Maintenance of Reflective Signs

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The deterioration of reflective sign sheeting in New York State is examined, and the effectiveness of sign washing and clear-coating for restoring or preserving reflectivity of enclosed-lens engineer-grade sheeting is assessed. Generally, little benefit was achieved by washing all signs in the fall. However, changes in sign brightness, as measured by a retroreflectometer, indicate that significant brightness loss may occur during winter due to dirt accumulation, but that most signs recover after spring rains. The few that do not recover are readily identified by daytime visual inspection and would be the best candidates for washing. A large portion of these chronically dirty signs are located along high-volume highways, close to the pavement, and in industrial areas. The practice of clear-coating did not help maintain sheeting brightness; for the small sample included in this study, it had a detrimental effect. Candidates for replacement can be determined by nighttime visual inspection. Daytime cosmetic appearance alone should not determine need for replacement because signs with cracked or otherwise deteriorated sheeting may still provide adequate night visibility. Average sheeting life could not be determined in this study because no records were available for signs that had been replaced. An examination of the signs still in service determined that service lives of 15 yr in New York State are not unusual for enclosed-lens sheeting. Sign-replacement rates reported by maintenance engineers confirm that engineer-grade sheeting may retain adequate reflectivity for 15 yr or more.

Traffic signs supply information to the motorist; to accomplish this task they must be adequately visible and legible under both day and night conditions. Visibility and legibility requirements have been the subject of considerable research and, by knowing the reflective properties of a sign, it can be predicted whether it will perform adequately to meet driver information needs.

The objectives of this study were to (a) determine the effects on sign sheeting reflectivity of two common maintenance practices--sign washing and clear-coating--and (b) estimate how long sign sheeting retained adequate reflectivity under typical conditions in New York State. In order to accomplish these objectives, a photometer had to be built or purchased that could collect the large amounts of reflectivity data needed.

Highway signs in New York State are constructed of reflective sheeting mounted on a rigid backing (or substrate) and a support structure. When this study began the state required the use of enclosed-lens (engineer-grade) reflective sheeting on highway signs, based on Federal Specification LS-300(A). New York State Department of Transportation standards have since been revised to require encapsulated-lens (high-intensity) sheeting for most signs installed on contract, although the Highway Maintenance Division still uses enclosed-lens sheeting. This study focuses on enclosed-lens sheeting, which represents the majority of signs actually in service around the state.

Signs deteriorate from a variety of causes, and eventually they must be either rehabilitated or replaced. As they age, traffic signs experience irreversible deterioration of the reflective sheeting from the effects of sunlight, weather, airborne abrasives, and air pollution. The sheeting may also experience a reversible dirt buildup from road spray and airborne particulates. This progressive deterioration gradually reduces the visibility and legibility of a sign to the point that a driver may no longer perceive the intended message in time to complete the required response, which results in a reduction in traffic control and safety. Therefore, maintenance practices that retard irreversible deterioration or correct reversible deterioration provide both economic and safety benefits. On the other hand, ineffective procedures not only waste time, but they also divert scarce resources from activities that may provide other benefits.

In 1966 the Highway Maintenance Division implemented a maintenance policy intended to extend the service life of traffic signs. Based largely on the recommendations of manufacturers and the apparent visual effectiveness of washing, this policy required periodic cleaning of all signs. Portable equipment was purchased for each of the 67 residencies in the state to accomplish this task. In the early 1970s an annual sign inspection program was implemented that, by means of nighttime inspections, was intended to identify any signs deficient in terms of legibility and visibility. In addition, research efforts were initiated to investigate specific signing practices and problems.

Hahn, McNaught, and Bryden (1) concluded in 1977 that a substantial proportion of the large guide signs in the state were not adequately legible. Part of this problem was attributable to limited sight distances caused by roadway geometry and overhead structures and to the inherent limitations of the sign materials. However, another part of the problem was also related to the physical deterioration of the sign materials, which had occurred in spite of maintenance activities. Because local priorities varied, as did the availability of personnel and equipment, sign maintenance practices eventually differed among residencies. This variation was further affected by local preferences for sign washing. In addition, some signs were clear-coated in an effort to retard deterioration. This procedure, which involved the application of a liquid coating over the sign face, was recommended by sheeting manufacturers at that time. It also became apparent to Department management that results of the annual inspection program varied from residency to residency. As a result, signs replaced in some counties were in better condition than those left in service elsewhere.

These variations in maintenance practices and sign-replacement policies pointed out the need to establish effective maintenance procedures that could be uniformly implemented in order to direct personnel and materials where they could provide maximum benefits. This study was initiated to determine the effectiveness of sign washing and clear-coating, and to determine how long enclosed-lens sheeting retained adequate reflectivity under typical New York State conditions.

It is recognized that signs may fail for reasons other than loss of sheeting reflectivity. However, problems such as vandalism and accident damage are site dependent and generally not related to properties of the sign material. Although information on these causes of failure may be important to the choice of sign materials, they are beyond the scope of this study.

INVESTIGATION

Deterioration Types

In order to address the objectives of this study it is necessary first to understand the deterioration modes experienced by sign sheeting. Drawing on information supplied by maintenance personnel, sign fabricators, and sheeting manufacturers, five types of sheeting deterioration were identified.

These types can best be understood after examining the physical makeup of enclosed-lens sheeting. This material consists of a layer of transparent plastic of the appropriate color in which glass beads are embedded. A metallic reflector shield is provided behind the plastic, plus a layer of adhesive and a protective liner that is removed during sign fabrication. The deterioration types normally encountered are as follows.

1. Clouding and color fading: Exposure to ultraviolet rays in sunlight and atmospheric pollutants may result in gradual clouding and deterioration of the transparent plastic and metallic reflector layers. This results in diminished color contrast between legend and background and may cause loss of reflectivity.
2. Cracking: Differences in thermal expansion between the sheeting and metal substrate are believed responsible for cracking. Brightness is not directly affected, but daytime appearance may suffer.
3. Abrasion: Microscopic surface deterioration, which produces a rough feeling on the originally smooth surface, may be caused by windborne particles or chemical corrosion. Brightness is adversely affected and daytime condition may appear dull because the plastic layer is less transparent.
4. Delamination: Full-depth separation of the sheeting from the substrate may result from insufficient adhesion caused by either manufacturing or fabrication problems. Internal layer separation within the sheeting may result from manufacturing problems. Either distress mode diminishes both brightness and daytime appearance.
5. Dirt accumulation: The accumulation of dirt on the sign is the most common type of deterioration; it affects most signs at various periods during their service life. Unless the dirt becomes deeply embedded, it can be removed by washing--either by natural rainfall or by maintenance activity--and the brightness and appearance of the sign can be restored.

Most older signs in New York exhibit the first four distress modes in varying degrees of severity, and all signs exhibit dirt accumulation. Frequently other distress modes, which may not be immediately recognizable, can be explained by a combination of these general types. For example, a deeply cracked or abraded surface may permit the underlying dark adhesive layer to bleed through and spread from the scar, thereby resulting in the appearance of metal corrosion on the surface of the sheeting.

The maintenance activities examined in this study address two of these five problems. Clear-coating was intended to reduce and restore the effects of minor abrasion, and washing removes dirt accumulation.

Rating Sign Condition

Both color and brightness contrast are important parameters that affect sign visibility and legibility. Under diffuse illumination--daylight or artificial nighttime illumination--sign brightness is generally adequate to permit detection. Color contrast provides much of the legend-background distinction required for legibility. Legends mounted on backgrounds with similar brightness but different colors are legible, but similarly colored legends and backgrounds with greatly differing brightness are much less legible.

At night under headlight illumination the observation angle between the light source and the driver's eye is small, and sign detection becomes dependent on the retroreflective properties of the background and legend. For detection, brightness contrast between the sign and its surroundings is most important; for legibility, brightness contrast between the legend and background is also important, playing an even greater role than color contrast.

Based on discussions with maintenance personnel and the examination of discarded signs, it is apparent that loss of reflectivity, as identified by the nighttime surveys, is the principal reason for sign replacement. Although funding limitations have reduced sign replacement to a general low level statewide, establishing priorities for replacement varies among residencies, which reflects the subjective nature of nighttime surveys. Although this variability is not usually great in terms of the condition of signs actually replaced, it does point out the need for an objective measure of sheeting reflectivity for use in this study to permit uniform and consistent evaluation of sign condition in the field.

Originally, it was considered desirable to develop a prototype instrument in-house for use in this project that could then be reproduced inexpensively for each of the 10 regional offices of the Department. This would permit uniform evaluation of sign-replacement needs around the state. Unfortunately, staff reductions early in this project made it impossible to accomplish this goal.

Instead, a commercial retroreflectometer--the Gamma Scientific Model 910B--was purchased for this project. This device consists of an internal light source and photocell. Target distance and incidence and divergence angles are controlled by the geometry of the equipment. Calibration is provided through the use of small discs of reflective sheeting in each standard color that were premeasured in the laboratory to establish their specific intensity. An evaluation performed by the Pennsylvania Department of Transportation (2) confirmed that the specific intensity of sign sheeting--candelas of reflected light per footcandle of incidence light per square foot of target ($cd/ft\text{-}c/ft^2$)--can be quickly and reliably measured by using this device, thus eliminating bias due to ambient light, viewing position, and individual rater. Although this instrument proved suitable for use in this project, it is too costly and time consuming for use in annual sign condition surveys.

Experimental Design

This study was designed to examine the effects of two maintenance activities: sign washing and clear-coating. In addition, an effort was made to relate reflectivity to sign age to determine the service life provided by enclosed-lens sheeting.

Two sample groups were selected to determine the effects of sign washing. The first group, which was located in the Albany area, was chosen to represent the general statewide sign population. A total of 153 signs were selected: 67 with white backgrounds, 53 with yellow, and 33 with green. Highway types included urban and rural expressways, urban arterials, and suburban and rural primary and secondary routes. Sign locations varied from immediately off the pavement to more than 20 ft from the pavement edge.

A second sample was selected in highly industrialized areas in and around Buffalo and Syracuse to represent severe environments in terms of dirt accumulation. This sample included 28 signs with white backgrounds, 17 with yellow, and 15 with green. Roadway types included urban and suburban expressways, arterials, and primary routes. Sign locations were similar to the Albany sample. For simplicity, these groups are referred to as the non-industrial and industrial samples.

Physical and historical data were recorded for each sign, including installation date (when available). Although these samples included a wide range of signs of different ages and conditions, badly deteriorated signs (those that were peeling, faded, or nonreflective) were not included because it was not considered worthwhile to continue maintaining such signs.

The reflectivity of each sample was measured four times: in the fall before and after washing, and in the winter and spring to determine the effects of the dirt reaccumulation. The Albany sample was measured during the winter of 1977-1978 and the Buffalo-Syracuse sample during the winter of 1979-1980. Washing was accomplished by a two-person field crew by using a portable pump, water tank, and mild industrial detergent. Reflectivity of each sign was first measured in its existing condition in the fall. Loose debris was then hosed off the sign surface, and it was scrubbed down by using a soft-bristle brush, taking care not to abrade the surface. The sign was then thoroughly rinsed and allowed to dry for a few hours to a few days before reflectivity was measured again. Winter measurements were made during a period when dirt accumulation would be near its peak from winter road spray combined with lack of rainfall during winter months; the spring survey was made after several heavy rainfalls had provided natural washing.

Reflectivity was measured only on the background sheeting. For white and yellow backgrounds, the nonreflective black legends provide negative contrast, and it is necessary only to measure background reflectivity. Most green signs included white button-reflector legends; although it would have been desirable to measure legend reflectivity, this was not possible with the instrument used. Thus the effect of dirt accumulation on the background was also assumed to represent legend condition.

Depending on the size of the sign, five replicate reflectivity measurements were made at four to nine locations across the sign face to obtain a fair representation of sign reflectivity. Generally, variability within the sign was not great. Five reflectivity measurements were deemed sufficient, and survey time was held to a reasonable level. This was especially important on larger signs, where ladders or scaffolds had to be moved between measurements.

The sign-installation dates were combined with measured reflectivity to provide a measure of sheeting life. However, this method has two built-in biases that may have failed to consider signs with shorter-than-normal service lives. First, a few badly deteriorated signs still in service were not included in the sample because they were no longer reflective and thus were not expected to benefit from washing. Second, signs that had been removed from service because of poor reflectivity, vandalism, accident damage, or other causes were not included. Thus, although the signs included in the survey indicate the range of service lives possible, they do not provide the overall distribution of service lives to be expected.

The survey sample taken to examine the effects of clear-coating was limited because of personnel limitations within the research staff and a general scarcity of clear-coated signs around the state with complete records to determine when they were coated. Nevertheless, one section of highway located in the Mohawk Valley west of Albany included a number of signs with green or white backgrounds installed in 1972 and clear-coated in 1973. In addition, one green sign had clear-coating applied to half its surface. Signs of similar age without clear-coating were located on the same or adjacent highways to compare with clear-coated signs. In all, five clear-coated green signs and six clear-coated white signs were compared to five non-clear-coated signs in each color, plus the additional half-treated sign.

Survey of Maintenance Practice

Sign inspection, repair, and replacement are performed by personnel from the Department's residencies. Telephone interviews were conducted with the resident engineer or sign foreman at each residency to determine current sign maintenance practices, special problems, and suggested improvements. Follow-up visits were made to three residencies to gather more specific information. The survey information collected was used in assessing data collected in the other phases of this project and in obtaining candidate signs and data on the ages of the signs.

RESULTS

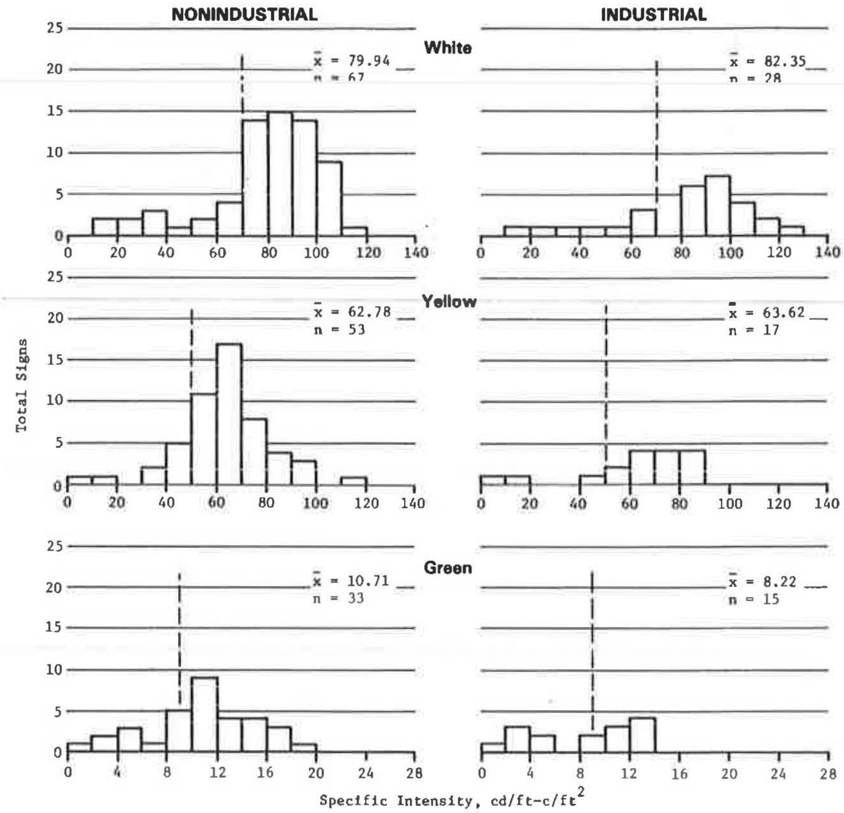
Effects of Brightness on Sign Performance

Distributions of average before-washing specific intensities measured for the 213 signs included in the two field samples are shown in Figure 1. Also shown are the minimum specification levels for new sheeting; the data indicate that less than 20 percent of the nonindustrial and 30 percent of the industrial signs were less than the minimum specification levels--most by only a small amount. Nevertheless, χ^2 test values indicate that the proportions of signs less than the specification level are not significantly different for the two samples for any of the three colors.

In order to evaluate the effects of washing and clear-coating, the effects of background brightness on sign detection and legibility must be understood. Other research on sign conspicuity (3) indicates that a large increase in brightness is needed to provide a noticeable increase in detection distance. For example, changing from enclosed-lens to encapsulated-lens sheeting, which is about a threefold increase in brightness, improves detection distance by only 20 percent under the best conditions. Even larger increases in background brightness have little effect on legibility. One recent report (4) also indicates that substantial decreases in background brightness less than the specified levels of enclosed-lens sheeting in most cases detract only slightly from legibility. For white and yellow engineer-grade sheeting with black negative-contrast legends, a specific intensity of 30 cd/ft-c/ft^2 provides almost the same legibility distance as sheeting at the specification level: 70 cd/ft-c/ft^2 for white and 50 cd/ft-c/ft^2 for yellow. For green background sheeting with encapsulated-lens or button-copy legends, a drop in background reflectivity to 5 cd/ft-c/ft^2 also provides nearly the same legibility as the minimum specification level of 9 cd/ft-c/ft^2. Further examination of the data in that report indicates that a decrease in specific intensity of 15 percent of the minimum specification level is about the smallest change that would be detectable under any conditions, even though substantially larger losses have little practical effect.

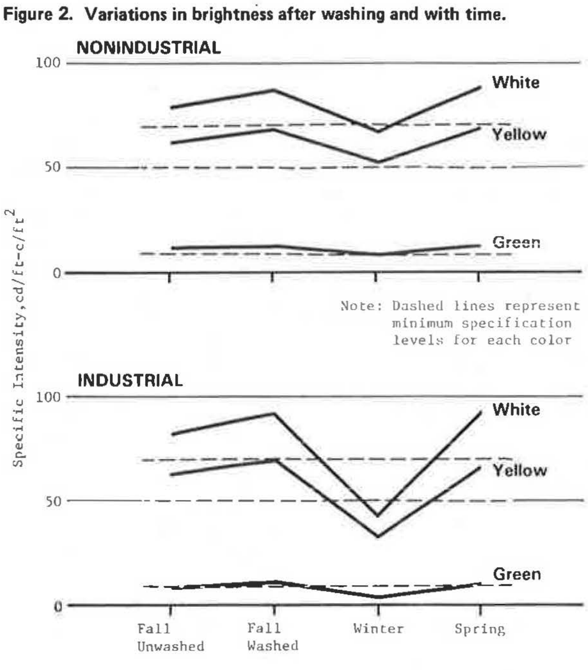
Because small losses in brightness due to dirt accumulation and abrasion may be detectable under some conditions and may be accumulative, thus indicating further loss of brightness with time, a brightness loss of 15 percent is considered in this analysis to be the lower limit of practical signifi-

Figure 1. Distribution of brightness measurements before washing.



Note: Vertical dashed lines are minimum specified specific intensities for new enclosed-lens sheeting.

Figure 2. Variations in brightness after washing and with time.



cance. Only when brightness loss exceeds this value is there any concern that sign performance may eventually suffer.

Effects of Sign Washing and Seasonal Changes on Dirt Accumulation

Changes in sign reflectivity after washing and with time are shown in Figure 2, which also shows average brightness for both industrial and nonindustrial samples in all three colors. Fall sign washing produced a small average increase in brightness, ranging from 7 to 11 percent for these six groups. Dirt accumulated again during the winter, and the average brightness losses ranged from 24 to 53 percent of the washed values. Following the spring rains most of the group averages returned approximately to the washed averages. By using the data in this figure, it appears that the industrial-area signs were subject to greater changes than the signs in nonindustrial areas. Although average sign brightness followed predictable trends, individual signs were subject to considerable variability from the group averages, and dirt accumulation was great enough to cause loss of legibility in some cases.

Although most signs improved somewhat after washing, a few appeared to have less reflectivity after washing, but this is attributed to instrument and measurement variability on already-clean signs. Few of the washed signs experienced brightness changes greater than the 15 percent level considered detectable to a human observer, and only one--a white, industrial-area sign--improved sufficiently to have a large impact on sign performance.

Most signs became dirtier during winter to the extent that brightness loss would be noticeable, and some were so dirty that sign performance would not be adequate. All signs that suffered reduced legibility because of dirt accumulation were readily apparent from simple daytime visual inspection. Those that did not appear visibly dirty did not experience significant brightness loss from the washed condition.

Following the spring rains, the average sign brightness returned to approximately the washed fall values. Nevertheless, there is again considerable variability within the samples, which indicates that individual signs are affected by their particular environments. Part of this variability is also attributable to instrument and measurement variability.

The data in Table 1 summarize the number of signs that experienced noticeable brightness changes (i.e., exceeding 15 percent of the minimum specification level) after washing and during winter, and also the number of signs that failed to recover within 15 percent of the washed value in the spring. The apparent differences between the nonindustrial and industrial groups were examined by using the χ^2 test. After washing, the proportion of signs that improved more than 15 percent was about the same for each sample--25 and 32 percent, respectively.

In winter a significantly larger proportion of industrial signs became noticeably dirty--90 percent compared with 65 percent for the nonindustrial group. Similarly, following spring rains a significantly larger proportion of industrial signs failed to return to within 15 percent of the washed values--27 percent compared with only 7 percent for the nonindustrial signs.

It has been shown that, with the exception of the winter period, most signs receive little benefit from washing because natural cleansing from rainfall achieves nearly the same effect. Nevertheless, it is also clear that some signs do benefit from washing. The data in Table 1 indicate the proportions of signs that benefit from washing; those proportions are not significantly different from the industrial and nonindustrial samples.

The data in Table 2 examine the other two environmental parameters that may be expected to affect dirt accumulation: traffic volume and distance from the pavement. The χ^2 test was again used to determine if signs close to higher-volume roads [i.e., within 11 ft of roads with annual average daily traffic (AADT) greater than 21,000 vehicles] responded more to washing and dirt accumulation than signs farther from the road or on lower-volume roads. After initial washing, this group did not respond significantly more than the remainder of the sample. During winter the signs at these locations from the nonindustrial sample experienced significantly more dirt accumulation than the rest of the sample: 83 percent had brightness loss of 15 percent or more compared with only 54 percent for the rest of the sample. Considering industrial signs, nearly the entire population experienced brightness losses greater than 15 percent. In spring most signs recovered to within 15 percent of the washed value. However, for both the nonindustrial and industrial samples, the proportion failing to recover was higher in the critical locations--close to high-volume roads.

It appears paradoxical that this critical category did not respond more to washing than the rest of the signs, considering that more of them failed to recover in the spring. However, the washed readings were taken in the fall, and it is possible that the additional 6-month exposure to rain would result in recovery of most of these signs still experiencing detectable dirt accumulation in the spring.

Further examination of the industrial sample revealed that a larger portion of these signs were close to high-volume roads: 25 of 60 signs compared with only 23 of 153 signs in the nonindustrial sample. This bias was unavoidable because roadways in the industrial areas where the signs were selected generally had high traffic volumes compared with the nonindustrial sample. The analysis so far has indicated that industrial signs became dirtier in winter and recovered less in spring. Further, it was revealed that winter dirt accumulation and failure to recover in spring were more critical for signs close to high-volume roads. The question then arises whether apparent differences between the two samples may be attributable to the higher portion of industrial signs located close to high-volume roads.

Table 1. Changes in brightness caused by dirt accumulation and washing.

	Signs			
		Exceeding 15 Percent Change		
Sign Group	Total	After Washing[a]	Winter[b]	Spring[c]
Nonindustrial				
White	67	14	43	5
Yellow	53	13	31	1
Green	33	11	15	5
Total	153	38	89	11
Industrial				
White	28	9	27	6
Yellow	17	5	15	3
Green	15	5	12	7
Total	60	19	54	16
All signs	213	57	143	27

[a]Washed-unwashed exceeds 15 percent of minimum specification value.
[b]Washed-winter exceeds 15 percent of minimum specification value.
[c]Washed-spring exceeds 15 percent of minimum specification value.

Table 2. Effects of traffic volume and distance from pavement on dirt accumulation.

	No. of Signs Affected by Distance from Pavement and Traffic Volume				
	≤11 ft		>11 ft		
Variable	≤21,000 AADT	>21,000 AADT	≤21,000 AADT	>21,000 AADT	Total
Total signs					
Nonindustrial	38	23	50	42	153
Industrial	8	25	8	19	60
Signs with change greater than 15 percent					
Washed-unwashed					
Nonindustrial	3	5	13	17	38
Industrial	3	11	0	5	19
Washed-winter					
Nonindustrial	10	19	29	31	89
Industrial	7	25	6	16	54
Washed-spring					
Nonindustrial	0	7	2	2	11
Industrial	1	12	0	3	16

That question is examined in Table 3, where each sample is stratified according to proximity to high-volume roads. After washing, no significant change is apparent between the industrial and nonindustrial samples for either subgroup. In winter the industrial sample close to high-volume roads fared slightly worse than the nonindustrial sample, but the proportions are too small to be examined by using the χ^2 test. Nevertheless, for those signs not close to high-volume roads, significantly more of the industrial signs experienced noticeable dirt accumulation than did the nonindustrial group: 83 versus 54 percent. Finally, spring recovery was slightly less for industrial signs in both subgroups, but differences between the two samples are not significant. Thus it appears that signs in industrial areas do experience somewhat more dirt accumulation that cannot be attributed solely to their location close to high-volume roads.

Clear-Coating

Before 1978 a major manufacturer of enclosed-lens sheeting recommended that signs be clear-coated in the field after approximately 4 yr of service. For signs exposed to road salts in northern climates, initial clear-coating was also recommended (5). However, clear-coating is no longer recommended in that company's literature. Further information on clear-coating was obtained from the survey of maintenance personnel, which determined that clear-coating has been virtually eliminated as a maintenance procedure. Most respondents considered clear-coating to be of little value, and some even indicated that it had damaged signs. Even when successful, adherence to strict application procedures was necessary in order to obtain satisfactory results. An earlier study by the Engineering Research and Development Bureau found that overspray from clear-coating seriously reduced the reflectivity of button copy (6).

One residency had been a strong advocate of clear-coating to prolong sign life and had maintained records of clear-coated signs, which permitted an examination of the effectiveness of this procedure. Route markers and guide signs installed along one route in 1972 were clear-coated in 1973. The field clear-coating applied after 1 yr was an attempt to obtain the same protection achieved with the initial clear-coating recommended by the manufacturer. These signs were inspected by research personnel in 1981, and reflectivity was measured on a sample of several signs. Observations and measurements were also made on a sample of signs of similar age on adjoining routes that had not been clear-coated.

Except for some slight surface abrasion, the clear-coated signs appeared to be in satisfactory condition. Nighttime inspection confirmed satisfactory visibility and legibility. Nevertheless, comparison with signs without clear-coating (Table 4) indicates that the latter remain much brighter. Green-background guide signs without clear-coating, ranging in age from 7 to 9 yr, were about 50 percent brighter than the 9-yr-old clear-coated signs. The white route-marker signs revealed an even greater difference: the 7-yr-old signs without clear-coating were, on average, more than 3 times brighter than the 9-yr-old clear-coated signs.

As noted earlier, along this same route one guide sign had clear-coating applied to half the surface while the other half was left uncoated. After 9 yr--8 yr after clear-coating--the coated portion was scaling while the uncoated side remained in good condition. Reflectivity measurements indicated that the uncoated side was 65 percent brighter than the coated portion.

In summary, manufacturers' recommendations and maintenance practice no longer include clear-coating as a standard procedure. Reflectivity measurements on a limited number of signs clear-coated after 1 yr

Table 3. Comparison of industrial and nonindustrial signs close to high-volume roads.

Condition	Signs with Brightness Change <15 Percent	>15 Percent	χ^2
Signs Close to High-Volume Roads[a]			
After washing			
Nonindustrial	18	5	–
Industrial	14	11	1.76
Winter			
Nonindustrial	4	19	–
Industrial	0	25	–
Spring			
Nonindustrial	16	7	–
Industrial	13	12	0.89
Signs not Close to High-Volume Roads[b]			
After washing			
Nonindustrial	97	33	–
Industrial	27	8	0.007
Winter			
Nonindustrial	60	70	–
Industrial	6	29	8.50[c]
Spring			
Nonindustrial	126	4	–
Industrial	31	4	–

[a] <11 ft and >21,000 AADT.
[b] >11 ft or <21,000 AADT.
[c] χ^2 exceeds 95 percent confidence level.

Table 4. Comparison of reflectivity of clear-coated and uncoated signs.

White Route Markers				Green Guide Signs				Partly Coated Green Guide Sign	
Coated		Uncoated		Coated		Uncoated		Brightness Measurement (cd/ft-c/ft)	
Avg Brightness (cd/ft-c/ft)	Age (yr)	Avg Brightness (cd/ft-c/ft)	Age (yr)	Avg Brightness (cd/ft-c/ft)	Age (yr)	Avg Brightness (cd/ft-c/ft)	Age (yr)	Coated	Uncoated
38.3	9	89.1	7	9.48	9	16.55	7	6.4	12.0
29.0	9	85.8	7	13.04	9	12.40	9	4.8	12.2
22.0	9	90.1	7	11.87	9	14.66	7	8.2	13.2
14.9	9	87.2	7	9.27	9	16.30	9.25	10.6	12.2
26.0	9	87.5	7	7.50	9	16.00	9.25		
36.0	9							7.5[a]	12.4[a]
		87.9[a]	7[a]	10.23[a]	9[a]	15.18[a]	8.3[a]		
27.7[a]	9[a]								

[a] Sample average.

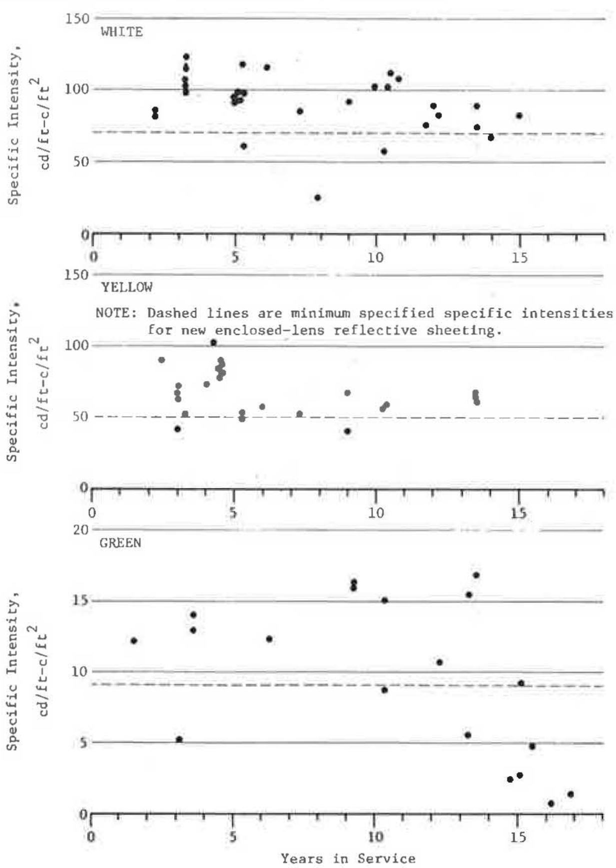
of service indicate that this procedure does not preserve sign reflectivity and may actually cause a more rapid drop in brightness.

Sheeting Service Life

The age and average brightness of 63 signs in the nonindustrial sample are shown in Figure 3. These are the only signs for which accurate age data could be obtained from maintenance records. Based on this sample it appears that almost none of the white or yellow signs have experienced substantial losses in reflectivity after as long as 15 yr in service, and the green signs generally remain in satisfactory condition for at least 13 yr. These data do not indicate a pronounced brightness loss with age, and it is obvious that some signs will provide service lives of 15 yr or more. Nevertheless, it should not be concluded from this sample that average sheeting life will reach this figure. It must be remembered that, of the signs still in service, only those in satisfactory condition were included in the original sample. In addition, signs already replaced because of unsatisfactory sheeting condition are not included. Some of these discarded signs were examined, and it was apparent that they were removed from service for various reasons, including loss of reflectivity, cracking, and vandalism. However, the installation date was included on only a few signs, and the dates when the signs were taken out of service were not provided in any cases. Thus these discarded signs confirmed that replacement occurs for a variety of reasons, but they did not offer any usable information relating to length of service provided.

Interviews with maintenance personnel also provided information about sheeting life. The average

Figure 3. Effects of age on brightness of washed signs.



life was estimated to be between 5 and 13 yr, although extreme estimates ranged from 3 to 20 yr. However, the statewide average replacement rate for unsatisfactory reflectivity was only 3 percent of the total annual sign population. The respondents pointed out that the life of any individual sign may vary considerably from the average. Factors that affect sign life include roadway type, sign location relative to the pavement, sign substrate, and local air quality. The direction a sign faces determines its exposure to ultraviolet radiation as well as to windblown abrasives. Nevertheless, for the 63 signs included in Figure 3, no relation between sign direction and reflectivity was apparent. Some signs facing in each direction are included among those still in satisfactory condition.

In order to obtain an unbiased estimate of sheeting service life, it would be necessary to start with a sample of new signs and follow the history of each to failure. However, even such an effort might be unproductive because of manufacturing changes that result in changes in the actual sheeting installed over time. Thus, by the time average sheeting life is reliably estimated, the material supplied may differ considerably from that tested.

It is impossible to estimate average life reliably for enclosed-lens sheeting based on these data, but based on experience of maintenance personnel around the state and on the long life of sheeting measured in this evaluation, the manufacturer's estimated life of 7 yr appears to be conservative for many of the signs in the state.

Interviews with maintenance personnel and night inspection visits confirmed that signs with deficient brightness are readily apparent at night. Thus, although this method is not precise, it is adequate for programming needed sign replacements. The interviews and field visits also indicated that signs occasionally are replaced because of severe cracking. For example, the badly cracked sign shown in Figure 4 has a specific intensity of 94.2 cd/ft-c/ft^2, and it still provides satisfactory nighttime visibility and legibility. Thus replacing

Figure 4. Badly cracked sign, but brightness is still satisfactory, with specific intensity of 94.2 cd/ft-c/ft^2.

signs based on daytime inspection alone may result in decisions based on aesthetics rather than night performance.

SUMMARY AND FINDINGS

Most of the 213 signs measured in a fall survey had background brightness close to or above the minimum specified levels for new white, yellow, and green engineering-grade reflective sheeting. Although most signs experienced a small improvement in brightness after washing, most improvements were too small to be of any practical significance in terms of legibility or visibility; i.e., less than 15 percent of the minimum specified brightness. During winter months dirt accumulation reduced the brightness of most signs, and some became so dirty that legibility was adversely affected. Nevertheless, spring rains restored nearly all the signs close to their washed brightness. Other than during winter months, when dirt accumulation may be severe in some cases, most signs appear to be kept sufficiently clean by natural washing, and little added benefit is achieved by washing in terms of legibility or visibility. Those few signs that would benefit from washing should be readily apparent from daytime inspection because of severe dirt accumulation on the sign face.

Signs close to high-volume roads and signs in industrial areas were subject to greater dirt accumulation during winter months, but most recovered their brightness after spring rains.

Clear-coating is no longer recommended as a standard maintenance procedure. Brightness from a limited sample of signs 7 to 9 yr old that were clear-coated after 1 yr of service indicated that this procedure did not help maintain sheeting brightness; it actually resulted in lower brightness values than sheeting that was not clear-coated.

Sufficient data could not be obtained to determine the average life or overall range of service lives provided by engineering-grade sheeting. Few signs included in this survey had brightness values below the minimum specification levels at ages up to 15 yr, but the study sample did not consider signs removed from service because of sheeting failure that may have occurred at an early age. Replacing signs based on daytime appearance alone may result in unnecessary replacement. Nighttime inspections, however, appear to provide ready identification of signs with deficient reflectivity.

Based on the results of this study, the following findings can be stated.

1. A fall survey of 213 highway signs constructed with engineering-grade reflective sheeting revealed that most had brightness values near or above minimum specification levels for new sheeting. However, this sample contained only signs that still appeared to be in serviceable condition.
2. Little benefit in terms of improved brightness was achieved by washing the signs in the fall.
3. Most signs experienced significant dirt accumulation during winter months, some to the point that legibility became inadequate for a period of time.
4. Signs located close to high-volume roads and in industrial areas experienced greater dirt accumulation during the winter.
5. Spring rains restored most signs to within 15 percent of their washed-fall brightness.
6. Signs that may benefit from washing, and then generally only during winter months, can be identified by daytime inspection.
7. Clear-coating after 1 yr in service did not maintain sheeting brightness. Instead, it had a detrimental effect on the small sample included in this study.
8. Average service life could not be determined in this study, but engineering-grade sheeting appears to be capable of providing at least 15 yr of service life in upstate New York.

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