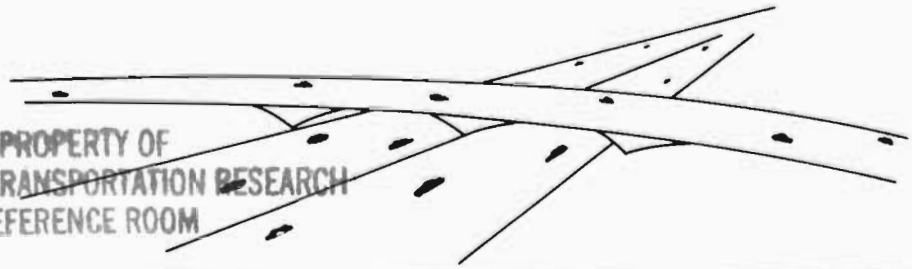


DEPARTMENTAL RESEARCH

Report Number 276-1F

EVALUATION OF GUIDE SIGN CONSTRUCTION MATERIAL

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

TLE PAGE

1. Report No.	2. Government Accession No.	
FHWA/TX-87/79+276-1F		

4. Title and Subtitle	5. Report Date
Evaluation of Guide Sign Construction Material	February 1987
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
H. Dexter Jones, SDHPT, District 12 Joseph G. Raska, SDHPT, Materials & Test Division (D-9)	Research Report 276-1F

9. Performing Organization Name and Address	10. Work Unit No.
State Department of Highways and Public Transportation P. O. Box 5051 Austin, Texas 78763	11. Contract or Grant No. Research Study 1-9-84-276-1F
	13. Type of Report and Period Covered FINAL
12. Sponsoring Agency Name and Address State Department of Highways and Public Transportation P. O. Box 5051 Austin, Texas 78763	14. Sponsoring Agency Code

15. Supplementary Notes

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

16. Abstract

Tests of materials that were started under Project 1-18-75-222 were continued under this project. The findings of 222 were further proven and expanded.

Sign panel coating materials based on thermosetting polyester and thermosetting polyvinylidene fluoride were proven to be satisfactory to be used in the construction of new Overhead Guide Signs. Acrylic cured aliphatic urethane, sign enamel, thermosetting polyester and reflective sheeting were proven as satisfactory materials for refurbishing deteriorated porcelain-enameled aluminum Overhead Guide Signs.

Even though this project has been terminated, numerous tests of materials that were started under this project and Project 1-18-75-222 will be completed. Reports of the test findings will be prepared and published as Special Study (SS) Reports.

As technology advances and new materials become available, the new materials will be tested under specifications developed under this project and 222. The tests will be carried out under normal work procedures. These test results will also be written and reported as SS Reports.

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	98	

Form DOT F 1700.7 (8-69)

EVALUATION OF GUIDE SIGN CONSTRUCTION MATERIAL

Research Report Number 276-1F

by

H. Dexter Jones
District Traffic Design Engineer
District 12

and

Joseph G. Raska
Materials and Test Paint Engineer
Materials and Test Division

Conducted by

District 12 and Materials and Test Division
in Cooperation with the
Transportation and Planning Division
Texas State Department of Highways and
Public Transportation

February 1987

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors wish to give special acknowledgement to Richard A. Oliver, Devidas B. Tulsiani, Randy Kier and James Walding of Maintenance Operations Division, Jon Underwood and David Hustace of Transportation Planning Division, Bob Hodge of District 2, Ben Bohuslov of District 13, Glen Sullivan of District 16, Waid Goolsby of District 18 and Manny Aguilera of District 24 for timely comments and guidance in this project and its predecessor Project 1-18-75-222.

We wish to give special appreciation to Districts 12 and 16 Sign Shop personnel for preparing signs and to Districts 12 and 18 Maintenance personnel for erection of signs on the roadways.

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

Tests of materials that were started under Project 1-18-75-222 were continued under this project. The findings of 222 were further proven and expanded.

Sign panel coating materials based on thermosetting polyester, and thermosetting polyvinylidene fluoride were proven to be satisfactory to be used in the construction of new Overhead Guide Signs.

Acrylic cured aliphatic urethane, sign enamel, thermosetting polyester and reflective sheeting were proven as satisfactory materials for refurbishing deteriorted porcelain-enameled aluminum Overhead Guide Signs.

Even though this project has been terminated, numerous tests of materials that were started under this project and Project 1-18-75-222 will be completed. Reports of the test findings will be prepared and published as Special Study (SS) Reports.

As technology advances and new materials become available, the new materials will be tested under specifications developed under this project and 222. The tests will be carried out under normal work procedures. These test results will also be written and reported as SS Reports.

SUMMARY

This project was a continuation of the materials work started under Project 1-18-75-222. This report will contain a compilation of the findings of 222 and this project (276).

Initially a survey of sign construction materials was made. The initial survey covered materials that had been used by this and the other states for the previous fifteen (15) years. This aspect of investigative work has continued since the initial survey.

Under the two projects seventy four (74) sign construction materials have been investigated and/or tested. The materials included background coatings, sheetings and substrates. Some are still being tested.

The above tests proved that sign panel coating materials based on thermosetting polyester, and thermosetting polyvinylidene flouride were satisfactory to be used in the construction of new Overhead Guide Signs. The coatings have shown in accelerated testing and field testing to give excellent durability and color retention. The projected minimum life for these two (2) coating materials is conservatively thirty (30) 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. Copies of the latest specifications are included as part of Appendix "B" of this report.

Numerous coatings were tested as possible coatings for the refurbishing of deteriorated porcelain-enameled aluminum Overhead Guide Signs. Acrylic cured aliphatic

urethane and GES-2C sign enamel have proven as satisfactory materials for the refurbishing work. The porcelain-enameled surface must be thoroughly cleaned, abraded with either coarse sandpaper or steel wool, cleaned again and then coated. Signs refurbished in this manner have been in field service for over ten (10) years and are still in very good condition. It is the recommendation of the authors that this means of relatively inexpensive refurbishing of Overhead Guide signs be utilized on a statewide basis.

The application of reflective sheeting to the background of deteriorated porcelain-enameled overhead guide signs was tried. Various means of application of the sheeting was tried. Large, rigid, flat aluminum overlay sheets finished with various reflective sheeting materials were applied to deteriorated sign panels. The reflective sheeting delaminated from the overlay sheets. The probable cause was the excessive thermal expansion and contraction stresses experienced by the large flat aluminum surfaces and possibly improper substrate preparation.

Thin flexible aluminum foil overlays were also used. The thin foil overlays also had reflective sheeting preapplied prior to the installation of the foil overlays to the deteriorated sign panels. The foil overlays were applied in place, that is the sign panels remained on the overhead sign structures. This type of overlay produced excessive wrinkles and bubbles that were very detrimental to night time legibility. The foil overlays also delaminated from the sign panels. The manufacturer has reworked the system and this type of overlay is still being evaluated.

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. This type of refurbished sign panels has been in field service for over ten (10) years and the signs are still in very good condition. The authors also recommend that this second means of relatively inexpensive refurbishing of Overhead Guide Signs be utilized on a statewide basis.

In arid climates as that experienced in El Paso, District 24, the porcelain enamel experiences a milder amount of deterioration than is experienced in other areas, especially in the coastal districts. It was found that by merely scrubbing the sign panel with a floor polisher and powdered chlorinated cleaner, the deterioration was removed from the panel surface. The text was replaced and the sign returned to service. This method of cleaning will not remove the heavy deterioration experienced in the coastal areas.

Thermosetting polyester appeared for several years to be a viable method for refurbishing porcelain-enameled aluminum extrusions. However, after some six years on the test rack at Corpus Christi, serious failure occurred in the form of total delamination, due to under film corrosion of the aluminum. Initial attempts to refurbish panels by various cleaning and abrading methods produced adhesion problems with thermosetting polyester. Excellent adhesion of the thermosetting polyester was achieved when the porcelain was completely removed by blasting. Unfortunately, complete removal left an aluminum surface with no conversion coating to inhibit corrosion of the aluminum. It is unknown when under film corrosion actually began, but sometime between five and six years of exposure at Corpus Christi, the test panels experienced total loss of adhesion.

Field exposure and accelerated testing showed that the opaque background coatings studied and recommended for use are more durable than the reflective sheeting backgrounds. As previously stated the accelerated projected life of the opaque

coatings is conservatively thirty (30) years. The anticipated life of the sheeting materials are as follows: engineer grade - 7 years, super engineer grade - 14 years and high specific intensity - 10 years.

Two (2) more manufacturers' reflective sheeting materials were tested, proven and placed on statewide usage. A new type of high specific intensity reflective sheeting that utilizes microprisms instead of reflective beads is now under test.

Investigation and testing of numerous types of sign substrates were made during the course of both projects. Aluminum honeycomb with its sandwich type of construction proved to be highly susceptible to delamination due to thermal expansion and contraction stresses. This type of construction also produced internal corrosion problems due to the adhesives used to glue the different sandwich elements into a complete unit. This type of substrate has been removed from use in Texas.

Aluminum flat sheet construction as a guide sign background substrate was also investigated and ruled out. This type of construction also produced irregular, buckled and delaminated panels due to the same thermal stresses. Reflective sheeting also delaminated due to the excessive movement of the flat surface.

Aluminum extrusions using alloy 6061-T6 proved to be one of the best substrates for guide sign construction. Care must be exercised not to allow several of the other alloys available in extrusions. Several of the alloys produce poor adhesion of the background coating materials. One of the prime causes of coating delamination is the fact that some of the alloys contain too much silica for proper coating adhesion.

Various plywood substrates were tried. The best overall plywood substrate pre-

sently available is High Density Plywood Type "A". This plywood has pressure and heat applied plastic faces to which the coating or sheeting is applied. A copy of the latest specification for High Density Plywood Type "A" is included as part of appendix "B" of this report.

Contrary to the manufacturer's warnings many full size sign panels were made by applying high specific intensity reflective sheeting onto the plastic faced plywood. These signs were primarily used in detouring of traffic through highway construction zones. The manufacturer stated that the signs would not last over two (2) years. The panels have been used for eight (8) years on numerous projects with many text and location changes and are still in use. However, they are now really reaching end of useful life. Large monetary savings were realized through the reuse of these plywood panels.

Caution must be used in the application of some opaque coatings on the plastic faced plywood panels. The release agent used to extract the plywood panel from the press after the application of the plastic face caused severe delamination of some opaque coatings, example, air dry polyvinylidene fluoride.

Under this project two (2) additional plywood substrate manufacturer's materials were tested for possible usage. The additional suppliers materials were proven and placed on statewide usage.

Several plastic substrates were tried as basic substrates and as overlays. Clear and opaque sheets of polycarbonate were tried. The plastic face sheets exhibited numerous types of failures and were abandoned. Several types and thicknesses of fiberglass panels were and are being tried. These tests are incomplete. Work in this material area is continuing. However, at present, the possible use of of this type of material does not look promising.

Guide sign panels utilizing steel sheets produced many undesirable problems, such as buckling and rusting. Because of the problems this type of material was removed from consideration.

Consideration should be given to the use of aluminum extrusions in the fabrication of ground mounted guide signs. It should be noted that the aluminum substrate is more durable than the plywood substrate. Although the initial construction costs might be slightly higher, this material would produce longer sign life and reduce maintenance costs.

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 ground mounted guide signs. This application of normally considered scrap materials could produce large savings of maintenance funds.

Several configurations of internally illuminated plastic faced signs were tried and abandoned. The signs exhibited poor daytime and nighttime legibility. The signs also presented numerous maintenance problems.

IMPLEMENTATION

The Department is currently realizing returns from the monies expended on this project and its predecessor Project 1-18-75-222. The savings are realized in the statewide usage of the sign coating materials, sheeting materials and substrates as researched and recommended. Further savings could be realized in the statewide usage of materials researched and recommended which are not currently being accepted and used.

The following materials have been tested, accepted and are being used statewide:

1. Sign panel coating materials based on thermosetting polyester and thermosetting polyvinylidine fluoride were tested and found satisfactory to be used in the construction of Overhead Guide Signs. The coatings have shown in accelerated testing and field testing to give excellent durability and color retention. The projected minimum life for these coating materials is conservatively thirty (30) years.

   Specifications for the polyester coating and the polyvinylidine fluoride coating have been written and issued. Copies of the latest specifications are included as part of Appendix "B" of this report.

2. Engineer grade, super engineer grade and high specific intensity reflective sheeting have proven satisfactory to be used in the construction of Overhead Guide Signs and Ground Mounting Guide Signs. The sheeting materials could be used on signs that are either lighted or unlighted. A copy of the latest specification is included as part of Appendix "B" of this report.

3. Aluminum extrusions using alloy 6061-T6 proved to be one of the best substrates for guide sign construction. Several other alloys available in extrusions produce poor adhesion of the background coating materials. One of the prime causes of coating delamination is the fact that some of the alloys contain too much silica for proper coating adhesion. A copy of the latest specification is included as part of Appendix "B" of this report.

4. High Density Plywood, Type "A" which has factory applied plastic facing has proven to be the best type of plywood to be used as a guide sign substrate. A copy of the latest specification is included as part of Appendix "B" of this report.

The following materials and/or procedures have been tested, proven as satisfactory and recommended but have not been accepted for statewide usage:

1. Acrylic cured aliphatic urethane and GES-2C sign enamel have proven as satisfactory materials for the refurbishing of deteriorated porcelain-enameled aluminum Overhead Guide Signs.

2. Deteriorated porcelain-enameled extrusions can be satisfactorily refurbished with the hand application of engineer grade, super engineer grade and high specific intensity reflective sheeting.

3. In arid climates the existing mild deterioration of the porcelain-enameled surface of Overhead Guide Signs can be removed with a floor polisher and powdered chlorinated cleaner.

4. Aluminum extrusions in the fabrication of ground mounted guide

signs would produce more durable signs.

5. Refurbished deteriorated porcelain-enameled extrusions could be used to produce durable, inexpensive ground mounted signs to replace existing deteriorated plywood guide signs.

The authors recommend that the above six (6) materials and/or procedures be approved for statewide usage.

The authors do not recommend the use of internal illuminated plastic faced signs.

I. SUBJECT

Evaluation of Guide Sign Construction Material.

II. PURPOSE

The objectives of the study are:

1. Continue field exposure, test fence exposure and weatherometer exposure of guide sign construction materials that are currently being evaluated.

2. Evaluate new guide sign construction materials as received that may be cost effective in the Department's signing program.

3. Develop and publish specifications for new guide sign construction materials as they are proven to be cost effective.

4. Develop and publish test procedures necessary to ensure that quality guide sign construction materials are received by the Department.

5. Continuously review currently used guide sign construction materials as to cost effectiveness.

III. CONCLUSIONS AND RECOMMENDATIONS:

Tests proved that sign panel coating materials based on thermosetting polyester, and thermosetting polyvinylidine fluoride were satisfactory to be used in the construction of new Overhead Guide Signs. The coatings have shown in accelerated testing and field testing to give excellent durability and color retention. The projected minimum life for these two (2) coating materials is conservatively thirty (30) years.

Specifications for the polyester coating and the polyvinylidine

fluoride coating have been written and issued. The coatings are being used on a statewide basis. Copies of the latest specifications are included as part of Appendix "B" of this report.

Acrylic cured aliphatic urethane and GES-2C sign enamel have proven as satisfactory materials for refurbishing of deteriorated porcelain-enameled aluminum Overhead Guide Signs. The porcelain-enameled surface must be thoroughly cleaned, abraded with either coarse sandpaper or steel wool, cleaned again and then coated. Signs refurbished in this manner have been in field service for over ten (10) years and are still in very good condition. This type of relatively inexpensive refurbishing Overhead Guide Signs should be utilized on a statewide basis.

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. This type of refurbished sign panels has been in field service for over ten (10) years and the signs are still in very good condition. This second means of relatively inexpensive refurbishing of Overhead Guide Signs should be utilized on a statewide basis.

In arid climates the porcelain-enamel surfaces of the Overhead Guide Signs deteriorate to a milder degree to same type of surfaces in the coastal areas. It was found that by merely scrubbing the sign panel with a floor polisher and powdered chlorinated cleaner the deterioration was removed from the panel surface. The text could be replaced

and the sign returned to service. This method will not remove the heavy deterioration being experienced in the coastal areas.

Based on accelerated tests on thermosetting polyester for new sign applications, it was considered as a good candidate for refurbishing deteriorated porcelain-enameled aluminum extrusions. Cleaning of the deteriorated porcelain surface by various chemical or mechanical means prior to application of the polyester coating produced poor adhesion of the polyester coating. Complete removal of the porcelain by blasting produced excellent adhesion of the polyester coating. However, panels placed on the test rack at Corpus Christi experienced total loss of adhesion of the polyeser coating in six years. Analysis showed the adhesion loss was the result of underfilm corrosion of the aluminum. The underfilm corrosion could be eliminated by application of a conversion coating, but then the total refurbishing process, from disassembling the sign to reassembling, becomes cost prohibitive, in that a totally new sign would cost less.

Field exposure and accelerated testing showed that the opaque background coatings studied and recommended for use are more durable than the reflective sheeting backgrounds. The accelerated projected life of the opaque coatings is conservatively thirty (30) years. The anticipated life of the sheeting materials are as follows: engineer grade - 7 years, super engineer grade - 14 years and high specific intensity - 10 years.

Large rigid flat aluminum overlay sheets to which various reflective sheeting was preapplied has been applied to deteriorated porcelain-enameled sign panels. The reflective sheeting delaminated from the

overlay sheets. The probable cause was the excessive thermal expansion and contraction stresses experienced by the large flat aluminum surfaces and possibly improper substrate preparation.

A thin flexible aluminum foil overlay was used. The thin foil overlay also had reflective sheeting preapplied prior to the installation of the foil to the deteriorated sign panel. The foil overlay was applied in place, that is, the sign panels remained on the overhead sign structures. This type of overlay produced excessive wrinkles and bubbles that were very detrimental to night time legibility. The foil overlay also delaminated from the sign panels. The manufacturer has reworked the system and this type of overlay system is still being evaluated.

Aluminum honeycomb substrate with its sandwich type of construction proved to be highly susceptible to delamination due to thermal expansion and contraction. This type of construction also produced internal corrosion problems due to the adhesives used to glue the different sandwich elements into a complete unit. This type of substrate has been removed from use in Texas.

Aluminum flat sheet construction as a guide sign background substrate was investigated and ruled out. This type of construction also produced irregular, buckled and delaminated panels due to the same thermal stresses. Reflective sheeting also delaminated due to the excessive movement of the flat surface.

Aluminum extrusions using alloy 6061-T6 proved to be one of the best substrates for guide sign construction. Care must be exercised not

to allow several of the other alloys available in extrusions. Several of the alloys produce poor adhesion of the background coating materials. One of the prime causes of coating delamination is the fact that some of the alloys contain too much silica for proper coating adhesion.

The best overall plywood substrate presently available is High Density Plywood Type "A". This plywood has a pressure and heat applied plastic face to which the coating or sheeting is applied. A copy of the latest specification is included as part of Appendix "B" of this report.

Contrary to manufacturer's warnings, many full size sign panels were made by applying high specific intensity reflective sheeting on to the plastic faced plywood. These signs were primarily used in detouring of traffic through highway construction zones. The manufacturer stated that the signs would not last over two (2) years. The panels have been used for eight (8) years on numerous projects with many text and location changes and are still in use. However, they are now really reaching end of useful life. Large monetary savings were realized through the reuse of these plywood panels. The large urban districts should consider making these type of signs and stocking them for use on numerous construction and reconstruction projects.

Caution must be used in the application of some opaque coatings on the plastic faced plywood panels. The release agent used to extract the plywood panel from the press after the application of the plastic face caused severe delamination of some opaque coatings. The delamination problem is easily eliminated by light sanding and wiping with a damp solvent rag or tac-cloth; this is good practice to apply any coating or

sheeting to plastic faced plywood.

Several plastic substrates were tried as basic substrates and as overlays. Clear and opaque sheets of polycarbonate were tried. The plastic face sheets exhibited numerous types of failures such as cracking, buckling, fading, etc. and were abandoned. Usage is not recommended.

Several types and thicknesses of fiberglass panels were and are being tried. These tests are incomplete. Work is continuing in this material area. Usage is not recommended until completion of tests. However, at this time, the possible usage of this material does not look promising.

Guide sign panels utilizing steel sheets produced many undesirable problems such as buckling and rusting. Because of the problems this type of material was removed from consideration. Usage is not recommended.

Consideration should be given to the use of aluminum extrusions in the fabrication of ground mounted guide signs. It should be noted that the aluminum substrate is more durable than the plywood substrate. Although the initial construction costs might be slightly higher, this material would produce longer sign life and reduce maintenance costs.

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 ground mounted guide signs. This application of normally considered scrap materials could produce large savings of maintenance funds.

Several configurations of internally illuminated plastic faced signs were tried and abandoned. The signs produced poor daytime and night time legibility. The signs also produced numerous maintenance problems. Usage of internally illuminated plastic faced signs is not recommended.

IV. MATERIALS

The following is a list of the guide sign substrate finishes that were evaluated and/or tested under this project and Project 1-18-75-222:

1. Thermosetting polyesters
2. Thermoplastic polyesters
3. Hybrid epoxy-polyesters
4. Thermosetting polyvinylidine fluoride
5. Air dry polyvinylidine fluoride
6. Polyvinyl fluoride films
7. Polyurethanes
8. Acrylic films
9. Acrylic liquids
10. Vinyl-toluene/acrylic copolymer
11. Acrylic urethane coatings
12. Epoxies
13. Alkyd liquids
14. Silicone solutions
15. Several sign enamels including GES-2C sign enamel
16. Polyvinyl chloride films
17. Polyvinyl chloride liquids
18. Thermosetting polyvinyl chloride

19. Engineer grade reflective sheetings
20. Super engineer grade reflective sheetings
21. High specific intensity reflective sheetings

Several chemical formulations and thickness of films liquids, thermo-setting coatings, thermoplastic coatings and sheetings were tried on several different substrates.

The following is a list of the guide sign substrates that were evaluated and/or tested under this project and Project 1-18-75-222.

1. Aluminum extrusions (several alloys)
2. Aluminum sheets (several thicknesses and alloys)
3. Steel sheets
4. Plywoods
5. Aluminum foils
6. Plastic sheets (several types and thicknesses)
7. Internal illuminated plastic faced signs

V. EQUIPMENT:

An Atlas weathometer was utilized for accelerated testing. A test rack facing southeast at 45° located on the roof of the five (5) story Transportation Planning Divisions Office Building in Austin, Texas was utilized for exposure testing. Another test rack facing southeast at 45° over salt water at Nueces Bay near Corpus Christi was also utilized for exposure testing. A storm destroyed the test rack near Corpus Christi. Another rack was built alongside the water at approximately the same location. Full sized panels were located on freeways in Houston, Corpus

Christi, San Antonio, Dallas and El Paso.

Color was determined on a Gardner Color Difference Meter. Infrared characteristics of coating materials were determined with a Perkin-Elmer 521 Grating Infrared Spectrophotometer. X-ray analysis of coating materials was determined with a Phillips X-ray Diffractometer. A 1980 Plymouth Volare station wagon equipped with a Numetrics DE-140 digital bidirectional distance instrument was used in the sign evaluation and legibility.

VI. PROCEDURE FOR DATA:

Performance data, such as durability with respect to chalking and color retention, was and is being evaluated in the field, on test racks and in the weatherometer. Most of the original test panels were produced at the same time. Panels for complete signs were also manufactured. In some cases where results appeared to be conflicting, additional test panels were prepared in the D-9 Laboratory in Austin. In addition, as new materials became available, panels using the new materials were prepared. Infrared spectra and X-ray diffraction patterns were run using routine techniques on the applied materials and unapplied materials, when possible, primarily for identification purposes.

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 thermal setting polyester, initially. However, in six years at Corpus Christi, panels experienced total delamination of the polyester coating.

Physical abrasion with coarse sandpaper or coarse steel wool produced satisfactory adhesion with acrylic cured aliphatic urethene and GES-2C sign enamel. Signs refurbished in this manner have been in field service for over ten (10) years and are still in very good condition.

Deteriorated porcelain-enameled extrusions were washed, abraded with coarse steel wool or medium grit sandpaper and then rewashed. Pressure sensitive engineer grade, super engineer grade and high specific intensity reflective sheeting was then hand applied to these extrusions. Slight defects such as small bubbles and wrinkles were experienced but these small defects have not proven to be a problem in the field or in durability of the sheeting. Signs refurbished in this manner have been in field service for over ten (10) years and are still in very good condition. Therefore, contrary to manufacturer's 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

be easily done in the departmental sign shops.

Large rigid flat aluminum overlay sheets finished with various reflective sheeting were applied to deteriorated sign panels. The reflective sheeting was applied to the overlay sheets prior to the application of the overlay sheets to the sign panels. The reflective sheeting delaminated from the overlay sheets. The probable cause was the excessive thermal expansion and contraction stresses experienced by the large flat aluminum surfaces. Possibly improper preparation of the substrate caused some of the delamination. A thin flexible aluminum overlay was used. The thin foil overlay also had reflective sheeting preapplied prior to the installation of the foil overlay to the deteriorated sign panel. The foil overlay was applied in place, that is the sign panels remained on the overhead sign structures. This type of overlay produced excessive wrinkles and bubbles that were very detrimental to night time legibility. The foil overlay also delaminated from the sign panels. The manufacturer has reworked the system and this type of overlay is still being evaluated.

In arid climates as that experienced in El Paso, District 24, the porcelain-enamel experienced a milder amount of deterioration than is experienced in other areas, especially in the coastal districts. It was found that by merely scrubbing the sign panel with a floor polisher and powdered chlorinated cleaner the mild deterioration was removed from the panel surface. The text was replaced and the sign returned to service. This method of cleaning will not remove the heavy deterioration experienced in the coastal areas.

VII. DISCUSSION:

Since ancient times man has placed signs along his travel ways as an information system to guide travelers. These signs began as simple small markers or signs. In early times the signs were small, crude, hand painted, nonreflective signs nailed to convenient trees and fence posts. As the narrow roads with few travelers became wider two-way highways with many travelers using faster modes of travel, the signs became large and more complex. By the twentieth century the major highway systems throughout the world required large roadside mounted signs. The use of reflective background signs began. The use of materials other than wood also began. As the complexity of the signing grew, the sign legibility, comprehension, reflectance and durability problems also grew.

Since the advent of multi-lane freeways and the interstate highway system, a new technique of signing has evolved---Overhead Signing. Overhead signing created a multitude of new 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 the needs of the motorist? The problems seem simple, yet this was a complete departure from signing on the roadway shoulder. The mounting, available materials, and accessibility to shoulder mounted signs becomes easy when compared to overhead signing.

Needless to say, the problems were defined and resolved one by one until, as a final result, overhead signing has become an effective, working identity on the roadway.

When overhead signing first became a reality, few materials were available that could be adapted to such uses. Porcelain-enameled aluminum was the only material available at the time with which to fabricate sign backgrounds with any resemblance of economics and durability.

FIGURE 1: Deteriorated Porcelain-enameled Sign in Houston, Texas

Recognizing the color retention problems associated with porcelain-enamel, particularly along the coast and in industrial atmospheres, new and better materials have been sought on a rather limited basis.

In the mid-sixties, polyvinylfluoride film was evaluated and found to be superior to porcelain-enamel. Polyvinylfluoride has much better color retention than porcelain-enamel, is apparently unaffected by marine and industrial atmospheres, and can be used on aluminum or plywood substrates.

During the same time acrylic film was investigated by the department. The acrylic film also proved to be superior to porcelain-enamel. The acrylic film also had better color retention than porcelain-enamel, but not quite as good as the polyvinylfluoride film. The acrylic was only slightly susceptible to the rigors of marine and industrial atmospheres. Several projects were contracted using these two (2) films on plywood substrates. The projects proved successful. However, due to limited

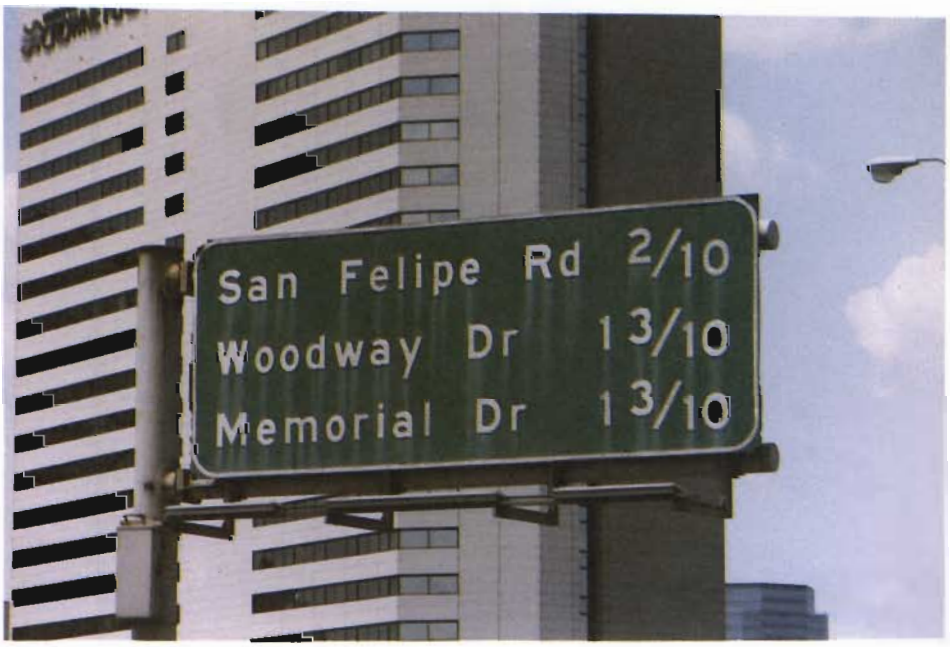


FIGURE 2: Polyvinyl Film coated plywood sign panel with porcelain-enameled cut out copy. The coating is still in excellent condition, but the plywood substrate is in poor condition due to internal core rot. Note the streaking from the porcelain-enameled copy.

usage, the films were virtually withdrawn from the market, leaving porcelain-enamel again as the available coating.

It must be noted that after twenty (20) years of field service, the films are in good condition, but the plywood substrates are in poor condition

due to internal core rot.

In view of the above stated problems the continuing experimentation by several departmental offices were combined into Project 1-18-75-222. Project 222 was closed out on August 31, 1984 and this project 1-9-84-276 continued the investigative work.

To facilitate these study efforts, the research staff was composed of traffic engineers from the field and personnel in the Austin offices that specialize in traffic engineering and signing. Virtually the same staff served on both projects. One unspoken ground rule applied to all investigations undertaken and the evaluation of results obtained. That rule is: Personnel preferences, beliefs and ideas about how things should be are minimized and are replaced with one objective--to determine the most economical methods and materials to obtain an in-place system that is as maintenance free as possible, and to satisfy the needs of the motorist. All systems are evaluated on a cost-per-year basis which includes initial cost and maintenance cost. With the above in mind, it was decided that all background materials would be evaluated in the field, on test racks and in the weatherometer.

Initially a survey of sign construction materials was made. The initial survey covered materials that had been used by Texas and the other states for the previous fifteen (15) years. This investigative work has continued since the initial survey.

A screening of coating materials began. Several materials used for other type coatings that were performing satisfactorily were included in the

studies. Please refer to Section IV. MATERIALS for a list of substrates and substrate finishes that were evaluated and/or tested under this project and Project 1-18-75-222.

Signs were fabricated utilizing the various substrates and coating materials and were placed on the operating freeway systems in Houston, Corpus Christi, San Antonio, Dallas and El Paso. As the individual panels were being made for complete signs additional panels were made for exposure rack testing and accelerated weatherometer testing. The completed signs, except the internal illuminated signs, utilized either reflectorized stick on copy and border, or removable button copy and border.

Panels for test rack and weatherometer testing were taken to the Materials and Tests Laboratory for testing. After receiving test panels in the laboratory, one panel of each material was numbered and placed on the roof mounted test rack in Austin. Another panel of each material was numbered and placed on the test rack in Corpus Christi. The test rack is located to the east side of the Nueces Bay Causeway on U. S. 181, facing southeast into prevailing wind at 45° to horizontal. The prevailing wind at the test rack site comes out of the Gulf of Mexico, across Corpus Christi Bay, and then crosses about 400 yards of land before reaching the test rack. Corrosion data shows this general area to be the most corrosive atmospheric marine environment along the Texas Coast. At periodic intervals, the test panels were and are evaluated for film and color retention characteristics.

Another panel of each material was cut so that at least two (2) 3 x 9 inch panels were obtained for weatherometer testing. The chromaticity

coordinates and brightness of each panel were determined on a Gardner Color Difference Meter before exposing in the weatherometer, and were determined again at various exposure intervals as well as making visual ratings. The weatherometer is an Atlas Sunshine Type fitted with an 18-102 (18 minutes of sunshine and rain, and 102 minutes of sunshine) cyclic gear.

The remaining pieces of the panels from which the weatherometer panels were cut were saved and processed for infrared and X-ray tests. Liquid coating samples and powdered coating samples were obtained. Infrared and X-ray analysis were made for identification purposes so a very small amount of coating could be removed from a completed sign panel to determine if the coating supplied was the one specified. The test also determines whether a thermosetting coating has been undercured, cured properly or overcured.

Initially signs utilizing thermosetting polyvinylidine fluoride, thermal setting polyester, polyurethane, vinyl toluene/acrylic copolymer and acrylic, alkyd and high specific intensity sheeting were fabricated and placed on the freeways in Houston. Later signs of other materials were also fabricated and placed on the freeways in Houston. Representative sign panels using what appeared to be the best materials were also fabricated and placed on freeways in Corpus Christi, San Antonio, Dallas and El Paso. This was done to gain performance data in other climatic conditions.

Also, at the beginning of project 222 an internally illuminated sign panel was placed on the freeway in Houston. The original sign configuration

produced poor daytime and nighttime legibility. The manufacturer tried several configurations of illumination and several types of face sheets. None of the revisions materially improved the legibility. In addition this type of sign produced numerous unacceptable maintenance problems. The sign was removed from the freeway and from further study on the project.

Numerous coatings 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. After approximately two (2) years on the roadway, fifteen (15) months on the test racks, and 600 hours of exposure in the weatherometer, the committee judged that coating materials based on thermosetting polyester and thermosetting polyvinylidine fluoride were satisfactory coating materials for Overhead Guide Signs. Specifications were written and the materials placed on statewide usage.

As stated previously 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. Figures 3 through 8 show various coatings and signs in the test program.

FIGURE 3

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	Polyvinylidene Fluoride	Extr. Alum.	Alcoa PPG	1-250 W 1-250 W Lights on	Nu Art Holophane	

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

Top extrusions coated with thermosetting polyester. Bottom extrusions coated with polyurethane. Polyurethane faded after two years.

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

FIGURE 4: Various experimental coatings. Some of which were not successful.

Air Dry Polyvinylidine Fluoride-Original Condition

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

FIGURE 5: Experimental Coating Durability Comparison

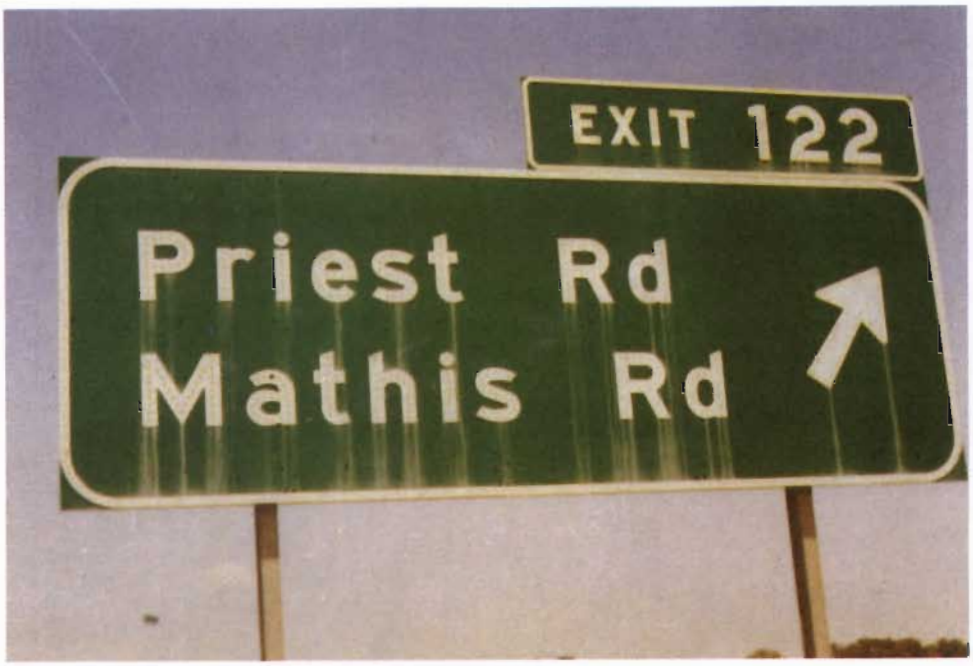


FIGURE 6: Thermosetting Polyester Coated Legend chalking and running down Engineer Grade Reflective Sheeting Background Sign in San Antonio.

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 thermosetting polyester. However, the above picture shows the problem experienced on a signing project in San Antonio.

Investigations proved 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.

Thermosetting Polyester Coating - Original Condition

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

FIGURE 7: Experimental Coating Durability Comparison

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

GES-2C Green Sign Paint without
Topcoat - 10 Years Field Service
Good Condition in regards to Color
and Surface Condition

FIGURE 8: 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 9 shows a thermosetting polyester panel in which the substrate was improperly cleaned prior to application of the coating. The improper cleaning caused serious delamination of the coating.

FIGURE 9: Showing Thermosetting Polyester Coating Delamination due to Improper Cleaning of Substrate Prior to Application of Coating

Even though production problems do exist with the recommended coatings, continuing exposure tests have proven them to be the best known available coatings.

Engineer grade reflective sheeting remains the most widely used reflective sheeting to be used on signing projects. However, high specific intensity reflective sheeting is gaining in usage due to the increased target value. For usage of high specific intensity reflective sheeting on construction projects see Appendix "C". Super engineer grade reflective sheeting is also gaining in fre-

quency of usage, but to a lesser degree than high specific intensity reflective sheeting.

Based on figures obtained from the manufacturers and the Equipment and Procurement Division (File D-4), the table below shows an estimated cost-per-year per-square foot of sign background coating. The figures do not include substrate cost, but do include application costs.

Material	Expected Life-Yrs.*	Cost/Ft.^{2} Initial	Cost/Yr.-Life
Engr. Gr. Sheeting	7	$0.83 - 1.03	$0.12 - 0.15
Super Engr. Gr. Sheeting	14	$2.10	$0.15
H. I. Sheeting	10	$3.23	$0.32
Urethane Acrylic	8**	$0.863	$0.108
PVF_2, Air Dry	7**	$0.612	$0.087
PVF_2, Thermal	20**	$0.601	$0.030
Porcelain	10	$1.00	$0.100
Polyester, Thermosetting	20**	$1.000	$0.050

*Expected life is determined as the anticipated time when chalking occurs to the point that the sign is unsightly.

**Weatherometer tests indicate that the PVF_2 air dry film may last ten (10) years or more, and the PVF_2 thermal film and thermosetting polyester may last thirty plus (30+) years or longer. Please note that the anticipated life of button copy reflectors is twenty (20) years plus. The above projections are based on 1200 hours of weatherometer exposure are equivalent to five years of actual field exposure.

All cost figures in the above table are based on quotes from producers, except that the three (3) sheeting costs are costs to the Department as of March 1986. Competition could and should shift the other cost data slightly one way or the other, depending on the quantity required on a project or group of projects let at the same time.

FIGURE 10: Two Thermosetting Polyester Coated Sign Panels that were placed on a contract installation in 1982.

Project objectives included finding a feasible and satisfactory method to refurbish existing deteriorated porcelain-enameled aluminum sign extrusions. A statewide survey was made. All of the major SDH&PT urban districts were contacted. It was found that all the urban districts had large stocks of deteriorated porcelain-enameled 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 mechanical and chemical cleaning and chemical etching methods were tried. Numerous background coatings were tried on these prepared panels. Acrylic cured alipathic urethane and GES-2c sign enamel produced satisfactory results on panels by abrading with coarse sand paper or steel wool. None of the other coatings, liquid or powder, produced satisfactory adhesion. Initial adhesion was achieved with thermosetting polyester when the original porcelain-enamel finish was completely removed by blasting. However, total delamination of the polyester coating was

experienced in six years when panels were exposed at Corpus Christi.

Even though many people involved in the projects did not believe that the coatings would succeed, Acrylic Cured Aliphatic Urethane and GES-2C Sign Enamel were tried. The deteriorated porcelain-enamel 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 ten (10) years of field service (Figure 11).

The porcelain-enameled sign panels do not severely deteriorate in arid climates. In the marine atmospheres of the coastal areas and the heavy industrial areas the porcelain-enameled sign panels deteriorate severely. District 24 (El Paso) has a arid atmosphere. Therefore, the porcelain-enameled signs in District 24 experience only mild deterioration. District 24 refurbished deteriorated porcelain-enameled signs in their sign shop by removing the text, washing the panels, applying a powdered chlorinated cleaner and scouring with a floor buffer. The panels were then rinsed, new text applied and then the completed sign panel was returned to service on the roadway (See Appendix D).

Sign Panel Refurbished Using Acrylic Cured Aliphatic Urethane after 10 Years Field Service

Sign Refurbished with GES-2C Sign Enamel after 10 Years Field Service

FIGURE 11: Refurbished Sign Panels

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 but rigid aluminum 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 preapplied reflective sheeting on the thin rigid aluminum overlay sheets. Five panels in Houston were refurbished using the thin (0.040" thickness) rigid aluminum overlay sheets. The sheets were precoated with high specific intensity sheeting. Two of the sign panels suffered severe delamination of the reflective sheeting from the aluminum overlay sheets. This delamination occurred after three (3) years of field service. These sign overlays were replaced by the manufacturer. It was at first believed that the delamination was caused by improper preparation of the aluminum overlay sheets prior to application of the reflective sheeting. The two replacement signs and one of the other original signs have suffered severe delamination of the reflective sheeting from the overlay sheets. The probable cause was the excessive thermal expansion and contraction stresses experienced by the large flat aluminum surfaces. However, improper preparation of the substrate may have been a contributing factor.

A thin flexible aluminum foil overlay was used on numerous overhead signs in San Antonio. The thin foil overlay also had high specific intensity reflective sheeting preapplied prior to the installation of the foil to the deteriorated sign panels. The foil overlays were applied in place, that is the sign panels remained on the overhead sign structures. This type of overlay produced excessive wrinkles and bubbles that were very detrimental to night time legibility. The foil overlays also delaminated from the sign panels. The manufacturer has

reworked the system and this type of overlay system is still being evaluated.

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 pressure sensitive 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 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 manufacturer's 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 sheet. This type of refurbishing can be easily done in the departmental sign shops. This is a relatively inexpensive method of refurbishing deteriorated signs.

Again contrary to manufacturer's warnings, many full size sign panels were made by applying high specific intensity reflective sheeting on to plastic faced plywood. These signs were primarily used in detouring of traffic through highway construction zones. The manufacturer stated that the signs would not last over two (2) years. The panels have been used for eight (8) years on numerous projects with many text and location changes and are still in use. However, they are now really reaching end of useful life. Large monetary savings were realized through the reuse of these plywood panels. Also two full size signs

FIGURE 12: Refurbished Sign Panels using High Specific Intensity Reflective Sheeting Applied Directly to the Aluminum Extrusions after 5 Years of service -Good Condition.

were fabricated in the Corpus Christi sign shop utilizing High Density plastic faced plywood as substrate and high specific intensity sheeting as the sign face. One of the signs utilized button removable copy and the other, high specific intensity stick-on copy. Both signs are performing satisfactorily after 10 years.

Caution must be used in the application of some opaque coatings on the plastic faced plywood panels. The release agent used to extract the plywood panel from the press after the application of the plastic face caused severe delamination of some of the opaque coatings.

Investigation and/or testing of all available types of sign substrates were made during the course of both projects. The primary method of the substrate testing was by making full size panels using the various substrates. Some of the substrates were covered with several different coatings and sheetings.

Aluminum honeycomb with its sandwich type of construction proved to be highly susceptable to delamination due to thermal expansion and contraction stresses. This type of construction also produced internal corrosion problems due to the adhesives used to glue the different sandwich elements into a complete unit. This type of substrate has been removed from use in Texas.

Aluminum flat sheet construction as a guide sign background substrate was also investigated and ruled out. This type of construction also produced irregular, buckled and delaminated panels due to the same thermal stresses. Reflective sheeting also delaminated due to the movement of the flat surface.

Aluminum extrusions using alloy 6061-T6 proved to be one of the best substrates for guide sign construction. Care must be exercised not to allow several of the other alloys available in extrusions. Several of the alloys produces poor

adhesion of the background coating materials. One of the prime causes of coating delamination is the fact that some of the alloys contain too much silica for proper coating adhesion.

Various plywood substrates were tried. The best overall plywood substrate presently available is High Density Plywood Type "A". This plywood has pressure and heat factory applied plastic faces to which the coating or sheeting was applied. It was learned, the hard way, not to seal all the edges. The bottom panel edges should be left unsealed. Sealing of all edges traps moisture in the core. The total sealing does not allow the plywood to breathe and thus causes accelerated core rot.

Several plastic substrates were tried as basic substrates and as overlays. Clear and opaque sheets of polycarbonate were tried. The plastic face sheets exhibited numerous types of failures such as cracking, crazing and brittleness and were abandoned. Several types and thicknesses of fiberglass panels were and are being tried. These tests are incomplete. Work in this material area is still continuing. However, at this time the possible use of this material does not look promising.

Guide sign panels utilizing steel sheets produced many undesirable problems not the least of which was rust. Because of the problems this type of material was removed from consideration.

Consideration should be given to the use of aluminum extrusions in the fabrication of ground mounted guide signs. It should be noted that the aluminum substrate is more durable than the plywood substrate. Although the initial construction costs might be slightly higher, this type of material would produce longer sign life and reduce maintenance costs. Remember the extrusions could be

recoated when the reflective sheeting reaches end of life.

Ground mounted guide signs 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 ground mounted guide signs. This application of normally considered scrap materials could produce large savings of maintenance funds.

Under both projects of seventy four (74) materials have been studied. Under Project 1-18-75-222, while also working on sign lights and sign functionality, forty two (42) coatings and substrates were studied from 1975 through 1983. In the last two (2) years under this project thirty two (32) additional coatings, sheetings and substrates have been evaluated and/or tested. Some are still being tested.

Even though this project has been terminated, numerous tests of materials that were started under this project and Project 1-18-75-222 will be completed. Reports of the test findings will be prepared and published as Special Study (SS) Reports.

As technology advances and new materials become available, the new materials will be tested under specifications developed under this project and 222. The tests will be carried out under normal work procedures. These test results will also be written and reported as SS reports.

APPENDIX A

EXPERIMENTAL SIGN BACKGROUND COATINGS

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

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-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 DIREC-TION	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 1¼ 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 1½ 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 B

CURRENT SIGN BACKGROUND

AND

BACKGROUND COATING SPECIFICATIONS

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-7100
Plywood Sign Blanks

I. Description: This specification shall govern for the furnishing of plywood panels for signs .

II. Materials: Plywood for highway signs shall be of a smooth, weather-resistant material and 4 feet by 8 feet or smaller and shall be of one piece construction free of either scarf or butt joints. Plywood shall meet the following requirements and shall bear legible grade-markings of the American Plywood Association (APA) or the Canadian Council of Forest Industries (COFI).

A. Color: Natural or color approved by the Engineer.

B. Plywood:
1. Classification: Group 1 Species.
2. Grade: Exterior.
3. Face Veneers: B-B or Better.
4. Inner Plys: B or C (Plugged) Jointed Core.
5. Veneer Defects, Permits and Bonding: Defects in Veneer, Permits and Bond of Veneers shall be in accordance with the latest revision of U. S. Product Standard PS-1 or Canadian Standard 0121.
6. Core Gaps: Gaps between adjacent pieces of core shall not exceed 3/8 inch and the average of all gaps occurring in a panel shall not exceed 3/16 inch. Core gaps and edge splits per 8 feet of crossband layer shall not exceed four in number.

C. Overlay Sheet:
1. Density: Unless otherwise specified, the overlay sheets on both sides of the plywood panel shall be high density. When permitted by the plans or specifications, the plywood panel overlay on one side shall be high density sheet and the opposite side may be medium density sheet. High or medium density overlay sheets shall meet the requirements of the latest revision of U. S. Product Standard PS-1 or Canadian Standard 0121.
2. Finish: The sheets shall present a finished surface that is hard, smooth, unbroken, and of such character that further finishing by paint or varnish is not required.

D. Complete Panel:
1. Flatness: Plywood for sign panels shall not deviate from a plane surface by more than two inches at any point.
2. Defects: All panels shall be free of dents, bruises, scratches, veneer, or overlay delaminations, paint stains, or other damage which would interfere with its use in sign construction.

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

Departmental Materials Specification: D-9-7110
Aluminum Sign Blanks

I. Description: This specification shall govern for the furnishing of aluminum substrates for signs including aluminum sheet or coil and extruded sign panels.

II. Materials: The materials listed below shall conform to the specifications shown unless otherwise specified by the Engineer.

A. Aluminum sheet or coil shall conform to the requirements of ASTM B209, Alloys 6061-T6 or 5052-H38. Sign blanks made from sheet or coil shall be free of buckles, warps, dents, cockles, burrs, and other defects and shall be essentially a plan surface. The backs of aluminum sign blanks fabricated from sheet or coil shall be treated with a proprietary chemical process such as Alodine 1200, Iridite 14, Bonderite 710 or Lyfanite in accordance with the manufacturer's instructions and recommendations. The coating shall be light colored, tight and free from powdery residues.

B. Aluminum extrusions (Aluminum Signs Type O) shall conform to ASTM B221, Alloys 6061 or 6063, T4 or T6 Temper.

C. Aluminum extrusions (RR Crossbuck Sign Panels) shall conform to ASTM B221, Alloys 6061-T6 or 6063-T6.

III. Documents: The supplier of aluminum sheet, coil, and extrusions shall furnish mill test reports from the manufacturer of the materials which reflect the chemical and physical properties of the aluminum.

IV. 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 fabrication of products for the Department will be paid for in accordance with the governing specifications for the products in which these materials are used.

ITEM 642

ALUMINUM SIGNS (Type O)

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 in a "continuous or batch" over 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 O) 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 Sings (Type O) shall be made at the unit price bid per square foot for "Aluminum Signs (Type O) which price shall be full compensation for furnishing sing 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-9-8500
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 materials 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 provision 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 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 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 materials 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 polyvinylflouride film bonded to the substrate surface with adhesive(s) approved by the polyvinylflouride film manufacturer.

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

3. Class C - Class C non-reflective background coating shall be a thermosetting polyester powder coating.

4. Class D - Class D non-reflective background coating shall be a thermosettring polyvinylidene coating applied over a primer recommended by the manufacturer of the polyvinylidene coatings.

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	1.0 min.
B	3.0 min.
C	4.0 to 12.0
D	1.0 min.*

* Film thickness of Class D 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 daycolor, 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

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 require-

ments 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 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 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 x 2 inch x 8 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. Durablity:

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	W-O-M	2000 hours
except orange)	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	0.300	40 Minimum
	0.290	0.320	Types A,B,D
	0.360	0.360	and F
	0.340	0.380	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 weather-ometer 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 overlay 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 minimum values:

Entrance Angle Degrees	Divergence Angle Degrees	Specific Intensity Cp./Sq. Foot/Foot-Can
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.

APPENDIX C

ADMINISTRATIVE CIRCULAR NO. 50-83

Use of High Specific Intensity Type Reflective Sheeting on Construction Projects

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

M. G. Goode
Engineer-Director

DISTRIBUTION:
District Engineers
Engineer-Manager
Division Heads
Resident Engineers

APPENDIX D

REVISING TEXT ON EXISTING OVERHEAD SIGNS

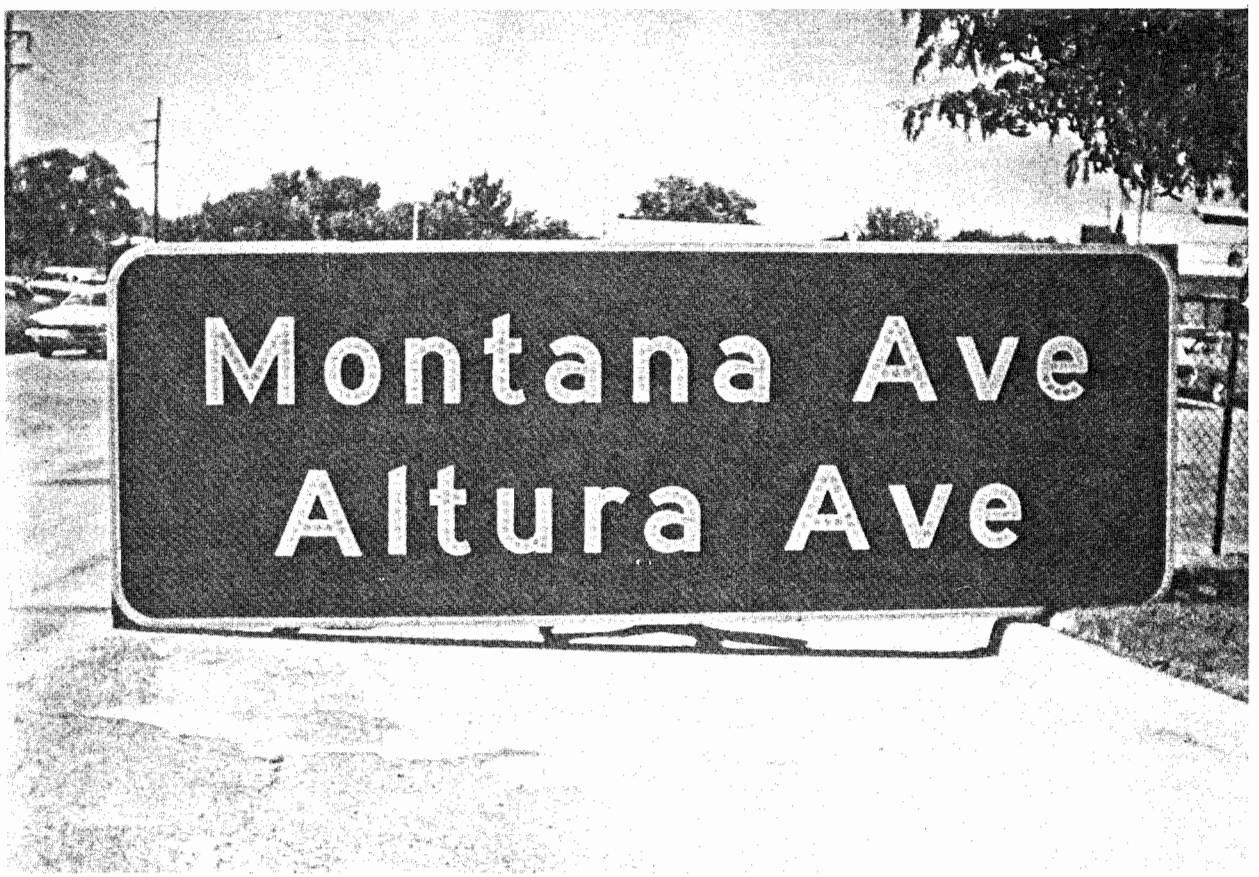
(Porcelain Enameled)

REVISING TEXT ON EXISTING OVERHEAD SIGNS

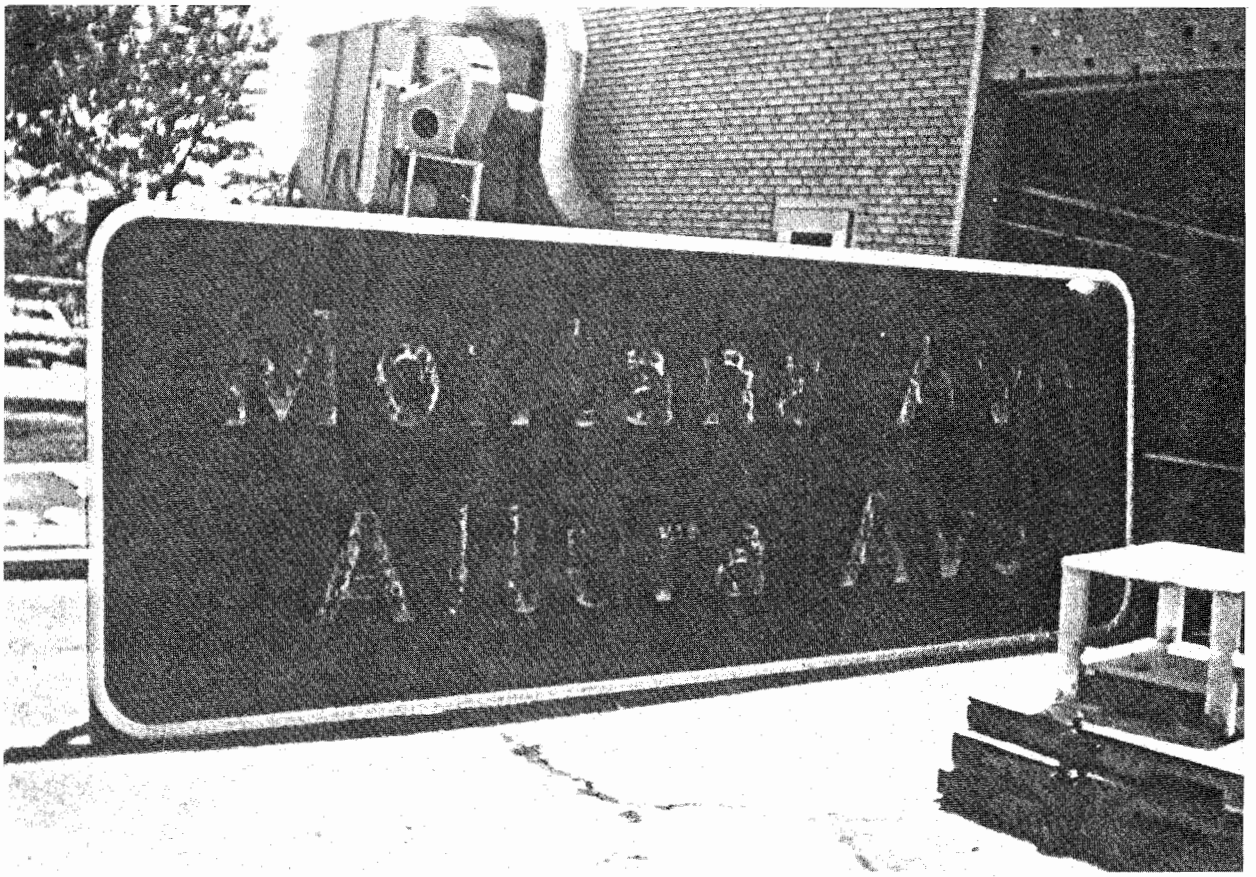
BY

MANUEL F. AGUILERA
SR. TRAFFIC ENGINEER
DISTRICT 24

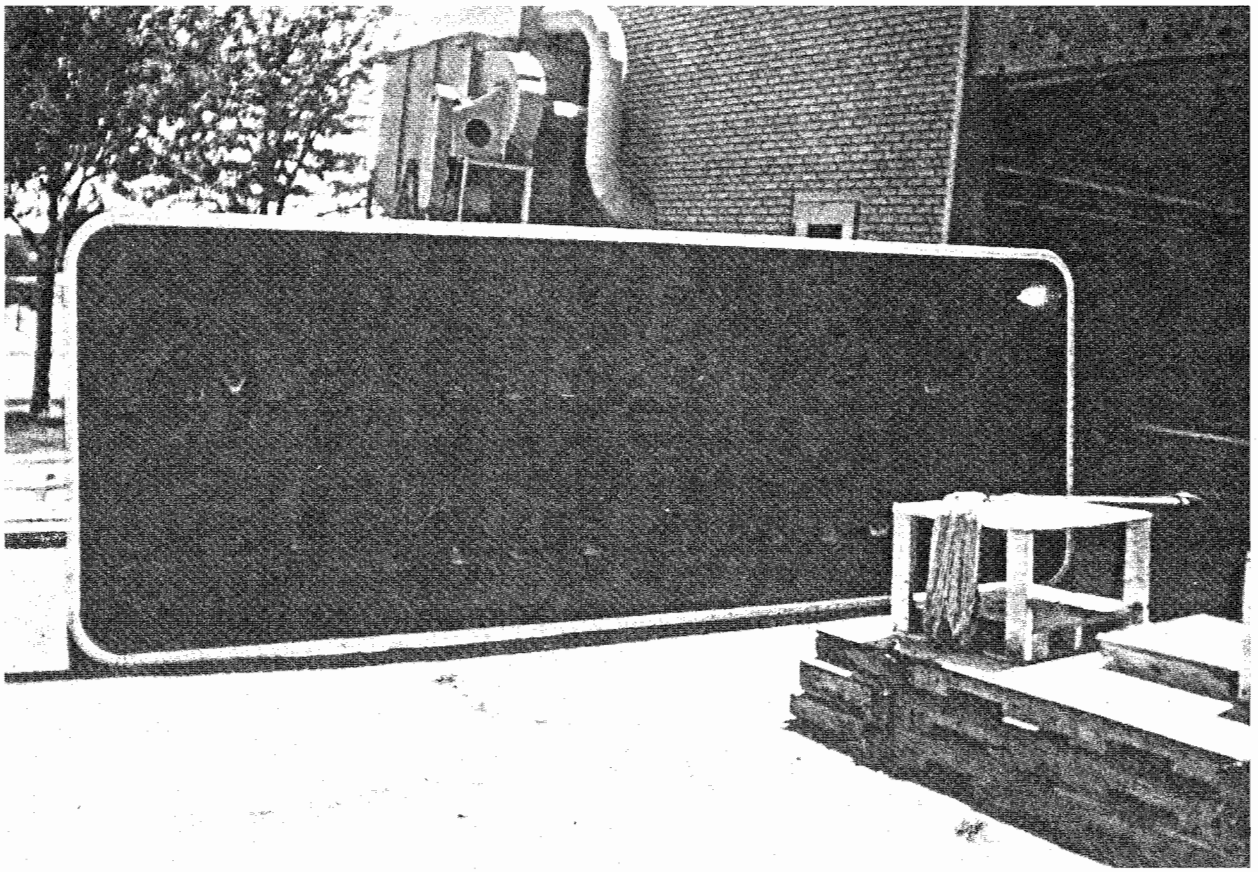
District 24 recently had a need to revise the text on twenty overhead sign bridge signs. Several alternatives were considered, such as fabricating new signs, overlaying with a thin material, repainting, or washing the panels with a porcelain cleaner. The following series of photographs show the results 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.



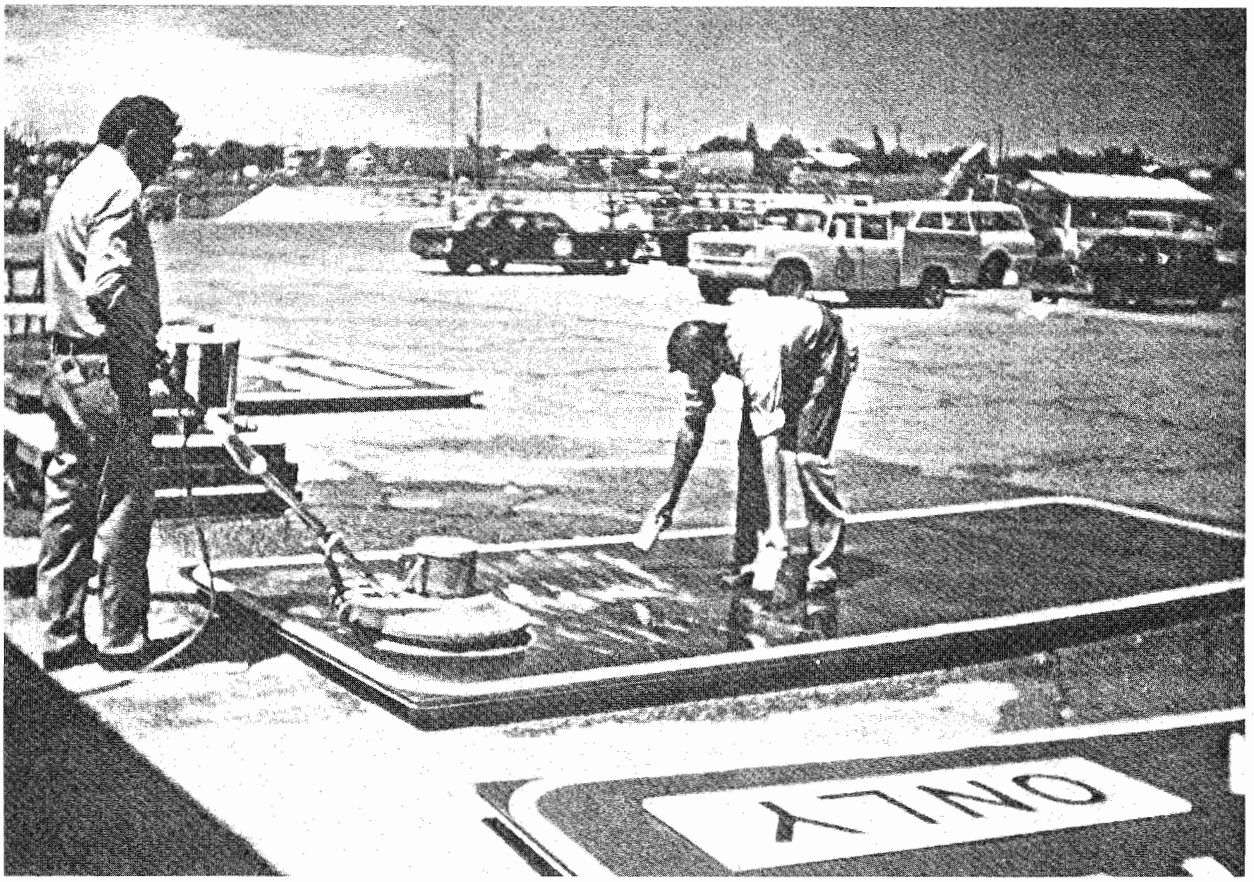
Sign as removed from sign bridge
with original text.



Sign with text removed.

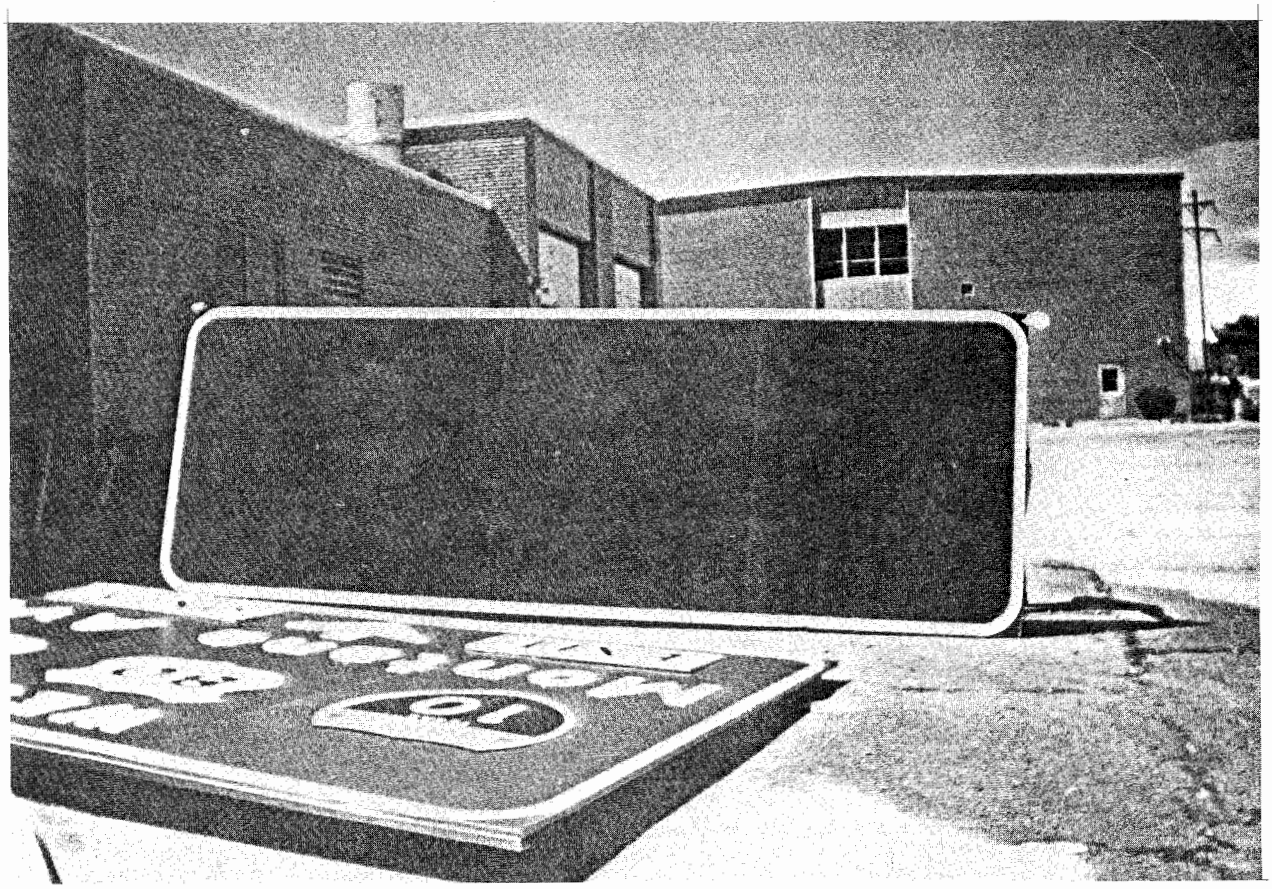


Sign blank washed with soap
and water.

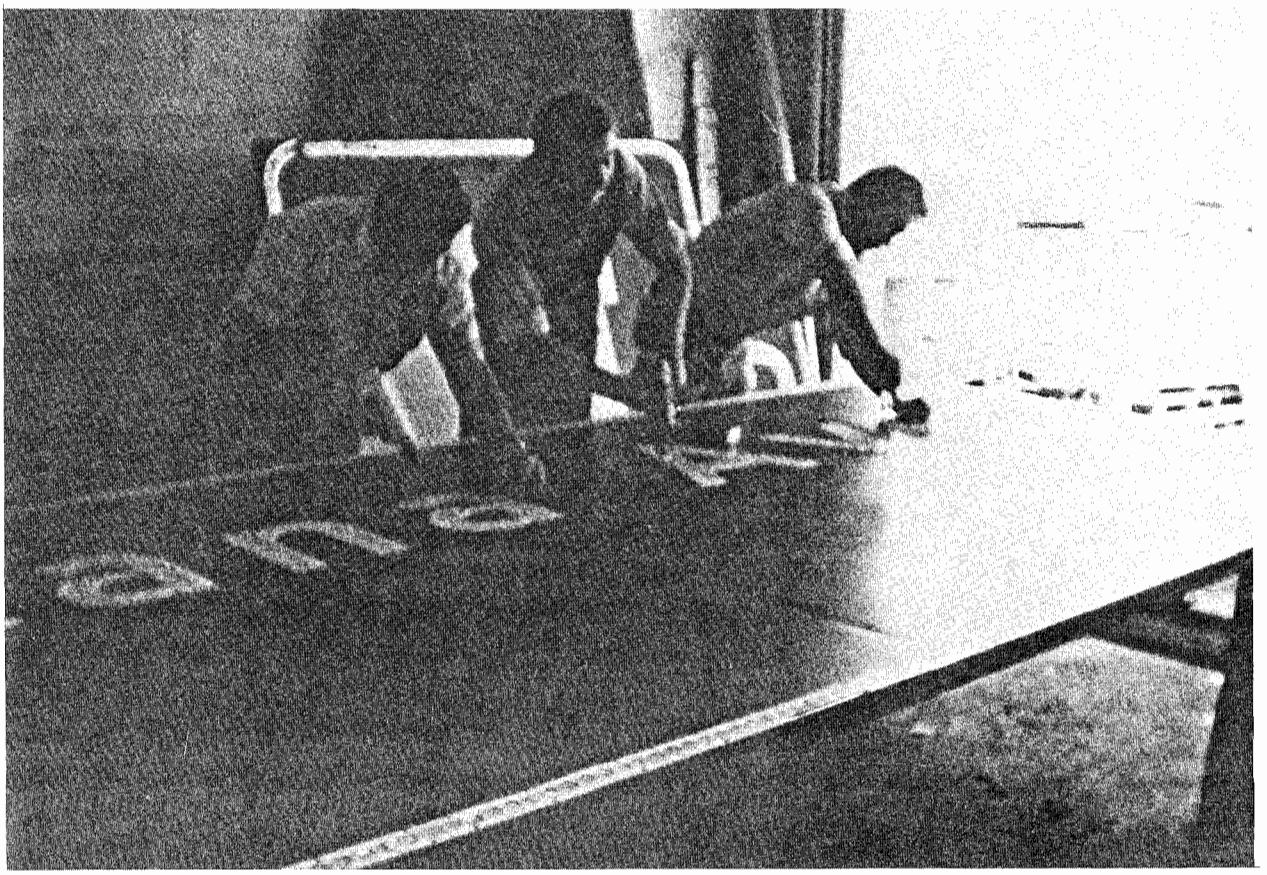


Sign blank scrubbed with floor polisher and powdered chlorinated cleaner.

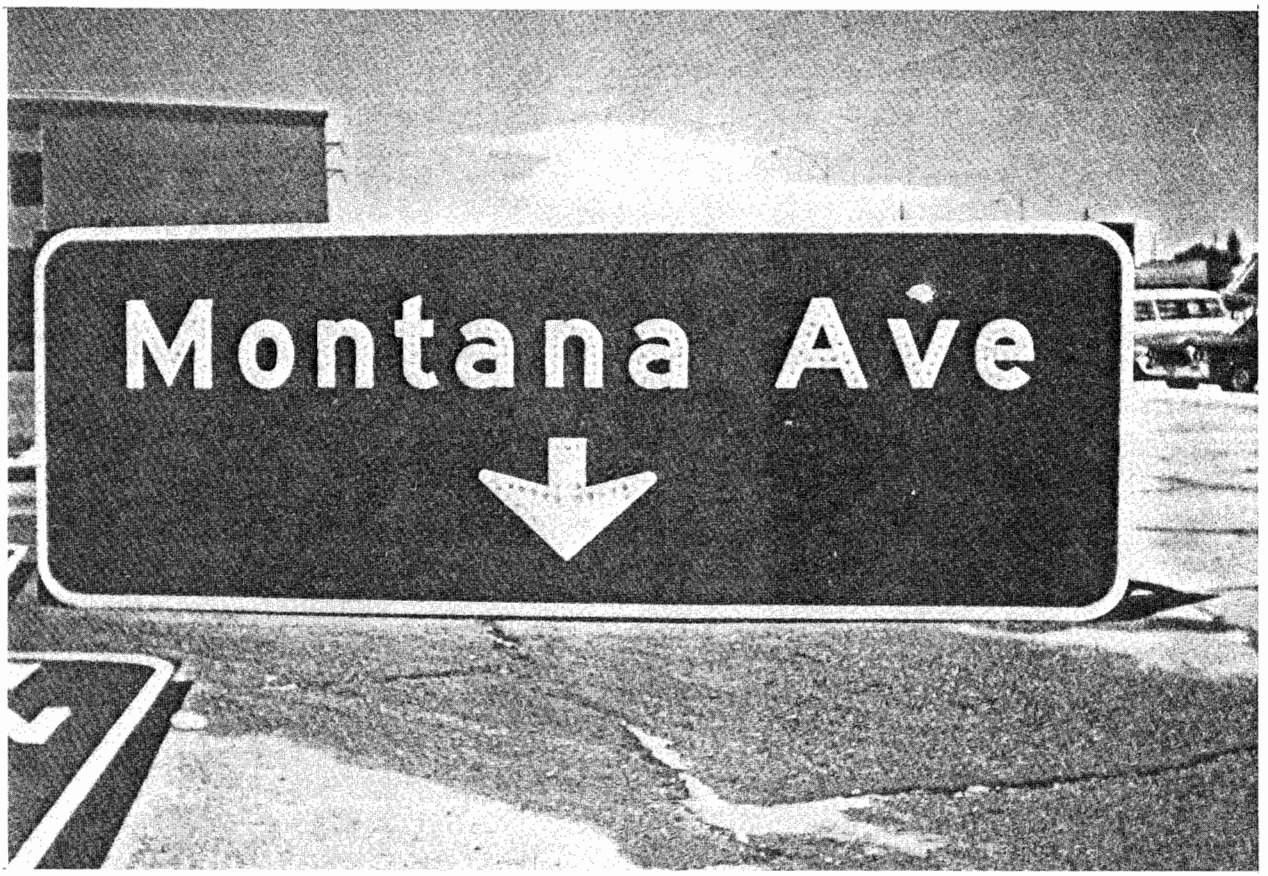
Sign blank rinsed and mopped dry.



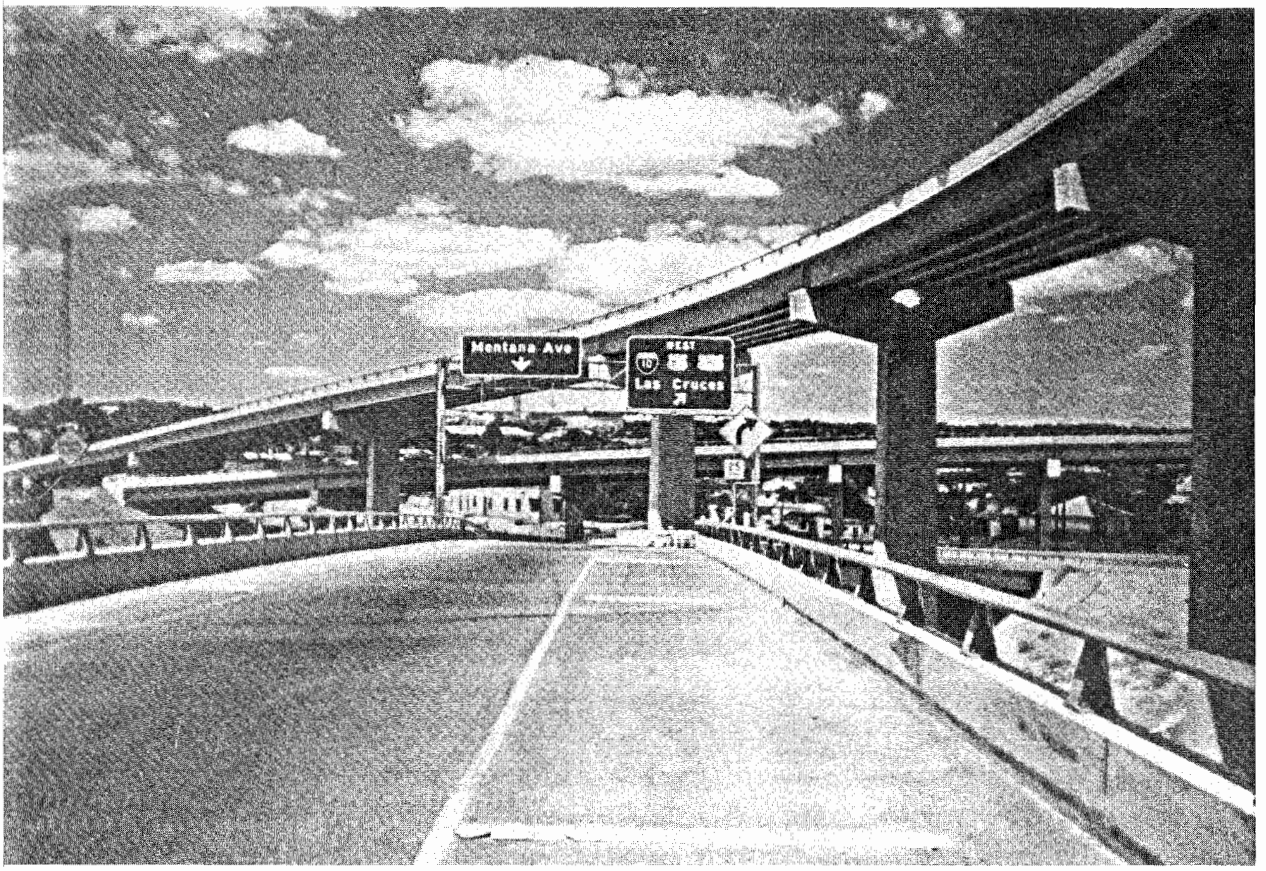
Sign blank after drying.



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. Out 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 E

BIBLIOGRAPHY

1. Pennwalt Corporation Technical Service Laboratory, Plastics Department, Final Report, KYNAR 500/Scotchlite Sign Material, TSR #1261, Written by Louis Micer, Tested by Louis Micer, 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 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 Columbus, 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. "A Limited Evaluation of Reflective and Non-Reflective Background for Overhead Signs"; FHWA-PA-78-19, Sept. 1978.

17. "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).

18. "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.

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

20. "Comparison Study of 3-M-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

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

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

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

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

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

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

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

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

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

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

31. "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.

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

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

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