# A DURABLE REFLECTIVE SIGN SYSTEM FOR LOW-VOLUME ROADS

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Some reflective signs on National Forest land are subjected to extreme temperatures and snow burial. Field units noted the reflective sheeting peeling from these signs after only one winter. In 1972 the Forest Service Missoula Equipment Development Center (MEDC) began testing outdoor signs of various substrates, reflective sheeting, application techniques, and clear coatings. The goal was to find the right combination of materials and manufacturing processes to produce a reflective sign that would remain maintenance-free for 7 years. The 3M Co. agreed to take part in the testing. After five winters of outdoor exposure, several combinations of substrate, reflective sheeting, application techniques, edge seal, and clear coatings were rated free of structural failure that would require maintenance. It was recommended that outdoor reflective signs for Forest Service use be manufactured as follows: (1) Engineering-grade sheeting and letters with heat-activated adhesive (HA) on aluminum substrate--cycled twice through the heat vacuum applicator and clear coated. (2) Engineering-grade sheeting (HA) and pressure-sensitive (PS) or HA letters on high-density overlay (HDO) plywood substrate--cycled twice through the heat vacuum applicator. When PS letters are used, the sheeting is cycled through the heat vacuum applicator once before applying the message and once after. (3) High-intensity sheeting (PS) with heat-activated letters on HDO plywood substrate--cycled once through the heat vacuum applicator. Signs are equally durable with silk-screened letters. The top edges of all signs are protected with Scotchcal brand transparent film.

## Acknowledgments

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## Field Evaluation

Reflective signs have been installed on National Forest land to conform with the Manual on Uniform Traffic Control Devices and the Highway Safety Act of 1966. When installation began on a broad scale, field units noted the reflective sheeting peeling along the edges after as little as one winter. This deterioration appeared to be more common at higher elevations, but also occurred at lower sites when signs were subjected to extreme temperature change, snow burial, ultraviolet rays, or all three.

Investigation by the Forest Service Missoula Equipment Development Center (MEDC) revealed that snow burial, extreme temperature change, and ultraviolet rays combine to destroy reflective signing in three basic ways:

1. Peeling of the legend (message) from the background sheeting.
2. Peeling of the reflective sheeting from the substrate (base material).
3. Separating (delaminating) of the layers that make up the reflective sheeting and legend. The first evidence of this type of failure is crazing of the reflective material--minute cracks that cause peeling or delamination if cracks become large enough.

It was important to find a solution to the deterioration for two reasons:

1. Reflectorized signs were adopted to increase traffic safety, because they communicate clearly to a driver day or night; peeling and delamination destroy the reflectorized sheeting, making the sign less effective.
2. Reflectorized signs are expensive --about $8.50 a square foot on the average--and maintenance or replacement due to premature failures is extremely costly.

MEDC began a project in 1972 to outdoor test signs manufactured of various combinations of substrates, reflective sheeting materials, application techniques, and clear coatings. The goal was to find the right combination of materials and manufacturing techniques to give Forest Service units a rugged reflective sign that would remain in service 7 years without maintenance.

The Forest Service was not the only agency experiencing problems with reflectorized signs. The Federal Highway Administration, Bureau of Land Management, National Park Service, Federal Prison Industries, Inc., and various transportation departments at the State and county level were concerned and asked to participate as observers in the outdoor tests. The American Plywood Association was also interested in the tests and asked to participate.

The 3M Co., manufacturer of much reflective sheeting in Forest Service signs, agreed to take an active part in the testing; and an agreement was entered into regarding the responsibilities of both the Forest Service and 3M. In 1976 two other major reflective sheeting manufacturers, Avery International and Mitsubishi/ Seibu International, entered into similar cooperative agreements to test samples of their reflective materials.

In 1977 a cooperative agreement was also completed with Finnish Plywood Association USA to evaluate the durability of the products of the three sheeting manufacturers on Finnish birch plywood overlayed with phenolic resin. Reflexite Corp. will enter testing in the summer of 1979.

This paper is divided into two parts. Part I describes the testing of 3M Co. products over the past five winters and makes specific recommendations for manufacturing signs with 3M products. Part II discusses Avery and Mitsubishi/Seibu materials, which have undergone outdoor testing for 2 years.

## Part I--3M Co.

### Test Objective

The objective is to test and evaluate as many different materials combinations as practical with accepted manufacturing processes, to provide information needed to produce a durable sign that will remain in service for 7 years without maintenance.

### Test Plan

In the fall of 1972, 3M Co. representatives and MEDC personnel met to design a cooperative test plan. At this meeting, guidelines for selecting sign materials, manufacturing processes, and testing methods were agreed upon. Test sites also were selected based on snowfall, extreme temperature change, and exposure to ultraviolet rays. Sites chosen were Hopewell Lake, N. Mex.--elevation, 3048 m (10,000 ft); Donner Summit, Calif.-elevation, 2134 m (7,000 ft); Mount Adams, Wash.--elevation, 1402 m (4,600 ft).

Test Sign Materials and Manufacturing. 3M and MEDC selected 50 different combinations of background sheeting, application techniques, top edge treatments, and clear coatings for initial testing. Aluminum and HDO (high-density overlay) plywood, the two basic sign substrates, were used for test signs.

The 3M Co. reflective background sheeting was engineering-grade brown with heat-activated adhesive; high-intensity green with heat-activated adhesive; engineering-grade brown with pressure-sensitive adhesive; high-intensity green with pressure-sensitive adhesive. Letters were high-intensity silver with heat-activated adhesive; engineering-grade silver with pressure-sensitive adhesive; and Control-Tac engineering-grade silver. Some letters were silk screened on the reflective sheeting.

To simulate the legend (message), the letters "E," "O," and "N" were selected because they represented the geometrical shapes found in the alphabet.

It was agreed that test signs would be produced by an impartial independent contractor. 3M would negotiate a contract with the sign manufacturer, provide all materials, and pay manufacturing costs. It was important that the sign contractor be willing to have 3M and MEDC representatives monitor the entire manufacturing process and provide technical advice. Ojo Caliente Craftsmen Cooperative, Ojo Caliente, N. Mex., was selected to produce the signs. This firm had worked closely with the Forest Service on other sign testing projects.

Evaluation of Test Signs. The Forest Service and 3M agreed on this system for evaluating test signs:

1. E--Excellent to good durability with no structural failures that would require maintenance (fig. 1).
2. L--Legible; sign message legible but maintenance would be required to prevent deterioration and for esthetic purposes (fig. 2).
3. NL--Not Legible; message unreadable, requiring immediate replacement or complete repair (fig. 3).

Figure 1. Test sign shows no structural failure that would require maintenance.


Figure 2. Test sign message is legible but maintenance would be required for esthetic purposes and to prevent further deterioration.

Figure 3. Test sign message is becoming unreadable and sign requires immediate replacement or repair.


These definitions of sign failure also were agreed to:

1. Peeling--Results when sheeting peels from the substrate; in the case of sign legend (message), when letters peel from background sheeting.
2. Delamination--Separation within the reflective sheeting.
3. Crazing--Fine cracks within the reflective sheeting. If cracks become large enough to break surface coating, peeling or delamination results.

Evaluations were to be performed as early as possible each spring by technical representatives from 3M and MEDC. Each sample would be photographed and evaluated; any difference of opinion between 3M and MEDC personnel would be settled at the test site, with MEDC reserving the right to make the final recommendation for reporting purposes. Signs that failed and would provide no further information would be removed from the test by MEDC.

Minimum critera for a sign combination to be considered successful were agreed upon: five of the six signs in the combination (two installed at each test site) would have to be rated "E" and the remaining one rated at least "L."

## Outdoor Weathering Tests

Some 300 test signs were manufactured in October 1972, using the 50 different materials combinations and application techniques (tables 1-3). One hundred signs each were installed at the California and Washington test sites in December 1972. Severe weather delayed the installation of the last 100 signs at the Hopewell Lake, N. Mex., site until April 1973.

All test signs measured 20 by 35 cm (8 by 14 in). They were installed 46 to 61 cm (18 to 24 in) above ground on wood posts then transferred later to steel U-channel posts set in rows (fig. 4). Signs faced south for maximum ultraviolet exposure in summer.

In the fall of 1974 seven new sign combinations of HDO and MDO (medium density overlay) plywood and ABS (acrylonitrile butadiene styrene) plastic substrates were manufactured and installed at each test site (table 4). The MDO plywood and ABS substrates were selected to provide the Forest Service with weathering data on additional substrates

Table 1.-- Reflective signs of 3M Co. materials on aluminum substrate, placed at test sites, 1972-73.

| Sign No. | Reflective materials | | Edge treatment | | | | Clear coatings | | | | Heat application | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Legend[a] | Sheeting[a] | Corners and edges square | Film #639[b] | #700 clear[c] | #800 clear[c] | #700 legend only[c] | #800 legend only[c] | #700 complete sign[c] | #800 complete sign[c] | Normal application | Double cycles |
| 1F1 | 2270 | 2279 | x | | | | | | | | | x |
| 1F2 | 2270 | 2279 | x | x | | | x | | | | | x |
| 1F3 | 3270 | 2279 | x | | | | | | x | | x | |
| 1F4 | 3270 | 3279 | x | | | | x | | | | x | |
| 1F5 | 9270 | 3279 | x | x | | | | | | | x | |
| 1F6 | 9270 | 3279 | x | | | | | | x | | x | |
| 1F7 | Silk screen | 3870 | x | | | | | | | | x | |
| 1F8 | 3870 | 2877 | x | x | | | | | | | x | |
| 1F9 | 2870 | 2877 | x | | | x | | | | x | | x |
| 1F10 | 2870 | 3877 | x | | | | x | | | | x | |
| 1F11 | Silk screen | 3870 | x | x | | | | | | | x | |
| 1F12 | 3870 | 3877 | x | | | x | | | | x | x | |
| 1F13 | 2270 | 2279 | x | | x | | | | | | | x |
| 1F14 | 2270 | 3270 | x | | x | | x | | | | x | |
| 1F15 | 3870 | 3877 | x | | | | | | | | x | |
| 1F16 | 3870 | 3877 | x | | x | | | x | | | x | |

NOTE: • Numbers refer to 3M Co. product numbers.
• Background sheeting placed one-half inch below top edge of sign on Nos. 13, 14, 15, 16.

[a] The following reflective materials were used for letters and sheeting:

2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
2870 = heat-activated, high-intensity silver;
2877 = heat-activated, high-intensity green;
3270 = pressure-sensitive, engineering-grade, silver;
3279 = pressure-sensitive, engineering-grade brown;
3870 = pressure-sensitive, high-intensity silver;
3877 = pressure-sensitive, high-intensity green;
9270 = Control-Tac engineering-grade silver.

[b] Scotchcal brand transparent film (#639) placed along top edge of sign for added protection against delamination; on signs 1F14 and 1F16, film placed on all edges.

[c] Scotchlite brand process color, #700 series used as clears and edge sealers for engineering-grade sheeting; #800 series used as clears and edge sealers for high-intensity sheeting.

Table 2.--Reflective signs of 3M Co. (high-intensity sheeting) on HDO plywood substrate, placed at test sites, 1972-73.

| Sign No. | Reflective materials: Legend[a] | Reflective materials: Sheeting[a] | Edge treatment: Corners and edges square | Edge treatment: Corners and edges rounded | Edge treatment: Film #639[b] | Edge treatment: #4150[c] Clear | Edge treatment: Paint | Clear coatings: #800 legend only | Clear coatings: #830 complete sign | Clear coatings: #831 complete sign | Heat Application: Normal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2F1 | 3870 | 2877 | x | | | | | | | | x |
| 2F2 | 3870 | 2877 | x | | x | | | x | | | x |
| 2F3 | Silk screen | 2877 | x | | | x | | | | | x |
| 2F4 | 2870 | 2877 | x | | | | | x | x | | x |
| 2F5 | Silk screen | 2877 | | x | | | | | | | x |
| 2F6 | 2870 | 2877 | | x | | x | | x | | | x |
| 2F7 | 2870 | 2877 | | x | | | | | x | | x |
| 2F8 | 3870 | 3877 | x | | | | | x | | | |
| 2F9 | 3870 | 3877 | x | | x | | | | | | |
| 2F10 | 3870 | 3877 | x | | | x | | x | | | |
| 2F11 | 2870 | 3877 | x | | | | | | | x | |
| 2F12 | 2870 | 3877 | | x | | | | x | | | x |
| 2F13 | 2870 | 3877 | | x | | x | | | | | x |
| 2F14 | 2870 | 3877 | | x | | | | x | | x | x |
| 2F15 | 2870 | 3877 | | x | | | x | | | | x |
| 2F16 | 3870 | 2877 | | x | | | x | x | | | x |

NOTE: • Numbers refer to 3M Co. product numbers.

2F15 - All edges and back received one coat of brown long oil primer and one coat of Benjamin Moore Co.'s polysilicone enamel (brown) before sheeting and second coat of enamel after sheeting.

2F16 - All edges and back received one coat of short oil primer and one coat of Benjamin Moore Co.'s polysilicone enamel (brown) before sheeting and second coat of enamel after sheeting.

[a] 2870 = heat-activated, high-intensity silver;
2877 = heat-activated, high-intensity green;
3870 = pressure-sensitive, high-intensity silver;
3877 = pressure-sensitive, high-intensity green.

[b] Scotchcal brand transparent film (#639) placed along top edge of signs for added protection against delamination.

[c] Scotchlite brand process color, #4150 series clears used as edge treatment for high-intensity sheeting.

Table 3.--Reflective signs of 3M Co. materials (engineering-grade sheeting) on HDO plywood substrate, placed at test sites, 1972-73.

| Sign No. | Reflective materials: Legend[a] | Reflective materials: Sheeting[a] | Edge treatment: Corners and edges square | Edge treatment: Corners and edges rounded | Edge treatment: Film 639[b] | Edge treatment: #700 clear | Edge treatment: Painted[c] | Clear coatings: #700 legend only | Clear coatings: #700 complete sign | Heat application: Normal application | Heat application: Double cycle |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3F1 | 2270 | 2279 | x | | | | x | | | | x |
| 3F2 | 2270 | 2279 | x | | x | | | x | | | x |
| 3F3 | 2270 | 2279 | x | | | x | | | | | x |
| 3F4 | 3270 | 2279 | x | | | | | x | x | x | |
| 3F5 | 3270 | 2279 | x | | | | x | | | x | |
| 3F6 | 3270 | 2279 | | x | | | | x | | x | |
| 3F7 | 9270 | 2279 | | x | | x | | x | | x | |
| 3F8 | 9270 | 2279 | | x | | | | | x | x | |
| 3F9 | 9270 | 2279 | | x | | | x | x | | | x |
| 3F10 | 2270 | 3279 | x | | | | x | | | | x |
| 3F11 | 2270 | 3279 | x | | x | | | x | | | x |
| 3F12 | 2270 | 3279 | x | | | x | | | | x | |
| 3F13 | 3270 | 3279 | x | | | x | | | x | | |
| 3F14 | 3270 | 3279 | x | | | | x | | | | |
| 3F15 | 3270 | 3279 | | x | | | | | | | |
| 3F16 | 9270 | 3279 | | x | | x | | x | | | |
| 3F17 | 9270 | 3279 | | x | | | | | x | | |
| 3F18 | 9270 | 3279 | | x | | | x | | | | |

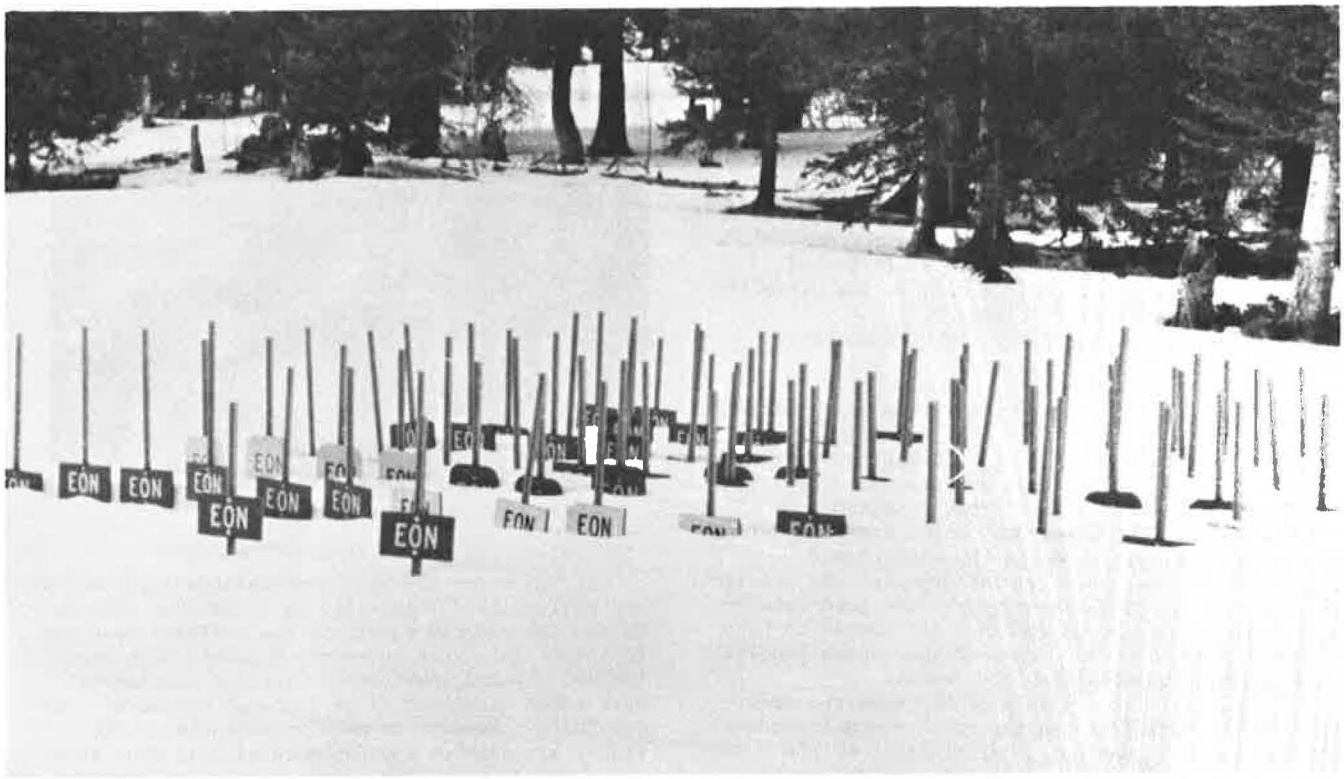
NOTE: Numbers refer to 3M Co. product numbers

[a] 2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
3270 = pressure-sensitive, engineering-grade silver;
3279 = pressure-sensitive, engineering-grade brown;
9270 = Control-Tac engineering-grade silver.

[b] Scotchcal brand transparent film (#639) placed along top edge of signs for added protection against delamination.

[c] 3F1 = Fuller Co. long oil base prime, 1 coat (4 ± 1/2 mil), then 4 coats Fuller oil base paint applied to edges and back of finished sign.
3F5 = Same as 3F1 except Benjamin Moore Co. short oil prime.
3F9 = Same as 3F1 except primer and 2 coats of paint before sheeting application; 2 coats after.
3F10 = Fuller Co. long oil base prime (1 coat) and Benjamin Moore Co. polysilicone enamel (brown) (4-1/2 ± 1/2 mil); 4 coats applied to edges and back of finished sign.
3F14 = Benjamin Moore Co. short oil base prime (1 coat) and polysilicone enamel (brown) (4-1/2 ± 1/2 mil); 4 coats applied to edges and back of finished sign.
3F18 = Benjamin Moore Co. short oil base prime (1 coat) and Fuller oil base paint (2 coats) before sheeting application; 2 coats after sheeting application.

Figure 4. 3M Company reflective signs undergoing outdoor exposure testing at Hopewell Lake, New Mexico, test site.




and manufacturing alternatives. One combination (4F3) had one letter coated with verathane; two combinations (4F6 and 4F7) had the top edge protected with two types of aluminum extrusions that were screwed to the sign. Sheeting for all combinations was applied with only a single cycle through the heat vacuum applicator, to determine the protective qualities of the verathane and the aluminum edging. The legend on all except 4F2 was hand applied.

In September 1977 12 new sign combinations using aluminum and HDO plywood were installed at the test sites to evaluate two new films (SJ8582X and SJ8583X) designed specifically to protect the top edge of a sign. Because the interest was in the bond between the substrate and the sheeting, no legends were put on the signs.

In the spring of 1978, 24 more combinations were installed to evaluate improved high-intensity and engineering-grade sheeting on aluminum and HDO substrates. Four combinations of 3M Co. materials on Finnish plywood were installed in 1977 and 1978.

## Test Results

The original 50 sign combinations were evaluated in 1974, 1975, 1976, and 1977. By 1977, only six combinations had weathered well enough to meet the minimum criteria of five signs rated "E," with the sixth sign rated at least "L" (fig. 5).

The six combinations were 1F2, 2F13, 3F2, 3F3, 3F10, and 3F11. 3F3 and 3F10 were then eliminated because they largely duplicated 3F2 and 3F11.

1F2 was the only successful combination that had an aluminum substrate (table 1). 2F13 was the only successful combination that had green high-intensity grade sheeting (fig. 6) (table 2). The remaining successful combinations (table 3) had brown engineering-grade sheeting, one with pressure-sensitive adhesives and one with heat-activated adhesives.

Figure 5. 3F11 test sign rated excellent after 6 years of outdoor exposure.


Figure 6. 2F13 was the only successful sign combination that had green high-intensity grade sheeting.

3F2 had Scotchcal brand transparent film (#639) on the top edge; the legend had been clear coated. 3F3 had been clear coated on the top edge. Analysis of other combinations indicated that the film was more effective than the clear coat in protecting the top edge of a sign. It was found that placing a coat of clear over heat-activated letters was unnecessary. 3F10 had the top edge simply painted, but this was found to be unsatisfactory in many other combinations.

The manufacturing variables--background sheeting, application techniques, edge seals, top edge treatment, clear coating--used in each of the four combinations were compared to identical variables in failed signs. In no case had these manufacturing variables been the cause of a sign failure.

Five years of outdoor testing also revealed these findings:

1. Peeling of background sheeting was generally more severe on aluminum than on plywood (fig. 7). Severe crazing occurred on high-intensity sheeting where clear coating had been applied.

2. The #639 film taped across the top edge of some test signs for added protection against peeling was deteriorating; it showed the most wear at Hopewell Lake where ultraviolet exposure was greatest. But the film continued to preserve the bond between the sheeting and the substrate. (It proved to have a useful life of 4 to 5 years--3 years when exposed to large amounts of ultraviolet rays.)

3. Placing the top edge of the sheeting down 1.27 cm (1/2 in) from the top on aluminum substrate did not prevent peeling or delamination of the sheeting. Of eight signs made this way for each test site, at Mount Adams, six were rated "L" and two were removed; at Hopewell Lake, four were rated "E" and four "L"; three were rated "E" and five "L" at Donner Summit.

4. Silk screened legends weathered well. There were no failures.

Figure 7. Background sheeting generally peeled more severely from aluminum than plywood.

Of the seven new sign combinations installed in the fall of 1974 (table 4), we found that legends on the ABS plastic substrate had suffered moderate to severe delamination at the Hopewell Lake site; the MDO plywood combinations (except one sample) were rated excellent after 3 years' exposure. The one failure appears to be more a result of the higher ultraviolet ray exposure at this test site. The plywood signs with aluminum over the top edge have not peeled at the top to date.

The samples with verathane over one letter have not failed in peeling, delamination, or crazing, but the letter is turning yellow after 3 years.

Samples installed in 1977 and 1978 do not have enough exposure to evaluate durability.

Table 4.--Reflective signs of 3M Co. materials, placed at test sites, 1974.

| Sign No. | Reflective Materials: Legend[a] | Reflective Materials: Sheeting[a] | Substrates: ABS Plastic | Substrates: MDO Plywood | Substrates: HDO Plywood | Edge Treatments: Corners & Edges Square | Edge Treatments: Corners & Edges Round | Edge Treatments: Flat Aluminum Over Top | Edge Treatments: Round Aluminum Over Top | Edge Treatments: Paint |
|---|---|---|---|---|---|---|---|---|---|---|
| 4F1 | 3270 | | X | | | | | | | |
| 4F2 | 2270 | | X | | | | | | | |
| 4F3 | 3270 | 2279 | | | X | | X | | | X |
| 4F4 | 3270 | 2279 | | X | | X | | | | X |
| 4F5 | 3270 | 2279 | | X | | X | | | | X |
| 4F6 | 3270 | 2270 | | | X | | X | X | | X |
| 4F7 | 3270 | 2279 | | | X | | X | | X | X |

Note: Numbers refer to 3M Co. product numbers.

4F3 - Short oil base primer; Fuller oil base paint (4-½ ± ½ mil.) on edges and back; one letter coated with Verathane.

4F4 - All edges and back received five coats (4½ mils.) of Benjamin Moore Co.'s. polysilicone enamel (brown) before reflective materials applied.

4F5 - Same as 4F4 except enamel added after reflective materials applied.

4F6 - Short oil base primer, Fuller oil base paint (4½ ± ½ mil.).

4F7 - Same as 4F6 except for difference of alluminum top edge.

Two samples of 4F1, 4F2, 4F3, 4F6, and 4F7 were put at each test site; three samples of 4F4 and 4F5 were put at each site.

[a] 2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
3270 = pressure-sensitive, engineering-grade silver.

## Discussion

Test findings indicate that the service life of reflective signs can be extended, using specific combinations of materials and manufacturing processes.

Based on 5 years of experience, the test procedure adopted appears to be effective in isolating premature failures. Its primary value is in testing products under real-use conditions, which cannot be simulated in the laboratory with today's technology.

In addition to rating each sign, careful examination was made of other features and notes were taken to document findings. Failures were examined in an attempt to correlate them with the unique materials combinations and manufacturing process.

One observation was that the life of plywood veneers are extended by using plywood substrates with rounded edges and painting them with polysilicone paint; the paint does not protect the top edge of reflective sheeting, however.

Another observation was that few of the edge seals prevented moisture from entering the plywood for the 5-year observation period. Paint over a short oil base primer peeled in 2 years; over a long oil base primer, in 5 years. Three clears were used to seal the plywood edge: #700, #800, and #4150. Plywood veneers treated with these were checking and cracking within 2 years.

From these observations, and from observing signs produced according to Southwestern Region specifications, it can be shown that four coats of Benjamin Moore polysilicone paint without any primer will protect plywood edges from moisture for more than 5 years. The edges must also be rounded to help reduce the stresses in the paint film.

## Conclusions

1. Specific combinations of substrates, reflective sheeting, top edge treatments, applications techniques, and clear coatings are available to substantially increase the service life of reflective signs. Four sign combinations met the desired criteria and should have a service life comparable to test goals.
2. Bonding the sheeting 1.3 cm (1/2 in) below the top of aluminum sheeting does not improve longevity.
3. MDO plywood looks like a promising substrate material, but additional exposure is needed before it should be adopted for use.
4. Improvements are needed before ABS plastics can be adopted for use.
5. An aluminum extrusion placed over the top edge of a sign appears to increase longevity. It is extremely costly and was made a part of the testing only to gain data on a method of sign protection that might be resorted to in the most extreme outdoor conditions when all other sign combinations had failed.
6. The Scotchcal brand sprint film (#639) is durable and can be used effectively but an ultraviolet inhibitor is needed to extend service life to 7 years.
7. Silk screened letters are durable. They can be considered an alternative to letters of reflective sheeting. Sheeting manufacturers' recommendations must be followed when applying the ink.
8. If a verathane coating over letters is durable, an ultraviolet inhibitor will need to be added to the verathane.
9. Although the bond between paint and sheeting is not adequate, the top edge bond is protected with #639 film.
10. Plywood edges should be rounded and painted to insure that moisture does not get into the sign so that checking and cracking of veneers can be avoided. Benjamin Moore polysilicone paint without primer will protect edges from moisture for more than 5 years.

## Recommendations

The recommendations that follow are based on 5 years of outdoor testing. Manufacturing and maintenance costs were considered during testing and are reflected in the recommendations. For example, black HDO, which is impervious to moisture is recommended, reducing maintenance costs; the optional use of group 1 B grade veneers on both sides of the substrate, instead of exterior-marine grade, to lower cost; and the elimination of a special primer for the edge paint.

1. It is recommended that outdoor reflective signs for Forest Service use be manufactured with these combinations of materials and processes (they are recommended equally, and their order of presentation has nc significance):

### Reflective Sign of Aluminum

Substrate: No. 6061-T6 plate stock conforming to ASTM Standard B209.

Background Sheeting: 3M Co.'s engineering-grade brown with heat-activated adhesives (#2279).

Legend: 3M Co.'s engineering-grade silver with heat-activated adhesive (#2270) or silk screened.

Manufacturing Process: (1) Double cycle through heat vacuum applicator. (2) Coat the legend with 3M Co.'s Scotchlite brand process color (#700) clear (follow instructions on container). Clear coating not required for silk-screen legend.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection, 7.6-cm-wide (3 in) film is recommended. For ease of handling and cleanliness, it should be applied in 61-cm-long (24 in) strip. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of sign 5 or more cm (2 in). The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

### Reflective Sign of HDO (High-Density) Overlay Plywood and High-Intensity Sheeting

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74; or all Douglas-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G 1 EXT PS 1-74, 5-ply, 1.3 cm (1/2 in); or 7-ply, 1.9 cm (3/4 in). (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: 3M Co.'s high-intensity green with pressure-sensitive adhesive (#3877).

Legend: 3M Co.'s high-intensity silver with heat-activated adhesive (#2870) or silk screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of .24 cm (3/32 in); round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rag. (5) Before sheeting,

apply two coats of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply two more coats of enamel after sheeting has been applied to substrate. (8) Apply legend and cycle once through heat vacuum applicator. Do not apply clears.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of 1.9 cm (3/4 in) plywood, 7.6 cm-wide (3 in) film is recommended. For ease of handling and cleanliness, apply in 61 centimeter-long (24 in) strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 5 cm (2 in). The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Reflective Sign of HDO Plywood and Engineering-Grade Sheeting

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74; or all Douglas-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G 1 EXT PS 1-74, 5-ply, 1.3 cm (1/2 in); or 7-ply, 1.9 cm (3/4 in). (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: 3M Co.'s engineering-grade brown with heat-activated adhesives (#2279).

Legend: 3M Co.'s engineering-grade silver with heat-activated adhesives (#2270); or 3M Co.'s engineering-grade silver with pressure-sensitive adhesives (#2270); or silk-screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of .24 cm (3/32 in); round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rag. (5) Before sheeting, apply two coats of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply two more coats of enamel to edges after sheeting has been applied to substrate. (8) Apply legend. If using heat-activated letters, cycle sign twice through the heat vacuum applicator. Do not apply clears. If using pressure-sensitive letters, cycle sheeting through heat vacuum applicator once before applying legend and once after. Do not apply clears.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of 1.9 cm (3/4 in plywood, 7.6-cm-wide (3 in) film is recommended. For ease of handling and cleanliness, apply in 61-cm-long (24 in) strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 2 inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Part II--Avery International & Mitsubishi/Seibu International

Since the Forest Service and 3M Co. began their cooperative testing the reflective sign materials 5 years ago, other companies have entered the reflective sheeting field. For this reason, the Forest Service invited these manufacturers to supply reflective materials for testing as 3M wasdoing. Two companies, Avery International and Mitsubishi/Seibu International, concluded cooperative agreements in 1976 with the Forest Service.

A test plan identical to the one agreed to by 3M was adopted, and separate test plots for the signs of both companies were set up at the existing test sites in California, New Mexico, and Washington. Plots were physically separated from each other and the 3M Co. plots but provided the same exposure to the elements.

Signs of Avery and Mitsubishi/Seibu materials were manufactured and installed at the test sites in November 1976. Signs of aluminum and plywood measured 20 by 35 cm (8 by 14 in); those of ABS plastic, 30.5 by 30.5 cm (12 by 12 in). Signs were installed 46 to 61 cm (18 to 24 in) above ground on steel U-channel posts set in rows. Signs faced south for maximum exposure to ultraviolet rays.

Signs were evaluated for the first time in June 1977. A discussion of each company's signs and an evaluation of them after one winter's exposure follows. Because this testing has been underway for only a short time, no conclusions or recommendations are included in Part II of this paper.

Avery International

Some 28 different sign combinations were produced by Ojo Caliente Craftsmen Cooperative, under MEDC and Avery supervision, with substrates of HDO and MDO plywood, aluminum, and ABS plastic. Heat-activated and pressure-sensitive engineering-grade white and green reflective sheeting was used. Avery does not now manufacture a brown sheeting.) The letters "E," "O," and "N" were selected to simulate the legend. Letters were either reflective sheeting or silk screened on the signs. Some edges were square, others were rounded. Scotchcal film (#639) was used as a top edge treatment, and polysilicone paint and various clears were used to seal the edges. Some of the HDO plywood signs were treated with Scotchlite brand process color #700 series clears; others were not to verify if the adhesives were durable without added protection.

In all, 168 test samples were installed at the three sites in November 1976.

The first evaluation took place in June 1977. After one winter of outdoor exposure, sheeting had peeled on several of the ABS plastic and aluminum substrates.

In the fall of 1977 three combinations of prototype sheeting and letters were installed at the three test sites.

By the spring of 1978 all combinations installed at both the Mount Adams test site and the Donner Summit test site demonstrated some degree of failure (fig. 8). However, at the Hopewell Lake site, only a few of the combinations exhibited any failure. As a result, Avery removed signs except those installed in 1977 from all sites.

In response to these failures, the company developed new materials, modified original formulations, including adding ultraviolet ray inhibitors, and adding tapes to the top edge of signs. Forty new

sign combinations were manufactured and installed in October 1978 (fig. 9). In addition, six combinations using Finnish Plywood substrate were also manufactured and installed at the same time.

Mitsubishi/Seibu International

MEDC and Mitsubishi/Seibu International representatives selected 42 sign combinations for testing. These were manufactured by Ojo Caliente Craftsmen Cooperative under the supervision of MEDC and company personnel. Substrates included HDO and MDO plywood, aluminum, and ABS plastic. Heat-activated and pressure-sensitive, engineering-grade brown and silver reflective sheeting underwent testing. "E," "O," and "N" were chosen to simulate the legend; in addition to the precut letters of reflective sheeting, some letters were silk screened. The edges of most plywood signs were painted with four coats of Benjamin Moore Co.'s polysilicone brown enamel; the edges of three signs were left unpainted and treated with a clear edge seal. In addition, the top edges of two plywood sign combinations were taped with Scotchcal transparent film (#639). Some signs were treated with clear coating; others were not to verify if adhesives were durable without the added protections.

Some 252 test samples were installed at the three sites in November 1976 (84 signs per site) (fig. 10). The first evaluation took place in June 1977. After one winter of outdoor exposure, we found that some of the sheeting was peeling from the ABS substrate. In the evaluation in 1978 peeling continued on the ABS plastic.

In the fall of 1977 Mitsubishi/Seibu requested the manufacture and installation of three more sign combinations (18 test signs). These signs were installed at Hopewell Lake and Donner Summit in October 1977 and at Mount Adams in Spring 1978. Combinations using Finnish plywood were installed in 1978.

Figure 8. Signs of Avery International materials after 2 years of outdoor exposure.

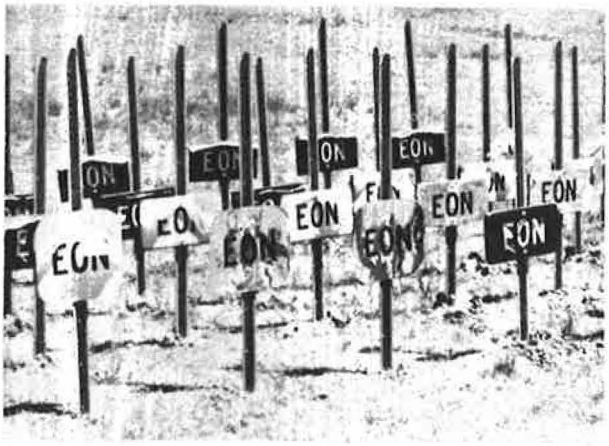


Figure 9. New Avery International sign combinations installed in October 1978.

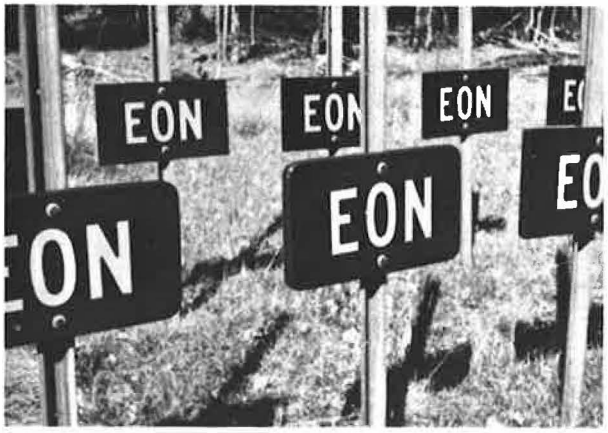



Figure 10. Signs of Mitsubishi/Seibu International materials after 2 years of outdoor exposure.