TECHNICAL REPORT STANDARD TITLE PAGE

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

4. Title and Subtitle
Evaluation of Overhead Sign Background Materials and Mercury Vapor Sign Lights

5. Report Date
August, 1983

6. Performing Organization Code

7. Author(s)
H. Dexter Jones, Joseph G. Raska, and Roger W. McNees

8. Performing Organization Report No.
Research Report 222-2F

9. Performing Organization Name and Address
State Department of Highways and Public Transportation
P. O. Box 5051
Austin, Texas 78763

10. Work Unit No.

11. Contract or Grant No.
Research Study 1-18-75-222

12. Sponsoring Agency Name and Address
State Department of Highways and Public Transportation
P. O. Box 5051
Austin, Texas 78763

13. Type of Report and Period Covered
Final

14. Sponsoring Agency Code

15. Supplementary Notes
Study conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

Overhead Guide Signs can be illuminated to sufficient target value and uniformity with certain 100 watt mercury vapor lighting units.

Coating materials based on thermal setting polyester, and thermal setting polyvinylidene fluoride have been found to be satisfactory coating materials for Overhead Guide Signs.

Liquid Urethane Acrylic, sign enamel, thermal setting polyester and reflectorized sheeting have been proven as satisfactory materials for refurbishing deteriorated porcelain-enameled aluminum Overhead Guide Signs.

Preliminary field evaluations and legibility studies indicate that approximately 40% of the Overhead Guide signs in the State would not require illumination if the legend is reflective.

17. Key Words	18. Distribution Statement
Signs Illumination	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	104	

Form DOT F 1700.7 (8-69)

EVALUATION OF OVERHEAD SIGN BACKGROUND MATERIALS AND MERCURY VAPOR SIGN LIGHTS

Research Report Number 222-2F

FINAL REPORT

Research Project Number 1-18-75-222

by

H. Dexter Jones
Supervising Designing Engineer
Houston Urban Office

and

Joseph C. Raska
Materials and Tests Paint Engineer
Materials and Test Division

Conducted by

Houston Urban Office, Materials and Test Division
and Texas Transportation Institute
in Cooperation with the
Transportation and Planning Division
Texas State Department of Highways and Public Transportation

May 1984

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors again wish to give special acknowledgement to Richard H. Oliver, Devidas B. Tulsiani and James Walding of Maintenance Operations Division, John F. Nixon and David Hustace, of Transportation Planning Division, Bob Hodge and Robert Jenkins of District 2, Thaddeus Bynum of Highway Design Division, John N. Lipscomb of District 12, Ben Bohuslav of District 13, Waid D. Goolsby of District 18 and Dr. Roger W. McNees of the Texas Transportation Institute for timely comments and guidance in this project.

Also, again special thanks are given to Districts 12 and 16 Sign Shop personnel for preparing signs and to District 12 Maintenance personnel for erection of signs and sign lights on the roadways.

In addition, deep hearted thanks are given to Manny Aguilera of District 24 and to the many participants in the legibility studies performed in Houston, Dallas and El Paso. They gave their own time in order to accomplish this work.

We also wish to express our thanks to the many people who worked with us in the preparation of the exhibits and other aspects of report preparation.

ABSTRACT

Overhead Guide Signs can be illuminated to sufficient target value and uniformity with certain 100 watt mercury vapor lighting units.

Coating materials based on thermal setting polyester, and thermal setting polyvinylidene fluoride have been found to be satisfactory coating materials for Overhead Guide Signs.

Acrylic cured aliphatic urethane, sign enamel, thermal setting polyester and reflectorized sheeting have been proven as satisfactory materials for refurbishing deteriorated porcelain-enameled aluminum Overhead Guide Signs.

Preliminary field evaluations and legibility studies indicate that approximately 55% of the Overhead Guide signs in the State would not require illumination if the legend is reflective.

SUMMARY

As stated in Report Number 222-1 Overhead Guide Signs can be illuminated to sufficient target value and uniformity with certain 100 watt mercury vapor lighting units. Most 175 watt and 250 watt mercury vapor lighting units present excessive brightness which reduces legibility, in particular the 250 watt units. The 100 watt mercury vapor units are presently being used on a statewide basis. This area of research is complete.

Report Number 222-1 covered the work in the area of sign background coatings. Many different coatings were investigated prior to the issuance of that report. The work on durability of the materials has continued since the issuance of the report. Thermal setting polyester and thermal setting polyvinylidene fluoride have been found to be satisfactory coating materials for Overhead Guide Signs. The coatings have shown in accelerated testing to give excellent durability and color retention for a projected minimum life of thirty years.

Specifications for the polyester coating and the polyvinylidene fluoride coating have been written and issued. The coatings are being used on a statewide basis. Additional work will be carried on in the subsequent Project 1-9-84-276, "Evaluation of Guide Sign Construction Materials".

Numerous coatings have been tested as possible coatings for the refurbishing of deteriorated porcelain-enameled aluminum Overhead Guide Signs. Acrylic cured aliphatic urethane and sign enamel have proven as satisfactory materials for the refurbishing work. The porcelain-enameled surface must be thoroughly cleaned, abraded with either coarse sand paper or steel wool, cleaned again and then coated. Signs refurbished in this manner have been in field service for over eight years. Contrary to sheeting manufacturers recommendations it was found that deteriorated porcelain-enameled extrusions can be satisfactorily refurbished

with the application of engineer grade, super engineer grade and high specific intensity reflective sheeting. The extrusions were merely cleaned, abraded and the sheeting was hand applied directly to the porcelain-enameled extrusions in the District 12 Sign Shop.

Thermal setting polyester has also proven satisfactory in refurbishing of deteriorated porcelain-enameled aluminum Overhead Guide Signs. Several means of cleaning the porcelain surface were tried. However, poor adhesion was experienced when the porcelain surface was merely cleaned. When the porcelain-enameled surface was completely removed, proper adhesion was experienced.

Field exposure and accelerated testing shows that the opaque background coatings studied and recommended for use are more durable than the reflective sheeting backgrounds.

Preliminary field evaluations and legibility studies have indicated that 55% of the Overhead Guide Signs in the State would not require illumination if the legend is reflective. Reflective backgrounds do not statistically increase legibility but do provide conspicuity (target value). Field evaluations of the Overhead Guide Signs were made in Houston, Corpus Christi, San Antonio, Dallas and El Paso. Legibility studies were performed in Houston, Dallas and El Paso. The field evaluations were based upon the findings of previous research projects in the areas of detection, recognition, legibility and reaction. The previous studies proved that if a sign has 1,100' to 1,200' of unrestricted sight distance the driver can perform the required driving tasks easily. If the driver can read and understand the text within these parameters on an unlighted, reflectorized legend sign, then the sign need not be illuminated. As previously stated 55% of the signs in Texas met the above requirements.

To check the above, legibility studies were performed in Houston, Dallas and El Paso. Thirty seven participants, male and female, all age brackets were used in both day time and night time runs. Signs were selected that contained reflective and opaque backgrounds, button and high specific intensity stick on copy, with sign illumination and without sign illumination and with freeway illumination and without freeway illumination. The legibility studies proved that there are no significant differences in legibility distances whether the freeway signs were lighted or unlighted, stick on copy or button copy and opaque or reflective background. The reflective background merely added conspicuity and did not increase the legibility distance of the sign. The sampling of the participants did not correspond with the population mix in the United States and was of insufficient quantity to statistically evaluate the effect of sign lighting in most cases.

As a direct result of this project several specifications and Administrative Circulars were issued. Also as a result of this project two new research projects have been approved, Project Number 1-18-84-277, entitled "Functional Characteristics of Guide Signs" and Project Number 1-9-84-276, entitled "Evaluation of Guide Sign Construction Materials".

IMPLEMENTATION

The Department is realizing returns from the monies expended on this project by the statewide usage of the sign coating materials researched and recommended.

The State is also realizing returns by the statewide usage of the 100 watt mercury vapor sign lights developed on this project. It is recommended that the State continue on a planned retrofit from the existing troublesome fluorescent sign lights to the 100 watt mercury vapor units. Thought should also be given to the replacement of the existing 250 watt mercury vapor units with the more energy efficient 100 watt units.

In arid areas or where minor to moderately deteriorated porcelain-enameled signs exist, they may be refurbished by cleaning and buffing of the enameled surface. Where deterioration has further progressed but the coating has good film integrity, the deteriorated porcelain-enameled aluminum sign panels can be easily and economically refurbished using acrylic cured aliphatic urethane or sign enamel. It is not recommended that the deteriorated panels be refurbished with thermal setting polyester unless the refurbishing is done on a large scale project. It will take a large amount of sign square footage to make the use of the polyester economically feasible. Deteriorated porcelain-enameled aluminum sign extrusions can be satisfactorily refurbished by cleaning, abrading and the hand application of engineer grade, super engineer grade or high specific intensity reflective sheeting. The cleaning, abrading and sheeting application can easily be done in departmental sign shops.

Results of this project indicate that ground mounted guide sign panels made from deteriorated porcelain-enameled aluminum extrusions refurbished with either engineer grade, super engineer grade or high specific intensity reflective sheeting can be used on a maintenance replacement basis for deteriorated plywood guide signs.

I. SUBJECT:

Evaluation of Overhead Sign Background Materials and Mercury Vapor Sign Lighting Fixtures.

II. PURPOSE:

The objectives of the study are:

A. Determine the feasibility of illuminating overhead signs with mercury vapor lighting fixtures.

B. Evaluate available coatings that show promise of producing satisfactory overhead sign backgrounds.

C. Determine a feasible and satisfactory method to refurbish existing deteriorated porcelain-enameled sign extrusions.

D. Determine the feasibility of using non-illuminated overhead guide signs with reflectorized copy. This study was to include opaque background signs and reflectorized background signs.

Objectives C and D of the study were incorporated after the study was begun.

III. CONCLUSIONS AND RECOMMENDATIONS:

Overhead guide signs can be illuminated to sufficient target value and uniformity with 100 watt mercury vapor lighting units. Most 175 watt and 250 watt mercury vapor lighting units present excessive brightness, which reduces legibility, in particluar the 250 watt units, refer to Report Number 222-1. The 100 watt units are the State Standard. It is recommended that the State continue on a planned retrofit from the existing troublesome fluorescent sign lights to the more efficient 100 watt mercury vapor units. Due to the reduced legibility thought should also be given to the replacement of the existing 250 watt mercury vapor units.

Coating materials based on thermal setting polyester, thermal setting polyvinylidene fluoride, polyvinyl fluoride film, acrylic film, acrylic cured aliphatic urethane and GES-2C sign enamel have been found to be satisfactory coating materials for Overhead Guide Signs. Thermal setting polyester and thermal setting polyvinylidene fluoride are presently being used on a statewide basis.

Acrylic cured aliphatic urethane and sign enamel have been proven as satisfactory materials for refurbishing porcelain-enameled Overhead Guide Signs. Thermal setting polyester has also proven satisfactory if the porcelain-enameled coating is removed prior to application of the polyester. It is not recommended that the deteriorated panels be refurbished with thermal setting polyester unless the refurbishing is done on a large scale project. It will take a large amount of sign square footage to make the use of the polyester economically feasible. Deteriorated porcelain-enameled aluminum sign extrusions can be satisfactorily refurbished by cleaning, abrading and hand application of engineer grade, super engineer grade or high specific intensity reflective sheeting directly to the extrusions.

Ground mounted guide sign panels made from deteriorated porcelain-enameled aluminum extrusions refurbished with either engineer grade, super engineer grade or high specific intensity reflective sheeting directly applied to the extrusions could be used on a maintenance replacement basis for deteriorated plywood guide signs. It should be noted that the aluminum substrate is more durable than the plywood substrate. Additional research is recommended on guide sign materials.

Preliminary field evaluations and legibility studies have indicated that approximately 55% of the Overhead Guide Signs in the State would not require illumination if the legend is reflective and if 1,100' to 1,200' unrestricted sight distance in advance of the sign exists. It is recommended that additional work on the functionality of guide signs be performed. As a result of this project, Research Projects 1-18-84-277, "Functional Characteristics of Guide Signs" and 1-9-84-276, "Evaluation of Guide Sign Construction Materials" have been approved.

IV. MATERIALS:

Thermal setting polyester, thermoplastic polyester, thermal setting polyvinylidene fluoride, air dry polyvinylidene fluoride, polyvinyl fluoride film, acrylic film, polyurethane, vinyl-toluene acrylate copolymer, acrylic coating, acrylic urethane coating, silicone solution, GES-2C sign enamel, thermal setting polyvinyl chloride and engineer grade, super engineer grade and high specific intensity reflective sheeting have been tested as substrate finishes. Substrate materials that were tested include new aluminum extrusions, old deteriorated porcelainized aluminum extrusions, high density overlay plywood and A-B Grade pine plywood.

V. EQUIPMENT:

A grided simulated sign panel and J-16 light meter were used to evaluate sign lights. Actual field exposure test racks at Austin and Corpus Christi and a weatherometer were used to evaluate weatherizing characteristics. A color difference meter, infrared spectrophotometer and x-ray diffractometer were used to evaluate physical and chemical characteristics. A 1980 Plymouth Volare station wagon equipped with a Numetrics DE-140 digital bidirectional distance instrument was used in the sign evaluation and legibility studies.

VI. PROCEDURE FOR DATA:

The procedure for collection of the coating and lighting data used on this project was described on page 3 of Report Number 222-1. The procedure in the background coating portion is continuing in this project and will continue in the subsequent project.

A survey was made of all the major SDH&PT urban districts. It was found that all the districts had large stocks of deteriorated porcelain-enameled aluminum extrusion sign panels in their respective storage yards. This stock was in addition to many deteriorated porcelain-enameled signs that were still in service. Various methods were tried to refurbish these deteriorated panels, including chemical cleaning and chemical etching. Various background coatings were tried with these cleaning and etching methods. None of the chemical cleaning and etching methods produced satisfactory adhesion of any of the powder or liquid coatings to the original porcelain-enamel finish.

Complete removal of the original porcelain-enamel finish produced satisfactory adhesion of the polyester and polyvinylidene finishes. However, the cost of the complete removal of the porcelain-enamel finish made this method of refurbishing prohibitive unless done on large volume projects. Physical abrasion with coarse sand paper or coarse steel wool produced satisfactory adhesion with acrylic cured aliphatic urethene and sign enamel. Deteriorated porcelain-enameled extrusions were washed, abraded with steel wool or sand paper, and washed again. Pressure sensitive engineer grade, super engineer grade and high specific intensity reflective sheeting were hand applied directly to the extrusions. Slight defects such as small bubbles and wrinkles were experienced but these small defects have not proven to be any problem in appearance in the field or in durability of the sheeting thus far. Therefore, contrary to manufacturers' recommendations,

deteriorated porcelain-enameled extrusions can be satisfactorily refurbished with pressure sensitive engineer grade, super engineer grade or high specific intensity reflective sheeting applied directly to the extrusions without the use of an overlay face sheet. This type of refurbishing can easily be done in the departmental sign shops.

Although out of the realm of this overhead sign project, the refurbished aluminum extrusions could be utilized in inexpensively upgrading of ground mounted signs as well as overhead signs. The refurbished aluminum subtrates are more durable than the presently used plywood. The reflective sheeting dictates the life of a sign not the background substrate. However, the aluminum substrate could again be refurbished with new sheeting.

Reports from previous research projects in the area of requirements for sign illumination were reviewed (See Apprendix I). The reports indicated that if a sign has 1,100' to 1,200' of unrestricted sight distance in advance of the sign the motorist can perform the required driving tasks easily if the sign has reflective legend and no sign illumination (Example: Robertson and Shellor Report - Bibliography Item No. 5, and Cleveland, Woods). The driver can recognize, read, comprehend and react within these parameters using unlighted, reflectorized legend signs. All overhead signs in Houston, Corpus Christi, San Antonio, Dallas and El Paso were evaluated using the aforementioned parameters. The results of the evaluations showed that an average of 55% of the overhead signs met the requirements and could possibly be non-illuminated (See Figure 3A). To check the above, legibility studies were performed in Houston, Dallas and El Paso. Houston departmental people from both the Houston Urban Office and District 12 Office were used in the study. District 18 departmental people were used in the abreviated study in Dallas. District 24 departmental people were used in the El Paso study. Departmental people were

used in all of the studies performed due to legal liabilities in the use of a state vehicle in the studies. In Houston and El Paso the participants were bracketed into age groups of 18-24, 25-34, 35-44 and 45 and over. Two male participants and two female participants were chosen for each age bracket, one with eye glasses and one without eye glasses. All brackets were attained in the Houston study. All brackets were not attainable in the El Paso study. Only one female and one male participant were used in Dallas.

In the Houston legibility study, signs included opaque backgrounds with reflectorized button copy, engineer grade and high specific intensity reflectorized backgrounds with 16" upper case and 12" lower case reflectorized button copy and high specific intensity reflectorized stick on copy. The signs were illuminated and non-illuminated and were located in sections of freeway that were illuminated with mercury vapor lighting and high pressure sodium lighting. The signs were also located in non-illuminated sections of freeway. Some were in urban sections of freeway and some in semi-rural sections.

In the Dallas study the signs were located on a rural section of freeway which ran east and west. In the westbound direction the signs had high specific intensity reflective backgrounds with reflectorized button copy. In the eastbound direction the signs had engineer grade reflective backgrounds with reflectorized button copy. All of the signs were non-illuminated.

The participants made both daytime and night time runs in all of the studies. On specific signs they were instructed to immediately say "NOW" when they could actually read the legend, not just recognize it. They were driving a 1980 Plymouth Volare station wagon equipped with a

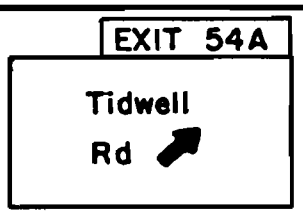
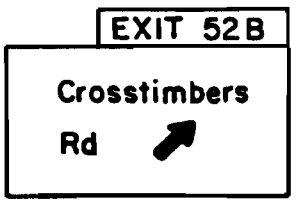
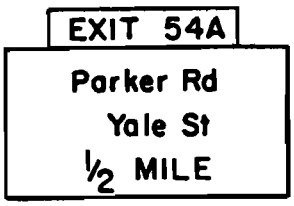
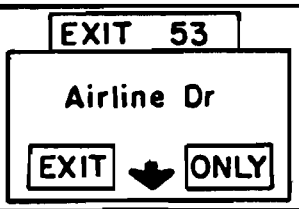
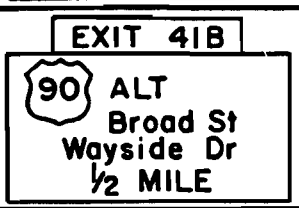
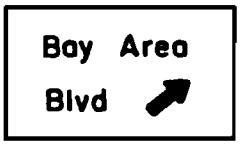
Numetrics DE-140 digital bidirectional distance instrument. When the participant said "NOW" the study supervisor would immediately clear the instrument. When the car came directly under the subject sign panel, the supervisor would immediately place the instrument on "HOLD". The instrument reading would therefore be the legibility distance of that particular sign. This method was used on all the studies. Sometimes the participant would read the sign aloud instead of saying "NOW" and as a method check sometimes the participant was told to read the sign. In all cases the legibility distance was recorded in the above manner. A discussion of the legibility study results is given in a latter portion of this report. Figures 1, 2 and 3 show typical signs, locations and participants in the legibility study.

It was planned to expand the legibility study to include overhead signs with super engineer grade reflective backgrounds. Signs were fabricated and erected in Houston. This work will be done on the subsequent project.

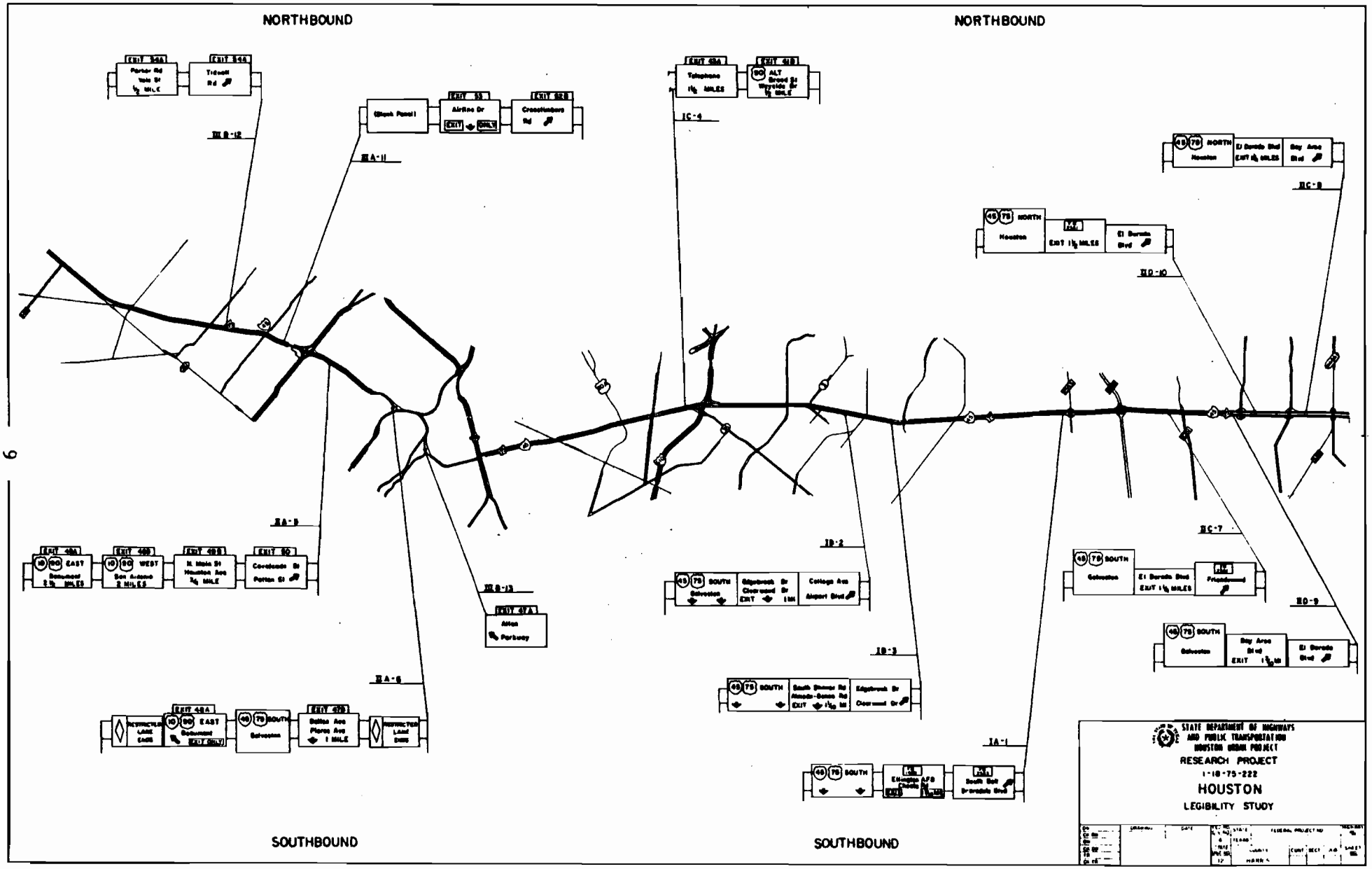
FIGURE 1
HOUSTON

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

1

SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
NORTHBOUND:		
IIIB-12A	 16" U.C. 12" L.C. (Typ.)	HI SP. INTEN REFL. BKGRD. HI SP. INTEN. STICK ON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIA-11A		HI SP. INTEN.REFL. BKGRD. HI SP. INTEN. STICK ON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIB-12B		HI SP. INTEN.REFL. BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIA-11B		HI SP. INTEN.REFL. BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS ON
IC-4		OPAQUE BKGRD. BUTTON COPY FWY ILL- H. M. HPS MERCURY SIGN LIGHTS ON
IID-10		ENGINEER GRADE REFL. BKGRD. BUTTON COPY FWY ILL- NONE NO SIGN LIGHTS
IIC-8		OPAQUE BKGRD. BUTTON COPY FWY ILL- NONE FLUOR. SIGN LIGHTS ON

Typical Signs - See Appendix "A" for complete listing of Houston, El Paso & Dallas signs.



Typical Layout - See Appendix "A"
For Houston, El Paso, & Dallas

FIGURE 2

PARTICIPANTS - HOUSTON LEGIBILITY STUDY

MALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Jeff Miller	Charles Hearn
25 - 34	Andy House Lewis Rhodes	Darrell Gloyna
35 - 44	Ed Vasut	Jerome Moore Gene Ritch
45 & Over	Leo Taggart Dick McCasland	Bob Hauck

FEMALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Sandy Gilliam	Janelle Homfeld Elizabeth Derrig
25 - 34	Pam Harper Pat Trippell	Linda Potcinske
35 - 44	Nancy Shaw	Carol Letz
45 & Over	Ann Walker	Sue Childress

FIGURE 3

Typical Participant List - See
Appendix "A"
For Houston, El Paso, & Dallas Lists.

SIGN PANEL SURVEY SUMMARY

CITY SURVEYED	MILES SURVEYED	TOTAL NO. OF OVHD. STRUCTS. SURVEYED	TOTAL NO. OF OVHD. STRUCTS. THAT WOULD NOT REQUIRE SIGN ILLUM.	% OF OVHD.STRUC. THAT WOULD NOT REQUIRE SIGN ILLUM.	TOTAL NO. OF OVHD. SIGN PANELS SURVEYED	TOTAL OF OVHD. PANELS THAT WOULD NOT REQUIRE SIGN ILLUM.	% OF OVHD. SIGN PANELS THAT WOULD NOT REQUIRE SIGN ILLUM.
San Antonio	105	255	101	40%	578	223	39%
El Paso	56	86	70	81%	246	200	81%
Corpus Christi	84	98	65	66%	209	139	67%
Houston	472	603	195	32%	1,272	430	34%
Summary	717	1,042	431	55%	2,305	992	55%

NOTE: The above survey was based upon an unrestricted sight distance of 1,100' to 1,200' in advance of the sign structures.

All signs had reflective legend.

Most of the signs surveyed had button reflectorized copy and ranged in age from 5 years to 20 years.

FIGURE 3A

VII. DISCUSSION:

As stated in Report Number 222-1 the advent of overhead signing created a multitude of problems in an effort to solve one traffic engineering problem: How does one make an in-place, legible, maintenance free sign unit with pleasing aesthetics that will fulfill all the needs of the motorists? The problems seem simple. However, some of the problems were really quite complex. Two of these problems were background coatings and sign illumination.

When overhead signing first became a reality porcelain-enameled aluminum was the only material available that promised any feasible durability. Fluorescent lighting was considered the only feasible way to produce a functional illumination system. In the coastal and industrial areas the porcelain-enamel coating deteriorated rapidly (Figure 4). The fluorescent sign lighting produced a multitude of maintenance problems that had not been experienced in indoor applications.

During the sixties two film coatings, polyvinyl fluoride (Figure 5) and acrylic were investigated by the department, and proven durable and satisfactory for use. Several projects were contracted using these two film coatings. The projects were successful. However, due to the limited usage, the films were virtually withdrawn from the market, leaving once again porcelain enamel as the only available coating.

Also in the sixties the first mercury vapor sign lights were developed through departmental experimentation. Even though these first mercury vapor units reduced maintenance due to reduced number of lamps and much longer lamp life, the lighting uniformity was not good and the units were not energy efficient.

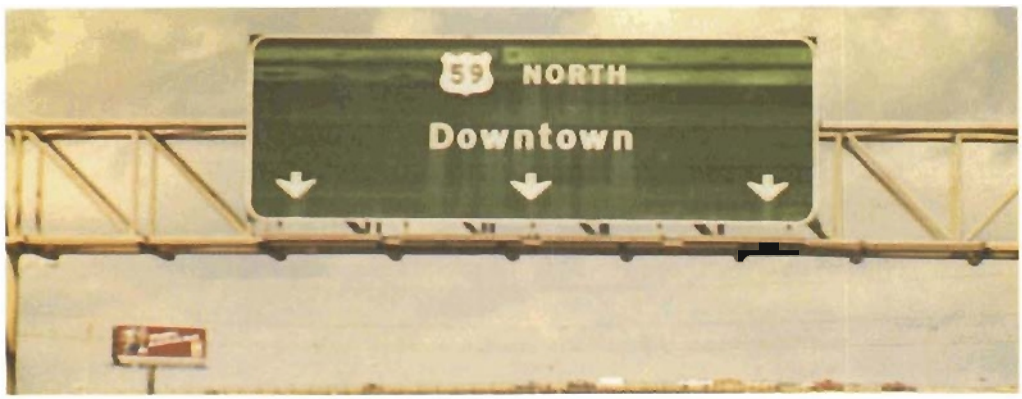


FIGURE 4: Typical Deteriorated Porcelain-enameled Sign Panels with Fluorescent Lighting

FIGURE 5: Polyvinyl Film coated sign panel with porcelain-enameled cut out copy. The sign was erected on a contract in 1966. The coating is still in excellent condition. Note the streaking from the deteriorated procelain enameled copy.

In view of the above stated problems the continuing experimentation by several departmental offices was combined into this project, Number 1-18-75-222. As explained in the previous project report, a concerted effort was expended in these areas of endeavor. Numerous coatings were tested using various testing methods. Numerous manufacturer's prototype fixtures were tested. A majority of the coating materials tested did not prove satisfactory for various reasons such as cracking, crazing, delamination from the substrate, fading and a multitude of other reasons. The testing proved that coating materials based on thermal setting polyester and thermal setting polyvinylidene fluoride are satisfactory coating materials for Overhead Guide Signs. These coatings are presently being used on a statewide basis.

Since the statewide usage of the above coatings began in 1977 testing of these coatings has continued. In addition, other coatings that have become available have been included in the test program. Some of the coatings did not survive past preliminary testing. After the preliminary tests proved early failures for various reasons, the coatings were removed from the project. A polyvinyl chloride coating does show promise. At the writing of this report, the PVC tests are not complete. The tests will be completed on Project Number 1-9-84-276. Figures 6 through 11 show various coatings and signs in the program.

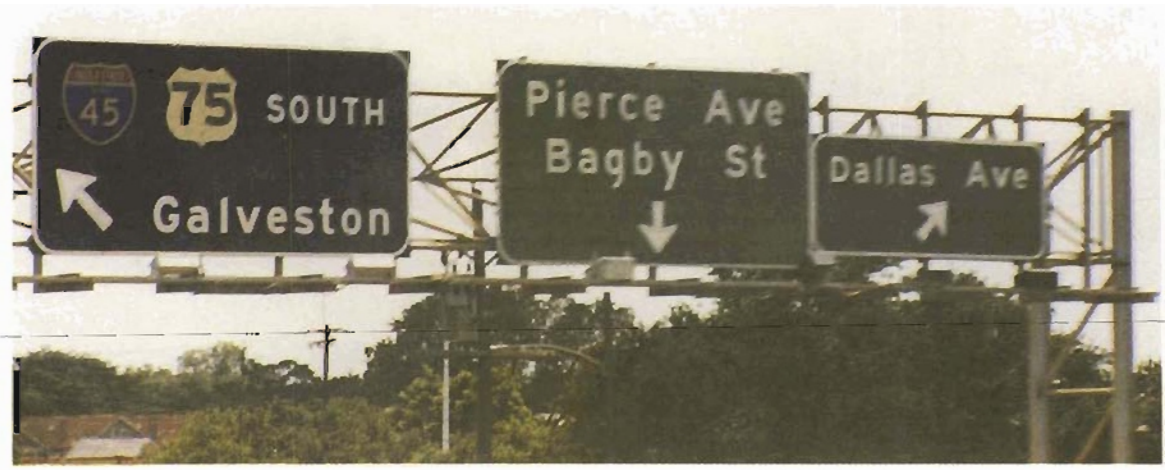
FIGURE 6

SIGN PANEL AND FIXTURE TABULATION
PROJECT I-18-75-222

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIRECTION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-1	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	8'0"x17'0"	45 75 SOUTH Galveston	Polyurethane	Med. Dens. Plywood	Hughson Chemical	2-250 W Lights on	Quality	
S-2	Overhead	RS-45-47-6	14+75	Left Coll.Rd.	S.B.	8'0"x15'0"	Pierce Ave Bagby St. ↓	Polyurethane	Extr. Alum.	Hughson	1-100 W 1-175 W Lights on	G.E. McGraw-Edison	
S-3	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	6'0"x18'6"	McKinney Ave NEXT LEFT	Polyvinylidene Fluoride	Extr. Alum.	Pennwalt	1-175 W 2-250 W Lights on	G.E. Crouse-Hinds	Lighted as one continuous area
S-4	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	6'0"x19'0"	Allen Parkway ↓ 1/4 MILE	Polyvinylidene Fluoride	Extr. Plywood	Pennwalt	2-250 W Lights on	Crouse-Hinds	
S-5	Overhead	RS-45-49-2	113+20	I.H. 45	S.B.	6'0"x12'0"	Quitman St ↗	Standard Green Sign Paint. No Topcoat	Med. Dens. Plywood	Sign Shop	2-1000 W Lights on	G.E.	Panel requested by File D-9. Fabricated by Dist 12 Sign Shop.
S-6	Overhead	RS-45-47-9	27+16.89	I.H. 45	S.B.	6'0"x16'0"	↖ Allen Parkway	High Intensity Reflective Sheeting	Overlay Sheet over Extr.	3M	(Exist. Fluor.) Lights off	N/A	Existing Lights to remain on structure and turned off.
S-7	Overhead	RS-2	199+50	U.S. 290	W.B.	8'0"x16'0"	FREEWAY ENDS 1 MILE	Sign Paint	Extr. Alum.	Alcoa-Sign Shop Repaired	Project Lights on	Contractor	Bottom 2 extrusions damaged in freight. Repaired the bottom 2 extrusions with polyurethane.
S-8	Overhead	RS-4	2862+00	U.S. 290	W.B.	8'0"x11'0"	FREEWAY ENDS	Polyester	Alcoa Extr. Alum.	Goodyear	Project Lights on	Contractor	Painted over damaged polyester coating.
S-9	Overhead	RS-45-47-6	14+75	Left Coll.Rd.	S.B.	5'0"x12'0"	Dallas Ave ↗	Polyvinylidene Fluoride	Extr. Alum.	Alcoa PPG	1-250 W 1-250 W Lights on	Nu Art Holophane	

Typical Experimental Signs - See Appendix "B" For Complete List

Top extrusions coated with thermal setting polyester. Bottom extrusions coated with polyurethane. Polyurethane faded after 2 years.



Three different experimental coatings on one structure. From left to right; sign enamel with acrylic top coat, polyurethane, and thermal setting polyester. The acrylic top coat peeled off, but the sign enamel is in good condition.

Figure 7: Various experimental coatings. Some of which were not successful.

Air Dry Polyvinylidene Fluoride - Original Condition

8 years Field Service - The release agent on plastic coated plywood substrate caused delamination. Coating delaminated after 5 years.

Figure 8: Experimental Coating Durability Comparison

Figure 9: Thermal Setting Polyester Coated Legend chalking and running down Engineer Grade Reflective Sheeting Background Sign in San Antonio.

The above sign was erected by contract in District 15 in San Antonio. Lab testing, exposure rack testing and field testing in Houston had produced satisfactory results with a thermal setting polyester. However, the above picture shows the problem experienced on a signing project in San Antonio.

Investigations have proven that the polyester coating used on the legend on the above sign was actually a hybrid polyester that included epoxy in the formulation. The epoxy caused the chalking. The hybrid coating did not meet the state specifications for polyester coating. Further testing of polyester is to be done in project 1-9-84-276.

Thermal Setting Polyester Coating - Original Condition

8 Years Field Service - Good Condition in regards to color and surface condition.

Figure 10: Experimental Coating Durability Comparison

GES - 2C Green Sign Paint without
Topcoat - Original Condition

GES - 2C Green Sign Paint without
Topcoat - 8 Years Field Service
Good Condition in regards to color
and surface condition

Figure 11: Experimental Coating Durability Comparison

Some of the coating production problems that have been experienced in contracts since the adoption of the recommended coatings have appeared in the experimental panels. Figure 12 shows a thermal setting polyester coated panel in which one end of one extrusion was not properly cleaned. The improper cleaning caused complete delamination of the coating.

Figure 12: Showing Thermal Setting Polyester Coating Delamination due to Improper Cleaning or Handling of Substrate during Coating Process - Otherwise in Good Condition in regards to Color and Surface Condition

Even though production problems do exist with the recommended coatings in continuing exposure tests have proven them to be the best known available coatings. The Expected Life-Years and Cost/Year-Life shown in the comparison table on page 22 of Report 222-1 is indeed conservative. All evaluations to date indicate a conservative anticipated life in excess of 30 years or double the life shown originally for polyester coating and polyvinylidene flouride coating.

The anticipated life for engineer grade reflective sheeting is 7 years. The anticipated life for super engineer grade reflective sheeting is 8 years. The anticipated life for high specific intensity reflective sheeting is 10 years. The anticipated life for button copy is 20 years plus.

Research Report Number 222-1 explained the procedures used in the development of new improved mercury vapor sign lights. With the cooperation of numerous lighting fixture manufacturers, this project has developed new improved mercury vapor sign lighting fixtures. The project has proven that overhead guide signs can be illuminated to sufficient target value and uniformity with certain 100 watt mercury vapor lighting units. Most 175 watt and 250 watt mercury vapor lighting units present excessive brightness which reduces legibility, in particular the 250 watt units. The 100 watt units are presently being used on a statewide basis. This portion of the project is considered to be complete (Figure 13).

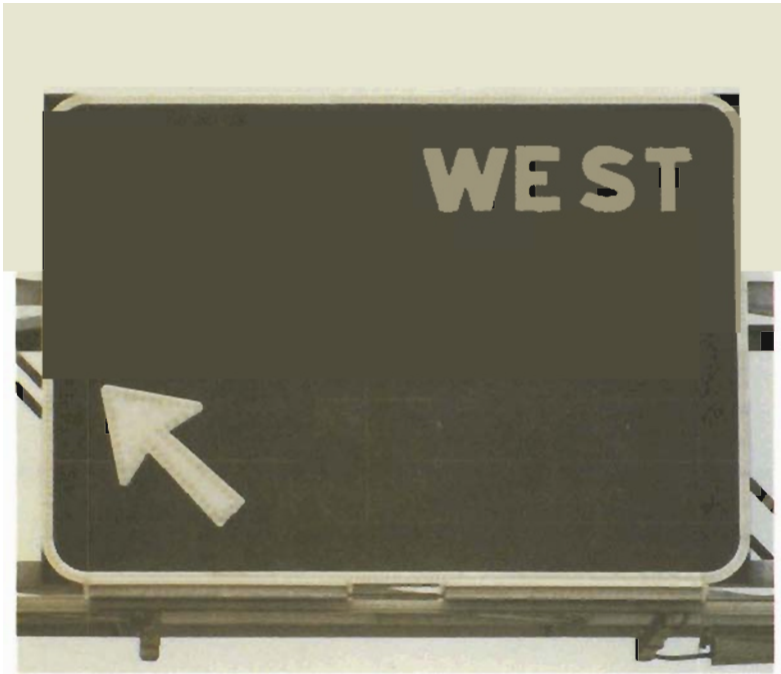
Figure 13: Two Thermal Setting Polyester Coated Sign Panels and 100 Watt Mercury Vapor Sign Lights. This contract installation was made in 1982.

The project objectives were expanded to include finding a feasible and satisfactory method to refurbish existing deteriorated porcelain-enameled sign extrusions. A statewide survey was made. All of the major SDH&PT urban districts were contacted. It was found that all of the districts had large stocks of deteriorated porcelain-enameled aluminum extrusions in their respective storage yards. These stocks were in addition to many deteriorated porcelain-enameled signs that were still in service.

Various methods were tried to refurbish these deteriorated panels. Various chemical cleaning and chemical etching methods were tried. With these cleaning and etching methods, various background coatings were used. None of the chemical cleaning and etching methods produced satisfactory adhesion of any of the powder or liquid coatings to the original porcelain-enamel finish. Complete removal of the original porcelain-enamel finish produced satisfactory adhesion of the polyester finish. However, the cost of the removal of the porcelain-enamel finish made this method of refurbishing prohibitive unless done on large volume projects.

Several proprietary coatings were tried that supposedly required mere washing and/or light abrasion with steel wool or sand paper. These proprietary coatings were not successful.

Even though many people involved in the project did not believe the coatings would succeed, Acrylic Cured Aliphatic Urethane and GES-2C Sign Enamel were tried. The deteriorated porcelain-enameled sign extrusions were washed. Abrasion was done with medium sandpaper or coarse steel wool. The panels were again washed. After drying, enough extrusions to make a sign panel were coated with Acrylic Cured Aliphatic Urethane. Additional extrusions to form another sign panel were coated with GES-2C Sign Enamel. The two sign panels are still in good condition after 7 years service (Figure 14).



Sign Panel Refurbished Using
Acrylic Cured Aliphatic Urethane after 7 years Field Service
(Best of the two coatings shown on this page)

Sign Refurbished with GES-2C Sign Enamel after 7 years Service

Figure 14: Refurbished Sign Panels

District 24 (El Paso) refurbished deteriorated porcelain-enameled signs in their sign shop by removing the text, washing the panels, applying a powdered mild abrasive porcelain cleaner and scouring with a large floor buffer. The panels were then rinsed, new text applied and reused on the roadway. The sign panels are in good condition after 5 years (See Appendix G).

Sheeting manufacturers recommended the use of reflective sheeting as a background material for refurbishing deteriorated porcelain-enameled aluminum signs. They recommended the application of the sheeting only on a thin overlay over the deteriorated sign panel. They recommended against the application of the sheeting directly to the deteriorated extrusions. Several panels were refurbished using the reflective sheeting on thin aluminum overlays. Five panels in Houston were refurbished using fairly rigid (thickness 0.040) aluminum overlay sheets which were coated with high specific intensity sheeting. Two of the sign panels suffered severe delamination of the reflective sheeting from the aluminum overlay sheets. These were replaced by the manufacturer. It is believed that the delamination was caused by improper preparation of the aluminum overlay sheet prior to application of the reflective sheeting. The remaining three panels and the replacement panels are still in good condition. The original panels have been in service for eight years (Figures 15 and 16). Numerous panels were refurbished in place on the sign structures in San Antonio using thin aluminum foil overlay sheets coated with high specific intensity reflective sheeting. These panels experienced severe bubbling and wrinkling in application. They are also experiencing rapid deterioration. The bubbles and wrinkles on the San Antonio signs are so severe that legibility is definitely impaired.

Refurbished Sign Panel using Rigid Aluminum Overlay
Coated with High Specific Intensity Reflective Sheeting
and High Specific Intensity Stick on Copy

Same as above after 8 years Service - Good Condition

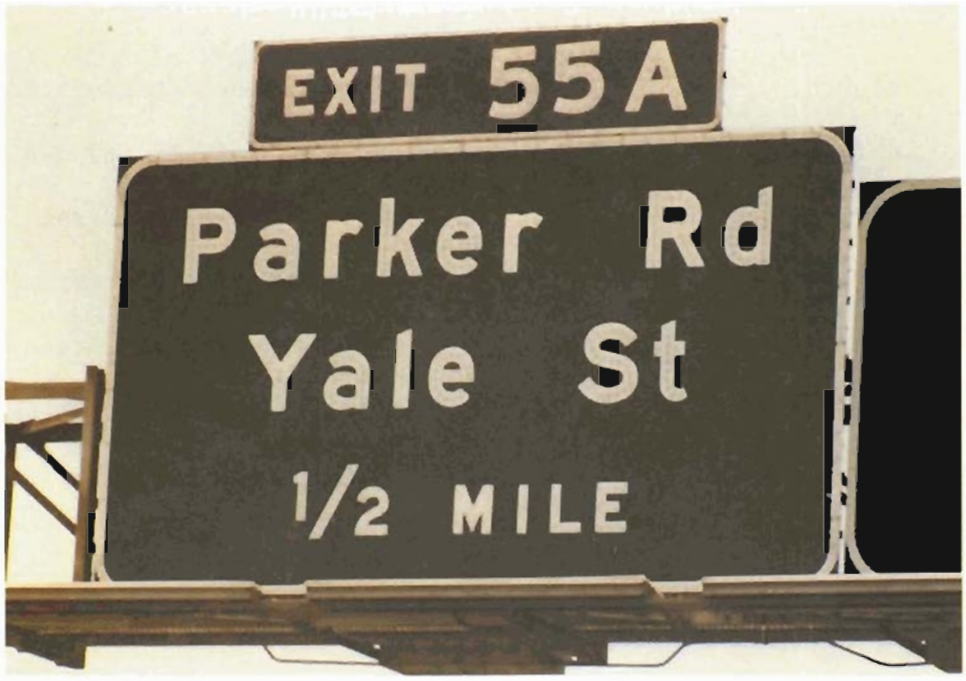
Figure 15: Experimental Reflective Sheeting Durability Comparison

Numerous panels have been refurbished in Houston in the District 12 Sign Shop by the application of reflective sheeting directly to the deteriorated porcelain-enameled aluminum extrusions. The extrusions were washed, abraded with steel wool and washed again. The reflective sheeting was hand applied directly to the extrusions. Engineering grade, super engineer grade and high specific intensity reflective sheeting have all been used in this method. The directly applied sheeting experienced some small bubbling and small wrinkles. These minor defects have not proven to be any problem in appearance in the field or in durability of the sheeting thus far.

Therefore, contrary to manufacturers recommendations, deteriorated porcelain-enameled extrusions can be satisfactorily refurbished with engineer grade, super engineer grade or high specific intensity reflective sheeting applied directly to the extrusions without the use of an overlay face sheet. This type of refurbishing can easily be done in the departmental sign shops. This type of refurbishing produced superior results compared with the use of thin foil pressure sensitive overlay sheets.

The rigid (thickness 0.040) riveted aluminum overlay sheets also produced satisfactory results.

The refurbished aluminum extrusions could be utilized in inexpensively upgrading ground mounted signs as well as overhead signs.



Refurbished Sign Panel using Rigid Aluminum Overlay Coated with High Specific Intensity Reflective Sheeting and Cut Out Button Copy.

Same as Above with High Specific Intensity Stick on Copy

Figure 16: Refurbished Panels after 8 years service - Good Condition

Figure 17: Refurbished Sign Panels using High Specific Intensity Reflective Sheeting Applied Directly to the Aluminum Extrusions after 3 years of service - Good Condition

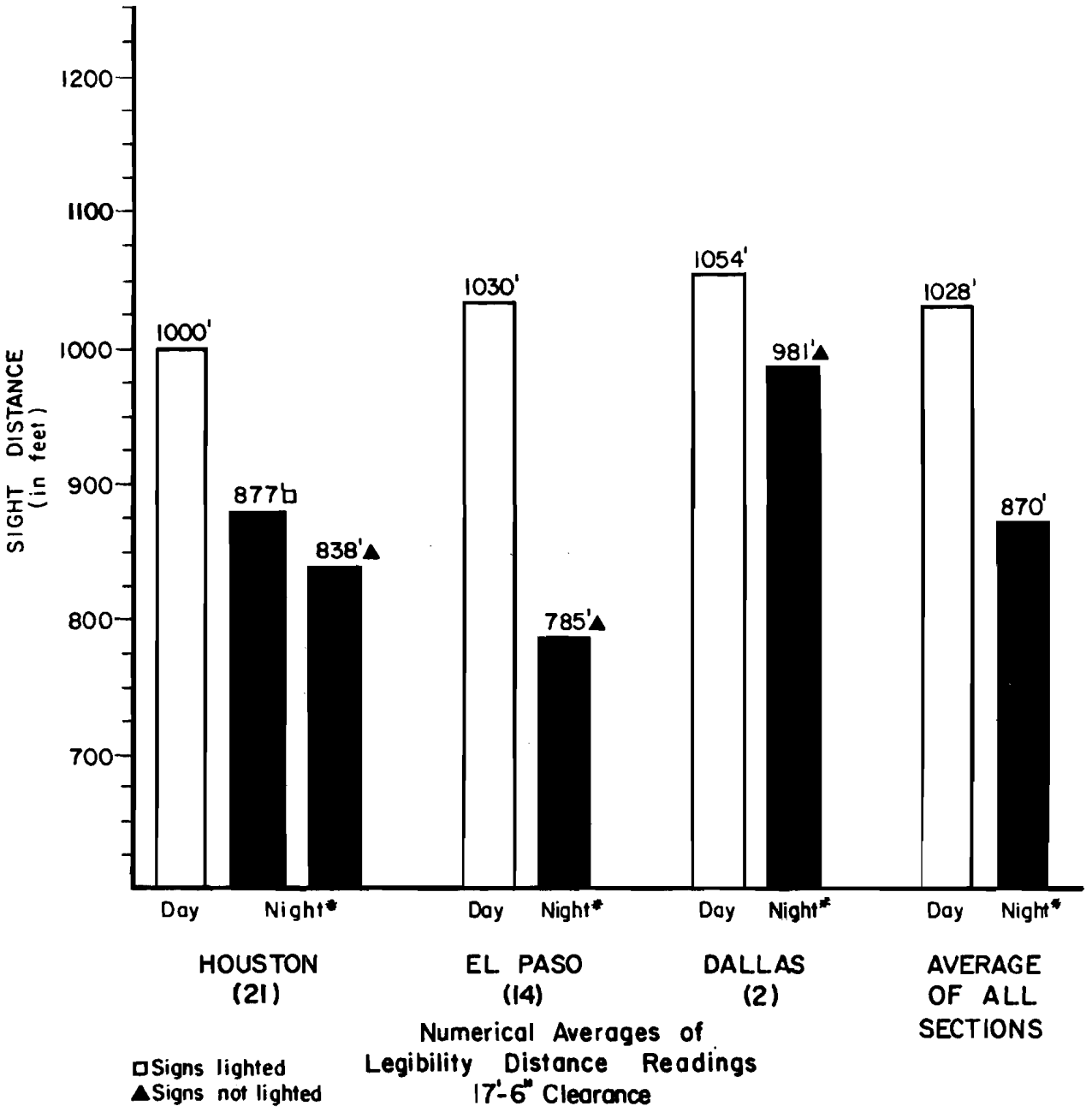
The scope of the project was again expanded by adding the task of determining the feasibility of using non-illuminated overhead guide signs with reflectorized copy. This study was to include opaque background signs and reflectorized background signs.

Reports from previous research projects in the area of requirements for sign illumination were reviewed. The reports indicated that if a sign has 1,100' to 1,200' of unrestricted sight distance in advance of the sign, the motorist can perform the required driving tasks easily if the sign has reflective legend and no sign illumination. The driver can recognize, read, comprehend and react within these parameters on an unlighted, reflectorized legend sign.

The overhead sign evaluation studies performed in Houston, Corpus Christi, San Antonio, Dallas and El Paso indicated that an average of 55% of the overhead signs met the requirements and could possibly be non-illuminated. This finding corresponds with the results of a similar study conducted in New Jersey. Legibility studies were performed in Houston, Dallas and El Paso. Figure 18 shows the numerical averages of the legibility distances. All the legibility distance averages fell below the 1,100' to 1,200' sight distance used in the sign evaluation studies.

The overhead sign structures in Houston are being raised to a minimum clearance of 21'-0" instead of the 17'-6" minimum clearance as specified in the Manual on Uniform Traffic Control Devices. The raising of the structures is being done because of the extremely high number of sign structures being knocked down by overheight loads and dump trucks with their dump beds in a raised position. Concerns were raised as to the possible decrease in legibility distance due to the increased mounting height of the signs. Figure 19 shows the legibility distance readings for seven of the participants in the Houston Legibility Study for signs mounted at 21'-0".

LEGIBILITY STUDY
RESEARCH PROJECT



*Night averages are with headlights on low beam

FIGURE 18

AVERAGE LEGIBILITY DISTANCE
HIGH SPECIFIC INTENSITY UNLIGHTED SIGNS
21'-0" Clearance - Low Beam

Participant's Name	Age	Sex	Average Legibility Distance Day	Night
Lewis Rhodes	33	Male	1144'	761'
Darrell Gloyna	28	Male	940'	627'
Nancy Shaw	37	Female	710'	615'
Ann Walker	47	Female	831'	673'
Linda Potcinske	34	Female	865'	752'
Carol Letz	44	Female	773'	650'
Sue Childress	48	Female	749'	534'

FIGURE 19

There appears to be no detrimental decrease in legibility. This corresponds with the finding of Woods and Rowan.

Texas Transportation Institute was contacted to assist in the statistical analysis of the legibility studies as performed. Dr. Roger W. McNees was requested to perform the statistical analysis. Dr. McNees' report will be published at a later date as part of the effort of Project 1-18-84-277.

The legibility studies indicated that there are no significant differences in legibility distances whether the freeway signs were lighted, unlighted, had high specific intensity stick on copy or button copy, or had opaque or reflective background. The reflective background merely added conspicuity (target value) and did not increase the legibility of the sign.

The sampling of the participants did not correspond with the population mix in the United States. Therefore, the legibility studies will be expanded in subsequent Project Number 1-18-84-277, "Functional Characteristics of Guide Signs".

APPENDIX A

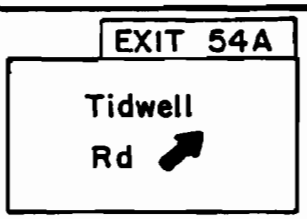
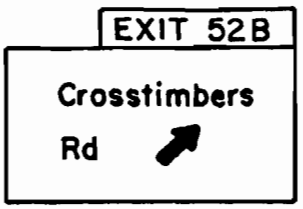
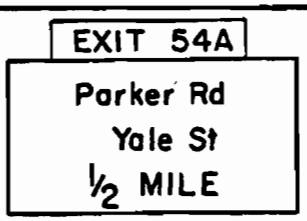
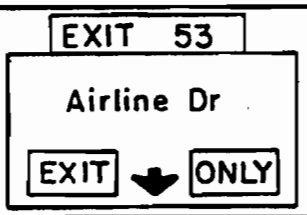
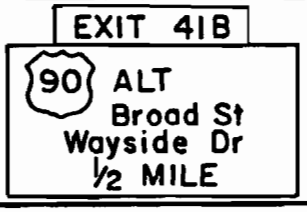
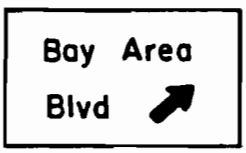
LEGIBILITY STUDY

Signs, Layouts, & Participants

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

HOUSTON

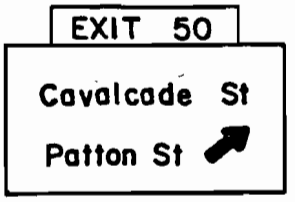
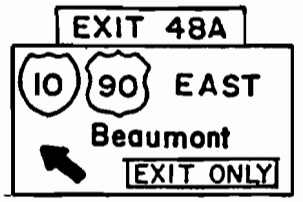
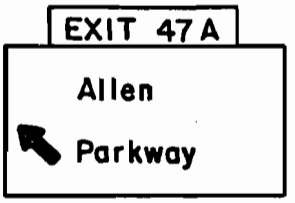
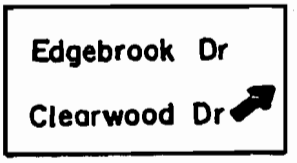
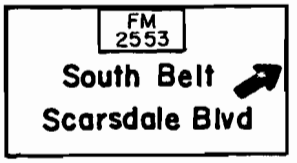
1

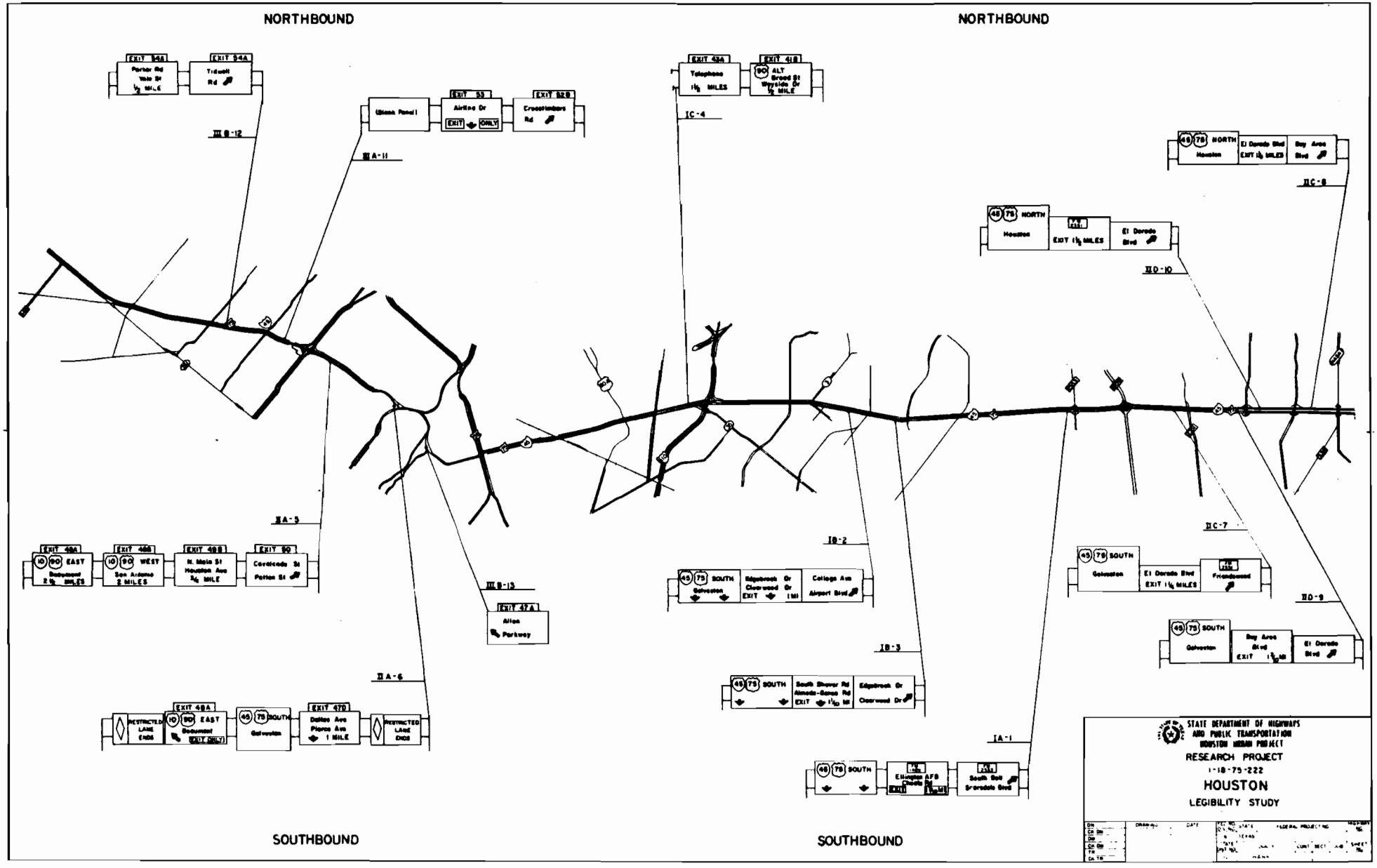
SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
NORTHBOUND:		
IIIB-12A	 16" U.C. 12" L.C. (TYP)	HI SP. INTEN. REFL. BKGRD. HI SP. INTEN. STICK ON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIA-11A		HI SP. INTEN. REFL. BKGRD. HI SP. INTEN. STICK ON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIB-12B		HI SP. INTEN. REFL. BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS OFF
IIIA-11B		HI SP. INTEN.REFL. BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS ON
IC-4		OPAQUE BKGRD. BUTTON COPY FWY ILL- H. M. HPS MERCURY SIGN LIGHTS ON
IID-10		ENGINEER GRADE REFL. BKGRD. BUTTON COPY FWY ILL- NONE NO SIGN LIGHTS
IIC-8		OPAQUE BKGRD. BUTTON COPY FWY ILL- NONE FLUOR. SIGN LIGHTS ON

LEGIBILITY STUDY
RESEARCH PROJECT
HOUSTON

2

1-18-75-222

SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
SOUTHBOUND:		
IIA-5	 16" U.C. 12" L.C. (TYP)	ENGINEER GRADE REFL. BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS ON
IIA-6		OPAQUE BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR MERCURY SIGN LIGHTS ON
IIIB-13		HI SP. INTEN. REFL. BKGRD. HI SP. INTEN. STICK ON COPY FWY ILL-MERCURY VAPOR FLUOR. SIGN LIGHTS ON
IB-2		OPAQUE BKGRD. BUTTON COPY FWY ILL- MERCURY VAPOR FLUOR. SIGN LIGHTS ON
IB-3		OPAQUE BKGRD. BUTTON COPY FWY ILL- NONE FLUOR. SIGN LIGHTS OFF
IA-1		OPAQUE BKGRD. BUTTON COPY FWY ILL- NONE FLUOR. SIGN LIGHTS OFF
IIC-7		OPAQUE BKGRD. BUTTON COPY FWY ILL- NONE FLUOR. SIGN LIGHTS ON
IID-9		ENGINEER GRADE REFL. BKGRD. BUTTON COPY FWY ILL- NONE NO SIGN LIGHTS


NORTHBOUND
NORTHBOUND
EXIT 54B
Parker Rd
Main St
½ MILE
EXIT 54A
Tidwell Rd
Union Pacific
EXIT 53
Airline Dr
EXIT ONLY
EXIT 52B
Crosstimbers Rd
EXIT 43A
Telephone
1½ MILES
EXIT 41B
90 ALT
Broad St
Wayside Dr
½ MILE
III B-12
III A-11
IC-4
45 75 NORTH
Houston
El Dorado Blvd
EXIT 1½ MILES
Bay Area Blvd
IIC-8
45 75 NORTH
Houston
FM 528
EXIT 1½ MILES
El Dorado Blvd
IID-10
IIC-7
IB-2
III A-5
III B-13
EXIT 49A
10 90 EAST
Beechnut
2½ MILES
EXIT 48B
10 90 WEST
San Antonio
2 MILES
EXIT 48B
N. Main St
Houston Ave
¾ MILE
EXIT 90
Cavalcade St
Patton St
EXIT 47A
Alton
Parkway
45 75 SOUTH
Galveston
Edgebrook Dr
Clearwood Dr
EXIT
College Ave
Airport Blvd
45 75 SOUTH
Galveston
El Dorado Blvd
EXIT 1½ MILES
FM 528
Friendswood
IID-9
45 75 SOUTH
Galveston
Bay Area Blvd
EXIT 1½ MI
El Dorado Blvd
IB-3
III A-6
RESTRICTED LANE ENDS
EXIT 48A
10 90 EAST
Beechnut
EXIT ONLY
45 75 SOUTH
Galveston
EXIT 47D
Dallas Ave
Pierce Ave
1 MILE
RESTRICTED LANE ENDS
45 75 SOUTH
South Shaver Rd
Almeda-Genoa Rd
EXIT 1½ MI
Edgebrook Dr
Clearwood Dr
IA-1
45 75 SOUTH
FM 1959
Ellington AFB
Clear Lake
EXIT
1½ MI
FM 518
South Belt
Brookside Blvd
SOUTHBOUND
SOUTHBOUND
STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
HOUSTON URBAN PROJECT
RESEARCH PROJECT
1-18-75-222
HOUSTON
LEGIBILITY STUDY

PARTICIPANTS - HOUSTON LEGIBILITY STUDY

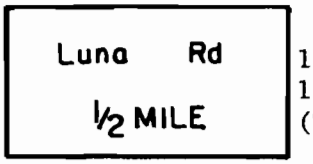
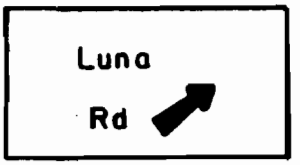
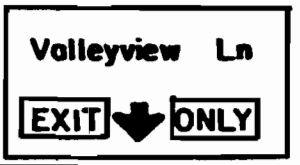
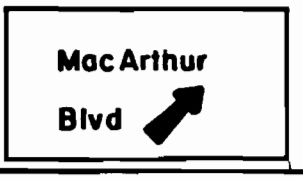
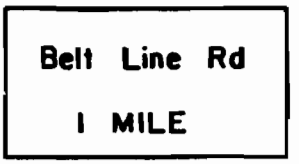
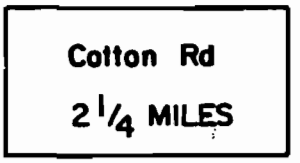
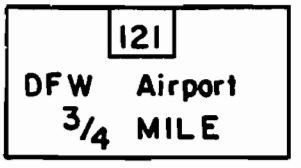
MALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Jeff Miller	Charles Hearn
25 - 34	Andy House Lewis Rhodes	Darrell Gloyna
35 - 44	Ed Vasut	Jerome Moore Gene Ritch
45 & Over	Leo Taggart Dick McCasland	Bob Hauck

FEMALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Sandy Gilliam	Janelle Homfeld Elizabeth Derrig
25 - 34	Pam Harper Pat Trippell	Linda Potcinske
35 - 44	Nancy Shaw	Carol Letz
45 & Over	Ann Walker	Sue Childress

DALLAS

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

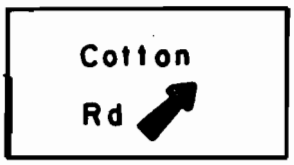
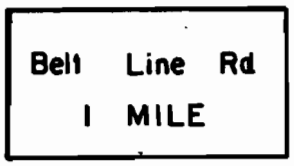
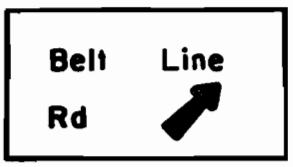
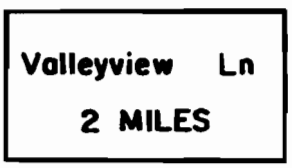
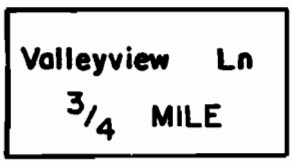
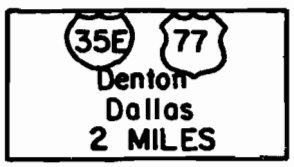
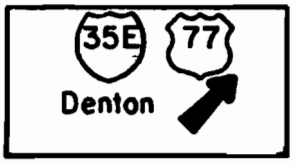
*NOTE: ALL SIGNS ON DALLAS STUDY ARE WITHOUT FREEWAY ILL. AND HAVE NO SIGN LIGHTS.

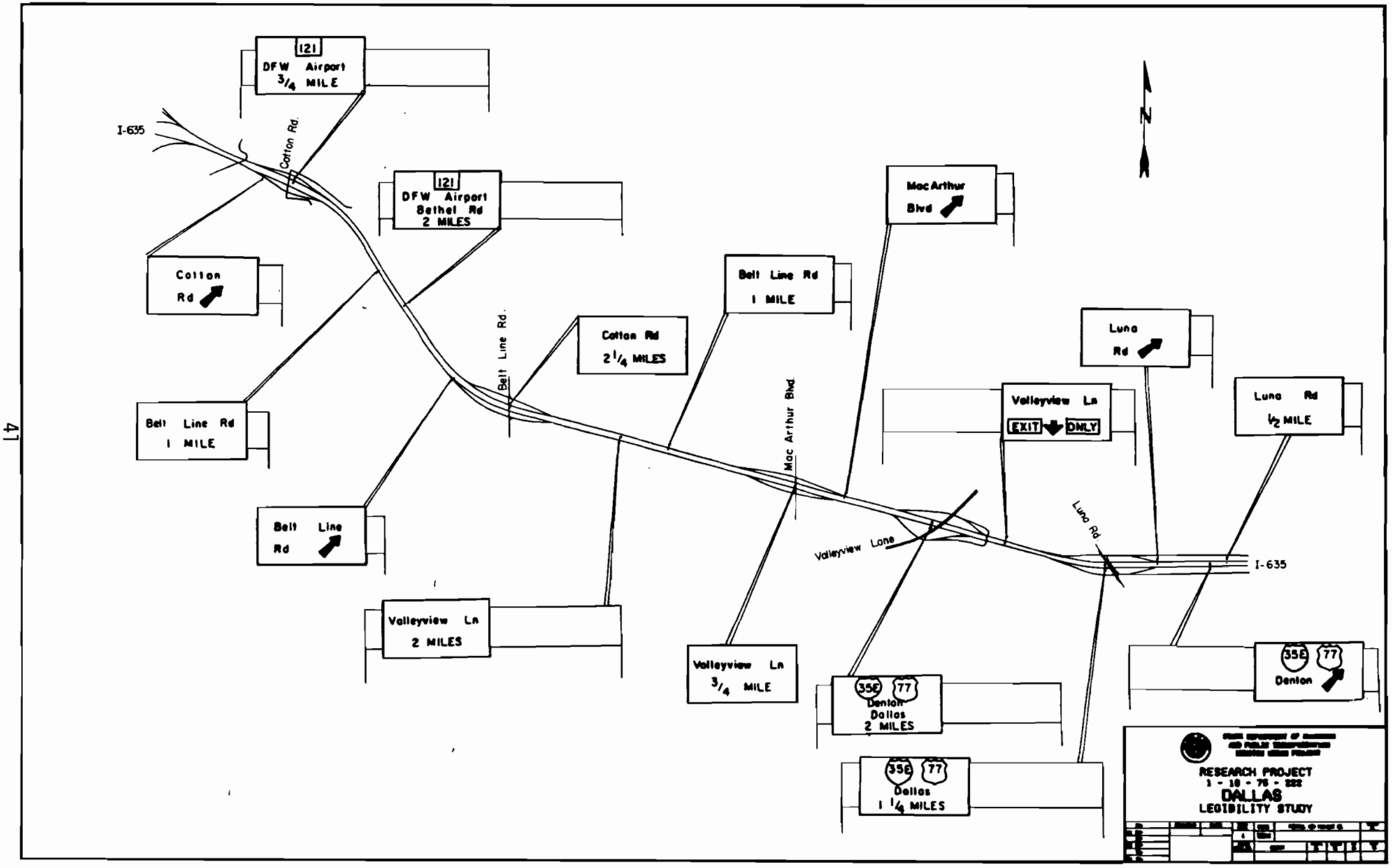
SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
WESTBOUND:		
I-WB	 16" U.C. 12" L.C. (TYP)	HI SP. INTEN. REFL. BKGRD. BUTTON COPY
II-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
III-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
IV-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
V-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
VI-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
VII-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY
VIII-WB		HI SP. INTEN. REFL. BKGRD. BUTTON COPY

DALLAS

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

*NOTE: ALL SIGNS ON DALLAS STUDY ARE WITHOUT FREEWAY ILL. AND HAVE NO SIGN LIGHTS.

SIGN NO. EASTBOUND:	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
I-EB	 16" U.C. 12" L.C. (TYP)	ENGINEER GRADE REFL. BKGRD. BUTTON COPY
II-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
III-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
IV-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
V-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
VI-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
VII EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY
VIII-EB		ENGINEER GRADE REFL. BKGRD. BUTTON COPY


121
DFW Airport
3/4 MILE
I-635
Cotton Rd.
121
DFW Airport
Bethel Rd
2 MILES
Mac Arthur
Blvd
Cotton
Rd
Belt Line Rd
1 MILE
Belt Line Rd.
Cotton Rd
2 1/4 MILES
Luna
Rd
Valleyview Ln
EXIT ONLY
Luna Rd
1/2 MILE
Belt Line Rd
1 MILE
Mac Arthur Blvd.
Belt Line
Rd
Valleyview Lane
Luna Rd
I-635
Valleyview Ln
2 MILES
Valleyview Ln
3/4 MILE
35E
77
Denton
Dallas
2 MILES
35E
77
Dallas
1 1/4 MILES
35E
77
Denton
RESEARCH PROJECT
1 - 18 - 78 - 222
DALLAS
LEGIBILITY STUDY

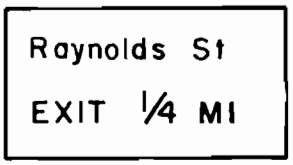
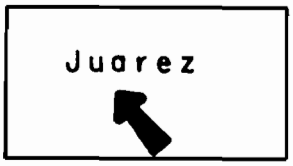
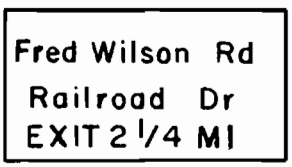
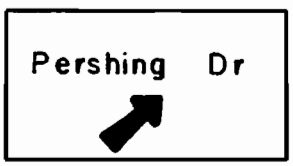
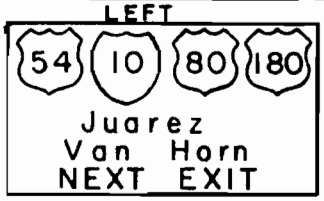
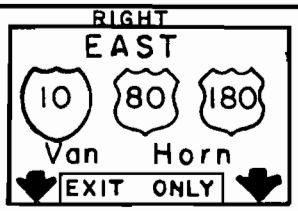
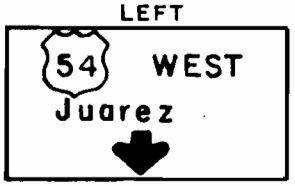
PARTICIPANTS - DALLAS LEGIBILITY STUDY

MALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24		
25 - 34		
35 - 44		
45 & Over		Leroy Wallen

FEMALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24		Ellen Lyon (Contact lenses)
25 - 34		
35 - 44		
45 & Over		

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

EL PASO

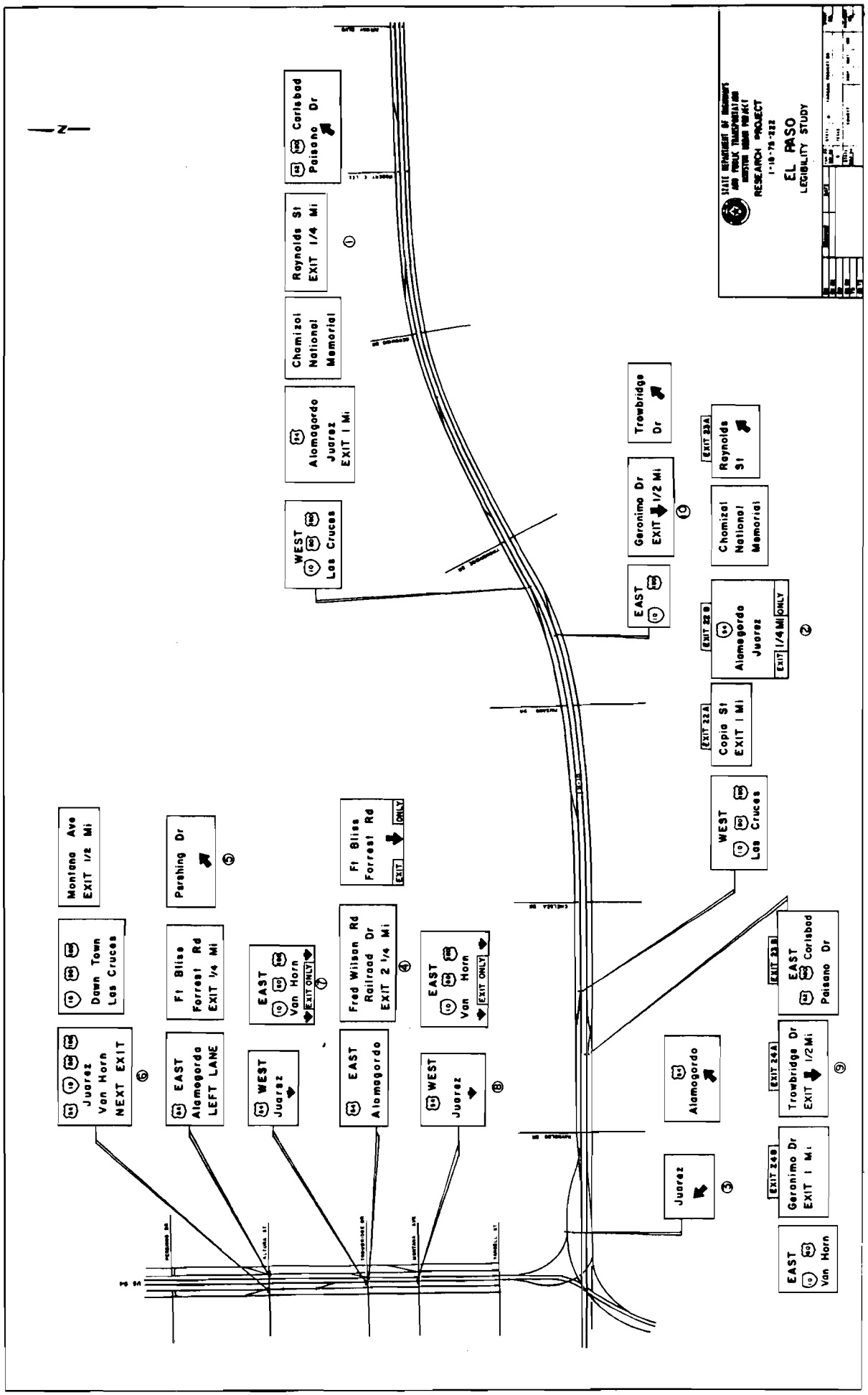
SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
1 - WB	2ND FROM RIGHT  16" U.C. 12" L.C. (TYP)	OPAQUE BKGRD. BUTTON COPY MERCURY VAPOR FREEWAY ILL.
2 - WB	CENTER LEFT OF BROWN  	OPAQUE BKGRD. BUTTON COPY MERCURY VAPOR FREEWAY ILL.
3 - WB to NB	LEFT  	OPAQUE BKGRD. BUTTON COPY MERCURY VAPOR HIGH MAST ILL.
4 - NB	CENTER  	OPAQUE BKGRD. BUTTON COPY HIGH PRESSURE SODIUM FRWY. ILL.
5 - NB	RIGHT  	OPAQUE BKGRD. BUTTON COPY HIGH PRESSURE SODIUM FRWY. ILL.
6 - SB	LEFT  	OPAQUE BKGRD. BUTTON COPY HIGH PRESSURE SODIUM FRWY. ILL.
7 - SB	RIGHT  	OPAQUE BKGRD. BUTTON COPY HIGH PRESSURE SODIUM FRWY. ILL.
8 - SB	LEFT  	OPAQUE BKGRD. BUTTON COPY HIGH PRESSURE SODIUM FRWY. ILL.

LEGIBILITY STUDY
RESEARCH PROJECT
1-18-75-222

EL PASO

2

SIGN NO.	TEXT	BACKGROUND MATERIAL & LIGHTING CONDITIONS
9-EB	2ND FROM RIGHT Trowbridge Dr EXIT ↓ 1/2 MI 16" U.C. 12" L.C. (TYP)	OPAQUE BKGRD. BUTTON COPY MERCURY VAPOR FREEWAY ILL.
10-EB	CENTER Geronimo Dr EXIT ↓ 1/2 MI	OPAQUE BKGRD. BUTTON COPY MERCURY VAPOR FREEWAY ILL.


EL PASO
LEGIBILITY STUDY
RESEARCH PROJECT
1-10-75-223
Carlsbad
Paisano Dr
Reynolds St
EXIT 1/4 Mi
Chamizal
National
Memorial
Alamogordo
Juarez
EXIT 1 Mi
WEST
Las Cruces
Trowbridge
Dr
Geronimo Dr
EXIT 1/2 Mi
EAST
Reynolds
St
Chamizal
National
Memorial
EXIT 22B
Alamogordo
Juarez
EXIT 1/4 MI ONLY
EXIT 22A
Copia St
EXIT 1 Mi
WEST
Las Cruces
EXIT 23B
EAST
Carlsbad
Paisano Dr
EXIT 24A
Trowbridge Dr
EXIT 1/2 Mi
Alamogordo
EXIT 24B
Geronimo Dr
EXIT 1 Mi
EAST
Van Horn
Juarez
Montana Ave
EXIT 1/2 Mi
Dawn Town
Las Cruces
Pershing Dr
Ft Bliss
Forrest Rd
EXIT 1/4 Mi
EAST
Van Horn
EXIT ONLY
Ft Bliss
Forrest Rd
EXIT ONLY
Fred Wilson Rd
Railroad Dr
EXIT 2 1/4 Mi
EAST
Van Horn
EXIT ONLY
Juarez
Van Horn
NEXT EXIT
EAST
Alamogordo
LEFT LANE
WEST
Juarez
EAST
Alamogordo
WEST
Juarez
N

PARTICIPANTS - EL PASO LEGIBILITY STUDY

MALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Mark C. Longenbaugh	Charles H. Berry, Jr.
25 - 34	Charles Veale	Raymond E. Lucero
35 - 44	Manny Aguilera	Richard Hubbard
45 & Over	A.L. "Butch" Martinez	Albert Andrew

FEMALE		
AGE GROUP	WITHOUT GLASSES	WITH GLASSES
18 - 24	Pamela K. Lester	Gloria Gomez
25 - 34	Maria Lucia DePlata	
35 - 44	Dale Atkinson	Mary Johnson
45 & Over		Rose Morton

SIGN PANEL SURVEY SUMMARY

CITY SURVEYED	MILES SURVEYED	TOTAL NO. OF OVHD. STRUCTS. SURVEYED	TOTAL NO. OF OVHD. STRUCTS. THAT WOULD NOT REQUIRE SIGN ILLUM.	% OF OVHD. STRUC. THAT WOULD NOT REQUIRE SIGN ILLUM.	TOTAL NO. OF OVHD. SIGN PANELS SURVEYED	TOTAL OF OVHD. PANELS THAT WOULD NOT REQUIRE SIGN ILLUM.	% OF OVHD. SIGN PANELS THAT WOULD NOT REQUIRE SIGN ILLUM.
San Antonio	105	255	101	40%	578	223	39%
El Paso	56	86	70	81%	246	200	81%
Corpus Christi	84	98	65	66%	209	139	67%
Houston	472	603	195	32%	1,272	430	34%
Summary	717	1,042	431	55%	2,305	992	55%

NOTE: The above survey was based upon an unrestricted sight distance of 1,100' to 1,200' in advance of the sign structures.

All signs had reflective legend.

Most of the signs surveyed had button reflectorized copy and ranged in age from 5 years to 20 years.

APPENDIX B

EXPERIMENTAL SIGN BACKGROUND COATINGS

SIGN PANEL AND FIXTURE TABULATION
PROJECT 1-18-75-222

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIRECTION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-1	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	8'0"x17'0"	(45) (75) SOUTH Galveston	Polyurethane	Med. Dens. Plywood	Hughson Chemical	2-250 W Lights on	Quality	
S-2	Overhead	RS-45-47-6	14+75	Left Coll.Rd.	S.B.	8'0"x15'0"	Pierce Ave Bagby St.	Polyurethane	Extr. Alum.	Hughson	1-100 W 1-175 W Lights on	G.E. McGraw-Edison	
S-3	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	6'0"x18'6"	McKinney Ave NEXT LEFT	Polyvinylidene Fluoride	Extr. Alum.	Pennwalt	1-175 W 2-250 W Lights on	G.E. Crouse-Hinds	Lighted as one continuous area
S-4	Overhead	RS-45-47-12	35+42.25	I.H. 45	S.B.	6'0"x19'0"	Allen Parkway 1/4 MILE	Polyvinylidene Fluoride	Extr. Plywood	Pennwalt	2-250 W Lights on	Crouse-Hinds	
S-5	Overhead	RS-45-49-2	115+20	I.H. 45	S.B.	6'0"x12'0"	Quitman St	Standard Green Sign Paint. No Topcoat	Med. Dens. Plywood	Sign Shop	2-1000 W Lights on	G.E.	Panel requested by File D-9. Fabricated by Dist 12 Sign Shop.
S-6	Overhead	RS-45-47-9	27+16.89	I.H. 45	S.B.	6'0"x16'0"	Allen Parkway	High Intensity Reflective Sheeting	Overlay Sheet over Extr.	3M	(Exist. Fluor.) Lights off	N/A	Existing Lights to remain on structure and turned off.
S-7	Overhead	RS-2	199+50	U.S. 290	W.B.	8'0"x16'0"	FREEWAY ENDS 1 MILE	Sign Paint	Extr. Alum.	Alcoa-Sign Shop Repaired	Project Lights on	Contractor	Bottom 2 extrusions damaged in freight. Repaired the bottom 2 extrusions with polyurethane.
S-8	Overhead	RS-4	2862+00	U.S. 290	W.B.	8'0"x11'0"	FREEWAY ENDS	Polyester	Alcoa Extr. Alum.	Goodyear	Project Lights on	Contractor	Painted over damaged polyester coating.
S-9	Overhead	RS-45-47-6	14+75	Left Coll.Rd.	S.B.	5'0"x12'0"	Dallas Ave	Thermosetting Polyester	Extr. Alum.	Alcoa PPG	1-250 W 1-250 W Lights on	Nu Art Holophane	

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIRECTION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-10	Overhead	RS-45-47-6	14+75	Left Coll.Rd.	S.B.	8'0"x16'0"	45 75 SOUTH Galveston	Special Green Sign Paint with clear acrylic topcoat	Med. Dens. Plywood	THD Shop	2-250 W Lights on	Hubbell	Panel requested by File D-9. Fabricated by Dist. 12 Sign Shop.
S-11	Overhead	RS-610-13-2	173+50	I.H. 610	W.B.	6'0"x12'0"	45 SOUTH	Polycarbonate	None	Tex Lite Lights on	1-175 W	Internal Illumination Lights on exist. sign.	Removed from project consideration. Sign Struct., panels & lights destroyed by truck.
S-12	Overhead	RS-45-52-2	266+40	I.H. 45	N.B.	6'0"x15'6"	Airline Drive EXIT ONLY	High Intensity Refl. Shtg.	Plywood	3M	(Exist Fluor) Lights on		Button copy.
S-13	Overhead	RS-45-52-2	266+40	I.H. 45	N.B.	6'0"x18'0"	Crosstimbers Rd.	High Intensity Refl. Shtg.	Plywood	3M	(Exist Fluor) Lights on		Stick on copy.
S-14	Overhead	RS-45-53-3	349+30	I.H. 45	N.B.	7'0"x18'6"	Tidwell Rd	High Intensity Refl. Shtg.	Alum. Overlay over Extrusions	3M	(Exist Fluor) Lights off		Stick on copy.
S-15	Overhead	RS-45-53-3	349+30	I.H. 45	N.B.	8'0"x14'0"	Parker Rd Yale St 1/2 MILE	High Intensity Refl. Shtg.	Alum. Overlay over Extrusions	3M	(Exist Fluor) Lights off		Button copy.
S-16	Overhead	RS-45-48-6	76+40	I.H. 45	N.B.	7'6"x17'6"	45 75 NORTH Dallas	Thermo Polyester	Plywood	Armstrong	(Exist Fluor) Lights on		Coated by Pioneer Powder Coating.
S-17	Overhead	RS-45-48-6	76+40	I.H. 45	N.B.	8'0"x17'0"	N. Main St Houston Ave 3/4 MILE	Thermo Polyester	Plywood	Polymer	(Exist Fluor) Lights on		Coated by Texas Powder-Kote Co.
S-18	Overhead	RS-45-49-3	118+00	I.H. 45	N.B.	8'0"x17'6"	N. Main St Houston Ave 1/4 MILE	Clear Coat Urethane	Porcelainized Extrusions	Jenkin-Guerin, Inc.	(Exist Fluor) Lights on		Clear coat urethane over deteriorated porcelain.

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIREC-TION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-19	Overhead	RS-45-49-8	133+00	I.H. 45	N.B.	6'0"x15'0"	Patton St 1/2 MILE	PVF_2 Air Dry	Porcelainized Extrusions	Desoto	(Exist Fluor)		Coated by File D-9.
S-20	Overhead	RS-45-50-2	157+90	I.H. 45	N.B.	8'0"x17'6"	Cavalcade St Link Rd 1/2 MILE	Engr. Gr. Refl. Shtg.	Porcelainized Extrusions	3M	(Exist Fluor) Lights on		Refurbished by File D-9.
S-21	Overhead	RS-45-50-2	157+90	I.H. 45	N.B.	6'0"x15'0"	Patton St	High Intensity Refl. Shtg.	Porcelainized Extrusions	3M	(Exist Fluor) Lights on		Refurbished by File D-9.
S-22	Overhead	RS-45-50-5	188+35	I.H. 45	N.B.	7'0"x17'0"	45 75 NORTH Dallas	Thermo Polyester	Porcelainized Extrusions	Armstrong	(Exist Fluor) Lights on		Coated by Industrial Coatings, Inc.
S-23	Overhead	RS-45-50-5	188+35	I.H. 45	N.B.	7'6"x20'6"	WEST 610 EAST 1/2 MILE	Thermo Polyester	Porcelainized Extrusions	Polymer	(Exist Fluor) Lights off		Coated by Industrial Coatings, Inc.
S-24	Overhead	RS-45-51-6	225+66	I.H. 45& I.H. 610 N. Loop		8'0"x11'6"	610 WEST	Urethane Acrylic	Porcelainized Extrusions		(Exist Fluor) Lights off		Coated by File D-9.
S-25	Overhead	RS-45-51-6	225+66	I.H. 45& I.H. 610 N. Loop		8'0"x11'0"	610 EAST	Sign Paint	Porcelainized Extrusions		(Exist Fluor) Lights off		Coated by File D-9.
S-26	Overhead	RS-45-54-2	369+40	I.H. 45	N.B.	9'0"x17'6"	Little York Rd 1 1/4 MILES	Thermo Polyester	Porcelainized Extrusions	Armstrong	(Exist Fluor) Lights on		Coated by Pioneer Powder Coating.
S-27	Overhead	RS-45-54-2	369+40	I.H. 45	N.B.	7'0"x17'6"	Parker Rd Yale St	Thermo Polyester	Porcelainized Extrusions	Polymer	(Exist Fluor) Lights on		Coated by Texas Powder-Kote Co.
S-28	Overhead	RS-610-17-1	220+20	I.H. 610 N. Loop	E.B.	7'0"x17'0"	610 EAST	Thermo Polyester	Porcelainized Extrusions	Armstrong	(Exist Fluor) Lights on		Coated by Industrial Coatings, Inc.

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIRECTION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-29	Overhead	RS-610-4-2	424+30	I.H. 610 S. Loop	W.B.	7'0"x12'0"	LEFT LANE ENDS 1 MILE	Engineer Grade Refl. Shtg.				Contract Lgts.	Dist. 12 Sign Shop (Safety Project)-Panel removed from structure.
S-30	Overhead	RS-610-3-2	473+50	I.H. 610 S. Loop	W.B.	7'0"x12'0"	LEFT LANE ENDS 1-1/2 MILE	Engr. Gr. Refl. Shtg.				Contract Lgts.	Dist. 12 Sign Shop (Safety Project)-Panel removed from structure.
S-1E	Overhead	RS-45-47-12S	35+42.25	I.H. 45	S.B.	6'0"x19'0"	Dallas Ave Pierce Ave EXIT ONLY	Existing Panel			3-250 W Lights on	Nu Art	Old Style Nu Art
S-2E	Overhead	RS-45-49-2	115+20	I.H. 45	S.B.	9'6"x16'6"	10 90 WEST San Antonio EXIT ONLY	Existing Panel			3-175 W Lights on	G.E.	
S-31	Grnd Mt		129+70	US-59	S.B.	7'6"x23'0"	Chimney Rock Rd City of Bellaire	High Intensity Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.
S-32	Overhead	RS-59-103	103+00	US-59	S.B.	9'6"x14'0"	ALT 59 SPUR 41 Sugar Land EXIT ONLY	Super Engr. Gr. Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.
S-32	Grnd Mt		873+00	US-59	S.B.	7'0"x13'0"	6 Texas EXIT 1/2 MILE	Super Engr. Gr. Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.

SIGN NO.	MOUNTING TYPE	STRUCT. NO.	STATION	HWY. NO.	TRAVEL DIREC-TION	SIGN SIZE	SIGN TEXT	TYPE OF COATING	TYPE OF SUBSTRATE	COATING MFGR.	NO. OF FIXTURES	FIXTURE MFGR.	REMARKS
S-33	Overhead	RS-59-380	380+40	US-59	N.B.	8'0"x17'0"	Fondren Rd. Bellaire Blvd. EXIT 1 1/4 MILES	Engr. Gr. Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.
S-34	Overhead	RS-59-380	380+40	US-59	NB	9'0"x16'6"	S. Gessner Rd. Beechnut St ↗	Super Engr. Gr. Refl. Shtg.	Plywood	Fasson	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.
S-35	Overhead	RS-59-439	439+65	US-59	NB	6'0"x17'6"	Hillcroft EXIT 1 1/2 MILES	Polyurethane	Porcelainized Extrusions		3-100 W Lights on	G.E.	Coated by Dist. 12 Sign Shop - Button copy.
S-36	Overhead	RS-59-439	439+65	US-59	NB	6'0"x21'6"	Fondren Rd ↗ Bellaire Blvd	Engr. Gr. Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.
S-36	Overhead	RS-59-520	520+00	US-59	NB	6'0"x16'0"	Hillcroft Ave. ↗	Super Engr. Gr. Refl. Shtg.	Plywood	3M	(Exist Merc) Lights off		Coated by Dist. 12 Sign Shop - Button copy.

APPENDIX C

CURRENT SIGN BACKGROUND COATING SPECIFICATIONS

ITEM 642

ALUMINUM SIGNS (Type 0)

642.1. Description. This item shall govern for the composition, application, sampling, testing, measurement and payment of complete, in place aluminum overhead guide signs.

642.2. Materials. Copies of Departmental Material Specifications are available from the State Department of Highways and Public Transportation, Materials and Tests Division, 38th and Jackson St., Austin, Texas, 78703.

(1) Background Materials Choice. Unless otherwise specified in the plans, the Contractor shall have the option to utilize either Class A, B, C, or D non-reflective background coatings conforming to Departmental Specification D-9-8500, "Non-reflective Background Coatings". The background coating on all aluminum overhead guide signs for any one project, however, shall be of the same generic material for each color.

(2) Sign Panel Substrate. Sign substrates shall be extruded aluminum and shall meet the requirements specified below. Aluminum for aluminum signs shall conform with the requirements of Departmental Specification D-9-7110, "Aluminum Sign Blanks", or similar alloy approved by the Engineer which is suitable for background coating to meet the specifications contained herein.

Extruded aluminum sign panels shall have a minimum thickness of 0.078 inch. Panels shall be of a 12-inch width except that one 6-inch width panel per sign may be used to obtain the specified overall sign height. Adjacent panels shall be attached to each other by means of bolts. The normal final background coating color is green but may be other colors as shown in the plans.

Sign faces are not acceptable if the variation of the surface in any direction exceeds an amount equal to 1/8 inch per foot of defect in width or height as the case may be. Any vertical or horizontal misalignment between panel faces shall not be greater than 1/16 inch.

(3) Stiffeners, Wind Beams and Fasteners. Stiffeners, wind beams and fasteners shall be stainless steel, galvanized steel, or aluminum, in accordance with Departmental Specification D-9-7120, "Sign Hardware". Dissimilar metals shall be so selected or insulated as to prevent corrosion.

(4) Sign Message. The sign message shall be of the size, type and color shown on the plans.

Reflectorized removable legend specified on the plans for various signs shall conform with Departmental Specification D-9-8400, "Reflectorized Removable Legend".

When sheet aluminum signs are required as a part of the sign message, they shall be reflectorized and shall conform with the plans in size and shape and with the Item, "Aluminum Signs (Type A)", latest revision thereto.

Sheet aluminum signs shall be attached to guide signs by screws or bolts as shown on the plans.

(5) **Sign Support Connections and Hardware.** Sign support connections shall be as shown on the plans or of the Contractor's choice subject to approval by the Engineer.

Connections shall be capable of developing the full strength of the sign.

If not specifically addressed on the plans, all bolts, nuts, washers, lock washers, and other hardware used in making the signs or support connections shall be galvanized steel, stainless steel or aluminum in accordance with Departmental Specification D-9-7120, "Sign Hardware". Dissimilar metals shall be so selected or insulated to prevent corrosion.

642.3. **Fabrication.**

(1) **Working Drawings.** Prior to fabrication, the Contractor shall submit for approval of the Engineer six prints of the working drawings for each aluminum overhead guide sign except that when there are two or more signs of identical design, the required prints of the working drawings for only one of the signs need be submitted. The working drawings shall show the details of the panels, wind beams, stiffeners, splices, fasteners, brackets, sign support connections, dichromate-sealed finish for aluminum hardware where required by the plans, and methods of attaching the message to the sign face.

In addition, the working drawings shall show interline spacing of the message in sufficient detail to check against the plans. Accompanying the working drawings, the Contractor shall submit the following: the manufacturer's name, the extrusion number, a dimensional cross section of the panel, and the manufacturer's calculated moment of inertia and section moduli for each type of extruded panel the Contractor proposes to use. Extrusions should be designed to the maximum spacing of sign supports shown in the plans.

(2) Splicing. Where splicing is required, the splicing shall be done by rivets, bolts, or other fasteners as shown on working drawings furnished by the Contractor subject to approval by the Engineer. Rivets or other fasteners shall be flush with the face side to provide a smooth, even surface for the application of background coating.

(3) **Fastening.** The pieces of substrate used in making the sign shall be fastened to stiffeners or wind beams as shown on the plans or on working drawings furnished by the Contractor subject to approval by the Engineer.

(4) **Panel Preparation.** All preparation of substrates used in making the signs, including cutting and drilling or punching of holes, except holes for attaching removable reflectorized legend, shall be complete prior to degreasing and application of background coating.

(5) **Background Coatings.** Surface preparation of the face side of the background substrate prior to application of various background coatings shall be as recommended by the manufacturer of the specific coating and approved by the Engineer. The face side of aluminum extrusion flanges shall be cleaned and prepared in the same manner as the sign panel face.

Application of the various coatings to the substrate shall be as per manufacturer's recommendations approved by the Engineer.

The acrylic polymer film (Class B) shall be applied to the face and a minimum of 1/2 of the outside face of aluminum extrusion flanges. The film may be factory overlaid or vacuum overlaid by the sign panel fabricator.

Thermoplastic or thermosetting polyester coatings (Class C) shall be shop applied and oven baked with proper pretreatment and primer (when recommended by coating manufacturer). The coating shall be applied to the sign face and outside surfaces of extrusion flanges. The back and/or inside surfaces of the extrusion flanges are not to be coated; unavoidable overspray in these areas may be permissible. Spray application shall be performed by air, airless or electrostatic techniques. Curing shall be performed in a "continuous or batch" oven according to coating manufacturer's recommendations and at no time shall 700 F be exceeded. The dry film thickness of the finish coating shall be a minimum of 0.004 inch and a maximum of 0.012 inch. The coating shall be uniform throughout and free of blemishes, blisters, pinholes, cracks, sags and crazing.

Polyvinylidene Flouride Plastic Thermosetting coatings (Class D) shall be shop-applied and oven-baked with proper pretreatment and primer. The coating shall be applied to the sign face and outside surfaces of extrusion flanges. The back and/or inside surface of extrusion flanges are not to be coated; unavoidable overspray in these areas may be permissible. Spray application shall be performed by air, airless, or electrostatic techniques. Curing shall be performed in a "continuous or batch" oven according to manufacturer's instructions. The dry film thickness of the coating shall be a minimum of one (1) mil (0.2-0.3 mil primer and 0.8 mil minimum of the top coat). The coating shall be uniform throughout and free of blemishes, blisters, sags or crazing.

642.4. Erection. Completed sign blanks and panels shall be transported, handled and stored in such a manner that corners, edges and faces

are not damaged. Any mars, scratches or other damage to the sign faces which are not visible when viewed as outlined in the *MANUAL OF TESTING PROCEDURES* at a distance of fifty (50) feet, shall be acceptable. Finished sign faces shall be stored off the ground in a vertical position and protected from the weather until properly erected.

Prior to erection, all bolt heads and hardware showing on sign faces shall be painted similar in color to the sign face.

642.5. Cleaning. The signs shall be cleaned prior to inspection. The signs shall be washed with a cleaning solution acceptable to the manufacturer of the sign coating to remove all grease, oil, dirt, smears, streaks, finger marks, and other foreign particles prior to shop inspection and prior to final inspection, after erection.

642.6. Sampling and Testing. Sampling and testing will be in accordance with the Department's *MANUAL OF TESTING PROCEDURES*, unless otherwise specified herein.

642.7. Measurement. Aluminum Signs (Type 0) will be measured by the square foot. Measurement will be made to the nearest 0.01 square foot of the area of the vertical front face of the signs erected as determined from the plans and specifications, with no deductions for rounding off corners, and no measurement will be made for area in excess of this minimum area.

642.8. Payment. Payment for Aluminum Signs (Type 0) shall be made at the unit price bid per square foot for "Aluminum Signs (Type 0)" which price shall be full compensation for furnishing sign panels; fabrication of the panels, any treatment of sign panels that might be required prior to application of the background coating; application of the background coating to the sign panels, the messages attaching to the sign faces; furnishing wind beams and stiffeners that are required, furnishing all bolts, rivets, screws, fasteners, clamps, brackets, and sign support connections; assembling and erecting the signs; washing and cleaning the signs after erection; and all other labor, materials and incidentals necessary to provide signs complete and attached to the sign supports.

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-8300
Flat Surface Reflective Sheeting

I. Description: This specification shall govern for the materials, composition, quality, sampling and testing of six types (Type A-engineer grade, Type B-super engineer grade, Type C-high specific intensity, Type D-conformable engineer grade with aggressive adhesive,Type E-engineer grade used for cut out legend, Type F-barricade sheeting) of flat surface reflective sheeting, as specified hereinafter. The intent of this specification is to obtain sheeting that is suitable for production of acceptable signs.

II. Bidder's and/or Supplier's Requirements:

A. Procurement by the State: All prospective bidders are hereby notified that, before any bid is considered, the material proposed for submission shall be a material of manufacture and product code or designation shown on the list of approved manufacturers of materials covered by this specification maintained by the Department.

B. Contracts: All contractors and/or sign fabricators are hereby notified that all flat surface reflective sheeting and screen inks, utilized in production of products for the Department, shall be a reflective sheeting or screen ink of manufacture and product code or designation shown on the list of approved manufacturers of flat surface reflective sheeting and screen inks maintained by the Department.

III. Payment:

A. Procurement By the State: Payment for all materials under this specification shall be in accordance with the conditions prescribed in the contract awarded by the State.

B. Contracts: All materials under this specification utilized in the production of products for the Department shall be considered as subsidiary to the bid item in the contract.

IV. Prequalification and Performance History:

A. Establishment of Performance History: Prospective Bidders and/or Suppliers who desire to establish a performance history for materials governed by this specification, should contact the Engineer-Director, State Department of Highways and Public Transportation, Austin, Texas 78701, Attention: File D-4. Prospective Bidders and/or Suppliers will be notified, after their material has been evaluated, as to conformance with requirements of this specification. Tentative approval may be granted after successful completion of any of the durability requirements hereinafter. Full prequalification will not be granted until successful completion of all durability requirements. Failure to successfully complete all durability requirements shall be grounds for cancellation of Tentative Approval.

B. Performance History: Some of the tests required by this specification extend over a prolonged period of time and some tests cannot be made after the material is applied. Therefore, testing for acceptance of materials supplied on any contract or State purchase order will only be considered on those materials which, in the opinion of the Materials and Tests Engineer, are identifiable as being a material having an established performance history of compliance with the criteria established by this specification.

C. Re-evaluation: When, in the opinion of the Materials and Tests Engineer, changes have been made in the composition, manufacturing process, or quality of a prequalified material that may affect its durability, a re-evaluation of the performance may be required. The Department reserves the right to conduct whatever tests are deemed necessary to identify a prequalified material and to determine if a change has been made in composition, manufacturing process or quality, that may affect its durability. Changes that are detected in composition, manufacturing process or quality, that may affect durability and have not been reported by the manufacturer shall be cause for removal of that material from the list of prequalified reflective sheeting materials.

D. Periodic Evaluation: The Department reserves the right to periodically evaluate the performance of materials. Samples for periodic evaluation of performance will be selected at random from materials submitted to the Department on contracts or direct State purchase orders. Failure of materials to comply with the requirements of this specification as a result of periodic evaluation, shall be cause for removal of those materials from the list of prequalified reflective sheeting materials.

V. Warranty:

A. Contracts: If it is normal trade practice for a sheeting manufacturer to furnish a warranty for sheeting, the warranty shall be provided to the Department for potential dealing with the warrantor. The extent of such a warranty will not be a factor in acceptance or rejection of sheeting.

B. State Purchases: Sheeting suppliers shall guarantee their material to be in accordance with the more stringent of the following two warranties:

1. Manufacturer's standard warranty.

2. Minimum warranty of compliance with the requirements of this specification shall be 5 years for Types A, E and D; 7 years for Type B; 10 years for Type C except orange; 3 years for Type C orange; and 2 years for Type F.

VI. Sampling and Testing: Sampling and testing shall be in accordance with the State Department of Highways and Public Transportation, Materials and Tests Division Manual of Testing Procedures.

Costs of sampling and testing are normally borne by the Department. However, the costs of sampling and testing of materials failing to conform with the requirements of this specification shall be borne by the Contractor or Supplier. Costs of sampling and testing of failing material shall be assessed at the rate established by the Materials and Tests Engineer, and in effect at the time of testing. Amounts due the Department for conducting such tests will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

VII. Material Requirements For Reflective Sheeting Materials:

A. General Requirements:

This specification covers the general and specific requirements for six Types, Type A, B, C, D, E and F, of reflective sheeting materials. All Types of reflective sheeting materials shall meet all requirements of this specification except when specific requirements are shown for a particular type of reflective sheeting material. Reflective sheeting shall consist of reflective lenses incorporated within the sheeting film in such a manner as to produce the required reflective characteristics, such as color and brightness. The outer surface of the reflective sheeting as exposed in use shall be smooth.

B. Film Characteristics:

1. Tensile Strength and Elongation: The numerical sum of the tensile strength per inch of width and the percent elongation of Type A, B, D, and E sheeting or sign faces shall not be less than 20.0. Furthermore, the tensile strength shall not be less than 5.0 and the numerical value of the percent elongation shall equal or exceed the numerical value of the tensile strength. Tensile strength shall be tested in accordance with ASTM D-828. Elongation shall be tested in accordance with ASTM D 987-48T. The sheeting or sign face shall be conditioned at room temperature (72 to 80 F.) for a minimum of 48 hours prior to testing.

2. Flexibility: Sheeting or sign faces, when applied according to manufacturer's recommendations, to clean and etched 0.015 inch x2 inch x8 inch aluminum panels, shall be sufficiently flexible to show no cracking when bent around a 3/4 inch mandrel. The sheeting shall be conditioned at room temperature for 48 hours prior to testing. The sheeting or sign faces shall be tested at 72 to 80 F and at any relative humidity between 50 and 80%.

3. Workability: The integrity of the film shall be such that when the sheeting or a completed sign face is trimmed, in the normal manner, to match the sign substrate, the film shall not crack, flake or chip on the sign panel or sign face side of the trim line.

4. Temperature Stability: At any combination of temperatures from 50 to 100 F and relative humidity from 20 to 90%, the sheeting shall permit cutting, application, and color processing. Unapplied sheeting will permit curing of process inks at temperatures up to 150 F and applied sheeting will permit heat curing of process inks at temperatures up to 200 F, unless recommended otherwise by the sheeting manufacturer and so stated in their technical literature.

5. Chemical Resistance: The surface of the sheeting or the face of a completed sign shall be chemical resistant to the extent that there will be no surface change when wiped with a soft, clean cloth dampened with VM&P, naphtha, mineral spirits, turpentine, mild soaps, or mild detergents.

6. Mildew Resistance: The sheeting shall evidence no fungus growth when tested by Federal Test Method 6271.1 under the following conditions:

    1. Test specimens shall be leached with water before inoculation.

    2. The test organism shall be pullularia pullulans.

    3. The length of the incubation period shall be 21 days.

C. Adhesive: The backside of the reflective sheeting shall be precoated with either a heat activated or pressure sensitive adhesive. No additional coats of adhesive shall be required to affix the reflective sheeting to the sign blank.

1. Heat Activated: Heat activated sheeting shall include a precoated tack free adhesive which will adhere to prescribed surfaces only when activated by temperatures above 175 F in accordance with manufacturers recommendations.

2. Pressure Sensitive: Pressure sensitive sheeting shall include a precoated pressure sensitive adhesive and shall be applied as specified by the sheeting manufacturer. In addition, the adhesive backing of the Type D reflective sheeting shall be such that the reflective sheeting or signs made of Type D reflective sheeting can be affixed to rough and porous surfaces such as concrete, asphalt, steel, brick,

wood, steel pipe posts, timber posts, aluminum and/or plywood. Type D reflective sheeting must be a product suitable for use on these substrates.

3. Protective Liner: A protective liner shall be attached to the adhesive to protect its adhesive qualities until the time of application of the sheeting. The protective liner, attached to the adhesive, shall be easily removed by peeling, without soaking in water or other solvents, and shall also be easily removed after accelerated storage for four hours at 150 F and 2.5 pounds of weight per square inch. Suppliers of reflective sheeting utilizing a porous, textured backing paper to protect the adhesive layer that is not suitable for use as a slip sheet for packaging of completed signs and/or sign panels, shall supply rolls of slip sheet paper in the various widths of reflective sheeting supplied. Square footage of slip sheet paper supplied in the various widths shall be the same as the square footage of reflective sheeting supplied in the various widths. Slip sheet paper supplied shall be considered as subsidiary to the reflective sheeting, and any costs, direct or indirect, shall be included in the bid price for reflective sheeting on State purchases.

4. Required Adhesion: Sheeting or sign faces applied (according to manufacturer's instructions) to clean, smooth, paintable surfaces, shall adhere so securely at temperatures of from -20 to 175 F, that it is impossible to peel, or pull, material from the adhering surfaces in pieces containing areas greater than two square inches. Adhesion tests will be run not less than 48 hours after application. Reflective sheeting with pressure sensitive adhesive shall be aged 36 hours at 140 F and allowed to cool at room temperature for 12 hours before testing adhesion characteristics.

5. Stain Resistance: The adhesive shall have no staining effect on the reflective sheeting.

D. Durability:

1. Sheeting: Sheeting or sign faces shall show no cracking, crazing, blistering, chalking, or dimensional change after weather-o-meter and exterior exposure. Exposure time for the various types of reflective sheeting shall be as shown in the following table.

Type of Sheeting	Type Exposure	Exposure Time
Type A & E & D	W-O-M	1200 hours
	Exterior-45°	18 months
	Exterior-90°	5 years
Type B	W-O-M	1400 hours
	Exterior-45°	24 months
	Exterior-90°	7 years
Type C (all colors except orange)	W-O-M	2000 hours
	Exterior-45°	30 months
	Exterior-90°	10 years
Type C, orange	W-O-M	720 hours
	Exterior-45°	9 months
	Exterior-90°	3 years
Type F	W-O-M	400 hours
	Exterior-45°	7 months
	Exterior-90°	2 years

Weather-o-meter exposure shall be in an Atlas Weather-O-Meter utilizing an 18-102 cam, in accordance with ASTM G23-81,Method 1, Type EH. Exterior exposure shall be facing south at the Department's exterior exposure test site in Austin, Texas or other locations, as deemed necessary by the Materials and Tests Engineer.

2. Process Inks: No process ink shall be removed, when tested according to Federal Test Method 6301, after a minimum of 96 hours after processing, or after exposure of the various types of sheeting as shown in the above table.

E. Color:

1. Diffuse Day Color:

a. Chromaticity Coordinates: The CIE chromaticity coordinates of all types of reflective sheeting, before and after weatherometer and exterior exposure, shall fall within the areas having the corner points and reflectance requirements for the various colors as shown in the following table.

CHROMATICITY COORDINATES

Color	Chromaticity x	Chromaticity y	Reflectance Y
White	0.310 0.290 0.360 0.340	0.300 0.320 0.360 0.380	40 Minimum Types A,B,D and F 27.5 Minimum Type C
Red	0.600 0.700 0.650 0.550	0.290 0.300 0.350 0.350	5-12, Types A,B, D and F 2.5-11, Type C
Orange	0.530 0.530 0.590 0.640	0.360 0.400 0.410 0.360	12-30
Brown	0.430 0.430 0.560 0.600	0.340 0.390 0.440 0.400	3-8
Yellow	0.440 0.490 0.540 0.490	0.460 0.510 0.460 0.410	30-60, Types A, B, D and F 14-30, Type C
Green	0.250 0.250 0.020 0.030	0.330 0.430 0.540 0.370	3.5-10
Blue	0.130 0.230 0.200 0.090	0.050 0.200 0.240 0.150	1.8-9

b. Tests: Color shall be determined in accordance with Test Method Tex-839-B.

2. Reflected Night Color: The reflected night color shall appear to be essentially the same as the day color when observed at 50 feet.

F. Gloss:

1. The sheeting's face and screened areas shall have an 85° gloss meter rating of not less than 35 both before and after weatherometer and exterior exposure.

2. Tests: Gloss will be determined in accordance with ASTM Method D523.

G. Optical Performance:

1. Specific Intensity: Reflective sheeting (for background) and reverse screened signs (using transparent ink) of the various sheeting types shall have the minimum brightness values, before exposure, as shown in the following tables. Minimum brightness values after weatherometer and exterior exposure shall not be less than 60 percent of the values shown in the following tables. Brightness values shall be determined at the divergence and entrance angles shown and shall be expressed in units of candle power per foot-candle per square foot.

a. Types A, D & F Reflective Sheeting

BRIGHTNESS VALUES

Color	Divergence Angle	Angle of Incidence 2°	10°	20°
White	0.2°	75	50	25
	1/3°	60	35	12
Blue	0.2°	6	3.0	-
	1/3°	2.5	1.5	-
Green	0.2°	7.0	4.0	-
	1/3°	4.5	2.0	-
Yellow	0.2°	18	14	6
	1/3°	12	8	4
Red	0.2°	7.5	5.0	2.5
	1/3°	5.0	2.5	1.0
Orange	0.2°	18	14	6
	1/3°	12	8	4
Brown	0.2°	2	1	-
	1/3°	1	0.6	-

b. Type B Reflective Sheeting

BRIGHTNESS VALUES

Color	Divergence Angle	Angle of Incidence -4	+30
White	0.2	140	65
	0.5	48	28
Yellow	0.2	70	33
	0.5	30	18
Green	0.2	30	8
	0.5	7	3.5
Orange	0.2	50	20
	0.5	15	10

c. Type C Reflective Sheeting

BRIGHTNESS VALUES

Color	Divergence Angle	Angle of Incidence -4	+30
White	0.2	250	140
	0.5	95	55
Green	0.2	30	17
	0.5	12	6
Yellow	0.2	170	90
	0.5	62	36
Red	0.2	30	19
	0.5	13	7.8
Orange	0.2	70	40
	0.5	25	15

d. Type E Reflective Sheeting

BRIGHTNESS VALUES

Color	Divergence Angle	Angle of Incidence 2°	10°	20°
White	0.2°	90	80	70
	1/3	60	50	40

2. Tests: Specific intensity will be determined in accordance with Test Method Tex-842-B.

H. Material Identification: Each container, carton, or box containing reflective sheeting shall clearly indicate the lot, batch, and/or roll number. The identification number or numbers shall also appear on the inside of the sheeting roll core. The number or numbers on the outside of the box and on the inside of the core shall match; mismatch of these numbers can and may be cause for rejection.

The Producer shall notify the Materials & Tests Engineer in writing of the size of his standard production lot (jumbo roll) if the lot size exceeds 32,500 square feet. Any lot exceeding either the 32,500 square feet maximum size or the stated lot size will be rejected.

VIII. Material Requirements, Screen Inks:

A. General Requirements: Screen inks shall be a material specifically formulated for use as a screen ink in the screening of sign faces and/or legend on reflective sheeting of the various types of reflective sheeting, as specified elsewhere in this specification.

B. Color: Screen inks of the various colors specified, as supplied or thinned in accordance with the manufacturer's instructions, when screened onto white reflective sheeting of the type as recommended by the screen ink manufacturer, and using a polyester screen equivalent to a 10-12xx silk screen, shall produce a color within the color requirements specified for the various colors of reflective sheeting in article VII.E.(1)(a) above. Color will be determined utilizing ink from sealed, unopened containers as received from the manufacturer.

C. Transparency: The transparency of properly thinned screen inks, other than Black Screen Ink, when screened onto white reflective sheeting of the type recommended by the ink manufacturer, using a polyester screen equivalent to a 10-12xx silk screen, shall be such that the minimum reflectivity of sign faces produced utilizing colored transparent screen inks on white sheeting shall be the same as the minimum reflectivity for reflective sheeting of the same color. Black screen ink shall produce total opacity.

D. Durability: Screen inks as recommended by the ink manufacturer for use on the various types of reflective sheeting shall exhibit the same durability as specified for that type of reflective sheeting.

IX. Sign Faces and Completed Signs: For all signs, sign panels, sign faces and traffic control devices that utilize reflectorized red and white, the quotient of white specific intensity / red specific intensity shall not be less than 5.0, nor more than 15.0. For all signs, sign panels, sign faces and traffic control devices that utilize reflectorized orange and white the quotient of white specific intensity / orange specific intensity shall not be less than 2.0, nor more than 15.0. For other signs utilizing combinations of reflectorized colors, the quotients of white specific intensity / other color or colors specific intensity shall not be less than 5.0.

X. Packaging: The material shall be packaged in containers that will permit normal shipping and storage without the material sustaining damage or becoming difficult to apply. Roll material shall contain no more than three (3) splices per 50 yard, linear measurement. The length of the roll core shall not be less than the width of the material. Pressure Sensitive Material: The ends of the material shall be cut square with an overlap splice of 3/8", (± 1/8") in width. Edges of the overlap splice are to be straight and square. Heat Activated Material: The ends of the material shall be cut square, butt jointed closely together and held securely in place with a removable tape.

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-8400
Reflectorized Removable Legend

I. Description: This specification shall govern for the materials, composition, quality, sampling and testing of reflectorized removable legend, as specified hereinafter.

II. Bidder's and/or Supplier's Requirements: All prospective bidders, suppliers, contractors, sign fabricators, and/or coaters are hereby notified that the materials utilized to coat the frames for the reflectorized removable legend shall be either polyvinylidene flouride plastic-thermosetting or thermosetting polyester prequalified under Departmental Specification D-9-8500, "Non-reflective Background Coatings."

III. Payment:

A. Procurement by the State: Payment for all materials governed by this specification will be in accordance with the provisions of the purchase order awarded by the State.

B. Contract: All materials governed by this specification utilized in the manufacture or production of sign faces, sign panels, and/or completed signs, shall be considered as subsidiary to the signs on which they are used.

IV. Sampling and Testing: Sampling and testing shall be in accordance with the State Department of Highways and Public Transportation, Materials and Tests Division Manual of Testing Procedures. Costs of sampling and testing are normally borne by the Department. However, the costs of sampling and testing of materials failing to conform with the requirements of this specification shall be borne by the contractor or supplier. Costs of sampling and testing of failing material shall be assessed at the rate established by the Materials and Tests Engineer, and in effect at the time of testing. Amounts due the Department for conducting such tests will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

V. Material Requirements:

A. General Requirements: This specification covers the general and specific requirements of reflectorized removable legend which shall consist of acrylic-plastic reflectors supported by embossed-aluminum frames. All reflectorized removable legend supplied on any one contract project shall be of the same manufacture.

B. Embossed Aluminum Frames: The aluminum frames design shall be the Federal Highway Administration's Standard Alphabet for Highway Signs, modified to accommodate the required reflectors. The frames shall be fabricated from 0.040 inch aluminum sheet conforming to the requirements of ASTM Specification B209 alloy 3003. The size and spacing of the holes for reflectors in the frames shall be such as to afford maximum night and day legibility and visibility to the finished figure.

C. Coatings: The fabricated frames shall be coated with either a Class A or Class B coating meeting the requirements of Departmental Specification D-9-8500, "Non-Reflective Background Coatings", except that the thickness of the Class B coating shall be 2.0 to 8.0 mils. The color of the coating shall be white, unless specified otherwise.

D. Acrylic-Plastic Reflectors: The reflectors shall be acrylic plastic and shall consist of a clear and transparent plastic face, herein referred to as the lens, and back material attached to the lens around the entire perimeter to form a homogeneous unit permanently sealed against dust, water and air. The reflectors shall be colorless. The lens shall consist of a smooth front surface free from projection or indentations other than for identification and a rear surface bearing a prismatic configuration such that it will effect internal reflection of light. The manufacturer's name or trade mark shall be moulded legibly into the face or back of the lens.

Reflectors shall be designed for installation as an integral part of the frame or otherwise securely affixed to the frame to prevent their displacement in handling or service. Frames in which reflectors are assembled by means of tape are unacceptable.

1. Optical Performance: The specific intensity of the reflectors shall equal or exceed the following minumum values:

Entrance Angle Degrees	Divergence Angle Degrees	Specific Intensity Cp./Sq. Foot/Foot-Candle
0	1/10	2000
20	1/10	800
0	1/3	1000
20	1/3	400

2. Seal Test: The reflectors shall comply with the requirements listed in Test Method Tex-845-B.

3. Heat-Resistance Test: The reflectors shall comply with the requirements listed in Test Method Tex-846-B.

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-8500
Non-reflective Background Coatings

I. Description: This specification shall govern for the materials, composition, quality, sampling and testing of non-reflective background coatings as specified hereinafter.

II. Bidder's and/or Supplier's Requirements: All prospective bidders or suppliers are hereby notified that, before any material is considered, the material proposed for submission shall be a material that has been previously submitted for testing and complies with the durability and other requirements of this specification.

III. Payment:

A. Procurement by the State: All materials governed by this specification will be paid for in accordance with provisions of the purchase order awarded by the State.

B. Contracts: All materials governed by this specification utilized in the production of sign panels or completed backgrounds, will be considered as subsidiary to the bid item in the contract.

IV. Prequalification and Performance History:

A. Establishment of Performance History: Prospective Bidders and/or Suppliers who desire to establish a performance history for materials governed by this specification, should contact the Engineer-Director, State Department of Highways and Public Transportation, Austin, Texas 78703, Attention: File D-9. Prospective Bidders and/or Suppliers will be notified, after their material has been evaluated as to conformance with requirements of this specification.

B. Performance History: Some of the tests required by this specification extend over a prolonged period of time. For this reason, the Department will only consider testing for acceptance those materials

which are determined by the Materials and Tests Engineer to be identifiable as a material having an established performance history of compliance with the criteria established by this specification.

C. Re-evaluation: When it has been determined by the Materials and Tests Engineer that changes have been made in the composition, manufacturing process, or quality of a material that may affect its durability, a re-evaluation of its performance may be required. The Department reserves the right to conduct whatever tests are deemed necessary to identify a material and verify its prequalification.

D. Periodic Evaluation: The Department reserves the right to periodically evaluate the performance of materials. Samples for periodic evaluation of per formance will be selected at random from materials submitted to the Department on contracts or direct State purchase orders. Failure of materials to comply with the requirements of this specification as a result of periodic evaluation, shall be cause for removal from the list of prequalified materials.

V. Sampling and Testing: Sampling and testing shall be in accordance with the State Department of Highways and Public Transportation, Materials and Tests Division Manual of Testing Procedures.

Costs of sampling and testing are normally borne by the Department. However, the costs of sampling and testing of materials failing to conform with the requirements of this specification shall be borne by the Contractor or Supplier. Costs of sampling and testing of failing material shall be assessed at the rate established by the Materials and Tests Engineer, and in effect at the time of testing. Amounts due the Department for conducting such tests will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

VI. Material Requirements: This specification covers the general and specific requirements for four classes of non-reflective background coatings. All classes of non-reflective background coating shall meet all requirements of this specification except when specific requirements are shown for a particular class of non-reflective background coatings.

A. Classes:

1. Class A - Class A non-reflective background coating shall be a thermosetting polyester powder coating.

2. Class B - Class B non-reflective background coating shall be a thermosetting polyvinylidene coating applied over a primer recommended by the manufacturer of the polyvinylidene coatings.

3. Class C - Class C non-reflective background coating shall be polyvinylflouride film bonded to the substrate surface with adhesive(s) approved by the polyvinylflouride film manufacturer.

4. Class D - Class D non-reflective background coating shall be an acrylic film bonded to the substrate surface with adhesive(s) approved by the acrylic film manufacturer.

B. Film Thickness: The various classes of non-reflective background coatings shall meet the film thickness requirements as shown below for the various classes.

Class	Film Thickness (Mils)
A	4.0 to 12.0
B	1.0 min. *
C	1.0 min.
D	3.0 min.

* Film thickness of Class B coating shall include primer and coating. Minimum thickness of primer shall be 0.2 mil and minimum thickness of the polyvinylidene coating shall be 0.8 mil.

C. Color: The diffuse day color, of all classes of non-reflective background coatings, before and after weather-o-meter exposure, shall comply with the color requirement specified below. Color requirements are defined by an enclosed area formed by using the CIE Chromaticity Coordinates as corner points and the listed Y reflectance limits. Color shall be tested in accordance with Test Method Tex-839-B.

CHROMATICITY COORDINATES

Color	Chromaticity		Reflectance
	x	y	Y
White	0.310	0.300	40 min.
	0.290	0.320	
	0.360	0.360	
	0.340	0.380	
Green	0.250	0.330	3.5-10
	0.250	0.430	
	0.020	0.540	
	0.030	0.370	
Yellow	0.440	0.460	30-60
	0.490	0.510	
	0.540	0.460	
	0.490	0.410	
Red	0.600	0.290	5-12
	0.700	0.300	
	0.650	0.350	
	0.550	0.340	
Brown	0.430	0.340	3-8
	0.430	0.390	
	0.560	0.440	
	0.600	0.400	
Blue	0.130	0.050	1.8-9
	0.230	0.200	
	0.200	0.240	
	0.090	0.150	

D. Gloss: The gloss of all classes of coatings at 60° (ASTM D523) shall be as follows:

Color	Gloss at 60°
White	60-90
Green	90 max.
Yellow	90 max.
Red	90 max.

E. Infrared Analysis: All coatings shall match the infrared spectra on file with the Department's Materials and Tests Division.

F. X-Ray Diffraction Analysis: All coatings shall match the x-ray diffraction pattern on file with the Department's Materials and Tests Division.

G. Applied Film Characteristics: All coatings shall meet the following requirements after the coatings have been applied to background substrate:

1. Adhesion: There shall be no removal of the coating when tested as follows: Using a sharp knife, make six or more parallel cuts at 1/8-inch intervals through the finish to substrate. Cross-hatch similarly. Apply Scotch cellophane tape firmly to scribed area. Pull tape off with a sharp jerk. No loss of adhesion shall occur.

2. Pencil Hardness: The applied coatings or films shall have a pencil hardness of F minimum in accordance with Gardner-Sward Point Testing Manual, method 5.1.2.16.

3. Durability: The applied coatings or films, when subjected to the following tests, shall exhibit no loss of bond strength, blistering, checking, crazing, chalking or other film appearance and/or adhesion defects.

Tests	Exposure Time
Boiling water immersion	100 hrs.
Fog Chamber (100 F & 100% R.H.)	12 wks.
Atlas Weather-O-Meter (18-102 cyclic gear, Test Method Tex-801-B)	3,000 hours

GES-2c, Green Enamel, Sign

	Pounds
Phthalocyanine Green, Sun Chemical Corp., Fastolux Green 264-0414	50
Light Chrome Yellow, Du Pont, Y-433-D	30
Titanium Dioxide, Rutile, Du Pont, R-900	30
Medium Oil Alkyd Resin, 50% Solids	610
Bentone 38	2
Butyl Alcohol	1
24% Lead Drier	6
6% Cobalt Drier	3
Anti-Skinning Agent	4
Mineral Spirits	65
Xylol	30
	831

Consistency: 68-78 KU
Grind: 7min. Particles: 8 max.
Gallon weight: ±.05 lbs. of theoretical gallon weight
Color: Match color standard (Spray outs must be used)
Skinning: No skinning within 48 hours (Test Method Tex-811-B).
Raw Materials Shall Meet the Requirements of Paint Specification D-9-1, 11-64.

APPENDIX D

ADMINISTRATIVE CORRESPONDENCE

&

CURRENT MERCURY VAPOR SIGN LIGHTING FIXTURE DETAIL SHEET

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
AUSTIN, TEXAS 78701

January 25, 1978

IN REPLY REFER TO
FILE NO. D-18T

TO: ALL DISTRICT ENGINEERS AND ENGINEER-MANAGER

SUBJECT: Standard Sheet for Mercury Vapor Sign Lighting Fixtures

Gentlemen:

Attached is a copy of Interstate Standard Sheet SL(MV), "Mercury Vapor Sign Lighting Fixtures." This standard sheet was developed as a result of Research Project 1-18-75-222 and will eliminate the use of Interstate Standard Sheet SL(MV-F), "Mercury Vapor Sign Lighting Fixtures Fixed Mounting Base," and SL(MV-A1) and SL(MV-A2), "Mercury Vapor Sign Lighting Fixtures Adjustable Mounting Base." The new standard sheet calls for using 100 watt clear mercury vapor lamps instead of 250 watt mercury vapor lamps presently being used for lighting overhead guide signs. The photometric data, color rendition and uniformity produced by the 100 watt mercury vapor lamp is similar to that produced by the 250 watt mercury vapor lamp using the same fixture spacing. This will reduce energy consumption and power costs.

Although use of fluorescent lighting fixtures is permitted, its use should be minimized due to the short life span of fluorescent lighting fixtures and constant maintenance problems. It is also recommended that wherever possible, mercury vapor sign lighting fixtures be used to replace existing fluorescent fixtures on a maintenance replacement basis utilizing the same spacing as shown in this standard sheet. This will reduce long-term maintenance costs as well as the exposure of maintenance personnel in the field.

This standard sheet should be used on future projects beginning with the May 1978 and subsequent lettings. Projects already submitted and currently under review, will be modified by this office. If you should have any questions concerning the above subject, please feel free to contact this office.

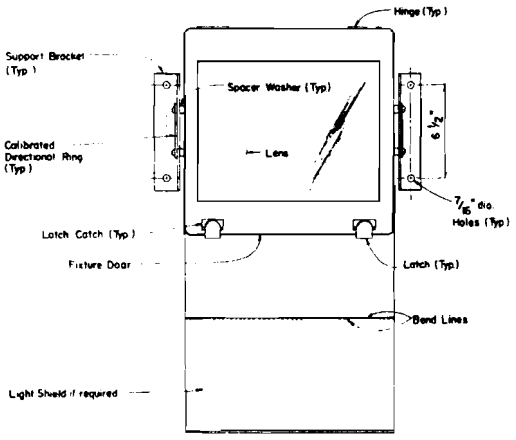
Sincerely yours,

B. L. DeBerry
Engineer-Director

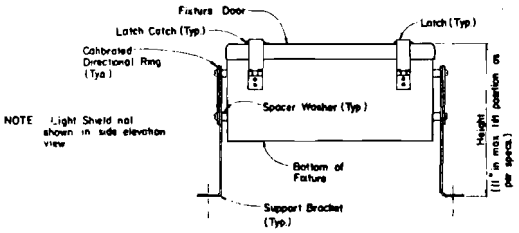
By:

Byron C. Blaschke, Chief Engineer
of Maintenance Operations

DT:id
Attachment

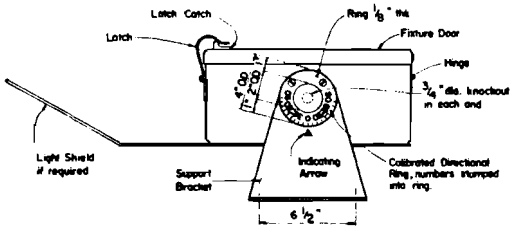


PLAN

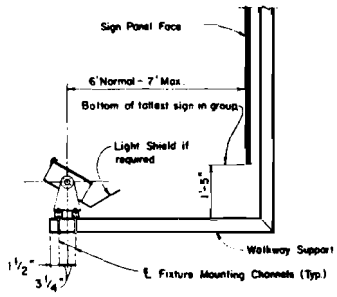


NOTE Light Shield not shown in side elevation view

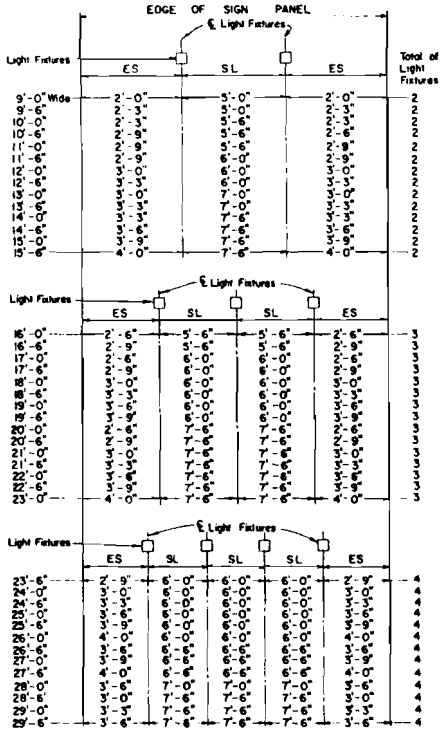
FRONT ELEVATION



END ELEVATION



MOUNTING DETAILS



SPACING FOR 100W MERCURY VAPOR LIGHT FIXTURES PER SIGN PANEL

GENERAL NOTES AND SPECIFICATIONS

Fixtures may be constructed of either aluminum, galvanized steel, or other approved weather-resistant materials and so constructed as to form a weathertight unit of sufficient strength to withstand normal installation and maintenance operations.

The fixture shall not exceed 2.0 square feet in projected area, nor exceed 35.0 pounds in gross weight, including ballast. The fixture shall provide aiming provisions that are continuously variable through all angles for 15 degrees on each side of the optimum aiming angle. Aiming shall be marked in 10 degree increments. Provisions shall be incorporated to positively lock the sign-light fixture in the desired position. Mounting provisions shall rigidly support the fixture and be compatible with mounting requirements as set forth in the plans. When aimed at any of the required variable angles, above a plane passing through and parallel to the base of the mounting, the overall height of the fixture above this plane shall not exceed 11 inches.

The optic assembly shall be constructed in such a manner that resilient gaskets are incorporated to maintain a positive seal against weather and other contaminants. The lens of the optic assembly shall be tempered glass. The cover to the optic assembly shall be so designed that the optic assembly may be opened for routine maintenance without the use of tools. A keeper shall be provided to prevent unintentional separation of the cover from the fixture housing.

The metal socket shall incorporate a means to positively reseat lamp removal and be attached to a high grade porcelain base that completely encases the metal shell. The socket shall be Underwriter's Laboratory approved.

The fixture may be internally or externally ballasted with a regulated output-type ballast designed to operate mercury vapor lamps. External ballast shall be in weatherproof encasement. During fluctuation of the primary voltage to the ballast up to ±13% of the center-rated voltage, the input wattage to the ballast shall not vary more than 8%, nor exceed 150% of the lamp-rated wattage. At center-rated voltage, the power factor shall not be less than 90%. Each ballast shall permanently and clearly indicate the following: Type Ballast, Type Lamp, Catalog Number, Voltage Rating, and Wiring Diagram (when stick-on or glue-on label is used, permanency will be considered satisfactory provided no more than 25% of the label can be removed in one piece.) Ballast shall be individually fused with easily accessible in-line 10 amp fuses. Lamps shall be 100-watt (or other wattage as specified in the plans), clear mercury vapor with a rated average life of not less than 24,000 hours.

The Department will bear the cost of testing all materials meeting the requirements of this drawing and the specifications. The contractor will bear the cost of testing all materials failing to meet the above requirements. Cost for testing failing materials will be deducted from amounts due the Contractor on Monthly and Final Estimates.

The 100-watt sign-lighting fixture (when mounted vertically five feet above, and horizontally one foot below, the midpoint of either short side of a horizontal rectangular area measuring eight feet by ten feet, with the fixture facing the center of the opposite short side, and when aimed at optimum angle (C note below 3) shall provide measured intensities of not less than 3.0 nor greater than 50 footcandles on any point within the previously defined rectangular area. Measured intensities on the surface of the previously defined rectangular area shall not increase at a rate greater than 2.6 in any one foot interval. Note: Optimum angle is that angle which produces equal measured intensities, in footcandles, on all four corners of the eight foot by ten foot rectangular area described.

Sign-lighting fixtures of wattages other than 100-watt shall meet the photometric requirements stated above when mounted, with respect to the sign, as shown in the plans.

All wired joints within fixture shall be waterproofed.

All electrical components furnished and installed shall be in compliance with National Electrical Code Specifications.

All Mercury Vapor Sign Lighting Fixtures that are to be mounted on Bridge Mounted Sign Structure shall be equipped with Vandal Guards approved by the Engineer. Vandal Guards shall not be paid for directly but shall be considered incidental to "Hwy Sign Lgt Fixt."

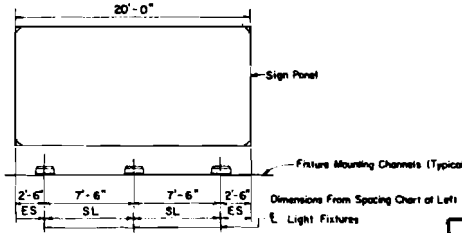
When shown in the plans or required by the Engineer, Light Shield shall be installed on Sign Lighting fixtures to prevent glare to the oncoming motorists. Light Shield shall be as approved by the Engineer.

The Supplier shall state the Optimum Angle or the indicator mark shall be centered on 0 at the Optimum Angle.

Sampling and testing shall be in accordance with the Department's "Manual of Testing Procedures." The fixture will be tested using a lamp furnished for the same project. The manufacturer shall submit a prototype fixture to the Engineer for approval before placement. An adequate number of sign lighting fixtures received for the project may be selected at random by the Department and tested to assure conformity with the specifications. It is not intended that the sign lighting fixtures will be damaged by the test procedures. All fixtures will be inspected and evaluated after energized and adjusted to determine final acceptance of the units.

Fixture Mounting Channels shall be continuous for entire length of walkway and shall be the same distance from the truss for the entire length of the channels.

The lighting unit shown is an example only and is not intended to specify a certain manufacturer's product. Other comparable commercial designs which meet the requirements of the specifications, and as approved by the Engineer, will be accepted.



EXAMPLE OF TYPICAL FIXTURE PLACEMENT
(FOR 20'-0" SIGN PANEL WIDTH)

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

MERCURY VAPOR
SIGN LIGHTING FIXTURE

SL(MV)

ORIGINAL DRAWING DATE 2-82					SHEET

82

APPENDIX E

ADMINISTRATIVE CIRCULAR 48-83

Use of Sign Lights on Overhead Signs

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

ADMINISTRATIVE CIRCULAR NO. 48-83

To: ALL DISTRICT ENGINEERS, ENGINEER-MANAGER AND DIVISION HEADS

Date: July 11, 1983

Subject: Use of Sign Lights on Overhead Signs

Expires: See below

Reference: Administrative Circular 56-75

File: D-18T

Gentlemen:

Reference is made to Administrative Circular 56-75 which transmitted Revision No. 1 to the D-18 Procedure Manual for Expressway and Freeway Signing. This Procedure Manual also includes Department policy on the use of certain materials and design concepts for overhead signs. Included is the provision that all overhead signs be independently illuminated.

The results of Research Project 1-18-75-222 indicate the need for a change in the Department's policy on the use of lights for all overhead signs. FHWA policy permits overhead signs without sign lights under some conditions only in rural areas. Therefore, it is also necessary to establish an easily determined boundary between urban and rural freeway sections. City population is not appropriate to use to distinguish urban and rural freeway sections since many small cities and unincorporated areas exist around major metropolitan centers which are very urbanized.

Since most of our urban freeways have continuous illumination and most of our rural freeways do not, the most practical dividing line between where lighted and unlighted signs would be permitted, is whether or not the freeway has continuous illumination. Generally, in metropolitan areas the continuous illumination system ends near the fringes of the urbanized area. Using the existence of continuous illumination as the deciding factor on whether external sign lights on overhead signs could be eliminated is logical, since the non-lighted reflective signs would be more effective in the reduced ambient light of a non-illuminated freeway section.

Based on,the above, the following is established as the Department Policy on use of sign lights for overhead signs.

AREA	NEW SIGN INSTALLATION	SIGN REFURBISHING
Rural	No sign lights*	(District option to remove or retain sign lights)*
Urban	Use sign lights	Use sign lights.

*In rural areas sign lights are to be omitted only when roadway curvature allows vehicle headlights to illuminate the sign for a distance of 1200 ft.

Unless otherwise approved by D-18, engineer-grade reflective sheeting background will be used when signs are not lighted and non-reflective background material will be used when signs are lighted.

The portions of the D-18 Procedure Manual for Expressway and Freeway Signing, transmitted by Administrative Circular 56-75, in conflict with the above are hereby canceled.

This Circular will remain in effect until its contents are incorporated into the appropriate Division Manuals.

Sincerely yours,

M. G. Goode
Engineer-Director

DISTRIBUTION:
District Engineers
Division Heads
Engineer-Manager
Maintenance Foremen
Resident Engineers

APPENDIX F

ADMINISTRATIVE CIRCULAR NO. 50-83

Use of High Specific Intensity Type Reflective Sheeting on Construction Projects

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

ADMINISTRATIVE CIRCULAR NO. 50-83

To: ALL DISTRICT ENGINEERS, ENGINEER-MANAGER AND DIVISION HEADS

Date: July 13, 1983

Subject: Use of High Specific Intensity Type Reflective Sheeting on Construction Projects

Expires: See below

Reference:

File: D-18T

Gentlemen:

The Federal Highway Administration's and the Department's joint Process Review Committee for Traffic Control through Construction Work Zones visited eight District Offices from April 1982 through May 1983, and have identified several items that could be improved to better accomplish the Department's goals in handling traffic safely through work zones.

One item that has been recommended by several Districts and that has been the subject of numerous research reports is the use of high specific intensity type reflective sheeting on construction traffic control devices. The Process Review Committee found that on urban projects, channelization devices require more cleaning and replacement than any other traffic control devices using a reflective surface. This is due, in part, to lower mounting height and lateral clearance requirements for channelizing devices. In addition, due to store fronts, advertising media and various other factors that are continuously competing for the driver's attention, construction traffic control devices used for channelization purposes should provide the most reflectivity possible.

High specific intensity type reflective sheeting has been found to provide a much better reflective surface on channelizing devices used in urban areas and requires less maintenance to achieve desirable reflectivity.

Therefore, in construction projects involving work in metropolitan areas, and based on the District Engineer's approval, the District may include a plan note on the Specification Data Sheets requiring the use of high specific intensity reflective sheeting on channelizing devices. The following note may be used:

> ITEM 502 - For this project, reflective surfaces on channelizing devices, such as cones, vertical panels, drums, and barricades shall be the high specific intensity type, flat surface, reflective sheeting and shall conform with Departmental Specification, "Flat Surface Reflective Sheeting," D-9-8300, Type C. Reflective surfaces on signs shall conform with Departmental Specification D-9-8300, Type A.

This Administrative Circular will expire when its contents are included in the appropriate Division Manuals.

Sincerely yours,

M. G. Goode
Engineer-Director

DISTRIBUTION:
District Engineers
Engineer-Manager
Division Heads
Resident Engineers

APPENDIX G

REVISING TEXT ON EXISTING OVERHEAD SIGNS

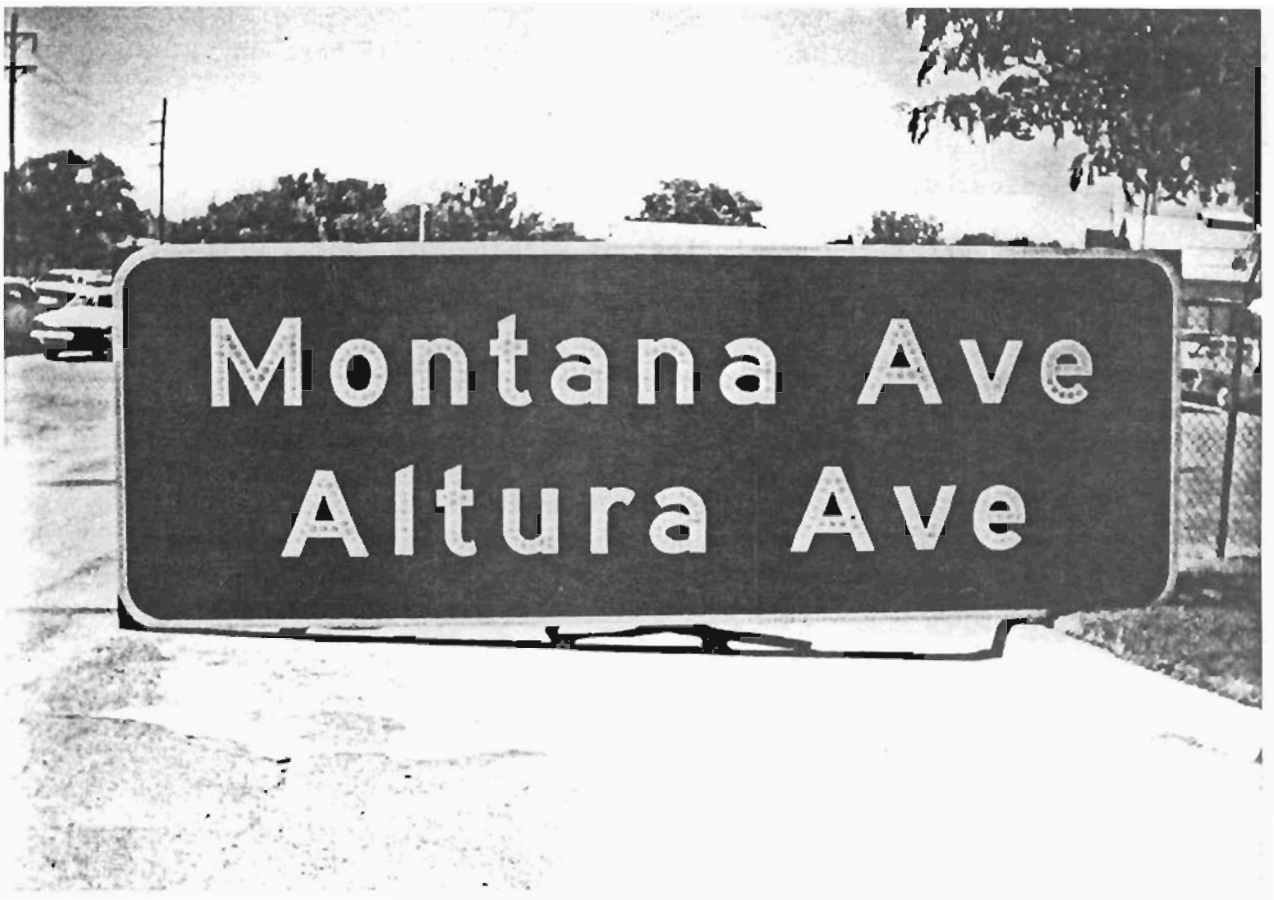
(Porcelain Enameled)

REVISING TEXT ON EXISTING OVERHEAD SIGNS

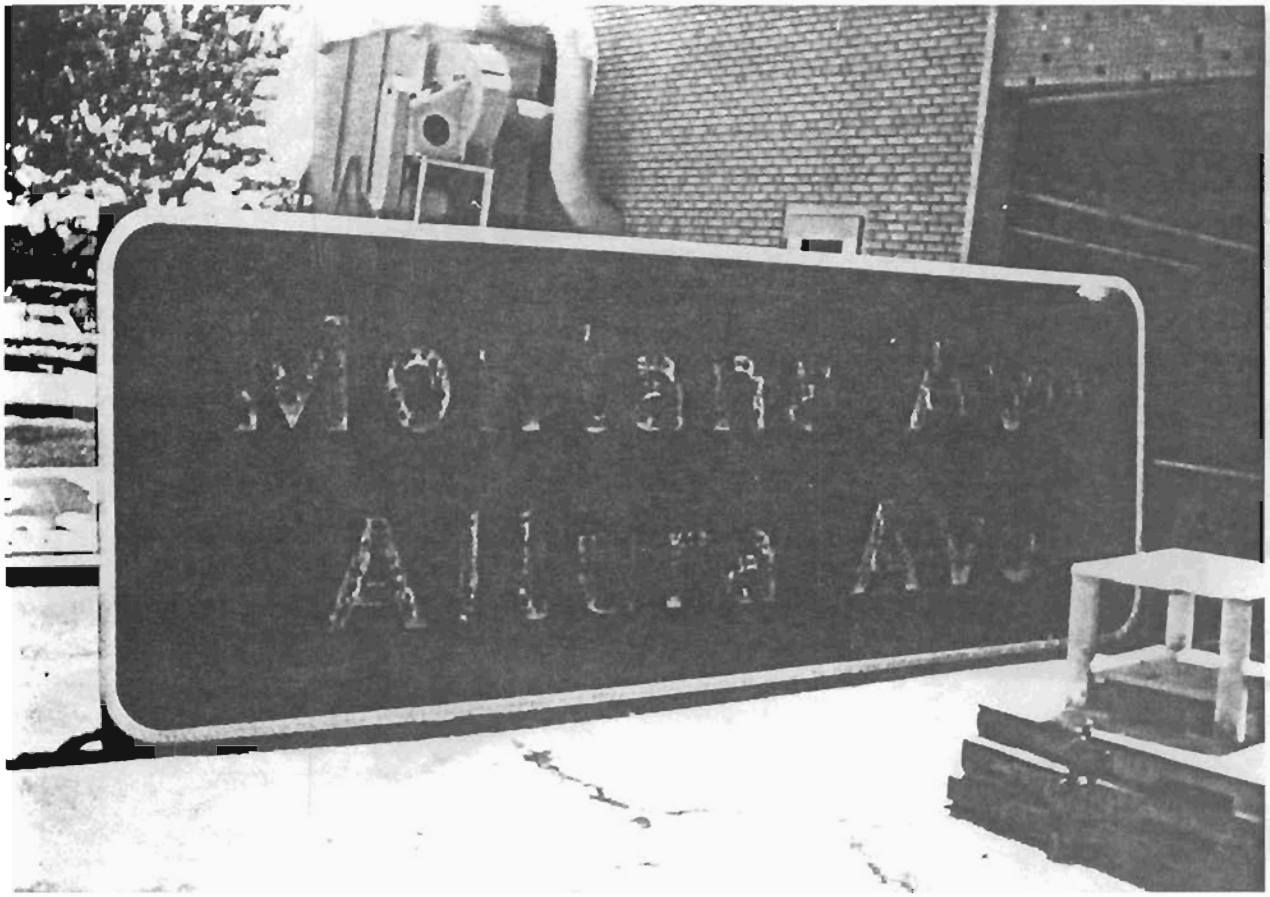
BY

MANUEL F. AGUILERA
SR. TRAFFIC ENGINEER
DISTRICT 24

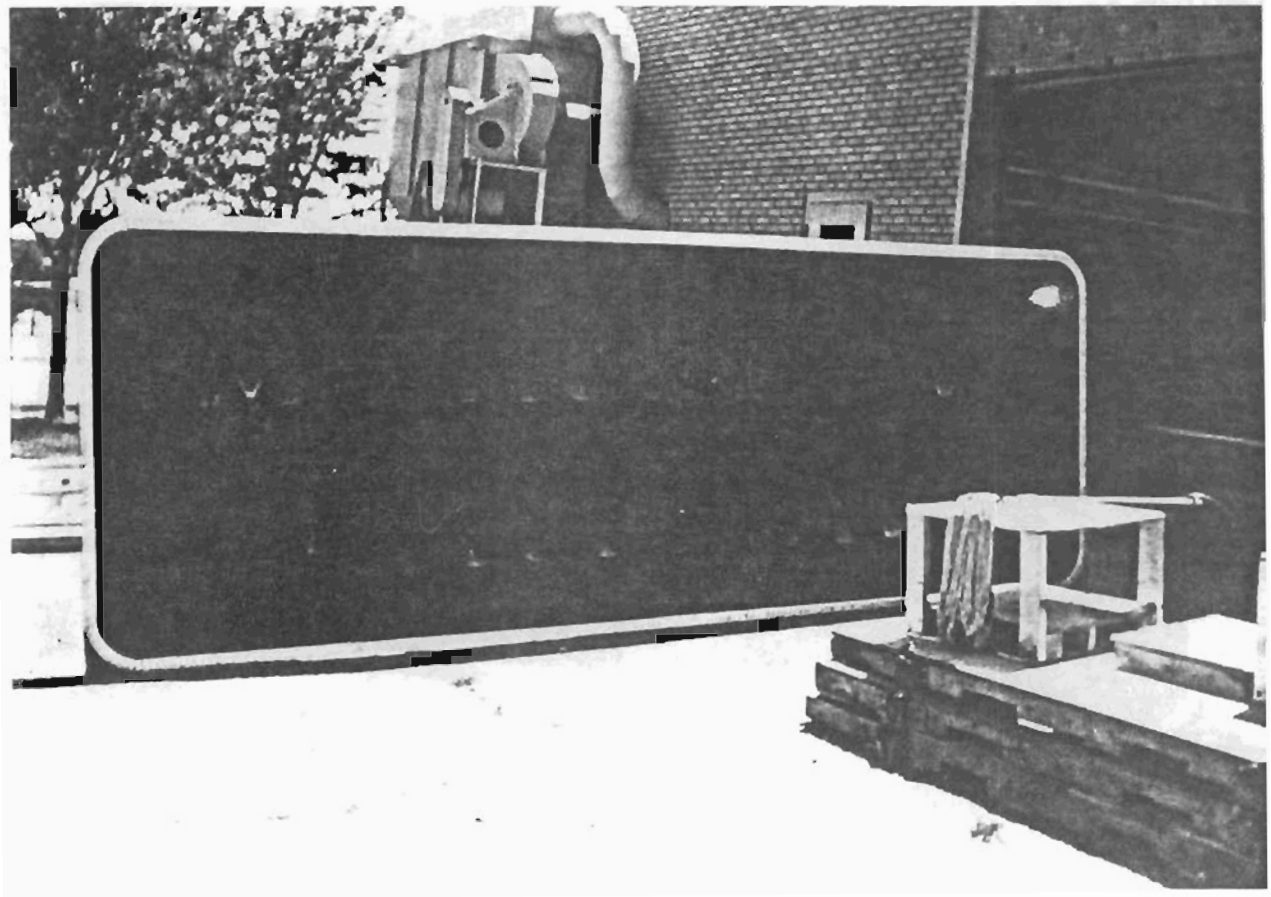
District 24 recently had a need to revise the text on twenty overhead sign bridge signs. Several alternatives were considered, such as fabricating new signs, overlaying with a thin material, repainting, or washing the panels with a porcelain cleaner. The following series of photographs show the results of our sign washing efforts on one of the signs we modified. We had similar results on all of the signs we revised. These signs had been in service approximately nine years.



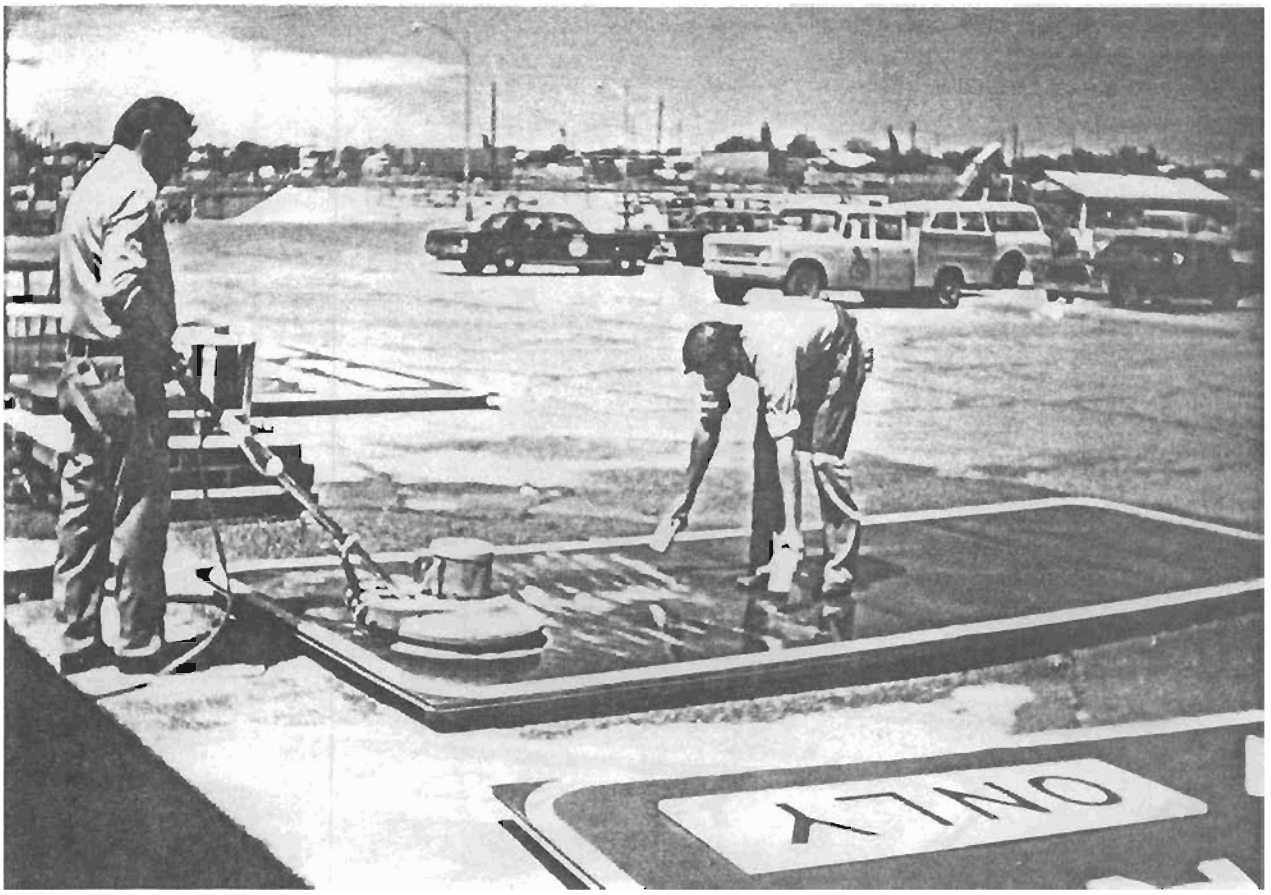
Sign as removed from sign bridge
with original text.



Sign with text removed.

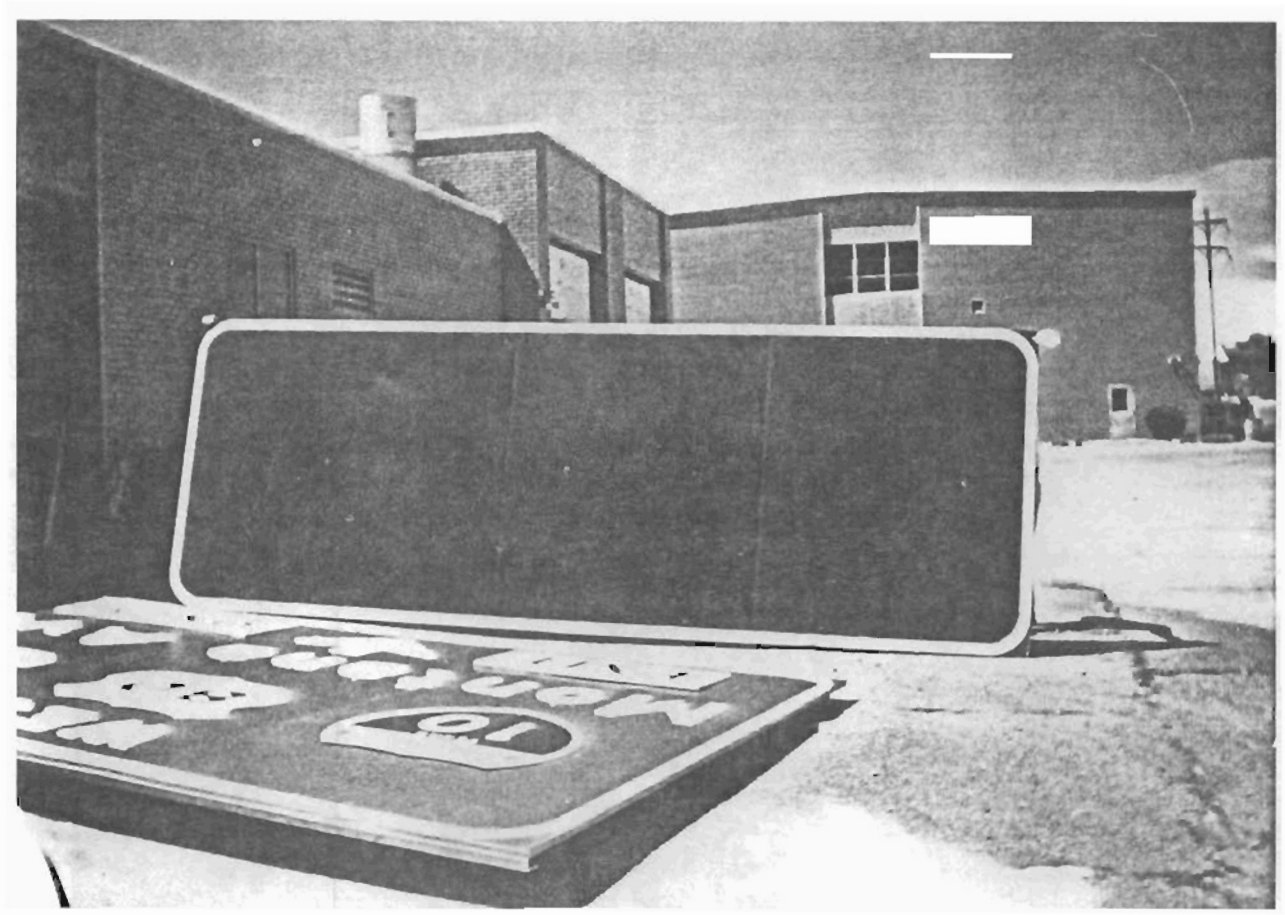


Sign blank washed with soap
and water.

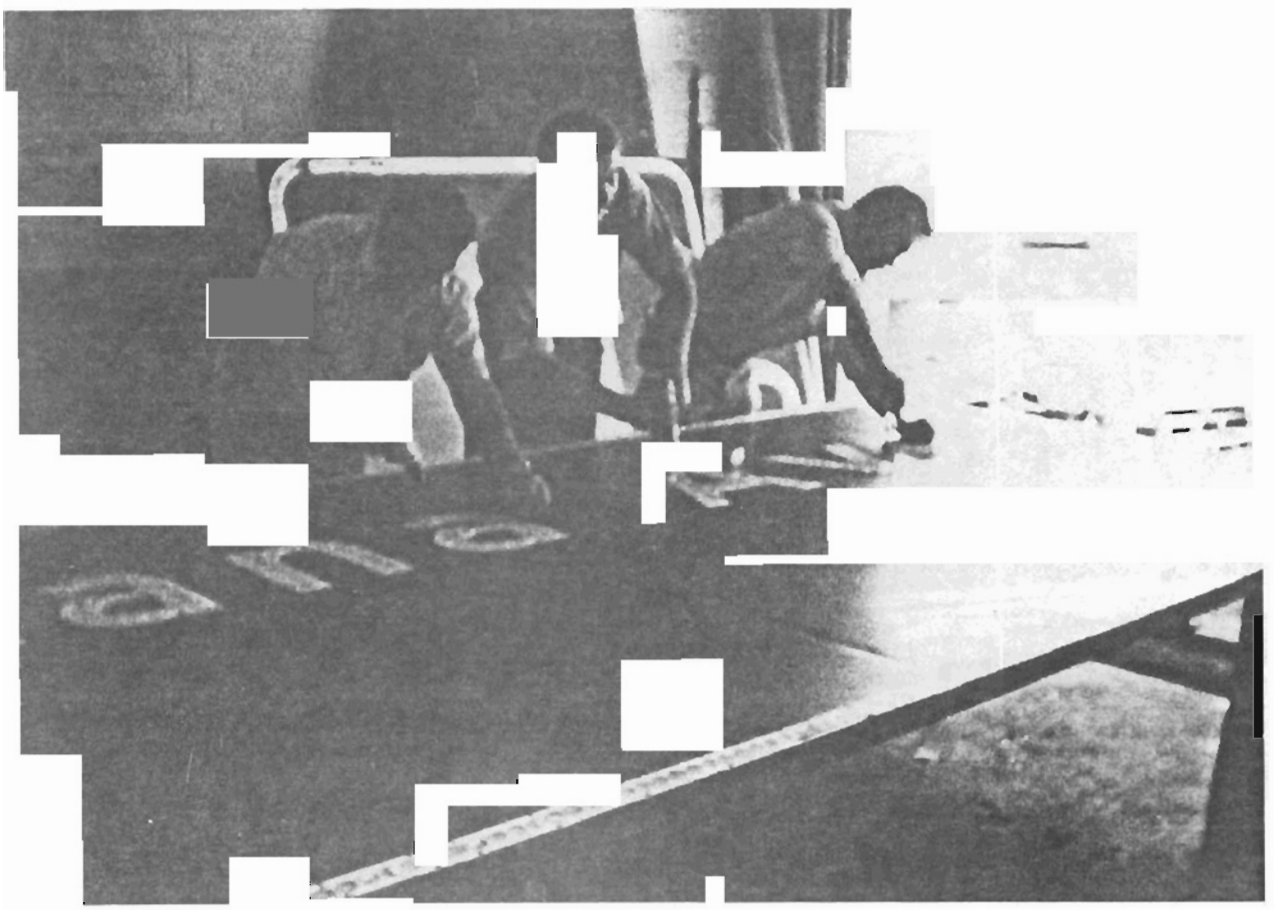


Sign blank scrubbed with floor polisher and powdered chlorinated cleaner.

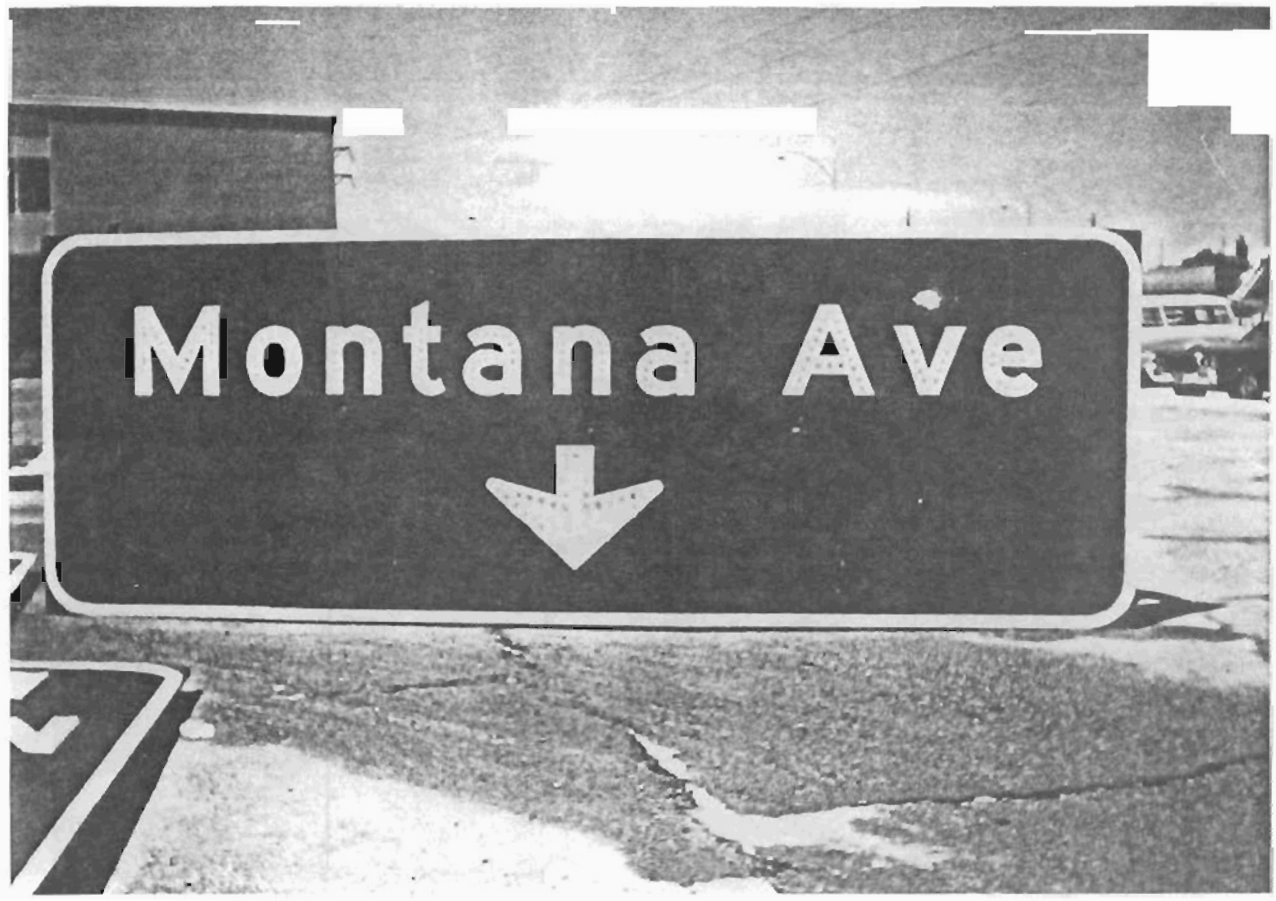
Sign blank rinsed and mopped dry.



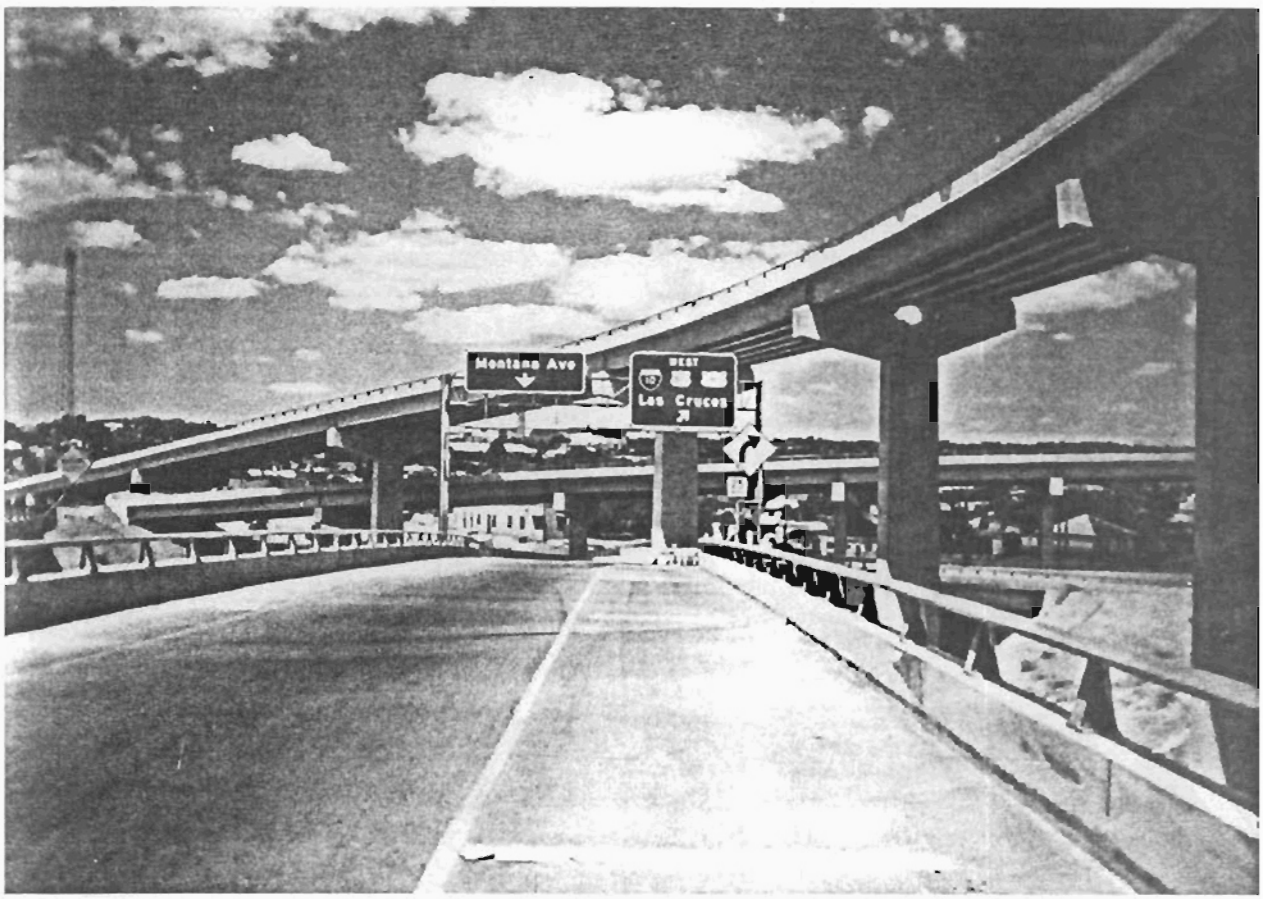
Sign blank after drying.



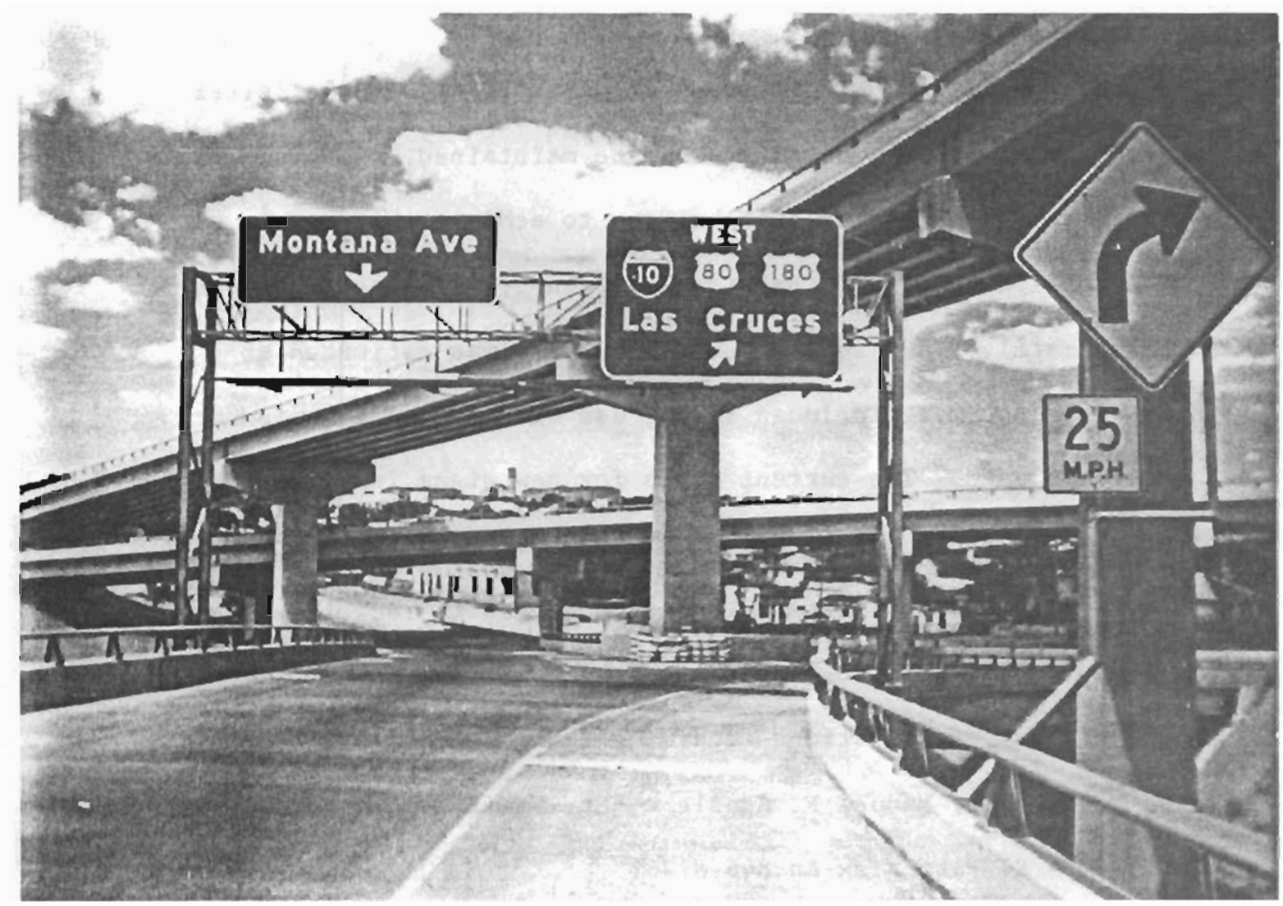
New text being applied to sign blank.



Sign with new text.



Sign installed on sign bridge.



Close up view of revised sign
on existing sign bridge.

We were careful to revise signs in which an acceptable letter to letter and row to row spacing could be maintained. Several signs were relocated on the sign bridges to achieve this.

The total area of all the signs revised by maintenance forces was approximately 2,000 square feet. Our cost was estimated at $1,840. This estimate includes labor, use of Department equipment, and materials used. The current price for new signs installed by contract is about $10 per square foot. One can readily see the savings involved by utilizing maintenance forces to recycle existing signs.

If you have any questions regarding this process, please feel free to contact Mr. Manuel F. Aguilera, Sr. Traffic Engineer, District 24 - El Paso, Tex-An 846-8776.

APPENDIX H

BIBLIOGRAPHY

Pennwalt Corporation Technical Service Laboratory, Plastics Department, Final Report, KYNAR 500/Scotchlite Sign Material, TSR #1261, Written by Louis Micer, Tested by Louis Micer, Approved by (can't read), Date: July 24, 1975.

2. NCHRP Digest 87-March 1976 "Current Practices in Use of Retroreflective Signing Materials"

3. Quarterly Progress Report to the National Cooperative Highway Research Program on Project 3-24 "Determine the Luminous Requirements of Retroreflective Highway Signing" for period Jan. 1, 1976 to March 31, 1976 from Highway Safety Research Institute, Institute of Science and Technology, The University of Michigan, Ann Arbor, Michigan 48100

4. "Evaluating Nighttime Sign Surrounds", H. L. Woltam & W. P. Youngblood, Minnesota Mining & Manufacturing Company, St. Paul.

5. "Using Encapsulated-Lens Reflective Sheeting on Overhead Highway Signs", R. N. Robertson & J. D. Shelor, Virginia Highway & Transportation Research Council, Charlottesville.

6. "Evaluation of High Intensity Sheeting for Overhead Highway Sign", R. N. Robertson, Virginia Highway & Transportation Research Council.

7. "Use of High Intensity Reflective Materials in Highway Signing", A Literature Review by R. N. Robertson, Virginia Highway Research Council, Charlottesville, August 1973, VHRC 73-R6.

8. "The Applicability of High Intensity Sheeting on Overhead Highway Signs", by R. N. Robertson & J. D. Sheldor, Virginia Highway & Transportation Research Council, August 1975, VHTRC 76-R3.

9. NBSIR 74-518 "Instrumental Colorimetry of Retroreflective Sign Materials", I. Nimeroff, W. A. Hall, August 1974, FHWA.

10. "Materials for Traffic Control Signs", James V. Musick, Chief Traffic Engineer, City of Coulumbus, Ohio.

11. "High-Intensity Reflective Materials for Signs" KYP-72-31, HPR-1(7), Part III by R. L. Rizenbergs, June 1972, Kentucky Department of Highways.

12. "The Luminous Requirements of Retroreflective Highway Signing" Report on NCHRP Project 3-24, For Presentation to 62nd Annual Meeting of AASHTO, November 16, 1976, Paul L. Olson, Arthur Bernstein, Highway Safety Research Institute, The University of Michigan.

13. "Performance of Signs Under Dew and Frost Conditions" by John W. Hutchinson, Dept. of Civil Engineering, University of Kentucky, Lexington, Kentucky, & Ted A. Pullen, Facilities Planning Division, Kentucky Department of Transportation, Frankfort, Kentucky, December 1976.

14. "High Intensity Reflective Materials for Signs", R. L. Rizenbergs, August 1974, Research Report 397, Division of Research, Bureau of Highways, Department of Transportation, Commonwealth of Kentucky.

15. "A Luminance Approach to Highway Sign Lighting", Lewin, I; Lighting Design & Application; V3, N6, Jun. 1973; p.23.

16. "Survey of Sign Lighting Design and Maintenance", Hansen, A. H. & Stevens, D. T.; Ohio Department of Transportation; Bureau of Design Services; Columbus, Ohio 43215; 01 May 74; 20 pp.

17. "Overhead Sign Illumination Relationships"; T.T.I. Research Report 5-8; Project 2-8-57-5; Donald E. Cleveland; August 1966.

18. NCHRP Digest 91 - January 1977 "Motorist Response to Guide Signing".

19. "Effect of Sign Illumination on Driver Behavior"; Research Project 103-1., NYSDOT-ERD-76-SR-44.

20. "Public Lighting in Shepway District Council"; T.G. Greening - V103N1/2; 02 Jan 76; pp. 23-24 (Journal of Institution of Municipal Engineers).

21. "Shadows over Public Lighting/Spending Can Be a Good Way To Save" KTO Cox V148N4397; 17 Sept 76; pp. 11-14 (Surveyor Public Authority Technology).

22. "What Cost Lighting?"; B. R. Austin V146 N4351; 31 Oct 75; pp. 12-15 (Surveyor Public Authority Technology).

23. "New Light Sources Will Save Energy"; Municipal Engineering; B. Dorrington; V153 N38; Analytic; Sept. 76; 2 pp.

24. "Programmed Change for Light Sources and Gear"; D. Sculthrope; V152 N37; 12 Sept 75; p. 1734; Municipal Engineering.

25. "Commonsense Approach to Economics in Lighting"; B. Austin; V152; 12 Sept 75; pp 1731-34; Municipal Engineering.

26. "Public Lighting--The Deadly Reckoning", B. R. Austin; V17 N6; June 76; pp. 262-263; Analytic; Traffic Engineering and Control.

27. "An 'X' in the Lighting Equation"; M. F. Singer, V7 N4; Aug 76; 2 pp; Traffic Engineering and Control.

28. "Lighting in 30th Street Underpass in I-676", M. S. Janoff, Franklin Institute.

29. "Effects of Illuminated Signs on Traffic Performance"; E. McNaught & K. C. Hahn, CN103-1; DOT.

30. "A Limited Evaluation of Reflective and Non-Reflective Background for Overhead Signs"; FHWA-PA-78-19, Sept. 1978.

31. "What are the Factors Affecting the Safety, Economics, and Flexibility of Overhead Signs, Sign Supports, and Sign Lighting Maintenance"; V28 Apr. 24, pp. 346-360 (Ohio DOT).

32. "Nighttime Legibility of Guide Signs"; Kenneth C. Hahn, Earl D. McNaught, & James E. Bryden; Research Report 50, Engineering Research & Development Bureau; New York DOT; August 1977.

33. "Plastic Coating of Street Furniture"; A. C. Green; Public Lighting; Dec. 74; Vol. 39.

"Comparison Study of 3-M Hi-Intensity and Engineer Grade Orange Reflective Sheeting for Construction and Maintenance Warning Signs"; Wisconsin Dept. of Transportation; Task Force, January 1978, Madison, Wisconsin Div. of Highways.
William H. Lautz, Chairman
Harold E. Jensen
Harvey A. Peterson
Stephen F. Shober
William G. Wiedenbeck

35. "Overhead Signs Without External Illumination"; Donald L. Woods & Neilon J. Rowan, Texas Transportation Institute.

36. "Luminance and Contrast for Sign Legibility and Color Recognition"; T. W. Forbes, Dept. of Psychology & Highway Traffic Safety Center, Michigan State University.

37. "Indirect Factors Affecting Reflective Sign Brightness"; H. L. Woltman and W. P. Youngblood, 3M Company, St. Paul, Minnesota.

38. "Roadway Sign Illumination"; Illuminating Engineering Society, Journal of; Illuminating Engineering Society; 354 East 47th St.; NY, NY 10017, Oct. 1974.

39. "Highway Signing Reseach - A Survey of Materials and Research Needs Relating to Their Use"; Harman, C.S.; Southwest Research Institute; July 1965.

40. "Effectiveness of Sign Background Reflectorization"; Power, L.D.; Highway Research Record, Highway Research Board.

41. "Roadside Sign Visibility"; Walton, N.E. & Rowan, N. J.; T.T.I., S.D.H.& P.T.; Dec. 1966.

42. "Night Legibility Distances of Highway Signs; Allen, T. M.; Highway Research Bulletin 58; No. 191.

43. "Sign Brightness & Legibility; Allen, T. M. & Straub, A. L.; Highway Research Board Bulletin 56; No. 127.

44. "Sign Brigthness in Relation to Position, Distance, and Reflectorization"; Straub, A. L. & Allen, T. M.; Highway Research Board Bulletin 57; No. 146.

45. "Measurements of the Nighttime Visibility of Signs and Delineators on an Austrialian Rural Road"; Hills, B. L.; Austrialian Road Research.

46. "An Evaluation of Encapsulated Lens Reflective Sheeting Signs"; Mississippi State Highway Department; Research Development Div; Traffic Control & Safety Div.; P. O. Box 1850, Jackson, Mississippi, 39205; Study No.61.

47. "PVC Illuminated Traffic Sign, Modern Plastics"; Apr. 1966; Vol.43, No. 8, p 62.

48. "Materials for Traffic Control Signs"; Musick, J. V.; Ohio Highway Engineering Conf. Proc./25th Annual Conf.; Apr. 1974; pp. 270-3.

49. "An Acrylic Reflecting Material Which Offers New and Unique Applications for Traffic Signs"; Hibbert, R. F.; Highway Research Board Bulletin; Mar. 51; No. 34; pp. 1-2.