TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
91		

4. Title and Subtitle	5. Report Date
EVALUATION OF RETROREFLECTIVE DURABILITY OF RAISED PAVEMENT MARKERS	August, 1975
	6. Performing Organization Code
7. Author(s) R. W. Kinchen and E. J. LeBlanc	8. Performing Organization Report No. 91
9. Performing Organization Name and Address Louisiana Department of Highways Research and Development Section P. O. Box 44245, Capitol Station Baton Rouge, Louisiana 70804	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Federal Office Building, Room 239 750 Florida Boulevard Baton Rouge, Louisiana 70801	13. Type of Report and Period Covered Final July, 1972-June, 1975 14. Sponsoring Agency Code

15. Supplementary Notes

Conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

The Louisiana Department of Highways began using reflectorized raised pavement markers on a large scale basis in 1967 when such markers were placed on the Mississippi River Bridge along Route I-10 at Baton Rouge. The Department has engaged in a considerable amount of research since 1967 in order to derive the most benefit from reflectorized raised pavement markers.

A standard test procedure for measurement of retroreflection of reflectorized markers has previously been developed and adopted. A supplemental specification was also written which now requires initial minimum retroreflection values before any given brand of marker may be placed on our highways. However, the specification does not address itself to the subject of retroreflective durability. Department policy alone has required a successful 12-month field performance by a given brand of marker prior to its acceptance for routine use.

This report documents a research effort to establish a rapid method of evaluating the nighttime retroreflective durability of reflectorized raised pavement markers and to develop source acceptance criteria keyed to this test method.

17. Key Words	18. Distribution Statement
Pavement marker, reflectorized, retroreflective durability,	UNRESTRICTED. May be obtained from the performing organization.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	46	---

Form DOT F 1700.7 (8-69)

R & D IMPLEMENTATION DATA SHEET

PART A

REPORTING STATE LOUISIANA

NOTE - The receiving office will code card Col. 3 thru 7, and 17 thru 25.

1 2 State	3 Yr	4 6 Id.Num.	7 UD	8 Cd	9 16 State Project No.	17 23 FCP Code	24 AP	25 Fnd	26 31 Proj. Start Date	32 37 Proj. Compl. Date	38 43 Date This Report
22					7360208		1	1	070172	063075	080675

44 47 STUDY COST TO DATE ($1000's): 0023

PART B

48 IS	49 IO	50 IP	51 IA	52 TA	53 RU	54 NI
2	1	3	3	1		

IMPLEMENTATION STATUS = (IS) in Col. 48
1 Implemented (ing) - Code Col. 49 & 42
2 Implementable - Code Col. 49, 50 & 51
3 No implementation planned - Code Col. 53 or 54

IMPLEMENTABLE BY OTHERS = (IO) in Col. 49
1 By most other states
2 Some other states
3 No other states
4 Other (Explain)

IMPLEMENTATION PLANS = (IP) in Col. 50
1 Will be implemented or underway in next 12 months
2 Will be implemented or underway in next 24 months
3 Implementation is planned, subject to action noted, in Col. 51

IMPLEMENTATION ACTION NEEDED = (IA) in Col. 51
1 Equipment changes or modifications needed
2 Administrative decision required
3 Need new or revised procedures, guidelines, manual, &/or standards or specifications
4 Training aids need to be prepared
5 Other (Explain)

NOT IMPLEMENTABLE = (NI) in Col. 54
1 Negative findings
2 Confirms present practice
3 Additional evaluation or study needed
4 Findings too complex
5 " impractical
6 " inconclusive
7 " unreliable
8 Other (Explain)

RESULTS POTENTIALLY USEFUL = (RU) in Col. 53
1 A phase, or one of a group of studies
2 Points up need for further research
3 Findings are theoretical in nature
4 Exploratory
5 Findings valuable in decision making
6 Other (Explain)

TRAINING AIDS USED, PLANNED OR NEEDED =
1 Workshops
2 Movies
3 Slides
4 Other
5 None used, but some are needed (Explain

PART C

55 56 Rep. State	57 62 Benefit End Date	63 64 Num. Mo.	65 SB	66 67 Accid Prev.	68 69 Lives Saved	70 73 Cash&Saved	74 77 User&Saved	78 79 Ben/C	80 Ys No
22	080675	01							1

State Reporting Implement.

TIME PERIOD OF SAVINGS & BENEFITS
Period ending date - Col's. 57 - 62
Total period in months - Col's. 63 & 64

TYPE OF SAVINGS OR BENEFITS = (SB) in Col. 65
1 Cash savings to agency
2 Highway user savings (monetary)
3 Savings probable but difficult to assess
4 Improved safety or convenience
5 Improved aesthetics, environmental aspects

For combination benefits, see manual for codes.

ESTIMATED No. of ACCIDENTS PREVENTS & NO. OF LIVES SAVED
No. of Accidents in Col's 66 & 67
No. of Lives saved in Col's 68 & 69

BEST EST. OF & SAVINGS THRU IMPLEMENTATION
Enter agency savings ($1000) in Col's 70-73
Enter user savings ($1000) in Col's 74 - 77

BENEFIT/COST RATIO (For reporting period)
Enter in Col's. 78 & 79, to nearest unit $, the benefits per research dollar invested

DID RESEARCH PAY OFF - Col. 80
If no estimate is possible, do you feel that benefits substantially exceeded the cost? Enter code, Yes = 1, No = 2

8 Card	9 80 R & D Study Title
B	EVALUATION OF RETROREFLECTIVE DURABILITY OF
C	RAISED PAVEMENT MARKERS
D	

NOTE

Type no more than 72 characters (Elite) per line including all spaces and punctuation. Use ALL CAPS

EVALUATION OF RETROREFLECTIVE DURABILITY OF RAISED PAVEMENT MARKERS

Final Report

By

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Research Report No. 91

Research Project No. 71-6C(B)
Louisiana HPR 1 (13)

Conducted by
LOUISIANA DEPARTMENT OF HIGHWAYS
Research and Development Section
In Cooperation With
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

AUGUST 1975

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IMPLEMENTATION STATEMENT

The test method presented in the Appendix for evaluation of the retroreflective durability of raised pavement markers has been submitted to the Department for consideration. Likewise, the special provision for retroreflective durability (also in the Appendix) has been submitted for review. The Department is urged to implement the test track procedure and accompanying durability criteria as rapid and objective means of source approval for reflectorized raised pavement markers.

SYNOPSIS

The Louisiana Department of Highways began using reflectorized raised pavement markers on a large-scale basis in 1967 when such markers were placed on the Mississippi River Bridge along Route I-10 at Baton Rouge. The Department has engaged in a considerable amount of research since 1967 in order to derive the most benefit from reflectorized raised pavement markers.

A standard test procedure for measurement of retroreflection of reflectorized markers was developed and adopted. A supplemental specification was written which now requires initial minimum retroreflection values before any given brand of marker may be placed on our highways. However, the specification does not address itself to the subject of retroreflective durability. Department operational policy has therefore required a successful 12-month field prequalification performance by a given brand of marker prior to its acceptance for routine use.

Highway research personnel have developed a rapid method of evaluating the nighttime retroreflective durability of reflectorized raised pavement markers. The method employs the Department's test track, and in approximately 12 work days simulates 12 months of roadway wear. Retroreflective durability standards keyed to this rapid test have been proposed for source acceptance of raised pavement markers.

It is recommended that the Department adopt the test track procedure and durability criteria proposed herein as means of accepting or rejecting sources of reflectorized raised pavement markers. An approved source should be re-evaluated at least once every year to insure the use of markers with sufficiently high nighttime retroreflective durability.

INTRODUCTION

Louisiana Department of Highways Research Report No. 60 (1)* reported significant accomplishments in the evaluation and application of raised pavement markers. A realistic method of measuring the brightness of raised pavement markers was presented in the form of test procedure LDH Designation: TR 604. A guide to reflectivity levels required of markers to perform specific functions under traffic was presented in the form of a supplemental specification.

The above report also concluded that laboratory load and heat resistance tests are inadequate means of evaluating the durability of raised pavement markers under traffic. Consequently, the report recommended additional research to ascertain whether or not the Louisiana Department of Highways test track could be used to evaluate the durability of raised pavement markers. Meanwhile, the Department was to require a successful 12-month field performance of a marker prior to its acceptance on a routine basis. (Twelve months was not intended to imply an expected life for a marker, but was merely a designated prequalification period.)

This report relates the findings of a project investigating the use of the test track to evaluate durability of raised pavement markers. The specific purpose of the study was to develop a quick but valid laboratory durability test for source acceptance or rejection of raised pavement markers.

* Underlined numbers in parenthesis refer to "Bibliography".

SCOPE

The scope of the study is as follows:

1. To determine the brightness levels which reflectorized raised pavement markers maintain after 12 months service under traffic.

2. To establish retroreflection decay trends for reflectorized raised pavement markers subjected to abrasion by the tire of the Department's test track.

3. To establish a laboratory (test track) durability test which will simulate 12 months of wear by actual traffic and durability criteria which will serve as a means of acceptance of raised pavement markers.

METHOD OF PROCEDURE

Method of Test for Brightness of Raised Pavement Markers, L.D.H. Designation: TR 604

Highway Research personnel measured the retroreflective characteristics of the raised pavement markers involved in this study in accordance with test procedure L.D.H. Designation: TR 604. However, during the course of the study this test procedure was radically revised.

L.D.H. Designation: TR 604-70 required the use of a Cintra Model 150 photometer (or equivalent), an accessory probe, a non-reflective light-shielded enclosure, and a standard reflective marker. In 1974, the Department's Materials Laboratory replaced the Cintra Model 150 with the Spectra Pritchard Photometer Model 180. Additionally, the light-shielded enclosure has been replaced with a larger (room-sized) non-reflective enclosure. Apparatus for the revised test procedure is shown in Figure 1 and merits further explanation.

The Pritchard photometer control console rests on the table at the right side in Figure 1. Reflectivity measurements in foot-lamberts are read on a primary digital display in conjunction with a secondary power-of-ten digital display. This control console is connected by an eight-foot cable to the optical head, the objective lens of which is shown as a small dark circle in the top center in Figure 1. The optical head simultaneously measures the intensity of the light and provides a view for the operator. A transit shown at the left side of Figure 1 supports and aligns the markers under evaluation. Two standard automobile headlights shown at the top center in the figure provide light to the marker.

The Pritchard photometer was factory-calibrated with a National Bureau of Standards-traceable luminance standard. Personnel of the Department's Materials Laboratory insure proper performance of the photometer by means of an internal calibration light source and an external calibration source (a designated pavement marker). Equally important for this study, the Pritchard photometer was calibrated with the Cintra Model 150 in effecting the transfer from the latter to the former.

FIGURE NO. 1

Equipment layout for Method of Test for Brightness of Raised Pavement Markers, L.D.H. Designation TR: 604 (Revised)

Determination of Marker Brightness Levels After 12 Months of Service on a Highway

Personnel of the Department's Concrete Research Unit placed 180 new raised pavement markers at 40-foot intervals along the centerline of the northbound roadway of Louisiana Route 1. This route is a multilane divided highway with access partially controlled. The northbound roadway is comprised of two lanes which serve approximately 16,000 vehicles per day. Research personnel had previously measured the retroreflection of the markers in accordance with the original test procedure LDH Designation: TR 604.

Sixty of the markers were Stimsonite 88 prismatic lens type with original retrorflection levels meeting Department requirements for Class IV markers. Sixty were Ray-o-lite prismatic lens markers, and sixty were Borg-Warner markers with individual glass reflective elements. These Ray-o-lite and Borg-Warner markers met requirements then existing for Class II markers. At the initiation of this study, Class II and Class IV markers represented the two levels of nighttime retroreflection required by the Department to perform specific functions. These levels are explained further under "Discussion of Results".

Each month for one year, highway research personnel removed four markers of each of the above three brand names from the portland cement concrete roadway in accordance with a non-biased sampling plan. These markers were tested for retroreflection in accordance with the original LDH Designation: TR 604. The 12-month retroreflection level was obtained from a statistically-based plot of percentage of original retroreflection versus time for each brand of marker.

Establishment of Retroreflection Decay Trends for Reflectorized Markers Subjected to the Abrasive Action of the Department's Test Track Tire

The test track was constructed during the previous research project (1). Plans for the test track were generously donated by the Republic Steel Corporation.

The major component of the test track is an automobile rear end assembly with one wheel removed. That end of the rear axle with the wheel removed is attached to a pivot at the center of the track. From this pivot, a one-and-one-half horsepower electric motor drives the rear-end assembly by means of a pulley attached to the differential. The tire moves around the concrete track at a speed of 1100 revolutions per hour (0.3 of a revolution per second), or approximately 10 miles per hour (4.5 meters per second), while traversing a circular path 16 feet (4.9 meters) in diameter. Wheel loads can be adjusted by the addition of weights to a steel box above the tire. A one-kip load was applied for this study.

Research personnel made improvements to the test track prior to and during the course of this research study. A roof was built to control moisture and debris conditions. A 6.70-by-15 inch (17-by-38.1 centimeter) smooth tread tubeless rayon tire was used to minimize rubber scuff marks which a treaded tire was producing on the pavement markers. Metal base plates were fabricated for mounting the markers on the test track and removing them therefrom. A right circular cylindrical container with an orifice at its base and with a tubular dispenser was fabricated and attached to the rear end asembly to apply sand to the track. A spray bar was installed around the base of the track to apply moisture thereon. The test track is illustrated in figures 2 and 3.

Figure No. 2
General View of Department's Test Track

Figure No. 3
Close-up View of Department's Test Track

The same three brands of markers that were evaluated on the roadway were evaluated for durability on the test track. The test track was operated under three sets of simulated environmental conditions to ascertain if any one set would be most appropriate for a standard test track procedure. These conditions were as follows:

1. Application of sand and water to the track
2. Application of sand without water to the track
3. Application of neither sand nor water to the test track.

Research personnel determined the initial retroreflection of the markers in accordance with the revised L.D.H. Designation: TR 604. The markers were then affixed to the detachable base plates by means of epoxy; the base plates were bolted to the concrete track; and the test track tire was passed over the markers.

Periodically, research personnel stopped the operation of the test track, removed the markers from the track, and measured retroreflection by the Department's standard test procedure. (Markers were clean and dry when measured.) The markers were then placed back on the test track and the tire was again set in motion. The research technicians continued this procedure until the retroreflection decay trends could be established for the three brands of markers studied.

Development of Test Procedure and Criteria for Durability Evaluation of Raised Pavement Markers

Retroreflective decay trends under various simulated environmental conditions were studied, and a test track procedure was developed for evaluating the retroreflective durability of raised pavement markers. Twelve-month marker roadway brightness levels were compared with test track marker retroreflection decay trends; and a special provision to a supplemental specification was developed, setting test track durability standards for raised pavement markers.

DISCUSSION OF RESULTS

Initial Retroreflection of Markers

Research personnel measured the initial retroreflection of markers evaluated on the roadway and of markers evaluated on the test track in accordance with L.D.H. Designation: TR 604. All markers used in the analyses met or exceeded the following optical requirements which the Department was enforcing at the initiation of this research study:

Class II Marker

Color	Retroreflectivity, Footlamberts, @ Angle of Incidence			
	@ 0°		@ 20°	
	Average	Minimum	Average	Minimum
Crystal Lens	40	30	24	18
Amber Lens	25	20	15	12
Red Lens	14	10	8	6

Class III and Class IV Marker

Color	Retroreflectivity, Footlamberts, @ Angle of Incidence			
	@ 0°		@ 20°	
	Average	Minimum	Average	Minimum
Crystal Lens	125	100	60	50
Amber Lens	80	65	35	25
Red Lens	25	15	15	10

Durability criteria explained later in this report were derived based on the above minimum values.

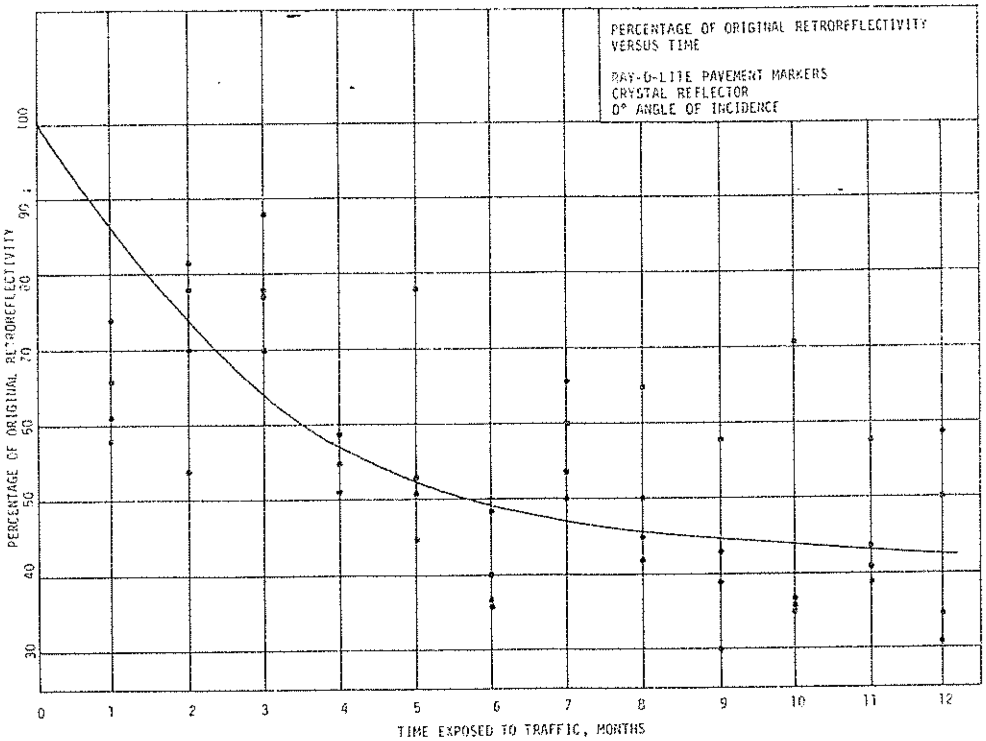
Determination of Marker Brightness Levels After 12 Months of Service on a Highway

As related earlier in this report, each month for one year research personnel removed four markers of each of three brands from Louisiana Route 1 and measured the markers' retroreflection in accordance with the Department's original standard test procedure. Retroreflective intensity levels were analyzed in terms of percentage of original retroreflection, since different markers were removed from the roadway and evaluated each month.

Figures 4, 5, and 6 on the following pages and figures 14 through 22 of the Appendix show the time-(and thus traffic-) related retroreflection decay curves for these road-tested markers. Both the crystal and red lenses were evaluated. Additionally, angles of incidence of both 0° and 20° were used. (Angle of incidence is the angle which the light from the headlamps of L.D.H. Designation: TR 604 makes with a perpendicular to the face of the reflective lens. The operator rotates the marker on a transit to establish this angle during the test.)

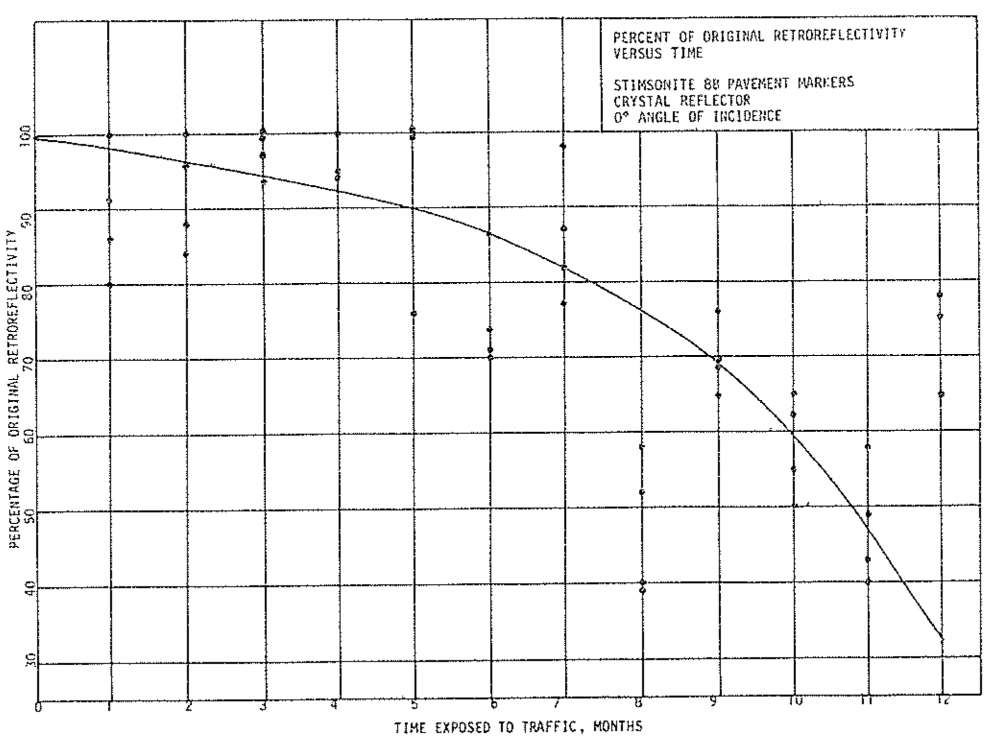
The retroreflection decay curves of figures 4, 5, and 6 and the accompanying figures in the Appendix are basically statistical, but were modified with engineering judgment as deemed appropriate by the authors. For example, the authors constrained all these mathematical curves to exhibit 100 percent retroreflection levels at zero months in time.

In striving to be objective, the researchers programmed roadway retroreflection data for the first 11 months and statistically predicted the 12-month marker brightness levels. Data representing retroreflection levels over an 11 month period seemed more than adequate to establish the sought decay trends. Hence, the authors considered the 12-month projected brightness levels to be more valid than field data gathered on a one-time basis for that twelth month. Actual twelve-month brightness data points are presented in the graphs for information only and in some cases (such as in figure 5) do indeed appear inconsistent with the overall trends established.



Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.

FIGURE 4

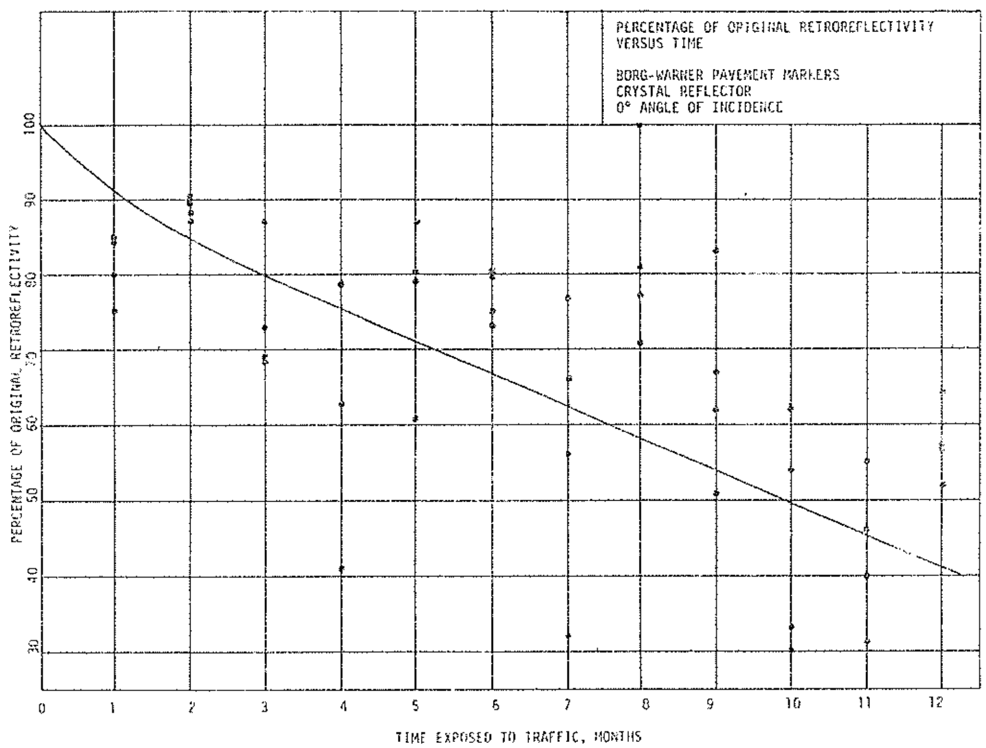


Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.

FIGURE 5

Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 4

Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 5



Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 6

Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 6

Test Track Durability

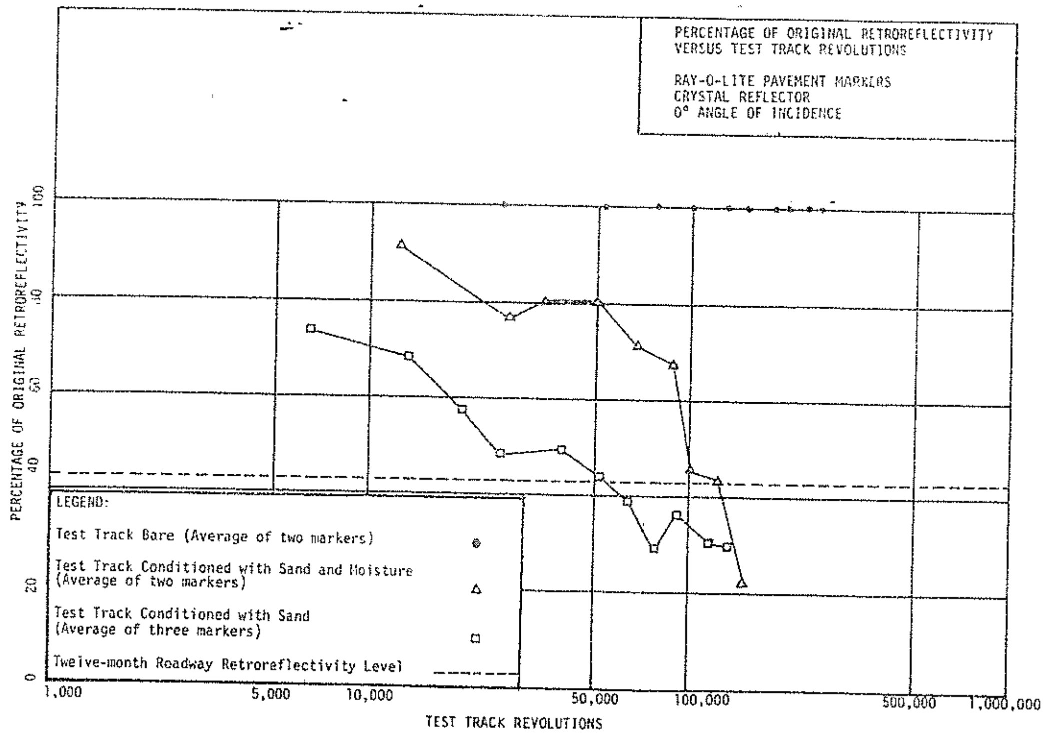
Highway research personnel placed samples of the subject three brands of traffic markers on the test track and established retroreflective decay trends for these markers. Roadway moisture and debris were simulated by the application of various combinations of water and sand. Figures 7, 8, and 9 depict the effects which sand and water had on the retroreflective durability of the given brands of markers. A horizontal line representing the 12-month statistical roadway level is superimposed upon each of these graphs.

For the cube-cornered Ray-o-lite and Stimsonite markers of figures 7 and 8, respectively, the addition of only sand grit to the track caused the most hasty drop in retroreflection. Moisture lessened the abrasive effect of the sand to a certain extent. Operation of the test track without sand grit or water brought no loss of retroreflection upon the markers.

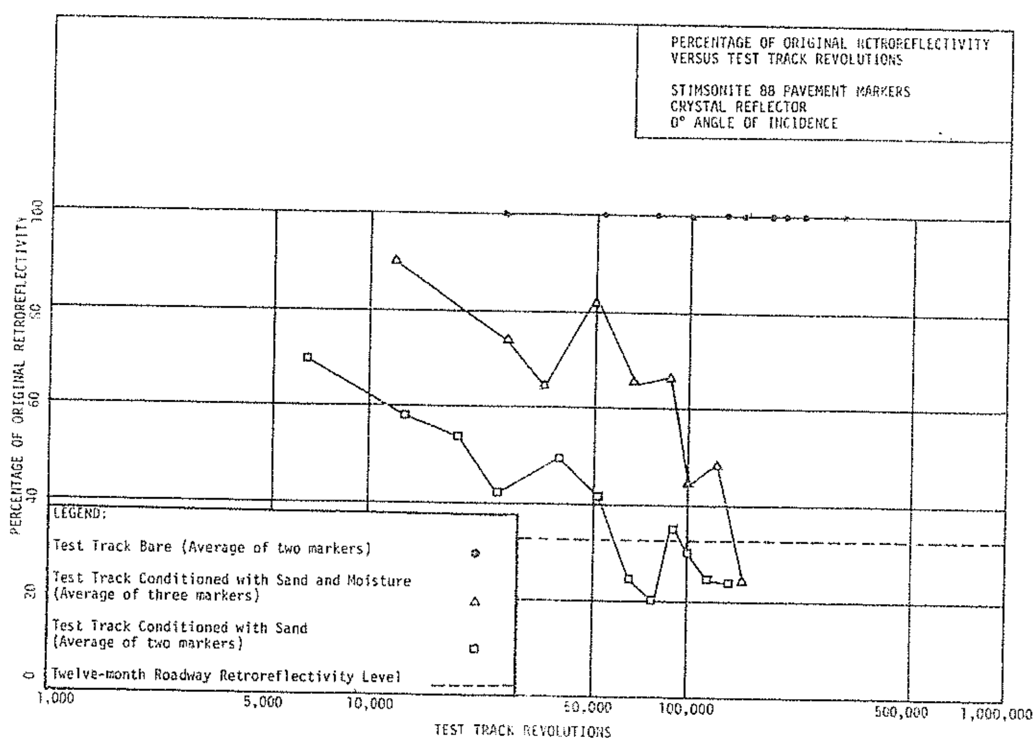
Considering time requirements and degree of definition of the above plots, research personnel deemed the application of sand grit alone to be the most appropriate technique for inducing wear upon prismatic raised pavement markers. Further analysis was hence keyed to the results of tests in which sand grit alone was applied to the test track. This procedure has been documented in test procedure form and is so presented as Appendix I.

Figure 9 depicts retroreflection decay curves for the Borg-Warner ten-bead complex lens marker with various combinations of sand and water applied to the test track. The beads of the marker are recessed, and the test track tire must literally wear down a protective portion of the acronitile butyl styrene shell before it can abrade the reflective "cat's eyes". Recessed reflective elements would thus seem ideal.

However, in measuring retroreflection of the field markers before and after a mild rinsing, research personnel found that this particular complex-lens (beaded) marker accumulated and/or retained roadway grit at a significantly faster pace than did the two brands of cube-cornered markers studied. Table 1 relates the brightness ~~differential of these markers before and after~~ cleaning.



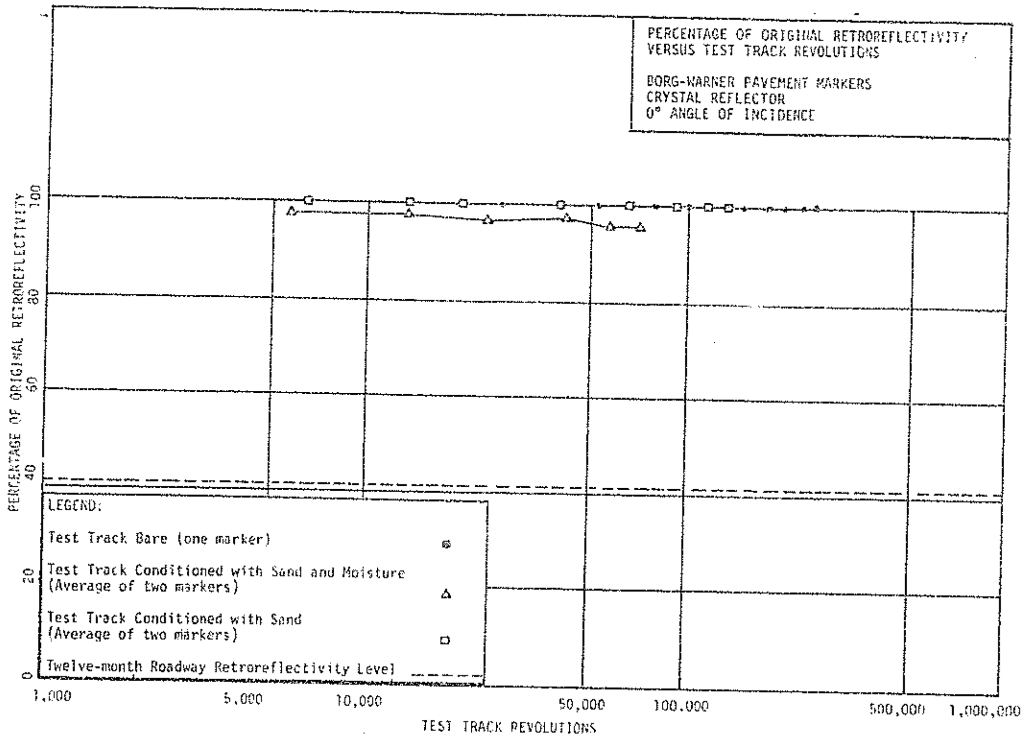
Various Test Track Retroreflectivity Decay Curves for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 7



Various Test Track Retroreflectivity Decay Curves for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 8

Various Test Track Retroreflectivity Decay Curves for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 7

Various Test Track Retroreflectivity Decay Curves for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 8



Various Test Track Retroreflectivity Decay Curves for Borg-Warner Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 9

Various Test Track Retroreflectivity Decay Curves for Borg-Warner Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 9

TABLE 1

EFFECT OF CLEANING ON RETROREFLECTION OF ROADWAY MARKERS

Time on the Roadway (Months)	Difference in Retroreflection Before and After Cleaning, (Percentage of Original Retroreflection)		
	Ray-o-lite Crystal Reflector 0° Angle of Incidence	Stimsonite Crystal Reflector 0° Angle of Incidence	Borg-Warner Crystal Reflector 0° Angle of Incidence
1	20	34	43
2	22	39	55
3	25	31	47
4	15	19	47
5	11	26	51
6	13	36	46
7	11	46	42
8	35	27	72
9	28	23	58
10	17	28	19
11	13	17	26
12	5	5	29
	Average 18	Average 28	Average 44

NOTE: 1. Monthly values for each brand generally represent an average from four pavement markers.

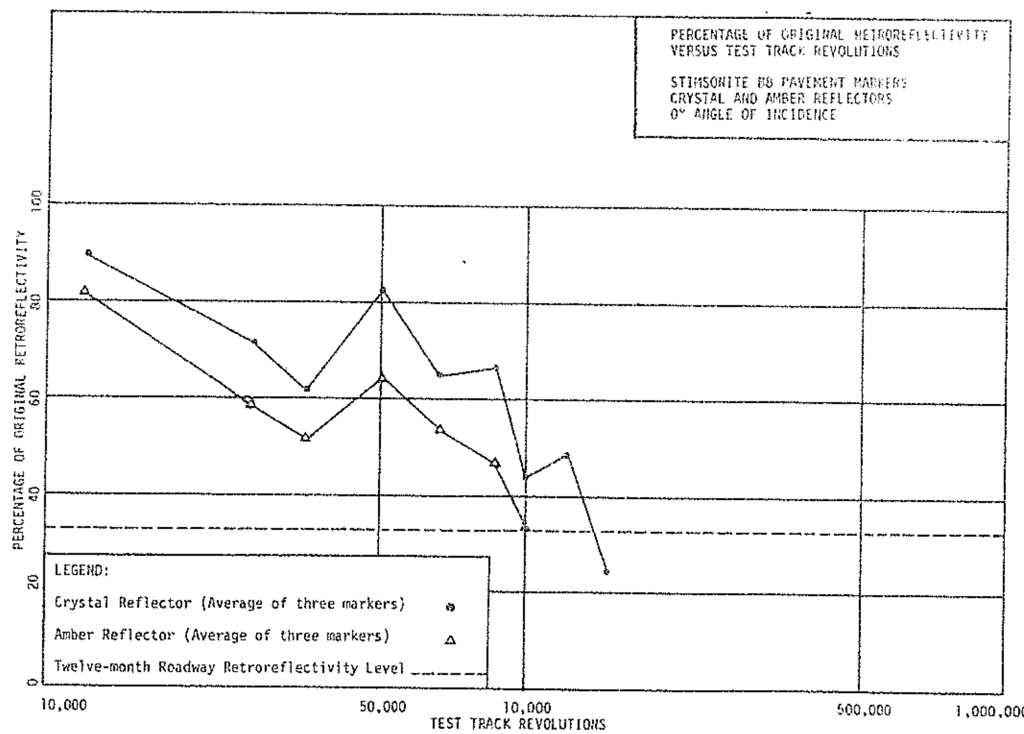
2. Crushed sugar cane was noted on the roadway while sampling markers at the eighth month. This very likely contributed to the above average before cleaning versus after cleaning retroreflection levels for the Borg-Warner and Ray-o-lite markers at the eighth month.

To return to the point at hand, the feasibility of test track evaluation of the retroreflective durability of markers with recessed reflective elements appeared questionable because of the initial inaccessable location of the beads to the test track tire. Field evaluation of markers with recessed reflective elements will be recommended.

A final topic of discussion under this subsection "Test Track Durability" will be retroreflective durability of cube-corner pavement markers with amber-colored faces on both sides. Sets of three Stimsonite 88 amber/amber and three Stimsonite 88 crystal/red markers were evaluated on the test track with a combination of sand grit and water applied. Figure 10 illustrates average retroreflective decay trends for these crystal lenses and for those amber lenses on the front sides of the amber/amber markers. These curves relate similar wear trends for the amber and crystal reflectors. (This is logical since infrared analyses indicated that the shells of amber/amber and crystal/red Stimsonite markers are virtually identical in composition.) Thus, the authors applied the crystal markers' 12-month roadway retroreflection loss (using percentage of original retroreflection) to the amber-colored markers in order to establish durability criteria for the latter markers. Such deduction was necessary because the initial scope of this study did not include placement of amber-colored markers on a roadway for evaluation. However, the large number of amber-colored markers which the Department employs on its two-lane roads dictates a need for durability criteria for such markers.

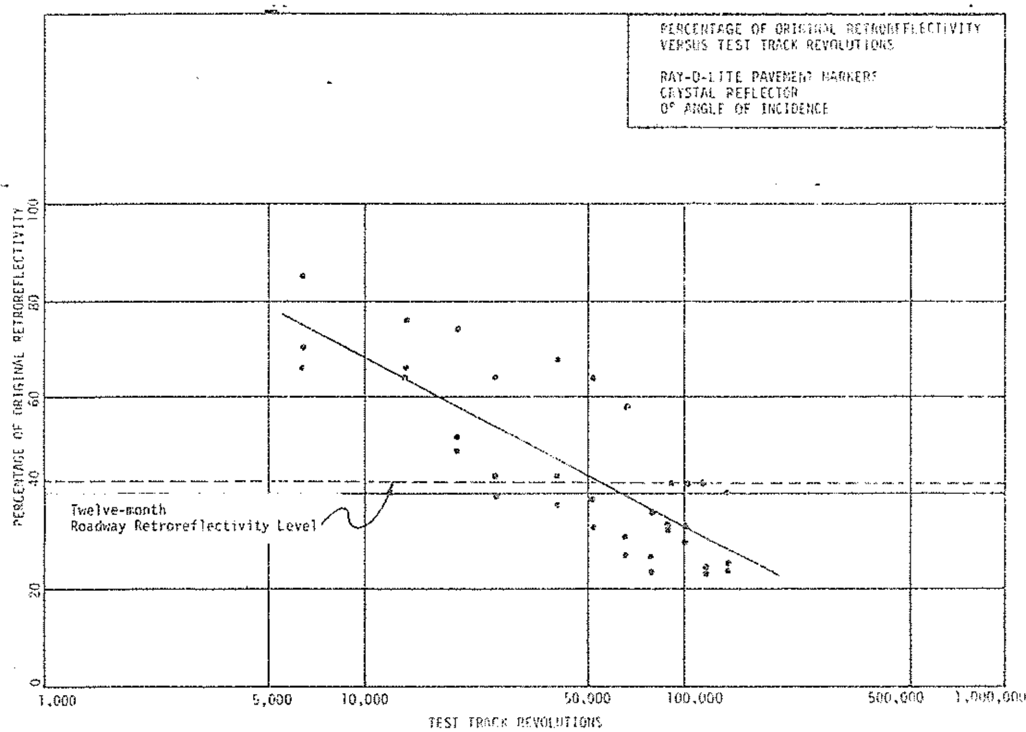
Criteria for Retroreflective Durability of Raised Pavement Markers

Figures 11 and 12 (and figures 23 through 28 of the Appendix) present retroreflective decay curves for Ray-o-lite and Stimsonite prismatic markers, respectively. (As mentioned previously, when these markers were selected for testing they represented the two levels of retroreflection required by the Department to perform specific functions.)

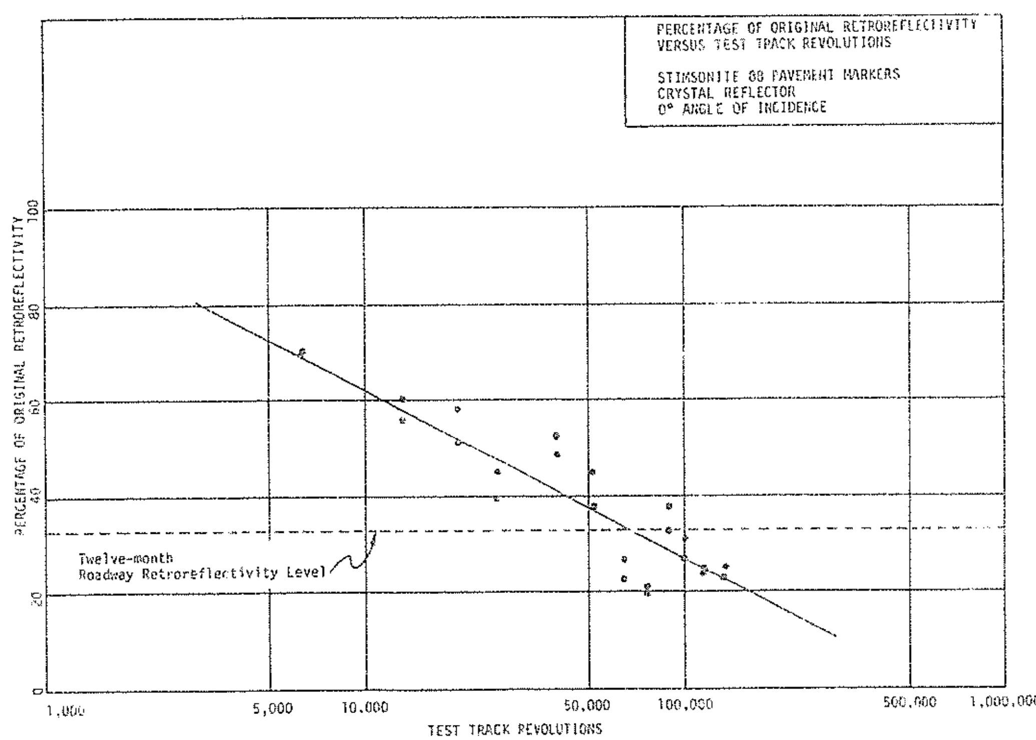


Test Track Retroreflectivity Decay Curves for Stimsonite 88 Crystal and Amber Markers, 0° Angle of Incidence.
FIGURE 10

Test Track Retroreflectivity Decay Curves for Stimsonite 88 Crystal and Amber Markers, 0° Angle of Incidence.
FIGURE 10



Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 11



Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 12

Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 11

Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 0° Angle of Incidence.
FIGURE 12

Superimposed upon each statistical decay curve in figures 11 and 12 is a horizontal line representing the corresponding 12-month roadway retroreflective level. The intersection of the statistical twelve-month field brightness level (in percentage of original retroreflection) with the laboratory decay curve reveals the number of test track revolutions which will simulate 12 months of wear by actual traffic. The percentage of original retroreflection values are applied mathematically to the minimum requirements for original retroreflection shown on page 9 to yield brightness levels in foot-lamberts.

The following retroreflective durability guidelines for raised crystal/red pavement markers have been obtained from figures 11 and 12 and 23 through 28 of the Appendix. The guidelines for amber-colored markers were assigned as discussed in the previous subsection. These guidelines are presented only for discussion of the end results of this research effort and do not constitute specifications or regulations.

Class II Markers

Class II markers shall conform to the following optical requirements when tested for retroreflection in accordance with Test Procedure L.D.H. Designation: TR 604 (revised):

Color	Minimum Retroreflection (Footlamberts) After 53,000 Test Track Revolutions	
	@ 0° Angle of Incidence	@ 20° Angle of Incidence
Crystal	13	6
Amber	9	4
Red	8	3

Class IV Markers

Class IV markers shall conform to the following optical requirements when tested for retroreflection in accordance with Test Procedure L.D.H. Designation: TR 604 (revised);

Color	Minimum Retroreflection (Footlamberts) After 67,000 Test Track Revolutions	
	@ 0° Angle of Incidence	@ 20° Angle of Incidence
Crystal	33	22
Amber	20	10
Red	11	7

The test track will be operated in accordance with Test Procedure L.D.H. Designation: TR 619 (proposed, as presented in the Appendix). If a marker has a reflective element which is recessed from contact by the test track tire of Test Procedure L.D.H. Designation: TR 619 (proposed), then the marker must undergo a 12-month field evaluation. After performing on a roadway for 12 months, the marker must exhibit retroreflection equal to or greater than that required above for the appropriate class of marker after test track evaluation.

Since the initiation of this study, the Department has specified that all reflectorized raised pavement markers shall conform to the requirements for the Class IV marker. A special provision, presented as Appendix II, defining initial average and minimum retroreflection values as well as the retroreflective durability requirements listed above for the Class IV marker is hereby recommended.

CONCLUSIONS

Highway research personnel have developed a rapid method of evaluating the nighttime retroreflective durability of raised pavement markers. The method employs the Department's test track and in approximately 12 working days simulates 12 months of roadway wear. Retroreflective durability standards keyed to this rapid test have been proposed for source acceptance of raised pavement markers.

RECOMMENDATIONS

It is recommended that the Department adopt the test track procedure and durability criteria proposed herein as means of accepting or rejecting sources of reflectorized raised pavement markers. An approved source should be re-evaluated at least once every year to insure the use of markers with sufficiently high nighttime retroreflective durability.

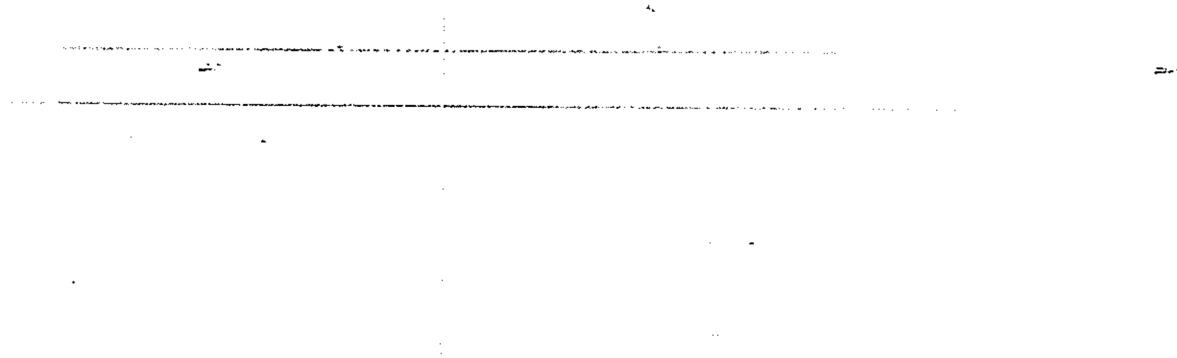
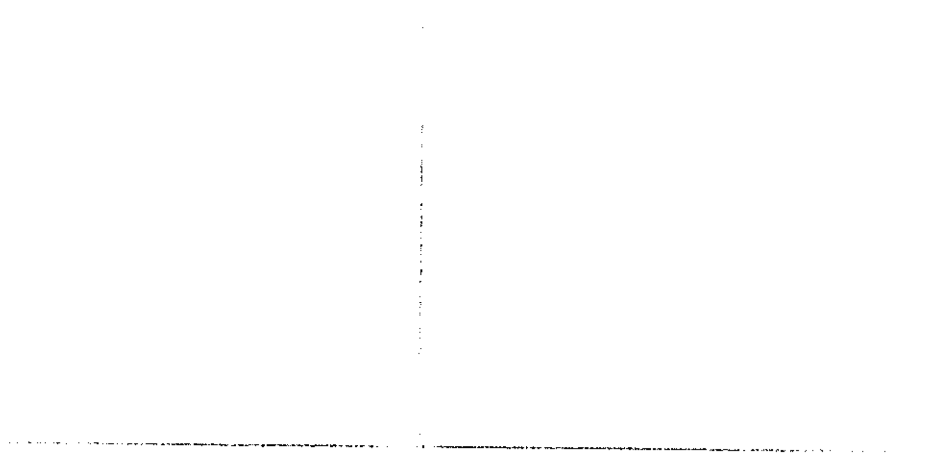


Figure 13
Reflectorized Raised Pavement Markers in a Scheme of Reflectorized Roadway Markings



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2. Hurst, D. R., and W. R. Tooke, Jr. Wet Night Visibility Study. Interim Report, Georgia Institute of Technology, November, 1973.

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METHOD OF TEST FOR

RETROREFLECTIVE DURABILITY
OF RAISED PAVEMENT MARKERS

L.D.H. DESIGNATION: TR 619 (PROPOSED)

Scope

1. This method of test is intended to determine the retroreflective durability of reflectorized raised pavement markers. This test is not applicable to markers with reflective elements which are recessed so as to be inaccessible to contact by the test track tire. Markers with recessed reflective elements shall undergo a 12-month field evaluation for retroreflective durability.

Apparatus

2. Test track with components and accessories as follows:

(a.) Portland cement concrete track enclosed by walls and a roof as a weatherproofing measure.

(b.) An automobile rear axle and differential with one wheel removed. The length of this assembly is approximately 80 inches (203 centimeters).

(c.) A pivot assembly at the center of the track to which is attached that end of the axle without a wheel.

(d.) A 6.70-by-15-inch (17-by-38.1-centimeter) smooth faced tubeless rayon tire for the one wheel attached to the axle.

(e.) A one and one-half horsepower electric motor to drive the tire along a circular path about the pivot assembly at a speed of 1100 revolutions per hour (0.3 of a revolution per second). The motor works through a pulley attached to the differential to effect the motion of the tire.

(f.) A box for weights supported above the tire by a spring-and-shock absorber assembly. A total wheel load of one kip shall be applied.

(g.) Six-by-15-inch (15-by-38-centimeter) metal base plate for mounting pavement markers on the track and removing them therefrom.

(h.) A right circular cylindrical container with an orifice and tubular dispenser at its base to apply sand grit to the test track at the rate of apprxomately 3000 grams per hour.

(i.) A mechanical counter to record the number of revolutions traversed by the tire.

(j.) A supply of sand grit which will pass a number 30 sieve but be retained on a number 100 sieve.

Sampling

3. A minimum of three specimens for a given brand of marker shall be tested by this procedure. All specimens so tested shall meet Department specification requirements for initial retroreflection as determined in accordance with LDH Designation: TR 604 (revised).

Procedure

4. (a.) The test marker is evaluated for initial brightness in units of foot-lamberts in accordance with LDH Designation: TR 604.

(b.) This marker is then attached to the center of the metal plate by means of epoxy. The metal plate is bolted to the test track in such a position to ensure proper alignment of the marker and tire. If the marker has both crystal and red lenses, the marker shall be positioned so that the tire impacts first on the crystal face. If the marker has amber-colored lenses, only one side will be evaluated and the marker shall be positioned so that the tire impacts first on this face.

(c.) The mechanical counter is zeroed. Also, the sand grit container is filled and the flow at the orifice is checked for one minute to ensure a flow rate of 50 (± 10) grams per minute. Periodic checks of the mechanical counter and the sand container are to be made throughout the test.

(d.) The test track tire is set in motion by actuating the off-on switch. After 20,000 revolutions the tire is stopped by means of the same switch, and the plate with the marker is removed from the track. The plate and marker are rinsed with water to remove sand grit and loose rubber particles. Excess water is removed from the marker by means of a soft dry cloth, and the marker is allowed to air-dry for at least 10 minutes. The marker is measured for brightness in accordance with LDH Designation: TR 604 (revised).

(e.) The plate with the marker is placed back on the track, and the tire is made to traverse a total of 67,000 revolutions. Brightness levels are to be checked after 40,000, 60,000, and 67,000 revolutions, also in accordance with LDH Designation: TR 604 (revised).

<u>Retroreflection Decay Relationship</u>

5. Plot test track tire revolutions along the X-axis and the corresponding retroreflection values in footlamberts along the Y-axis. Une one-cycle semi-logarithmic graph paper or rectangular coordinate graph paper with an appropriate grid. A general decrease in retroreflection with an increase in revolutions would depict a normal retroreflection decay curve.

Report

6. The curve plotted in paragraph 5 is the report. Record the average retroreflection value in footlamberts after 67,000 revolutions for all the specimen markers of a given brand so tested.

Normal testing time is 12 days.

SPECIAL PROVISION
TO
SUPPLEMENTAL SPECIFICATIONS
SECTION 731
RAISED PAVEMENT MARKERS

(Supplementary to Part VII, Standard Specifications)

Subsection 731.02, MATERIAL REQUIREMENTS AND COMPOSITION, is revised as follows:

Class IV Markers

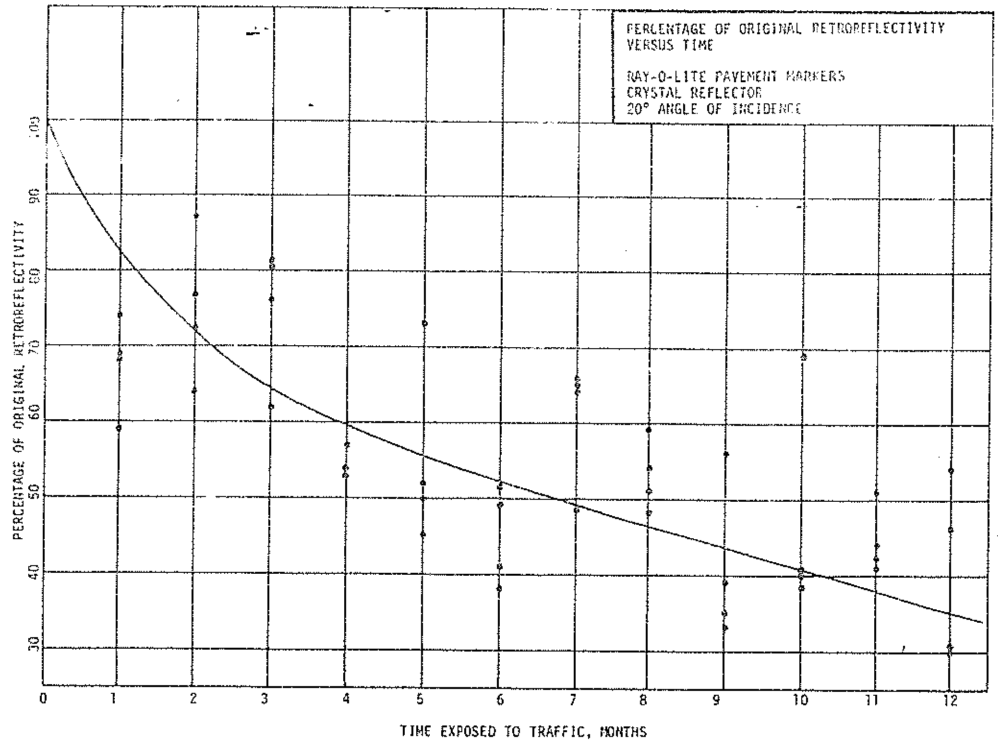
B. Optical Requirements. Class IV markers shall conform to the following requirements when tested for retroreflection in accordance with test procedure L.D.H. Designation: TR 604 (revised):

Color	Retroreflection (Footlamberts) @ 0° Angle of Incidence		
	Initial Average	Initial Minimum	Minimum After 67,000 Test Track Revolutions
Crystal	125	100	33
Amber	80	65	20
Red	25	15	11

Color	Retroreflection (Footlamberts) @ 20° Angle of Incidence		
	Initial Average	Initial Minimum	Minimum After 67,000 Test Track Revolutions
Crystal	60	50	22
Amber	35	25	10
Red	15	10	7

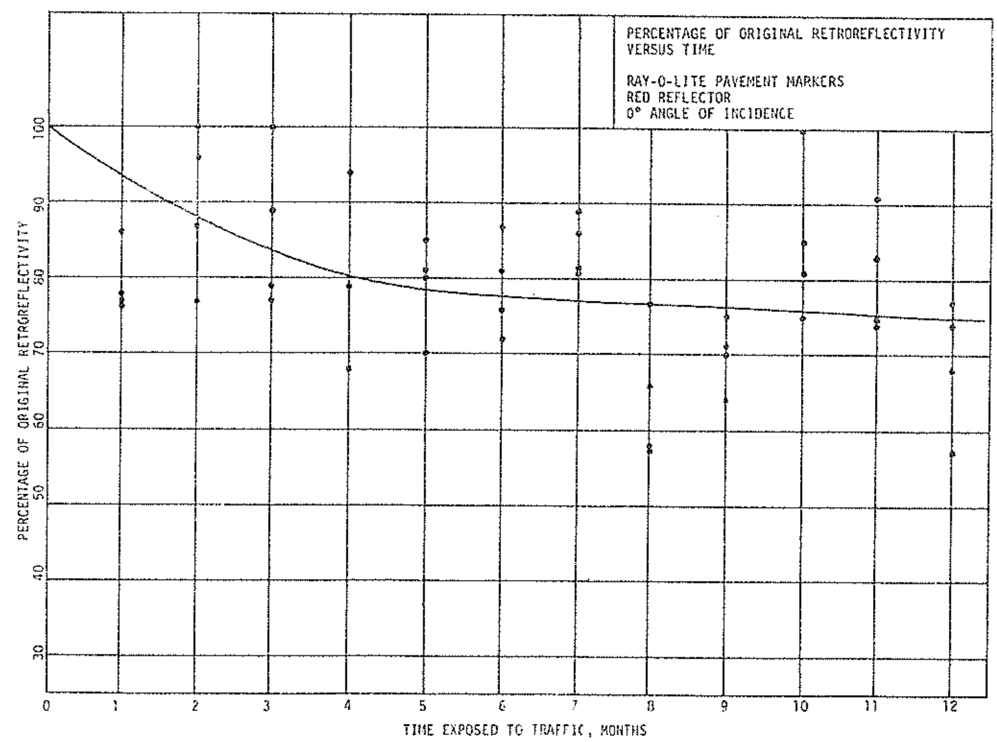
The test track will be operated in accordance with test procedure L.D.H. Designation: TR 619. If a marker has a reflective element which is recessed so as to be in accessible to contact by the test track tire, then the marker must undergo a 12-month field evaluation. After performing on a roadway for 12 months, the marker must exhibit a retroreflection equal to or greater than that which is required above after test track evaluation.

Sampling: A number of the Class IV markers specified and proposed for use by the contractor will be selected at random for testing and submitted to the Department's Laboratory. Ten markers shall be sampled per 1000 markers or portion thereof. All 10 markers representing a lot of 1000 markers shall be subjected to the retroreflection tests outlined under Optical Requirements. At the completion of the retroreflection tests, three of the markers shall be tested for heat resistance, three for impact resistance, and four for load resistance. Failure to conform to the requirements of any of the four types of tests shall constitute failure for the 1000 markers represented by the 10 samples.



Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 20° Angle of Incidence.

FIGURE 14

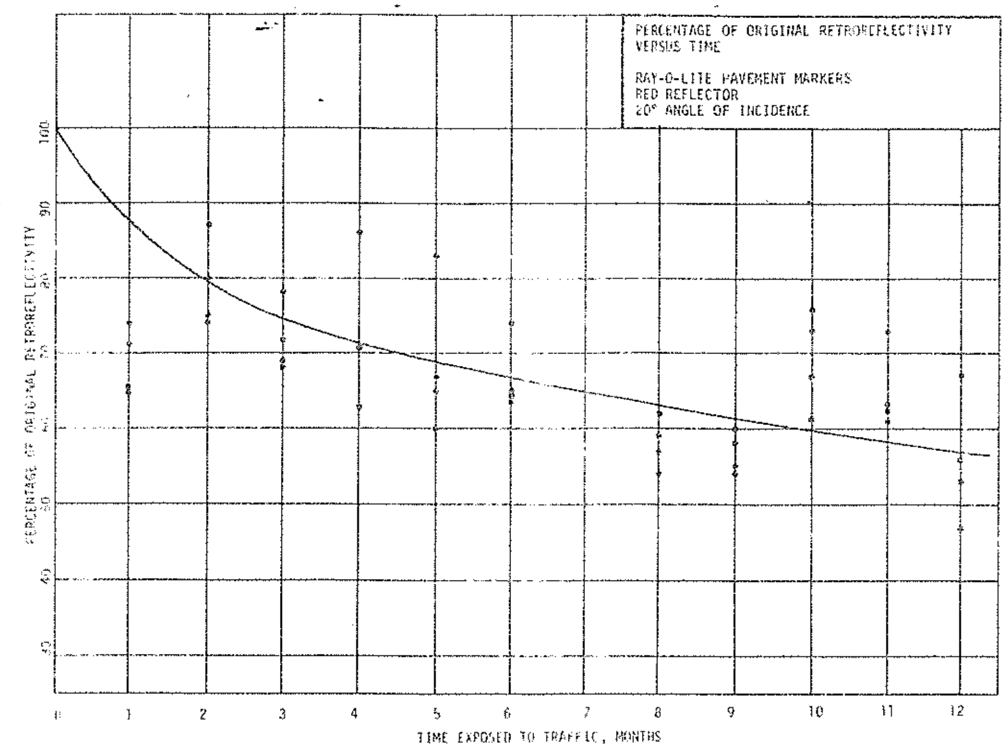


Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 0° Angle of Incidence.

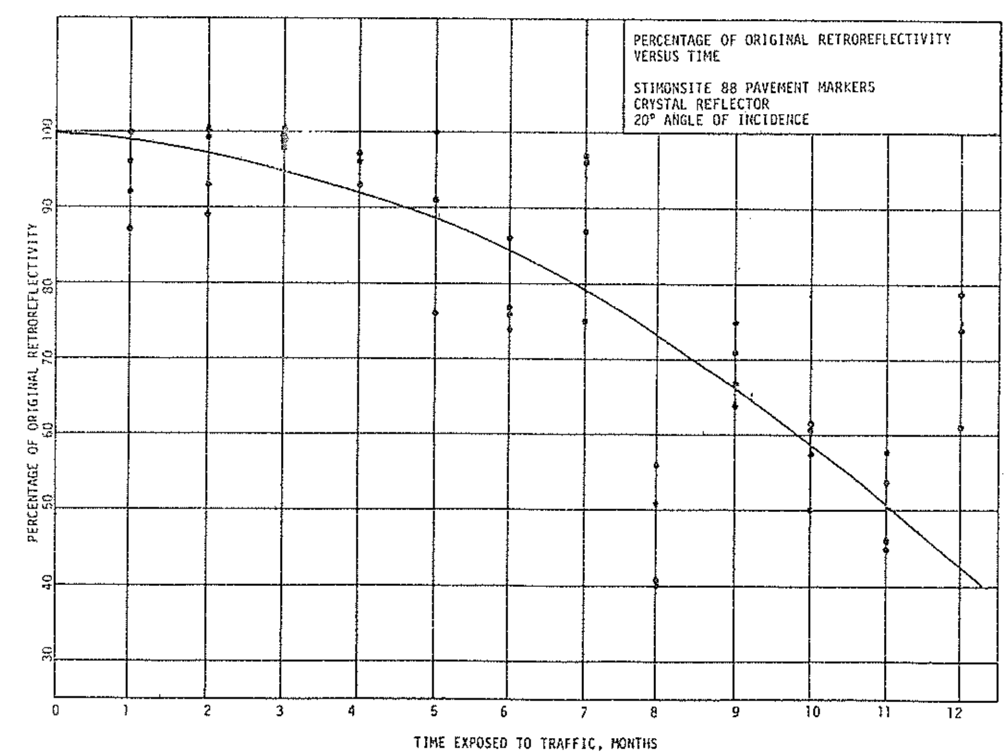
FIGURE 15

Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 14

Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 15



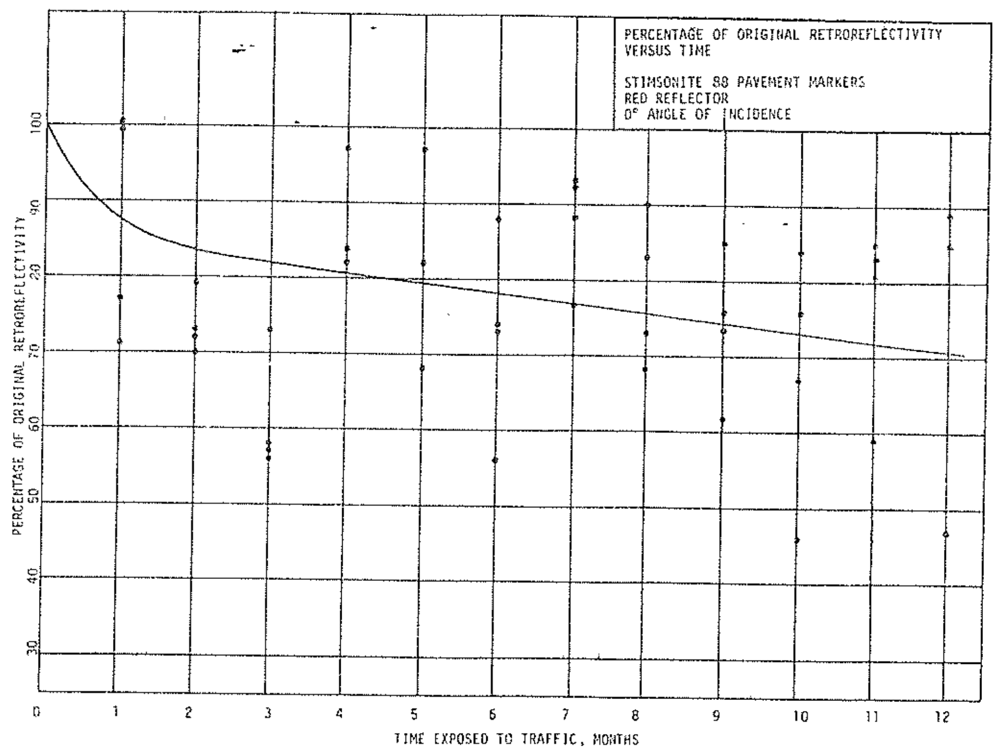
Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 16



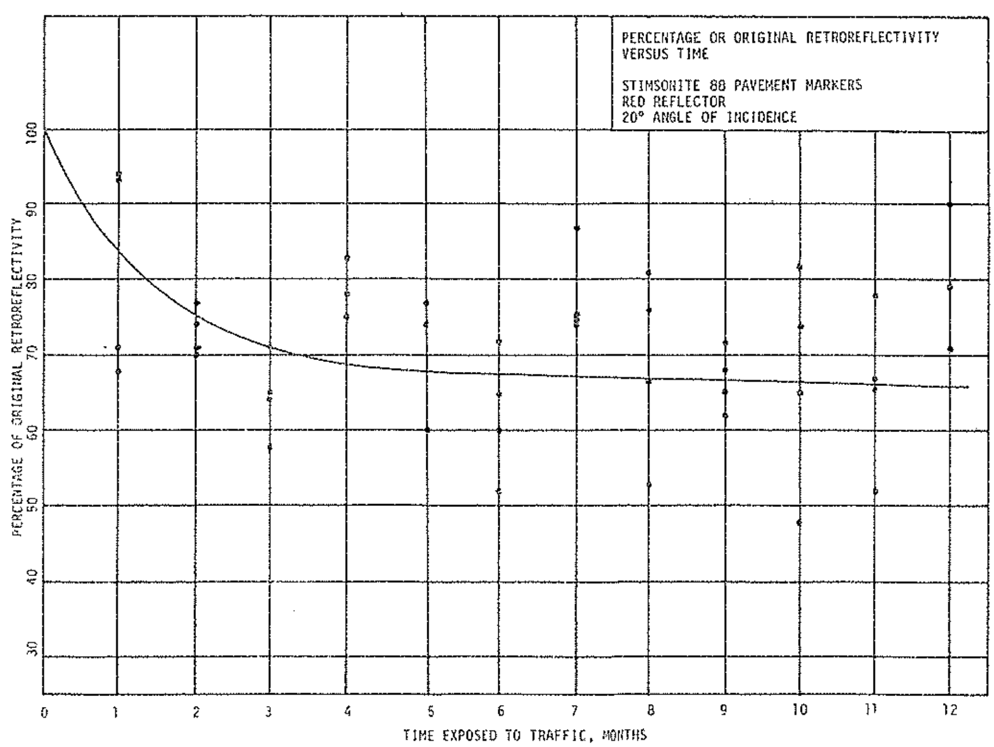
Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 17

Roadway Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 16

Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 17



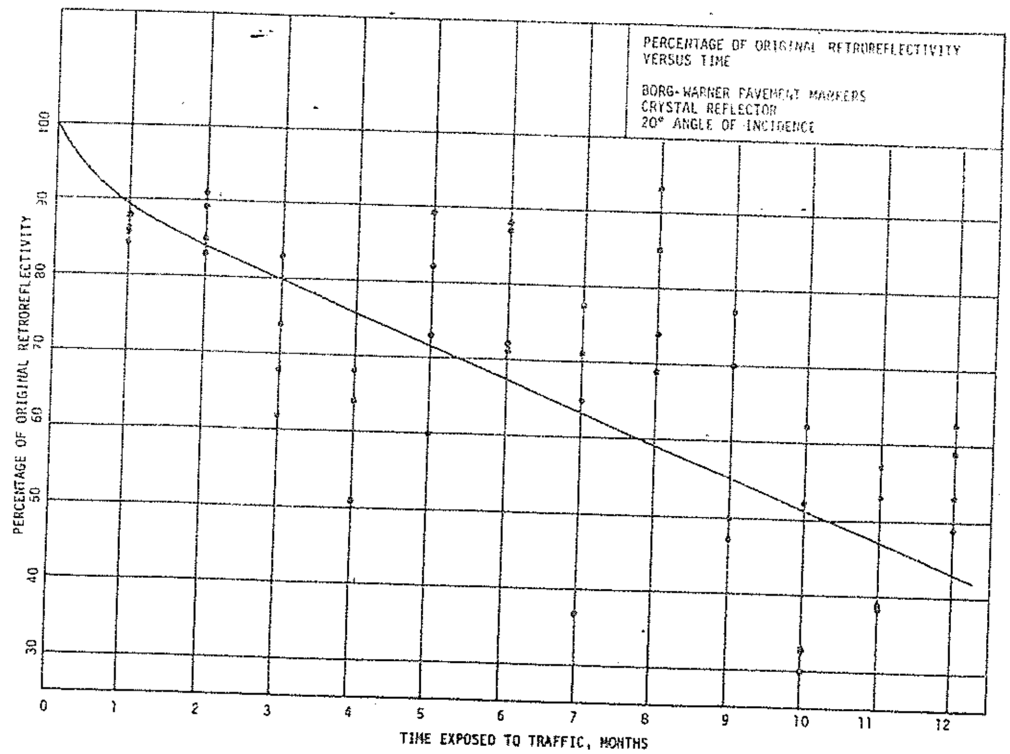
Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 18



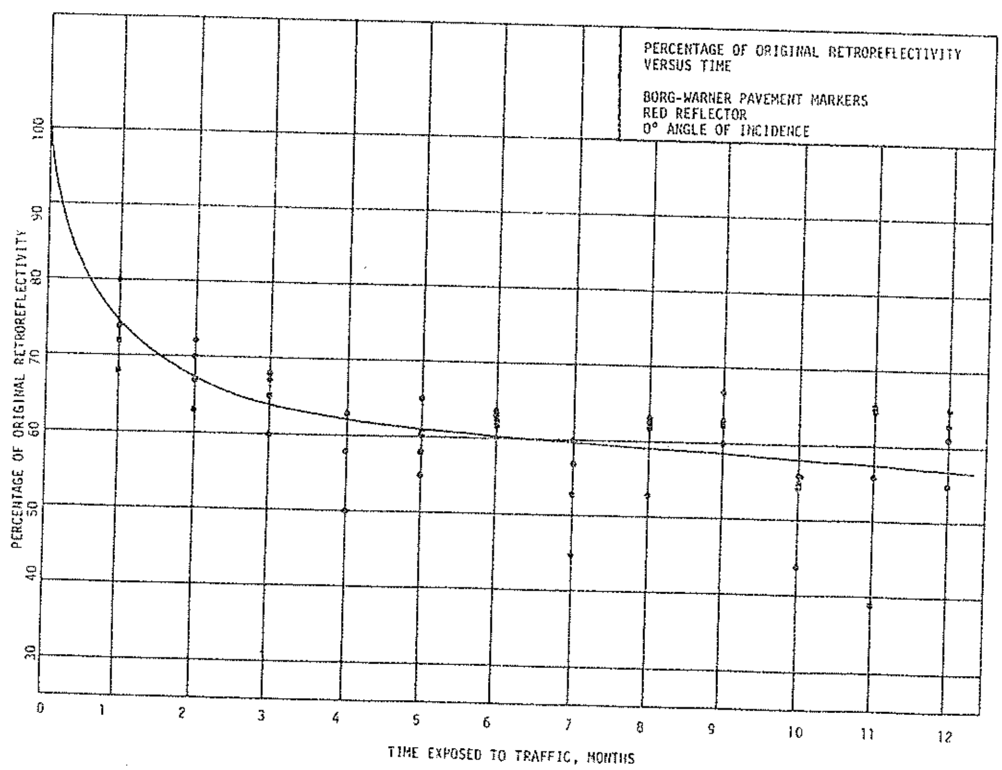
Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 19

Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 18

Roadway Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 19



Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 20



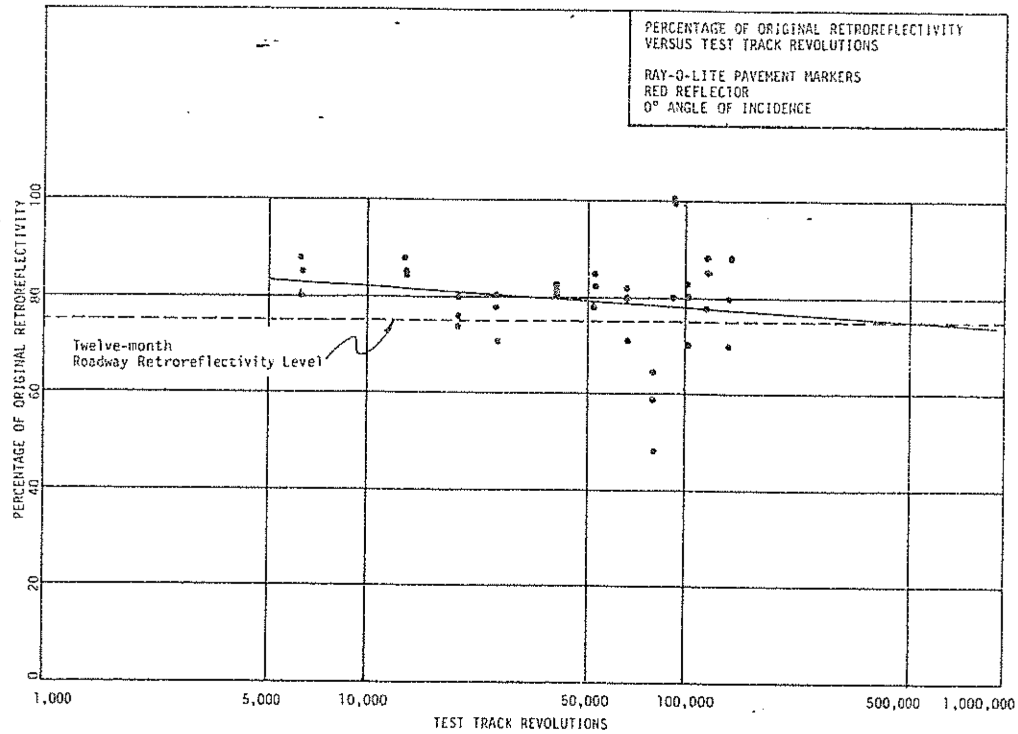
Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 21

Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 20

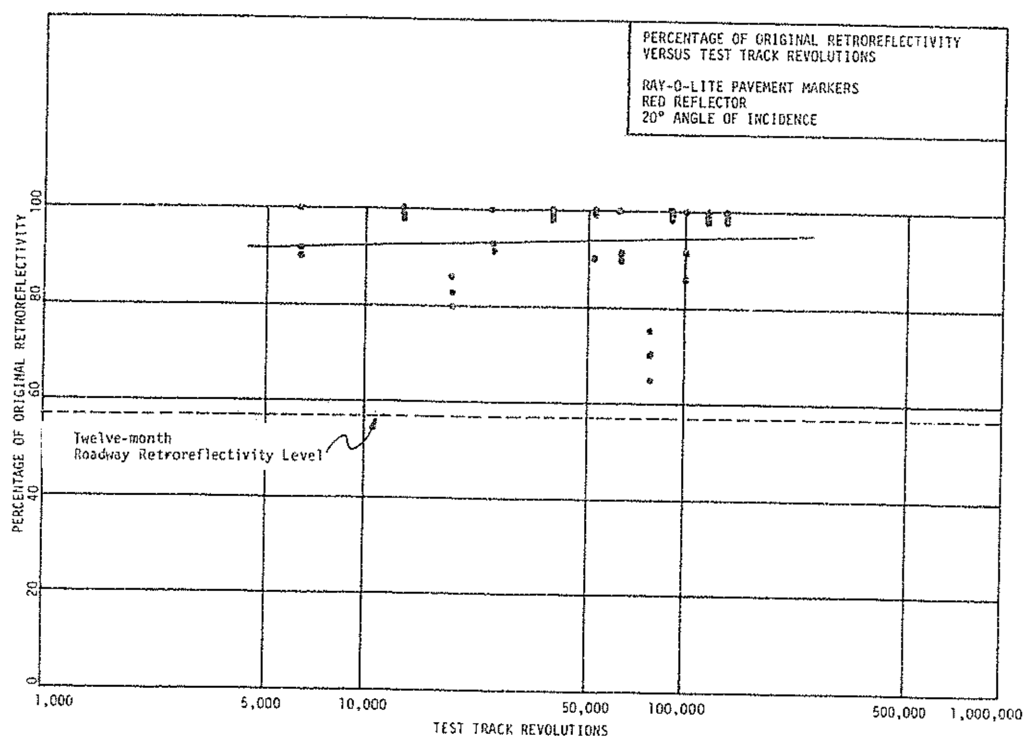
Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 21

Roadway Retroreflectivity Decay Curve for Borg-Warner Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 22

Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 23



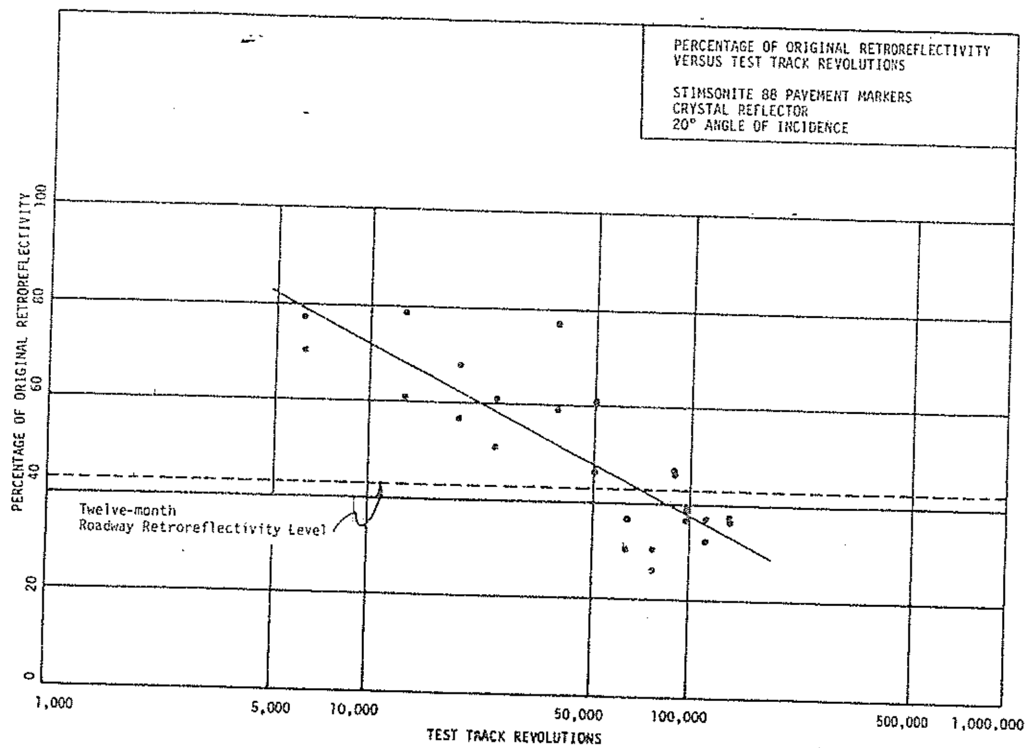
Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 24



Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 25

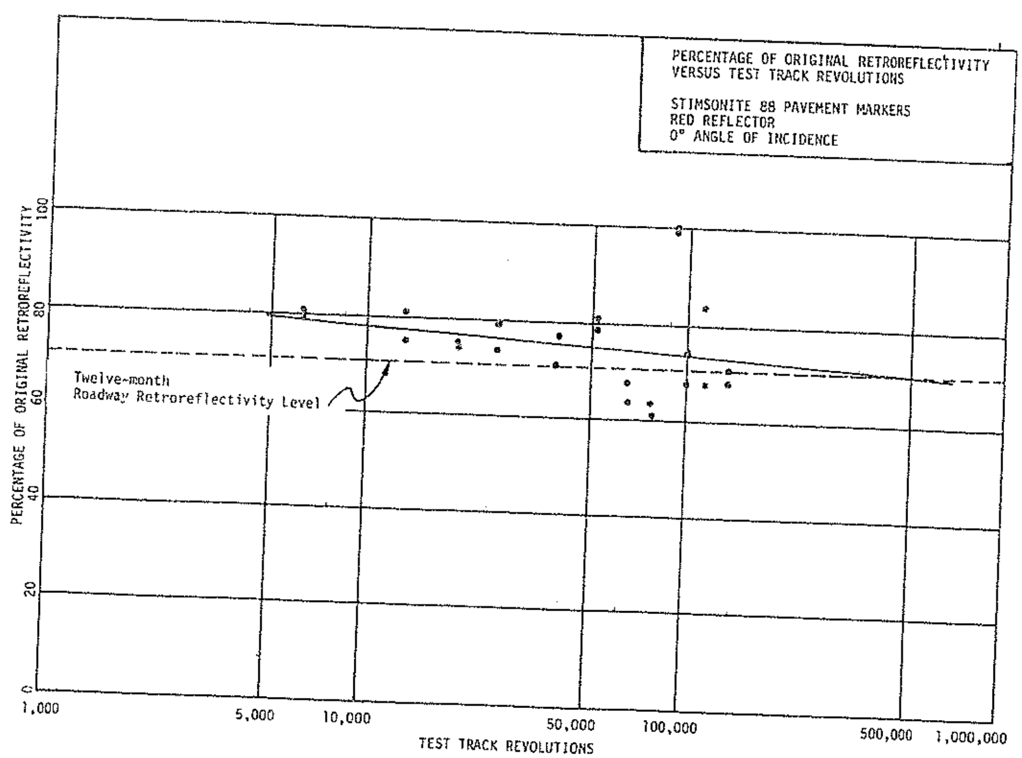
Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 24

Test Track Retroreflectivity Decay Curve for Ray-O-Lite Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 25



Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 20° Angle of Incidence.

FIGURE 26

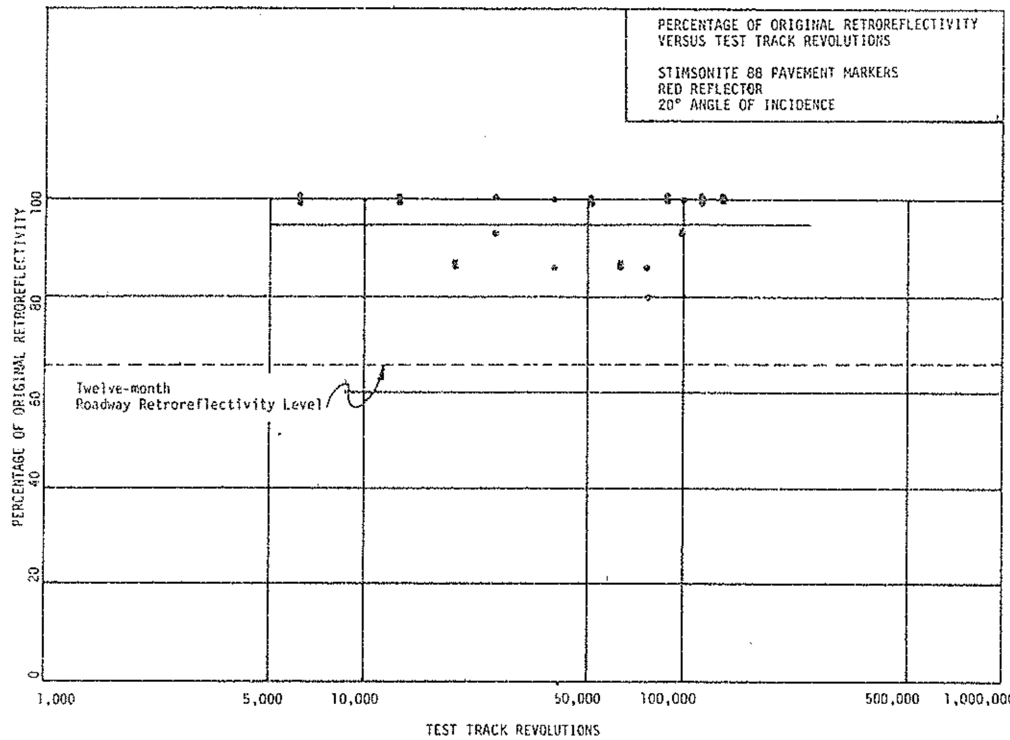


Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 0° Angle of Incidence.

FIGURE 27

Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Crystal Reflectors, 20° Angle of Incidence.
FIGURE 26

Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 0° Angle of Incidence.
FIGURE 27



Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 28

Test Track Retroreflectivity Decay Curve for Stimsonite 88 Markers, Red Reflectors, 20° Angle of Incidence.
FIGURE 28

APPENDIX I

Method of Test for

RETROREFLECTIVE DURABILITY OF
RAISED PAVEMENT MARKERS
L.D.H. DESIGNATION: TR 619 (PROPOSED)

APPENDIX II

Special Provision
to
SUPPLEMENTAL SPECIFICATIONS
SECTION 731
RAISED TRAFFIC MARKERS

(Proposed)

APPENDIX III

Supplemental Figures