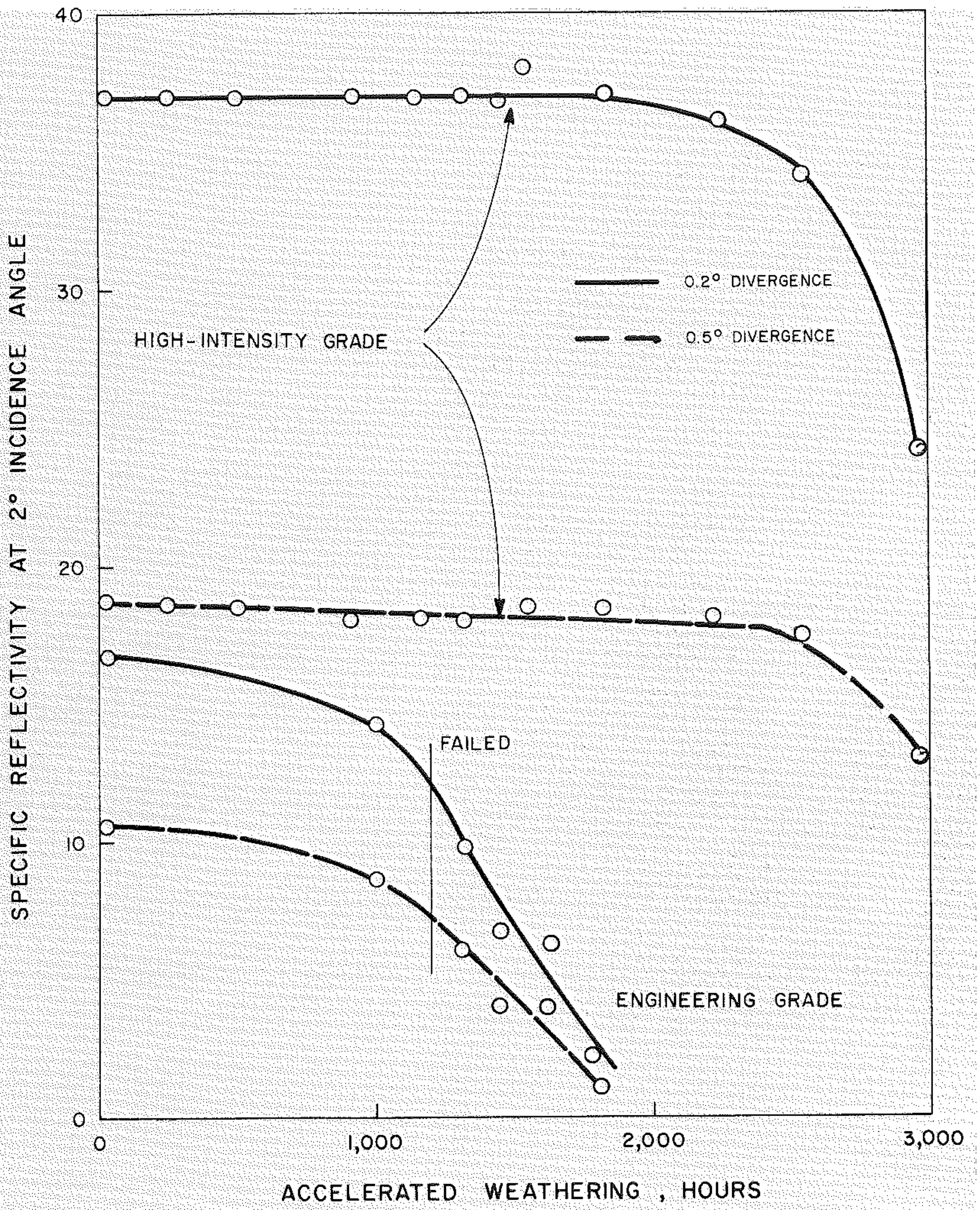


Figure 9. Accelerated Weathering of Red (Reverse Screened) Scotchlite Sheeting.

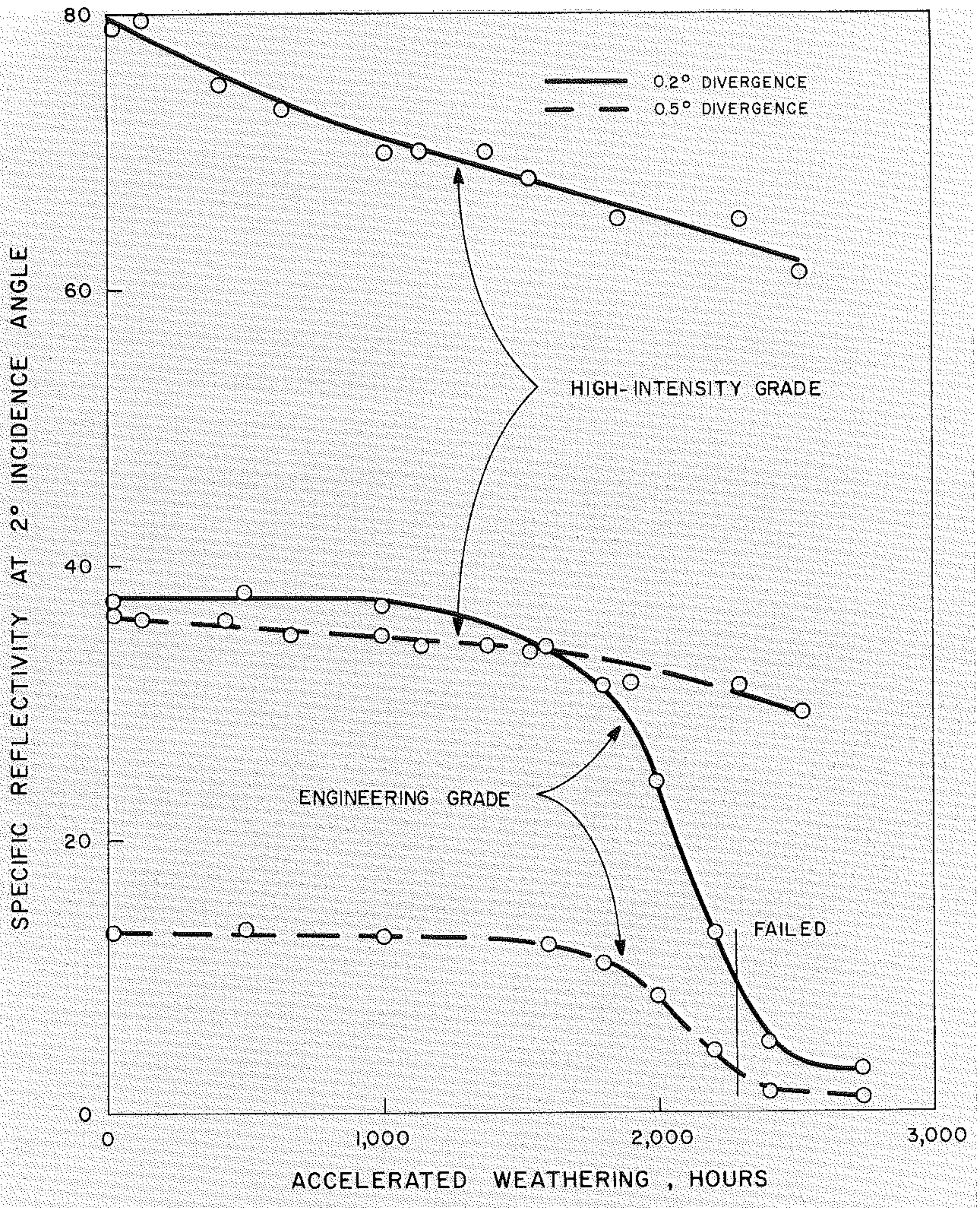


Figure 10. Accelerated Weathering of Orange Scotchlite Sheeting.

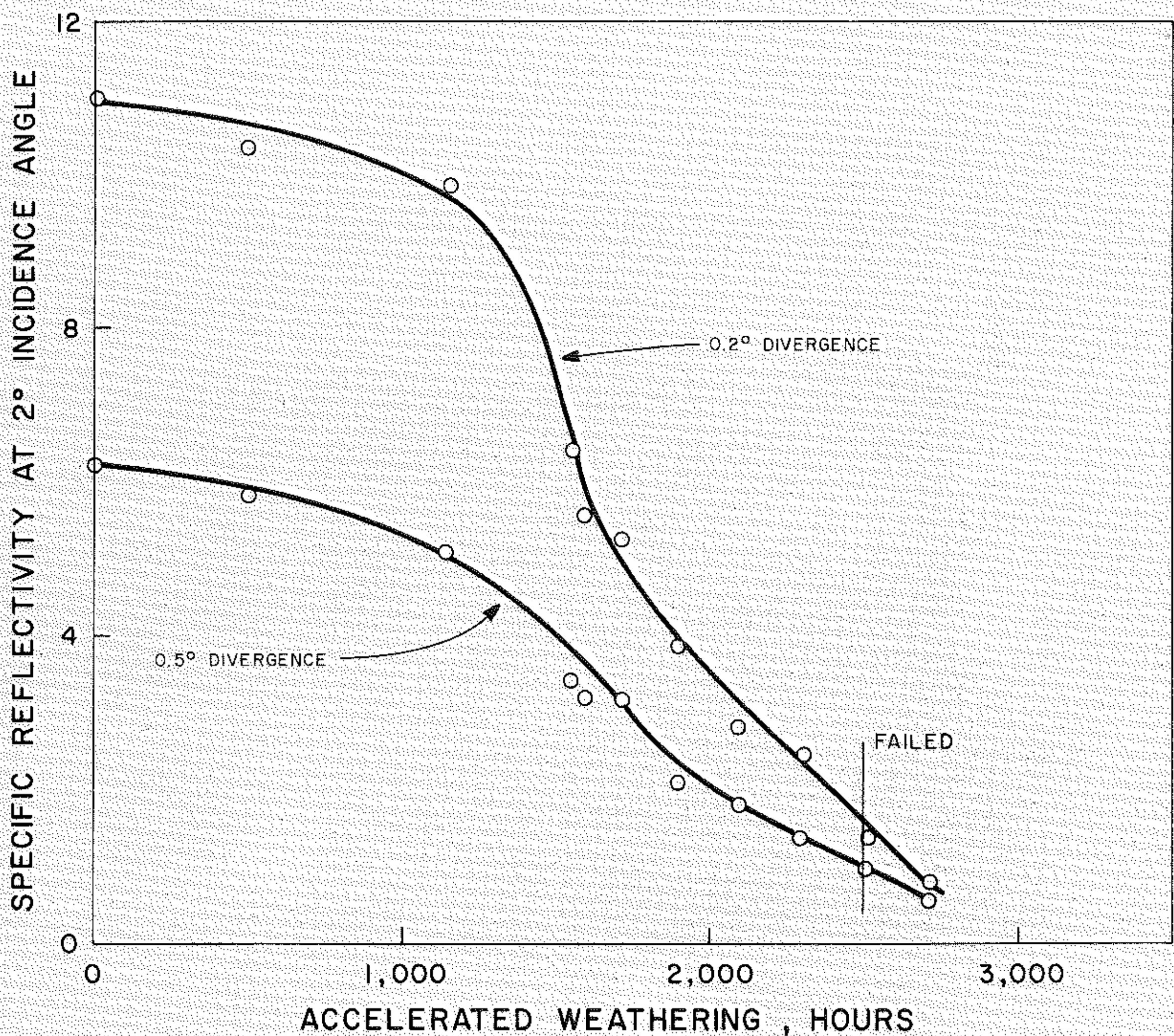


Figure 11. Accelerated Weathering of Blue Engineering Grade Scotchlite Sheeting.

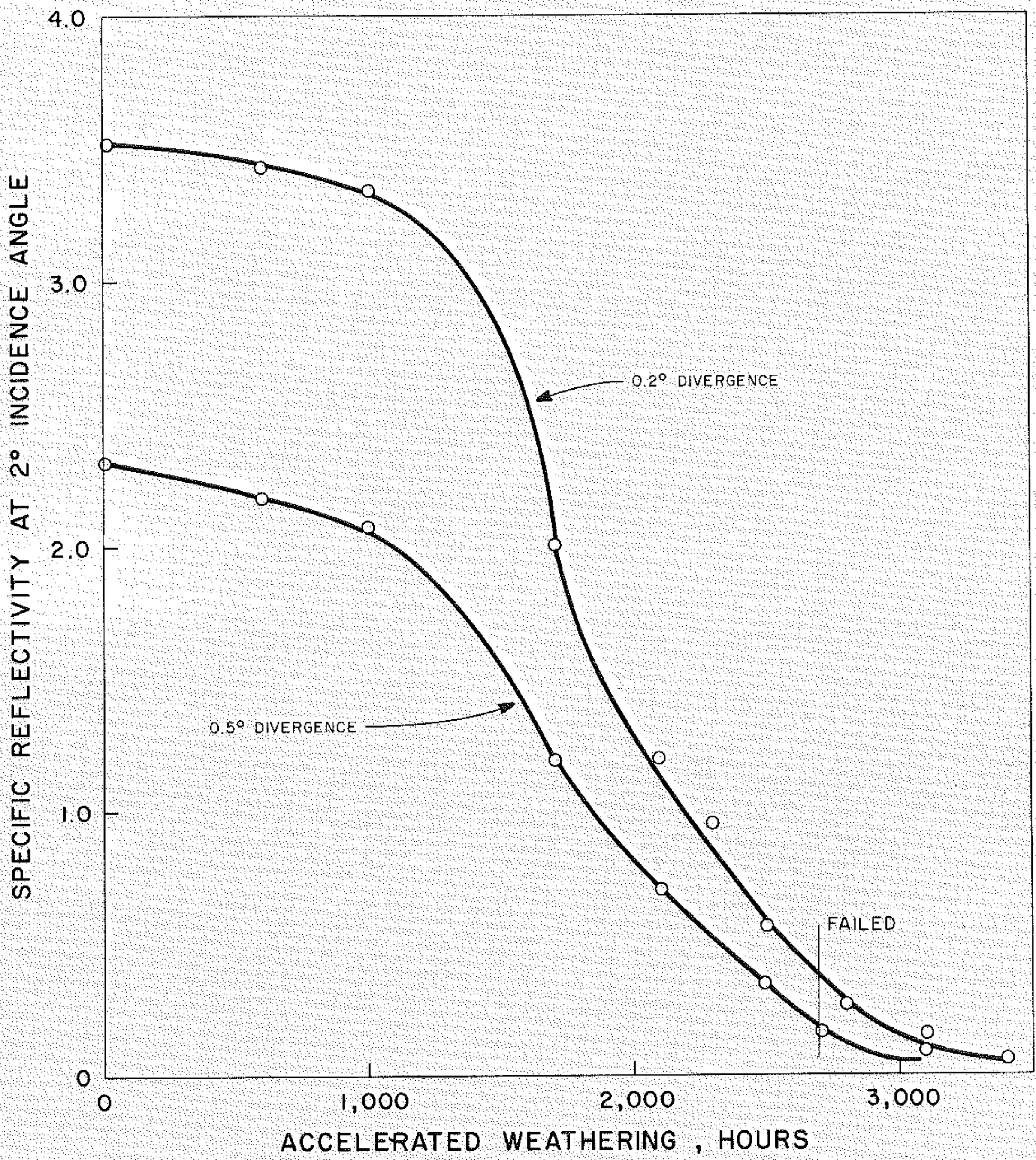


Figure 12. Accelerated Weathering of Brown Engineering Grade Scotchlite Sheeting.

REFERENCES

1. Rizenbergs, R. L., *Development of Specifications for Reflex-Reflective Materials,* Division of Research, Kentucky Department of Highways, October 1970.

2. Youngblood, W. P. and Woltman, H. L., *A Brightness Inventory of Contemporary Signing Materials for Guide Signs*, **Record 377,** Highway Research Board, 1971.

3. Adler, B. and Straub, A. L., *Legibility and Brightness in Sign Design,* **Record 366**, Highway Research Board, 1971.

4. Woltman, H. L., *Brighter is Better*, a discussion prepared by the Minnesota Mining and Manufacturing Company, 1971.

5. Seymour, W. M., Deen, R. C., and Havens, J. H., *Traffic Control for Maintenance on High Speed Highways,* **Research Record 484,** Transportation Research Board, 1974.

6. *Evaluation of Reflective Sign Material*, Louisiana Department of Highways, January 1973.

7. Rizenbergs, R. L. *High-Intensity Reflective Materials for Signs*, Division of Research, Kentucky Department of Highways, June 1972.

8. Rizenbergs, R. L. *High-Intensity Reflective Materials For Signs*, Division of Research, Kentucky Bureau of Highways, May 1973.

APPENDIX A

SPECIAL PROVISION NO. 89-B
ON REFLEX-REFLECTIVE MATERIALS

and

TABLES ON EQUIVALENT, CONVENTIONAL TUNNEL-PHOTOMETER VALUES FOR MINIMUM REFLECTIVITY OF CLASS A AND CLASS B (TYPE I) REFLECTIVE MATERIALS

KENTUCKY DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS
SPECIAL PROVISION NO. 89-B

REFLEX-REFLECTIVE MATERIALS

This Special Provision covers the requirements for Reflex-Reflective Materials and shall be applicable when indicated in plans, proposals, or bidding invitations.

I. GENERAL REQUIREMENTS

The reflective materials specified herein shall exhibit a daylight appearance which is unaffected by viewing angle and which is exemplified by diffuse surfaces. Retro- or reflex-reflective, optical elements shall be an integral feature of these materials. The optical systems shall be functionally faithful to the geometry associated with nighttime driving and sign-viewing conditions. They shall utilize the light incident from automobile headlights and shall return a substantial portion of it along the driver's line of sight. The materials shall not exhibit spurious iridescence or luminescence but shall, unless intently specified, faithfully exhibit the same color and appearance under directional lighting as in daylight. All materials and prepared sign faces shall be free from cracks, tears, ridges, humps, discoloration, or other objectionable blemishes. The material shall also be resistant to the formation of appreciable fungus growth. All materials procured for fabrication of finished signs by the Bureau or its agent shall comply with all the requirements attendant to the methods and procedures of fabrication as recommended by the manufacturer and/or as prescribed by the Bureau. Failure of a material to comply, or to render impossible the successful fabrication of a finished sign, shall cause the material to be rejected as unsatisfactory for the purpose intended.

II. OPTICAL DESIGN

The design of materials covered by this specification shall represent either a lens-mirror optical system or a prismatic optical system, in the sense that those terms normally apply to basic forms of reflex-reflecting materials.

III. DESIGNATION OF MATERIALS BY METHOD OF APPLICATION

The method or means by which a material is applied or attached shall appropriately designate the material as being in one or more of the following categories:

Type I. Glue-on Materials, including prefabricated sheeting, laminates, prepared sign faces or decals, suitable for application to prepared flat or curved surfaces by the use of adhesives. Sheeting materials shall present a finished surface suitable for receiving stenciled messages or paint overlays. All materials in this group shall be further identified in accordance with the adhesive required for application, as follows:

P. Pressure-Sensitive - Adhesives which secure the sheet material to the prepared surfaces when subjected to pressure by a rubber roller or vacuum envelope.
S. Solvent-Sensitive - Adhesives which are activated by a light application of solvent immediately before the reflective material is pressed onto the prepared surfaces.
T. Thermo-Sensitive - Adhesives requiring heat to soften the adhesive prior to or at the time pressure is applied in a manner described above.

The method of application for any Type I material shall produce a surface free from cracks or tears, ridges or humps, discolorations, or other objectionable blemishes; and when intended for use on mildly embossed surfaces, as stated in the invitation for bids, the material and method of application in combination shall provide an unblemished and unbroken surface comparable to that obtainable with smooth surfaces.

Type II. Screw-on or Bolt-on, demountable legend and border consisting of individual reflectorized letters, numerals, symbols, borders and corner radii. The materials shall be readily adaptable to surfaces with Type I materials. All materials in this group shall be further classified in accordance with their physical features as follows:

A. Bold Face Letters, numerals, symbols or borders cut or formed in the desired outline of specified size and shape, and having integral reflex-reflective characteristics.

B. Button Inserts consisting of plastic prismatic reflex-reflective optical systems combined to form the outline of letters, numerals, symbols or borders and mounted in embossed frames of specified material and finish.

C. Medallions or Brilliants of plaque-like construction, having the desired size and shape to form the outline of the letters, numerals, symbols or borders. Individual plaques shall, in accordance with the bidding invitation, have surfaces either entirely reflectorized or only partially reflectorized.

Type III. Screw-on or Bolt-on demountable delineator units consisting of either cut or formed material of specified size and shape. The delineator units shall be readily attachable to mounting posts. All materials in this group shall be further classified according to their physical features as follows:

A. Delineator Unit consisting of plaque-like construction and having plastic prismatic reflex-reflective optical system to form a single reflectorized surface.
B. Delineator Unit of plaque-like construction consisting of button inserts or other individual reflex-reflective optical systems combined to form the shape of the delineator unit and mounted in frames of specified material and finish.
C. Delineator Unit consisting of Type I materials.

Type IV. Paint-on or Spray-on coating compounds suitable for application by brush or spray for marking surfaces for safety to insure their visibility at night.

IV. OPTICAL REQUIREMENTS

A. Method of Test. The apparatus used for reflectivity measurements shall be a modified ESNA Reflex-Photometer manufactured by the Elastic Stop Nut Corporation of America. The optical alignment, arrangement of essential elements and associated instrumentation are illustrated in the Schematic Diagram of the ESNA Reflex-Photometer included herein.

The procedure employed in the use of the ESNA Reflex-Photometer shall consist of measuring the intensity of the light incident (I) upon the material to be tested and the reflected light (R) from the material at the photocell location shown on the schematic diagram for the angles of divergence and incidence (defined below) as required for the particular type of material. Yellow, red, amber, orange, and brown materials shall be tested by introducing an appropriate color filter in the measurement of incident light intensity. Detailed measurement procedures may be obtained from the Bureau of Highways upon request.

B. Definitions.

1. Angle of Divergence shall mean the angle subtended between observer's line of sight and direction of light incident on the reflecting surface at the center of the illuminated area.

2. Angle of Incidence shall mean the angle between the direction of incident light at the center of the illuminated area and the normal to (perpendicular to) the reflecting surface.

3. Specific Reflectivity shall mean candlepower returned at a given angle of divergence and incidence by the reflecting surface for each foot-candle of illumination at the reflecting surface and normal to the central incident ray on a unit area of the material or on a unit reflector.

C. Calculations. Specific Reflectivity shall be calculated using the general formula as shown below:

$$S.R. = (R \times d^2 \times K)/(I \times A)$$

where S.R. = Specific Reflectivity, in terms of candlepower per foot-candle per unit area or per unit reflector,

R = Reflected light intensity,

I = Incident light intensity,

d = Distance from test material to photocell, in feet,

A = Area of test material in square feet or square inches as specified for a given material,

NOTE: "A" is to be deleted for materials where Specific Reflectivity is calculated on a unit reflector.

K = Transmission factor of color filter, if used. (Red - Kodak Wratten Filter A; Yellow-two (2) Kodak Wratten Filters No. 15; Amber - ESNA Filter; Orange - Kodak Wratten Filter No. 22; Brown - Kodak Wratten Filters #21 and 22, and ESNA Filter Green.)

D. Reflectivity. The reflective materials, including all colors of the prepared sign faces, shall have the following minimum Specific Reflectivity expressed in units as denoted for the various materials classified in Section III:

Type I, Type II-A, and, if applicable, Type II-C materials, having a minimum gloss value of 40 as specified in Section VII A, shall exhibit minimum Specific Reflectivity, expressed in candlepower per foot-candle per square foot of the material, according to the following classification of brightness levels:

		Divergence Angle					
		0.5°			0.2°		
		Incidence Angle			Incidence Angle		
CLASS	COLOR	4°	15°	30°	4°	15°	
A	Silver-White	29	24	15	60	50	
A	Yellow	30	25	15	50	40	
A	Green	4.3	3.1	2.1	7.4	5.4	
A	Blue	3	2.5	2	5	4	
A	Red	7	6	4	13	11	
A	Orange	12.5	11	5	21	17	
A	Brown	0.27	0.21	0.12	0.78	0.65	
B	Silver-White	70	60	45	160	145	
B	Yellow	50	40	30	100	90	
B	Green	10	8	4	19	16	
B	Blue	9	8	5	15	12	
B	Red	12	10	7	26	22	
B	Orange	23	20	15	50	45	

Type II-B and Type II-C materials shall exhibit the following minimum Specific Reflectivity expressed in terms of candlepower per foot-candle per square inch of the material:

	Divergence Angle					
	0.5°			0.2°		
	Incidence Angle			Incidence Angle		
COLOR	0°	15°	30°	0°	15°	
Silver-White	3	2	Min. 0.1 Avg. 0.4	11	8	

Type III materials shall exhibit the following minimum Specific Reflectivity expressed in terms of candlepower per foot-candle per unit reflector:

	Divergence Angle					
	0.33°			0.1°		
	Incidence Angle			Incidence Angle		
COLOR	0°	10°	20°	0°	10°	20°
Silver-White	40	34	15	110	100	45
Amber	25	20	9	60	55	25

Type IV materials shall exhibit the following minimum Specific Reflectivity expressed in terms of candlepower per foot-candle per square foot of the material:

	Divergence Angle					
	0.5°			0.2°		
	Incidence Angle			Incidence Angle		
COLOR	4°	15°	30°	4°	15°	
White	8	7	6	15	13	
Yellow	5	4	3	9	8	
Black	5	3.5	3	8	6	

V. COLOR REQUIREMENTS

The diffuse daylight color of yellow, red, blue, green, and brown sign materials or prepared sign faces shall conform to the Color Tolerance Charts issued by the Federal Highway Administration and referred to as Highway Yellow (PR Color # 1), Highway Red (PR Color # 2), Highway Blue (PR Color # 3), Highway Green (PR Color # 4), Highway Brown (PR Color # 5), and Highway Orange (PR Color # 6). Comparisons with the respective Color Tolerance Chart may be made according to the instructions on the chart or by viewing the material and superimposed chart at a greater distance but oriented perpendicular to the viewer and under clear sky conditions but away from direct sunlight. Conformity by either method of comparison viewing shall comprise a basis for acceptance. Silver-white materials shall not exhibit an objectionable shade or tint.

The diffuse daylight color of reflective coating compounds (Type IV materials) shall be within the Munsell color limits listed below, when determined in accordance with ASTM D-1535-68 Section 5 and shall have reflected nighttime color as noted.

	DAYLIGHT COLOR			NIGHTTIME COLOR
Color	Munsell Notation – Matte Collection			
	Hue	Value	Chroma	
White	N	8.0 Minimum	–	Silver-White
Yellow	8.5YR-5.0Y	7.0 Minimum	12.0 Minimum	Yellow
Black	N	3.0 Maximum	–	Silver-White

VI. DURABILITY REQUIREMENTS

The reflex-reflective materials designated as Type I, Type II-A, Type IV, and, if applicable Type II-C and Type III-C, materials when processed and applied in accordance with recommended procedures shall be weather resistant and, following testing in a weatherometer and subsequent cleaning, shall show no appreciable discoloration, cracking, peeling, blistering, fading, dissolving, dimensional changes, nor otherwise display visible evidence of deterioration. The materials shall not be removable from the aluminum panels without damage.

The weatherometer apparatus shall conform to the requirements for Type E of ASTM G 23, and the reflex-reflective materials shall be exposed in the apparatus in accordance with ASTM D 822 and/or ASTM D 1499, as appropriate, for the number of hours indicated below.

Material	Reflectivity Class	Hours of Exposure
Fabricated Sheeting	A (all colors)	1,000
	B (all colors, except orange)	3,000
	B (orange only)	1,000
Prepared Sign Faces	A (all colors)	700
	B (all colors)	1,500

The test cycle shall consist of 102 minutes of light only followed by 18 minutes of light and water spray. After the exposure, the Specific Reflectivity of the weathered materials shall not be less than 80% of the specified minimum brightness values. No process colors shall be removable after weathering when scratched through the color surface and by applying cellophane tape over the scratched area and then removing the tape with a quick motion.

Sealed reflectors designated as Type II-B and Type III-A, and, if applicable Type II-C and Type III-B, shall be tested for adequate sealing against dust, water and water vapor, and resistance to heat as follows:

A. Seal Test. Submerge representative material samples in water bath at room temperature and apply a vacuum equal to five inches of mercury for five minutes. Restore atmospheric pressure and leave samples in water bath for 5 minutes. Inspect samples for water intake.

B. Heat Resistance Test. Place reflectors in a horizontal position on grid or perforated shelf in a circulating air oven at 175° F for a period of 4 hours, then remove and cool in air at room temperature. The samples shall show no significant change in shape or appearance.

Durability testing may be waived when previous tests by the Bureau have substantiated the durability of a particular material; however, the Bureau may elect to sample and test any and all shipments at its discretion and conduct tests whenever they are judged to be necessary to assure compliance with the specification.

VII. OTHER REQUIREMENTS AND TESTS (Type I Materials)

A. Surface Sheen. The surface sheen or specular gloss of the material shall be measured before and after accelerated weathering with a Gardner, Model 85 PG-2, 85-degree glossmeter in accordance with ASTM-D-523.

B. Shrinkage. A 9-inch by 9-inch sample of reflective sheeting shall be checked for shrinkage at standard room conditions (75° F, 50% RH) by removing the liner and placing the material on a flat surface. Ten minutes after the liner removal, the material shall not exhibit dimensional change in excess of 1/32 inch, or after 24 hours, more than 1/8 inch.

C. Adhesion. When applied to a smooth degreased and slightly acid etched aluminum surface, the adhesive of the reflective sheeting shall produce a bond to support a 1 3/4 pound weight for 5 minutes without peeling for a distance of more than 2.0 inches. The test shall be conducted after two 2-inch by 6-inch pieces have been subjected to a temperature of 160° F and a pressure of 2.5 pounds per square inch for 4 hours and allowed to attain equilibrium at standard room conditions. One 1-inch by 6-inch specimen shall be cut from each piece and the liner removed, and 4 inches of one end of each specimen applied to a test panel. The panels are to be suspended in a horizontal position with the specimen facing downward. The weight shall be attached to the end of each specimen and allowed to hang freely.

VIII. SAMPLING

For the purpose of sampling, a shipment shall consist of the amount of material received in one delivery even though it may represent only partial delivery of the contracted quantities. Samplings shall be made from at least three widely separated and indiscriminately chosen packages of like materials included in the shipment. Samples to be submitted for reflectivity, color and durability testing shall be as follows:

Type I and Type IV Materials. Samples of either material shall be applied as recommended, to 3-inch by 9-inch properly degreased and slightly acid etched aluminum panels. Whole prepared sign faces shall be submitted as complete units. Edges shall be clean and neatly trimmed.

Type II and Type III Materials. Three complete letters, numerals, symbols, borders, corner radii, medallions or delineators selected at random. In cases where the units purchased are not of sufficient size to provide test specimens of at least 2 inches in width and 6 inches long or 1 1/2 inches in diameter, the largest size available shall be submitted.

IX. PACKAGING

All materials shall be suitably and substantially packaged; and shall have the name and address of the manufacturer or vendor, contract or purchase order number, kind of material, trade name, and net contents plainly marked on each package or container.

X. MEASUREMENT FOR PAYMENT

Sheet materials such as Type I materials shall be measured by the square foot, except prepared sign faces shall be measured in units. Type II materials shall be measured by assembled complete units and Type III materials shall be measured by units. Liquid materials (Type IV) shall be measured by gallons, or by pounds, as specified.

APPROVED 4-26-73

J. R. Harbison

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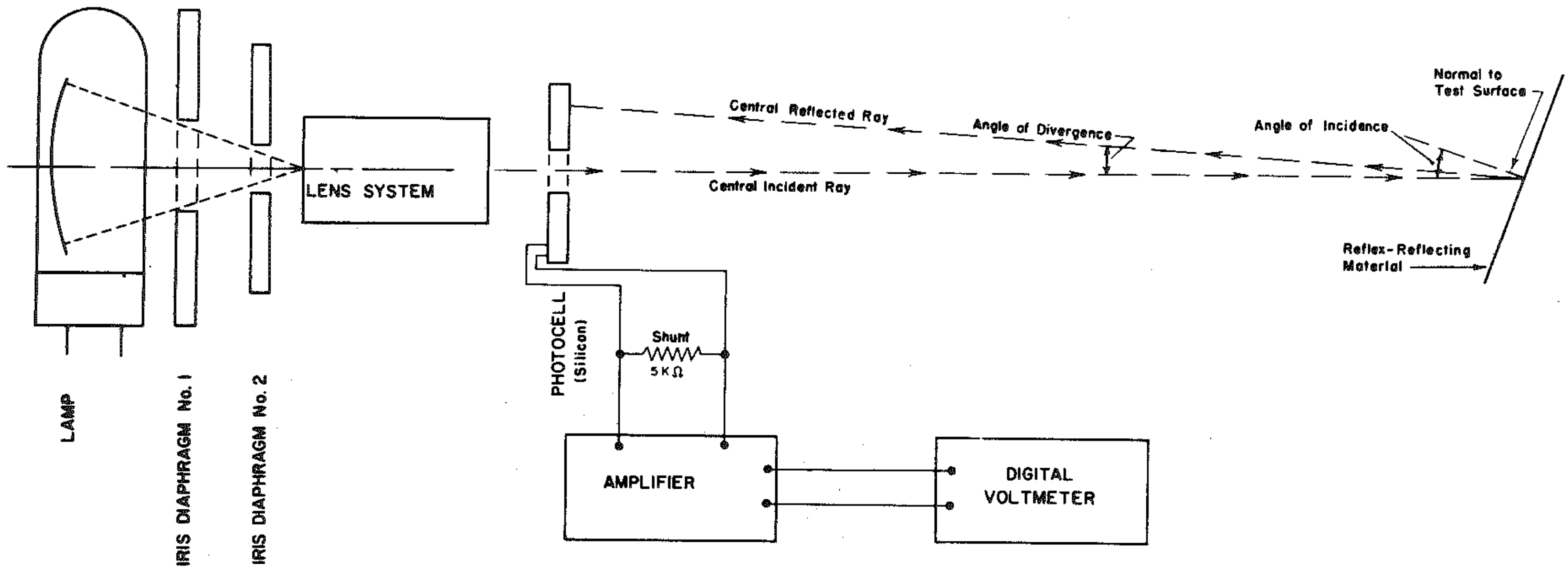
STATE HIGHWAY ENGINEER

(See page 4 of 4 for Schematic Diagram of Reflex-Photometer.)



SCHEMATIC DIAGRAM OF REFLEX-PHOTOMETER

TABLE A - 1

EQUIVALENT, CONVENTIONAL TUNNEL-PHOTOMETER VALUES FOR MINIMUM REFLECTIVITY OF CLASS A (TYPE I) REFLECTIVE MATERIALS
(comparative measurements provided by Minnesota Mining and Manufacturing Company)

COLOR	INCIDENCE ANGLE (DEG.)	0.5° DIVERGENCE ANGLE	0.2° DIVERGENCE ANGLE
Silver White	4	30	69
	15	25	56
	30	14	
Yellow	4	21	41
	15	18	32
	30	10.5	
Green	4	4.5	9
	15	3.9	7.5
	30	2.5	
Blue	4	2	4
	15	1.9	3.3
	30	1.2	
Red	4	5.2	11.4
	15	4.7	10.2
	30	2.2	
Orange	4	13.5	25
	15	12.7	21
	30	5.5	
Brown	4	0.35	1.0
	15	0.32	0.48
	30	0.19	

TABLE A-2

EQUIVALENT, CONVENTIONAL TUNNEL-PHOTOMETER VALUES FOR MINIMUM REFLECTIVITY OF CLASS B (TYPE I) REFLECTIVE MATERIALS
(comparative measurements provided by Minnesota Mining and Manufacturing Company)

COLOR	INCIDENCE ANGLE (DEG.)	0.5° DIVERGENCE ANGLE	0.2° DIVERGENCE ANGLE
Silver White	4	72	215
	15	63	195
	30	55	
Yellow	4	48	131
	15	38	105
	30	31	
Green	4	10	29
	15	8.3	25
	30	5.3	
Red	4	11.5	30
	15	9.2	25
	30	7.3	
Orange	4	17	48
	15	15	42
	30	12	

APPENDIX B

RECOMMENDED USE OF REFLECTIVE MATERIALS IN SIGNING

RECOMMENDED USE OF REFLECTIVE MATERIALS IN SIGNING

1. Legibility of signs depends upon the brightness (luminance) of the sign (message and background) and the contrast between message and background. The message may be reflectorized or opaque, depending on the sign type. Color of the materials, of course, should remain the same at night as in daylight. Messages composed of Type I materials in reflectivity Class B (High-Intensity Grade Scotchlite) or Type II-B (button inserts) may be used with Class A sheeting (Engineering Grade Scotchlite) for background, but under no circumstances should Class A legend be used with Class B background since proper contrast under nightime illumination would not be provided.
2. Selection of like materials for all components in a sign, or sign types within a signing project, is important for nighttime legibility and uniform appearance. The entire sign legend, including route markers, should consist of materials within the same reflectivity classification.
3. Low-beam headlight illumination of signs at night has become usual on most roadways today because of increased traffic volumes. Use of the brightest materials should, therefore, be considered foremost wherever sign illumination levels are expected to be low. Two-lane, rural roads with ADT's of 1,000 or less would not materially benefit from brighter materials. Here, Class A reflectivity materials may be adequate. However, durability of the materials may be an overriding consideration.
4. Temporary signing, or signs which may be expected to be replaced within a few years after installation, do not, of course, require materials with exceptional durability characteristics -- such as Class B materials. Sign legibility and uniform appearance of signs at a location on the roadway section does have to be considered and may, therefore, override durability considerations.
5. Relative durability or service life of each material should always be considered in the selection process. Class A materials are not expected to last as long as Class B materials. Incorporation of unlike materials in a sign will result in obsolescence of the sign even though portions of the sign, such as Class B legend, may show no appreciable loss in reflectivity.
6. The real cost of the sign face depends upon the price of the materials, expected service life, and maintenance and replacement labor and equipment rental costs. Therefore, cost per unit service life is the proper index in comparing materials. Durability of Class B materials greatly exceeds that of Class A materials, and Class B materials are, therefore, preferable for use in all signs.
7. Letter size in the message, and therefore the viewing distance, and placement of the sign has been found to be of importance in selection of reflective materials. Reflectivity Class B materials in large signs are most effective at the greater viewing distances and are proportionally less effective in smaller signs. Signs placed furthest from the traffic stream receive least illumination from headlights and, therefore, require brighter materials (Class B) to be legible at distances for which the sign was designed.
8. Overhead signs illuminated with independently mounted light sources will not benefit appreciably from incorporation of brighter materials unless the light fails. Increased durability of Class B materials may be an overriding consideration. In the event of power failure, the brighter materials would provide considerably improved legibility over Class A materials.
9. Overhead signs illuminated by vehicle headlights only should consist of the brightest materials available because headlights, especially on low beam, provide very limited illumination. Here, Type I, Class B materials, because of their wide-angle reflective characteristics, would be most effective.
10. Brighter and more durable materials, and materials possessing other desirable characteristics, can be expected to become available. Their evaluation and consideration from the standpoint of specification requirements and usage should be an ongoing activity to insure use of the most suitable and economical materials in sign reflectorization.