# PROTECTIVE COATINGS FOR HIGHWAY METALS

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

# PROTECTIVE COATINGS FOR HIGHWAY METALS

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## SUMMARY

This report relates steps taken by the Department to minimize coatings maintenance on metal appurtenances used on the highway system. The appurtenances covered are those used in significant tonnages such as guardrail, bridge railings, and bridge structural steel girders.

Lowering the cost of maintaining these appurtenances in functional condition and an aesthetically pleasing appearance has long interested several Department Divisions, though Testing and Research was delegated to integrate the efforts under Research Project 49 G-50, authorized in 1949. Subsequently, this project was given special emphasis; and with approval of the Federal Highway Administration was carried as a cooperative project under the Highway Planning and Research Program, covering evaluations scheduled for July 1, 1964 to July 1, 1969.

The scheduled evaluations varied for the different appurtenances. Prior to the initiation of the HPR program, the Department had switched from painting steel beam guardrail to galvanizing them on both new construction and as a maintenance recoating procedure. Some of these galvanized guardrail were found to suffer "white rusting" deterioration. Determining the extent and the causative mechanism for the premature deterioration was an objective of this project. The study showed that white rusting occurred only during some winters, and preferentially at some locations--with encasement in snow or salt-laden snow a requisite--though we could not isolate the exact causative mechanism. It appears almost exclusively the first winter on new installations when the galvanizing has not yet oxidized to develop its own protective coating. Protecting the new galvanizing with a short-lived coating, like a chromate conversion type, appeared as an obvious corrective. However, we were unable to find a low-cost source for such coating to economically justify application on 100 percent of the footage to protect the 5 percent that would be affected.

Evaluations scheduled for our standard steel bridge railings were similar to those for the beam guardrail since these were also being galvanized rather than painted, when the HPR phase began. The galvanized bridge railings, however, were seldom affected by white rusting deterioration, for unknown reasons.

The Department's decision to galvanize the steel beam guardrail and bridge railings rather than painting them was most prudent since generally for the same cost, the galvanizing yielded a coating system providing protection at least twice as long as paints.

Subsequent to the galvanizing requirement for railings, the Department on new construction placed in service exposure a variety of more maintenance-free railing materials including aluminum-alloy, unpainted low alloy

steel, and concrete. Currently, the latter is finding favor for safety considerations.

For coating bridge structural steel girders, the Department has conducted laboratory screening tests on paint systems followed by in-service tests of the superior systems. On the basis of these evaluations, we have moderately revised the individual paint specifications, increased the thickness requirement from 3 to 4 coats of paint yielding a 5+ mil thickness, and substituted sandblasting of the steel for the former hand cleaning. This paint system has a service life of about 15 years, which is undesirably low, however, giving the Department a current maintenance repainting work load of 180 bridges per year. In an effort not to add to that statistic, the Department has recently required the low alloy unpainted steel for bridge girders on new construction; actually a parallel endeavor of the solution to this maintenance problem.

# INTRODUCTION

## The Problem

The purpose of this study is to evaluate currently specified precoating cleaning procedures, coating compositions, and application methods on highway structural metals to determine their comparative abilities to protect the base metal from deterioration. The intent is to determine the best system of cleaning, coating, and application--on a performance and cost basis--for coatings on highway metal components exposed to the Michigan environment.

The Department has long recognized the importance of sound protective coatings for highway metals and accordingly, in 1949, established Research Project 49 G-50, "Study of Protective Coatings for Structural Steel." In the past, this problem has been handled within several Divisions of the Department, resulting in the accumulation of considerable background material; but the pressure of other work with its required budgeting of effort has prevented a systematic analysis of this problem and integration of the information.

The recent increase in Interstate mileage, built to higher standards requiring more appurtenances and attendant bridge structures whose structural steel members require periodic coating maintenance, has placed increasing emphasis on the value of superior protective coatings; partially because of the difficulty and expense of restricting and controlling traffic during maintenance recoating operations.

## Scope

This study pertains to the protection of ferrous metals used for outdoor highway applications. In particular, two methods of protection will be studied, paint and galvanized coatings. Particular emphasis will be placed on highway applications where severe environmental problems currently exist, such as beam-type guardrail, bridge railing, and structural beams for bridges. The durability of various paints and methods of application, and of galvanized coatings, will be evaluated under controlled laboratory conditions and in field tests.

## Objectives

This study is aimed at developing information on the following specific categories:

1) To determine the environmental factors such as weather, humidity, stacked snow, and de-icing salts, that are responsible for the phenomenon of "white rust" formation and deterioration of galvanized guardrail which had occurred quite extensively during the 1961-62 winter season.

2) To develop, by field inspection and analysis of affected rail, a laboratory environment that duplicates field attack on galvanized coatings; then use this controlled laboratory environment in testing and developing corrective measures for this type of deterioration.

3) To develop information on service life of paint coatings from field inspections, repainting schedules, and controlled field tests.

4) To develop improved methods of cleaning, prepainting, and application procedures by means of accelerated weathering tests (with laboratory equipment) using Department methods and practices for control purposes.

5) To compare performance of topcoat paints for structural steel under accelerated weathering tests using current Departmental paint specifications for control purposes.

6) To coordinate information on current service life of test coatings with their costs for an economical analysis covering the different highway applications.

## Project Schedule

The above three paragraphs, Problem, Scope, and Objectives are essentially as written in the Project Proposal presented in February 1963. Subsequently, it was approved by the Department and submitted to the Federal Highway Administration for approval as a Highway Planning and Research project meriting Federal financial participation.

The approval was subsequently obtained. The study was to run in two phases for a total of five years. The first phase of three years was scheduled from July 1, 1964 through June 30, 1967; it was to include all laboratory work and most of the field work. The second phase from July 1, 1967 through June 30, 1969, under a reduced work load, was to consist mainly of inspections to evaluate relative performance of coating systems placed in field tests under the first phase. Because the project study fell behind in use of programmed time and in attaining objectives, in the spring of 1967 the Department asked for approval to carry the second phase study under a standard work load, rather than a reduced work load as originally proposed. This was approved by the Federal Highway Administration.

The research described herein was carried out by the Research Laboratory of the Michigan Department of State Highways and Transportation in cooperation with the Federal Highway Administration. The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

## STEEL BEAM GUARDRAIL

As mentioned earlier, this study was to concentrate on reducing coatings maintenance by finding: 1) improved coatings for steel materials used in large quantities on the Michigan highway system; or, 2) alternate materials. These materials were: steel beam guardrail, bridge railing, and bridge structural steel. The study would concern construction coatings and/or materials, and maintenance coatings for existing structures and appurtenances.

Prior to World War II, guardrail was not extensively used. That which was used consisted of stranded galvanized cable, sometimes overcoated with white paint by maintenance personnel. Maintenance was not a significant problem under low and slow traffic and less demanding de-icing and snow removal requirements.

After World War II, the cable guardrail began giving way to the plate type which evolved through several configurations until the current one was reached, now a National and International standard. The steel guardrail was factory primed and, after installation, overcoated with two coats of white paint to provide good hazard delineation. However, with increasing traffic and its demands, this paint system could not withstand the corrosive effect of de-icing salts, snowplow abrasion in the cold of winter, and impingement of aggregates thrown out by vehicle tires, so it had to be topcoated on about a two-year cycle. Since guardrail mileage had also increased, this was presenting a maintenance problem.

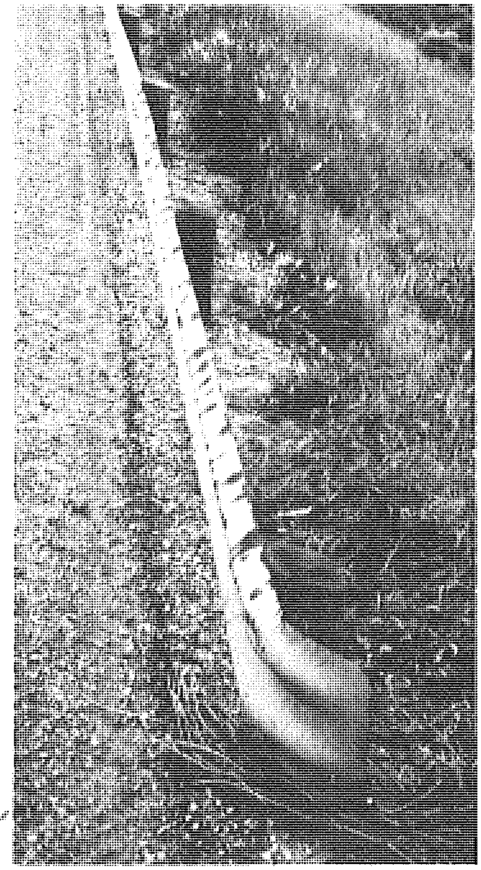


Figure 1. Typical 12-year old galvanized guardrail, showing spotty weathering-away loss of zinc coating (brown rusting) on the top portion, spreading from the cut ungalvanized long edge (June 1969).

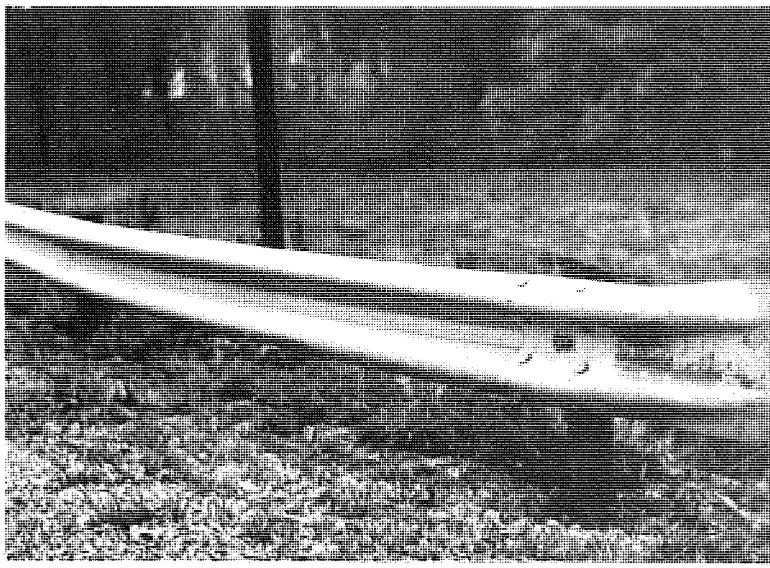


Figure 2. During its first year of installation, guardrail end-shoe on I 94 west of Kalamazoo shows spotty loss of galvanizing (dark areas = brown rusting) and some white rusting while the adjoining long railings are in good condition (November 1960).

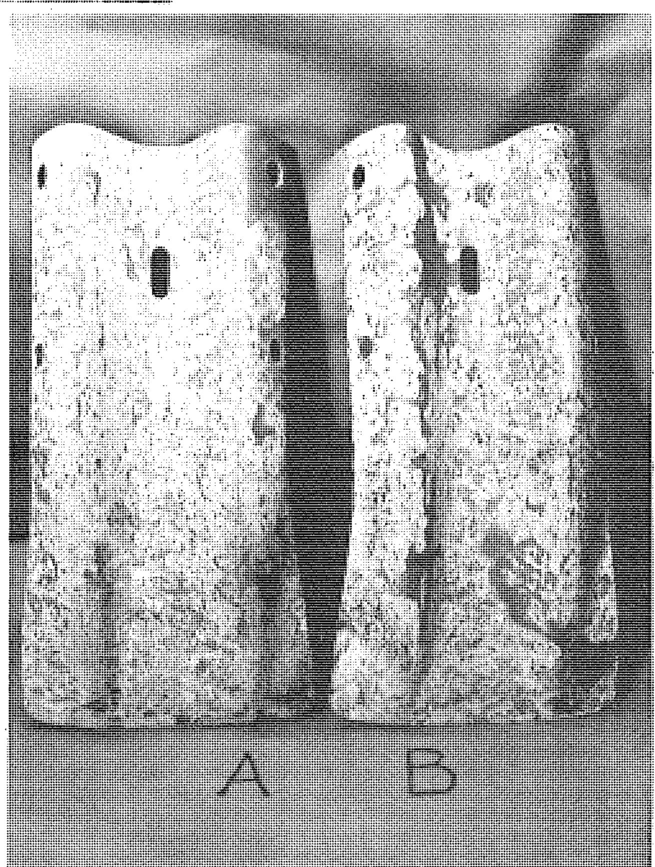



Figure 3. Example of "white rust" formed on galvanized guardrail during first winter of exposure on I 96 at Grand Rapids. Rusting was not confined to end-shoes, though photo shows faces of a dismantled pair brought into the Lab for study (March 1962).

## Galvanized Guardrail

In 1957, as an experimental preventive maintenance measure, the Department substituted galvanized for painted guardrail on two construction projects: M 78 east of Lansing, and on the medians of two freeways in Detroit. Topcoating with white paint to improve delineation was judged unnecessary and was not required. The installations met with quick acceptance and resulted in the Department's revision of specifications requiring the galvanizing. To our knowledge, we were one of the first states to adopt the galvanizing revision.

The two original galvanized installations have been maintenance-free, regarding coatings, during their 15 years of service. For several years now, they have been showing a progressive loss of galvanizing on their top portions which will shortly require some action (Fig. 1). On a few subsequent installations, notably I 96 near Farmington, and US 127 north of Jackson, the weathering-away loss of galvanizing has been at a slightly faster rate, for unknown reasons. Governing specifications required 12-gage metal, galvanized in accordance with current ASTM A525, Coating Class 2.50 oz/sq ft of metal (original specifications required Coating Class 2.25 oz), though minor amounts were obtained galvanized in accordance with ASTM A123 with 2 oz/sq ft of surface.

Within a couple of years of adoption of galvanizing for the guardrail, sporadic complaints were received concerning localized deterioration of the galvanized coatings. Figure 2 shows one such complaint area where the end-shoe showed spotty loss of zinc coating, while the abutting straight rail was in the normally good condition for installations less than one year old. Incidentally, about 72 end-shoes were installed under this contract with about one-third of them showing some deterioration at a survey time in November 1960. All of the latter showed white rust attack with the four worst ones showing some brown rusting as well (base metal corrosion signifying complete loss of galvanizing). The worst end-shoe of the four is shown in Figure 2.

In the spring of 1961, and particularly in 1962, localized aggressive deterioration of galvanizing was noted on some new installations, the latter notably on the currently designated I 96 between Grand Rapids and Muskegon. This roadway, an Interstate freeway, is about 40 miles long; with most of it opened to traffic in late 1961. Much of the galvanized guardrail was installed shortly before the opening. In March-April 1962, as the snow piled against the guardrail began to melt and compact, areas of guardrail were revealed having incrustations of white rust, a bad case of which is shown in Figure 3. The occurrence of this was spotty, with the spots varying in length from inches to perhaps 100 ft. About 10 percent of the total guardrail footage showed some coating deterioration, evidenced mostly by the white rust. Generally, when this was scraped off a zinc underlayer was revealed; occasionally a black underlayer was revealed which we dubbed the "inner zinc-alloy layer," thereby signifying a more severe or deeper corrosion. A small percentage of the affected area exhibited the brown rusting signifying complete loss of the galvanized coating.

From all of the aforementioned, it was deduced that galvanizing on Michigan guardrail would generally provide a much more durable coating than painting, though a problem of chance premature deterioration of the galvanizing, via white rusting, did exist as evidenced on the I 96 installations. The extent of the latter made Department personnel aware of the existence of the problem and soon its presence in other locations throughout the State was being noted and reported. It was subsequently decided that we study, under this project, the prevalence, causes, and possible correctives of this premature deterioration.

Prevalence of White Rusting on Galvanizing and Its Causes

Upon receipt of the above complaints regarding deterioration of the galvanizing, we consulted the literature and contacted several trade organizations, such as the American Zinc Institute, Galvanizing Institute, et al.

We obtained information that galvanized materials were subject to white rusting, sometimes called "wet and/or humid storage stain," when stored under humid and/or condensing conditions with the materials closely packed so as to receive variable ventilation.

Returning to the complaint shown in Figure 2, it was evident that deterioration of galvanizing on the end-shoes did not occur after installation because the adjoining sections of guardrail showed no corrosion. Consequently, it had to happen before installation. We analyzed the problem of the "white and more severe brown rusting" on some of the end-shoes as being due to improper storage either at the producer's or after delivery at the construction site. Perhaps a contributing factor was the overstressing and consequent faulting of the coating on the pregalvanized sheet (ASTM A93) during the forming of the end-shoe. To correct this, the Department issued a directive to project personnel to check for improper storage of guardrail (and culverts) at the construction site, and setting guidelines for the acceptance and rejection of galvanized materials showing white rusting. The producers were informed of the directive in order to minimize white rusting in their storage facilities. In addition, we requested that end-shoes be hot-dip galvanized after forming.

Returning to the complaint exemplified in Figure 3 we reviewed our inspection notes covering the I 96 and other projects and list the following findings:

1) White rust deterioration of galvanized coatings on installed guardrail in Michigan is somehow connected with winter's snows and its removal process from roadways, since its presence is first noted after the spring thaw.

2) Significant (not minor or rare) white rusting deterioration on galvanized guardrail does not occur every winter.

3) When it does occur, it does so preferentially on new guardrail during its first winter of service. It is spotty; generally less than 15 percent of the total footage is affected on any project.

4) It is not confined to, but more apt to occur on, lower sections of guardrail; and on the faces (Fig. 4). It is more apt to occur in certain locations, e.g., under the outside edges of a grade separation, on ramps, on the west side of a north-south roadway (Fig. 5), and the south side of an east-west roadway.

5) White rust product (a mixture of zinc hydrates and carbonate, with a trace of chloride) sloughs off during additional weathering and may, if attack is not severe, give little visual evidence of its original presence within a few years. Unquestionably, the weathering away loss of galvanized coating had been accelerated during the interim. Brown rusted areas do enlarge slowly (Fig. 6).

Besides the general white rusting type of attack described above, we have noted a rarer type which we dubbed "sparse freckle," consisting of several attack spots (generally less than 3 in. diameter) on a single rail; generally confined to one, two, or three adjoining rails. We have ascribed this type of attack to impingement and temporary retention of salt crystals and/or salt-slush mixture during a roadway de-icing and snowplowing operation. Though the attack may be severe in the affected spots, it is not extensive in area.

Reviewing the five characteristics of white rusting on galvanized guardrail listed above, we have not deduced the exact causative mechanism for this occasional and spotty occurrence. We do know that something about the snowplowing operation can affect it, as explained below. The I 96 roadway, referred to previously, passes through three counties: Kent, Ottawa, and Muskegon. During the winter of 1961-62, each had a contract with the Department for snowplowing within its boundaries. The bad attack of white

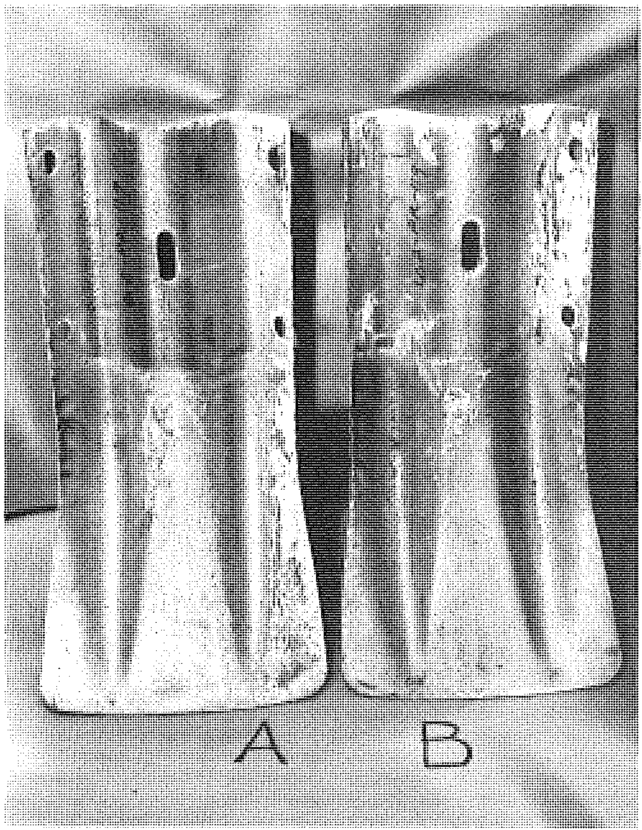
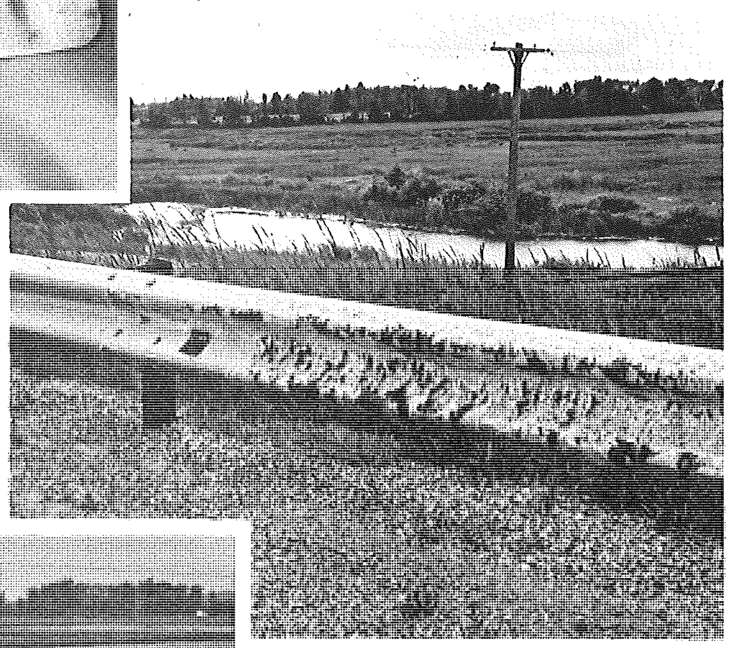



Figure 4. Backs of end-shoes shown in Figure 3. White rusting is non-existent or very light as compared to faces (March 1962).

Figure 5. Galvanized guardrail shows white and brown rusting when photographed after about 7 years of service. Left rail is unaffected showing spotty variability of attack. Abutting rails on right (not shown) were affected. Rails are on on-ramp to US 27 near Ithaca; on the west side of a north-south roadway (July 1967).



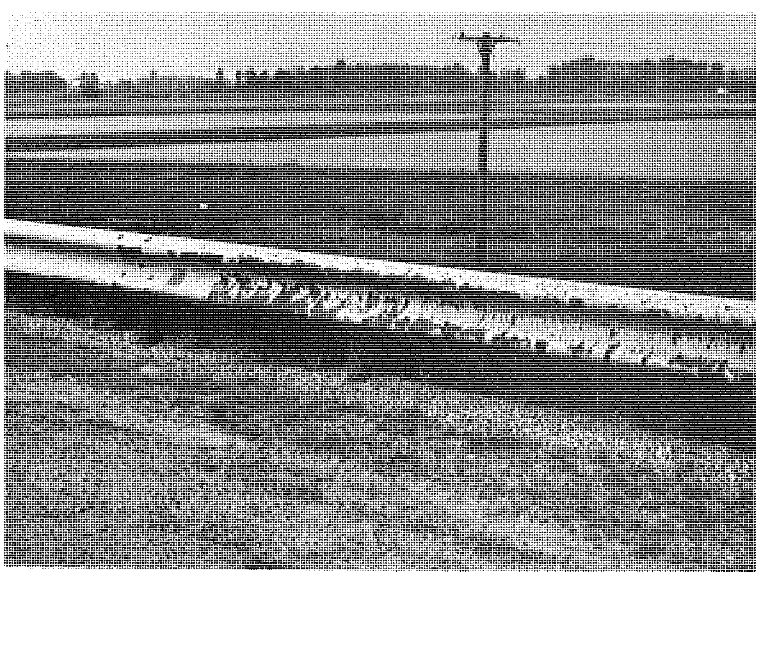


Figure 6. Same as Figure 5, after 12 years of service, showing that additional loss of galvanizing is not rapid. Dark rectangle near guardrail post carries study identification number (June 1972).

rusting noted in the spring of 1962 on I 96 was present in Kent and Muskegon Counties, but almost non-existent in central Ottawa County[1]. The amounts of snowfall received during the winter (Table 1) do not correlate with the results.

TABLE 1
AVERAGE SNOWFALL (in.) RECEIVED

| Year | Kent | Ottawa | Muskegon |
|---|---|---|---|
| 1959-60 | 76.1 | 91.6 | 94.4 |
| 1960-61 | 52.5 | 59.8 | 67.3 |
| 1961-62 | 69.4 | 88.5 | 105.8 |
| 1962-63 | 72.2 | 103.6 | 119.0 |
| 1963-64 | 53.7 | 88.9 | 101.3 |

Reviewing the above, if difference in the amounts of winter snowfall were a contributing factor, then the following winter of 1962-63 should have been worse for white rusting. Yet there were no complaints from that area in the spring of 1963.

This is confirmed on a statewide basis since Michigan has a large variability in amounts of yearly snowfall. Our southeastern counties average about 20 in. per year, while our northwestern counties average 100 to 200 in. per year; yet the white rusting has not been confined to the highest snowfall counties but has been fairly widespread, though we've had no bad attacks reported from the southeastern counties.

Simulated White Rust Environment

One of the objectives of this study was to determine the causes of white rusting on field installations of guardrail and use this information for building a simulating chamber in the laboratory where corrective measures for this deterioration could be tested and developed.

Coating technologists know that white rust on galvanizing can easily be produced in the laboratory by exposure in a salt spray cabinet operated at room temperature, or a humidity cabinet operated at above room temperature; and less readily in accelerated weathering equipment (Weatherometer) operated with the water-spray cycle at about 145 F.

[1] Part of the reason may be that some of the guardrail in Ottawa County had been installed before 1961.

Though realizing the above, a coatings technologist knows he cannot use any of the above equipment in laboratory screening tests to determine the relative field performance of paints on steel vs. galvanizing, particularly regarding coatings for a service exposure such as bridge steel, where white rusting of galvanizing would be uncommon. Accordingly, we felt we could not use any of the above standard pieces of laboratory equipment because they did not duplicate service exposure. Since we never did determine the exact service environment causing the white rusting on installed galvanized guardrail, a simulating laboratory test chamber could not be built. Therefore, we would have to use field sites for evaluating merits of potential corrective treatments.

## Corrective Measures

We mentioned earlier that the worst incidents of white rusting on galvanized guardrail, which the laboratory has been able to check, have occurred on new installations during the first winter of service; a probable explanation is as follows.

Observing galvanizing after it's put into road service, one notices that the initial glossy surface slowly dulls during weathering. Literature explains that the surface is "converted" to zinc corrosion products that are normally protective. Our experience confirms the latter, showing that this natural conversion coating confers much immunity to galvanizing against future attacks of white rusting. Since the full conversion may take about a year to form in the Michigan environment, galvanized guardrail installed any time during the construction season in Michigan would not have developed the immunity before exposure to the following winter's snows.

From the aforementioned, the natural suggestions for correctives of the white rusting phenomenon are, 1) topcoats to serve as barriers; 2) chemical conversion of the galvanized surfaces; and, 3) substitute materials.

1) Topcoats - When the Department first made sizeable installations of galvanized guardrail in 1957, we had no data on the probable service life of galvanizing for this purpose. The Laboratory was aware that some users of galvanizing opted to use it as the primer of a coating system rather than as a total system. For information purposes, we accordingly removed some of the new railings and topcoated them with two-coat paint systems. The paint primers were selected for use on galvanizing (one, incidentally, was an epoxy-ester yellow traffic paint then being purchased by the Department) while the final coat was an aluminum paint to blend with the appearance of the galvanizing. The Laboratory topcoated galvanized railings were then

re-installed on the M 78 project, east of Lansing. Since then, there have been minor differences in the performance of the paint topcoats (and some rails have been replaced because of collision damage) but, generally, all remaining have significantly increased the life of the galvanizing, perhaps have almost doubled it (Fig. 7).

Despite these findings, the Laboratory has not tried to convince the Department to topcoat all new galvanized guardrail, since we felt that the Department adopted the galvanizing of guardrail to avoid having to paint it, and would not be receptive to reinstituting the painting. Moreover, considering other factors such as expense of added painting and the short life of some due to collision damage, other more suitable and economical solutions to optimize the service life of the galvanizing would be available. (For information, starting in 1973 the Department specified the low alloy unpainted steel for most of our metal guardrail.)

After the white rusting attack on galvanizing of guardrail on I 96 mentioned earlier, the Department, in 1963, instituted project 63 NM-90 to evaluate the merits of a fairly heavy, composite asphalt-aggregate, shingle-type, coating on two corroded areas of guardrail on I 96. Other states were also evaluating the coating. Field applications of the coating on the installed guardrail consisted of; cleaning, spray application of the bituminous binder, and modified sandblast blowing-in of the gray aggregates. The coating proved much more susceptible to scraping damage from traffic and snowplows than the galvanized coating, though in other respects it was performing satisfactorily during four years of service when the project was terminated (Fig. 8).

Subsequently, our thoughts turned to evaluation of a low cost, thin, fugitive-type coating on guardrail that would primarily protect the galvanizing from white rusting during the first winter of service, before it was able to develop its own conversion protective coating during weathering. The coating should be capable of spray application on the newly installed guardrail, preferably by a self-contained spray rig that could be moved along the installation. The coating would have to adhere to new galvanizing, preferably without a prior special cleaning and/or degreasing operation.

Since the Laboratory was evaluating petrolatum base rustproofing compounds, as covered by SSPC-PS 8.01 specification, for speciality uses, it was decided to extend the evaluation as an anti-white rust coating for galvanized guardrail. Incidentally, this type compound is currently finding extensive use as an auto underbody rustproofing coating.

Accordingly, we obtained the following two such compounds for field test, plus a clear acrylic lacquer as an extra:

Figure 7. Galvanized guardrail installed on M 78 in 1957. Foreground rail was topcoated, with line at mid-length the terminus of different systems. Background rails, not coated, show galvanizing loss along tops, as in Figure 1. Rail dent shows mild collision damage (August 1972).

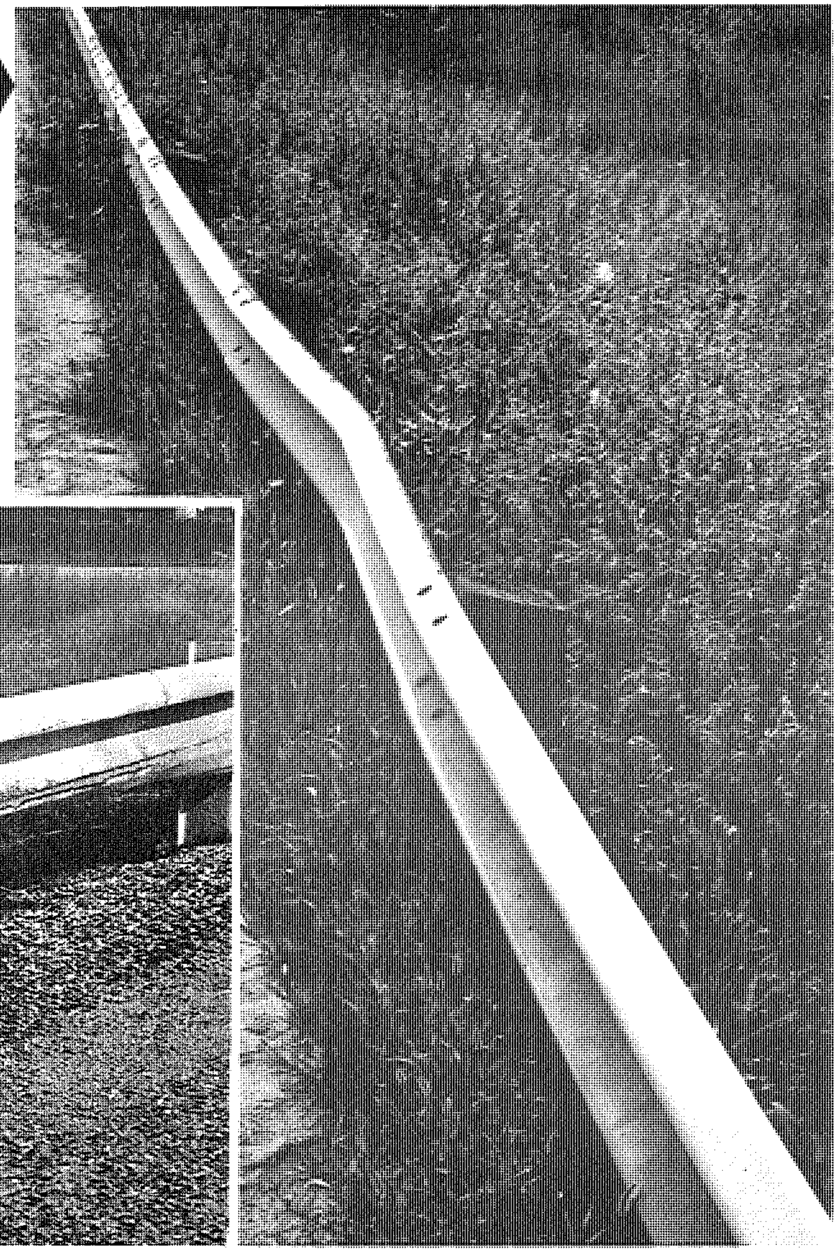
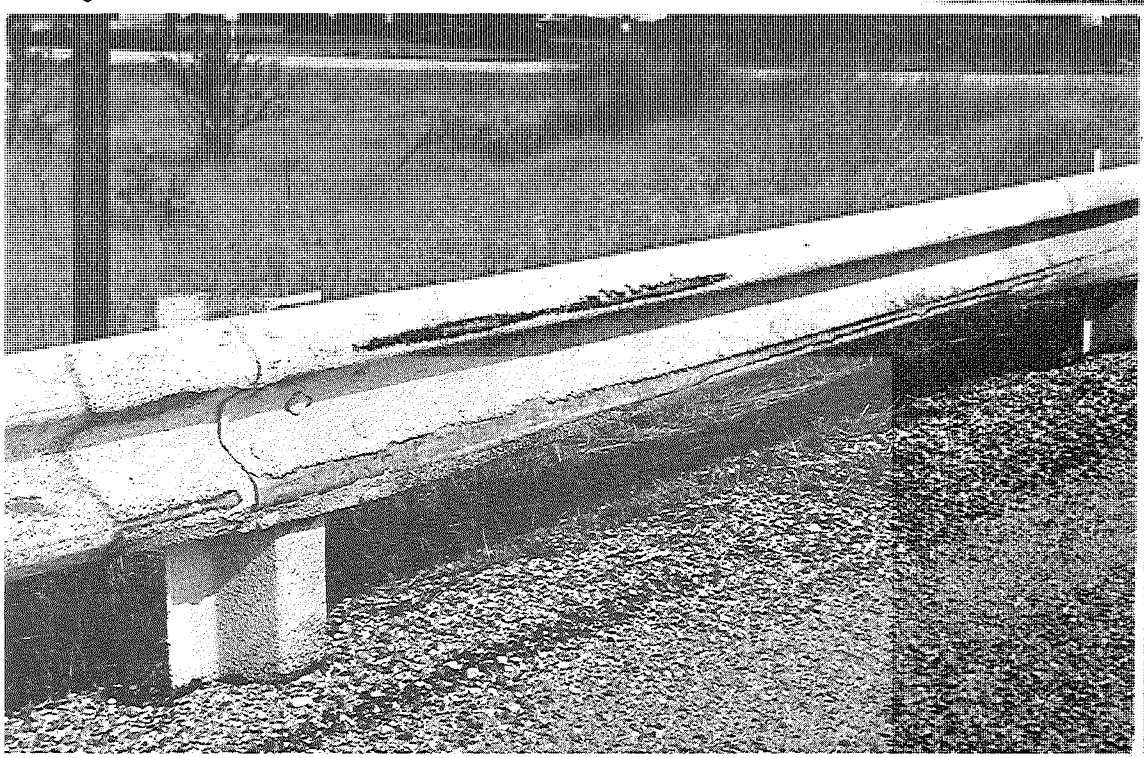


Figure 8. Test composite asphalt-aggregate coating is removed from ridges of guardrail by traffic and/or snowplows during 4 years of service. Short area of uncoated railing, at left, still shows effect of white rusting attack of 1961-62 winter (June 1967).



a) Tectyl 127 C UV - an aluminum pigmented petrolatum base coating of about 55 percent solids.

b) Kencote 60 - a petrolatum base coating of about 51 percent solids to which was added 1-1/4 lb/gal of chromated aluminum pigment paste.

c) Tectyl 151 - a clear acrylic base lacquer of about 20 percent solids.

These topcoats were spray applied on installed galvanized guardrail on new construction not yet opened to traffic on:

a) 3,660 lin ft on US 131 north of Grand Rapids (October 22, 1969) using eight test areas, and adjoining areas as uncoated controls (Fig. 9).

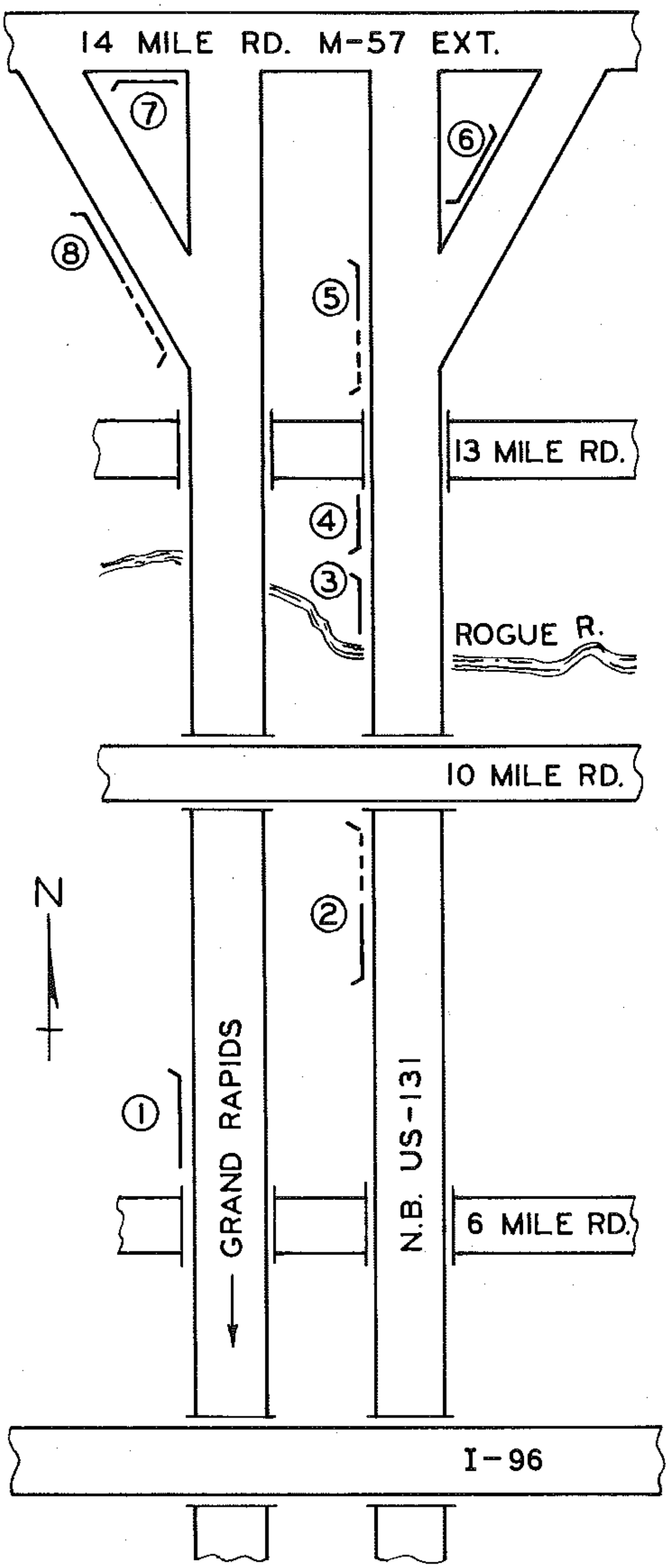
b) 3,790 lin ft on I 496 in west Lansing (November 5 through 12, 1969) using nine test areas, and adjoining areas as uncoated controls (Fig. 10).

c) 3,150 lin ft on I 496 and US 127 in southeast Lansing (November 25 to December 1, 1970) using nine coated areas, and adjoining areas as uncoated controls.

The test guardrail areas topcoated were selected to be locations most liable to show white rusting as discussed earlier. Regarding the application, we found the two petrolatum base coatings quite viscous and coherent and difficult to atomize with our airless spray equipment during the cool fall weather when applied. Incidentally, it is quite standard for roadway projects to be completed with installation of guardrail towards the end of a construction season to be followed by a late year official opening. The acrylic lacquer, however, sprayed nicely; but being transparent, it was difficult to control and to assure proper thickness of application.

How well the above test coatings protected the new galvanizing against white rusting was not determined from the field tests, since unfortunately the exposures were made in areas during the wrong two winters, as per previous observations that deteriorating attacks on galvanized guardrail did not occur every winter (as presented earlier). As it happened, the environmental conditions responsible for this problem did not develop, as evidenced by lack of significant white rusting on the un-topcoated control area guardrail.

However, in the 1970-71 winter exposures, it was noted that in several separate localized areas the snow apparently encased the lower section of the guardrail during part of the winter and somehow was able to partially




LEGEND:

No. 151 Clear

Area 1 - 300 lin ft
Area 2 - 480 lin ft
(Sta. 747+ to 752+)
Area 3 - 375 lin ft
Area 4 - 1,100 lin ft

No. 127C Aluminum

Area 5 - 300 lin ft
(Sta. 1019- to 1022-)
Area 6 - 610 lin ft
Area 7 - 140 lin ft
Area 8 - 360 lin ft

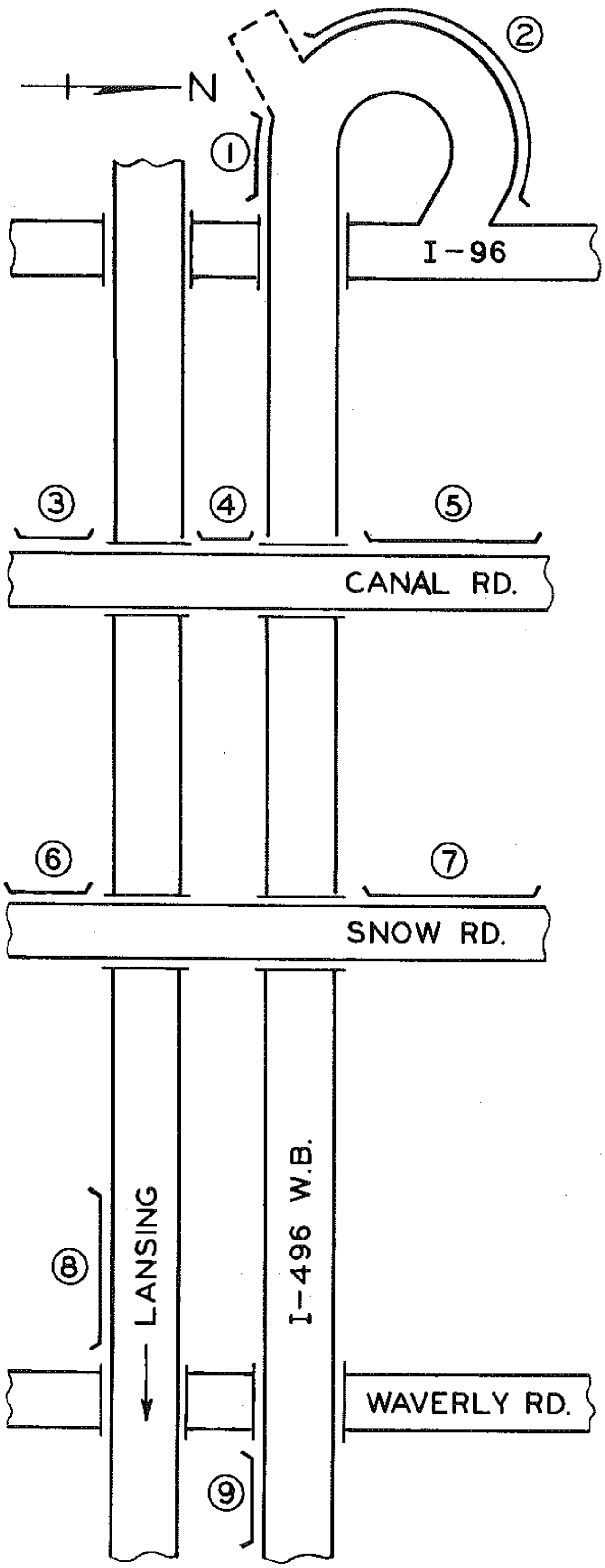
NOTES:

Area 1 galvanizing installed in fall '68 ; all others installed in summer through fall '69 . Area 1 showed no white rusting over winter exposure, unopened to traffic. Galvanizing is a mixture of pregalvanizing and hot dipped.

Uncoated control guardrail areas are not shown except for 'dotted' portions of areas 2, 5, and 8.

Coatings were applied on October 22, 1969 at about 45 F; a light wind was blowing.

Figure 9. Location of test topcoated galvanized guardrail on US 131.




LEGEND:

No. 151 Clear

Area 1 - 250 lin ft
Area 2 - 1,010 lin ft

No. 127C Aluminum

Area 6 - 690 lin ft
Area 7 - 775 lin ft

Kencote No. 60 +Aluminum pigment

Area 3 - 88 lin ft
Area 4 - 388 lin ft
Area 5 - 88 lin ft
Area 8 - 250 lin ft
*Area 9 - 300 lin ft

NOTES:

*Guardrail installed in fall '68 ; prevalvanized with long edges ungalvanized. No white rusting apparent during over-winter exposure, unopened to traffic. All others installed in November '69 , consisting of 'Syro' pregalvanized rails with long edges galvanized.

Uncoated control guardrail areas are not shown.

Coatings applied on November 5 - 12, 1969 at generally below 50 F.

Figure 10. Location of test overcoated galvanized guardrail on I 496.

strip or remove the petrolatum base coating in spots along the snow line and in addition leave a light etch of white rusting on the topcoat-stripped galvanizing. Similar etching of the galvanizing was noted on adjoining uncoated control area guardrail. A similar partial stripping or removal of another petrolatum base coating off the lowest areas of an ungalvanized steel bridge railing was noted on coating tests being conducted by a county in western Michigan.

Regarding the weatherability of the two aluminum pigmented petrolatum based coatings, it was noted that they (test application thickness estimated at 1 mil, minus) were apt to darken and show a blotchy appearance, the latter due apparently to differences in thickness. This was more apparent on exposures facing north (Fig. 11). Complete weathering away of the coatings will take two to five years; and one to three years for the tested clear acrylic coating, whose test application thickness was estimated at 0.4 mils, minus.

2) Chemical Conversion of the Galvanized Surface - Since the natural conversion of the surface of a galvanized coating during outdoor service exposure develops a protective "oxide" coating against subsequent white rusting, reviewing the possibility of a forced conversion was indicated.

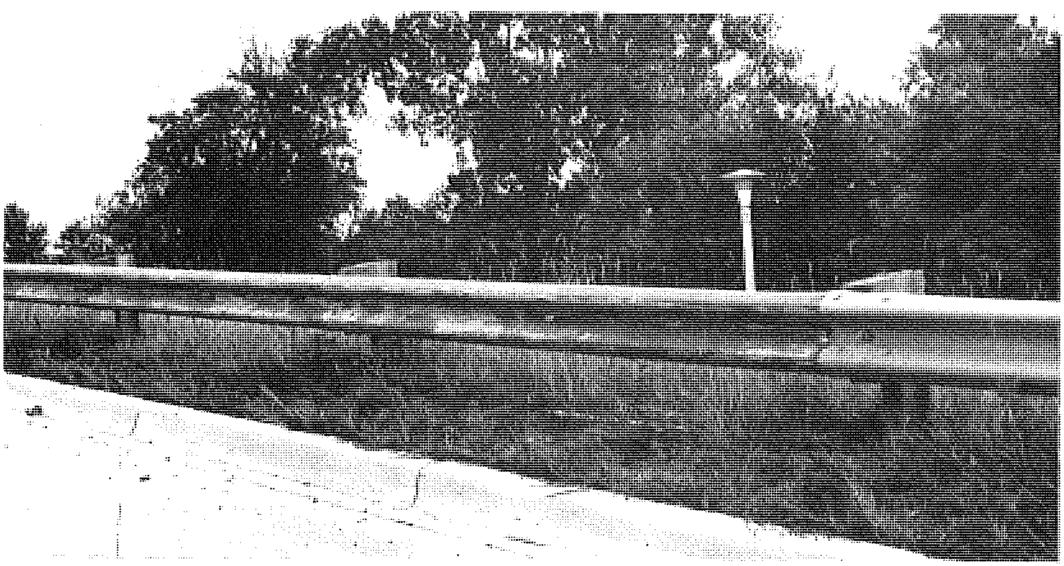


Figure 11. Aluminum pigmented petrolatum-base coating darkens and shows blotchiness as it weathers away, facing north. Partial rail, on right, is untopcoated galvanizing used for comparison; neither shows white rusting. Service exposure was minus two years in August 1972.

In doing this, we found that ASTM specification B 201-55T regarding, "Chromate Finishes on Electrodeposited Zinc and Hot-Dipped Galvanizing," covered one such chemical conversion. It noted, "The primary purpose of chromate finishes on zinc is to retard or prevent the formation of white corrosion products, such as basic zinc carbonate, on exposure to stagnant water or to atmospheres containing moisture or salt water." The specification covers evaluating the efficacy of the chromate coating by continuous exposure to the salt-spray test for agreed upon periods of time.

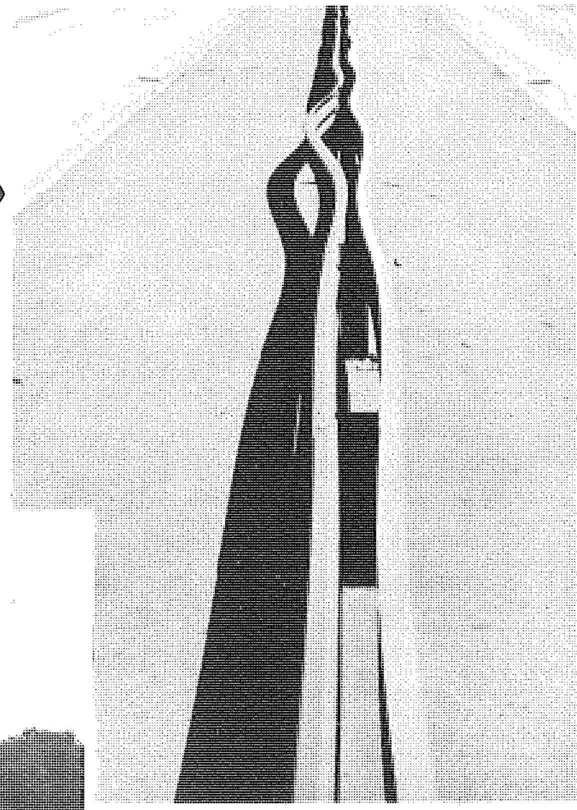
Accordingly, the Laboratory did chromate some galvanized specimens to varying weights or thicknesses and found that a fairly heavy chromate coating (distinct orange color) did withstand more than 100 hours of salt spray exposure and two months of stacking in the presence of moisture without noticeable white rusting. The thinner and lighter colored coatings had progressively lower resistance. An interesting proprietary chromate treatment called "Hinac," that required a short baking at 400 F and could be furnished in a clear or colored finish, also did well in laboratory tests in retarding white rusting.

None of the chromated galvanizing was field evaluated on guardrail installations, however, for three reasons: 1) though the treatment is considered low cost, this is only true if the galvanizer has such facilities; 2) we found no ready galvanizer or commercial chromator to furnish the finish; and, 3) we had no assurance of being able to place the treated guardrail where they would be exposed to white rusting that first winter (this in accordance with experience that white rust attacks occur during some winters and even then on only some of the total guardrail footage).

3) <u>Substitute Materials</u> - Many alternates have been suggested as improvements for the galvanized guardrail. The Department has, or is evaluating the following.

a) Aluminum Guardrail. We are evaluating the performance of aluminum guardrail on two projects. The first was installed in 1959 on structure X01 of 33034 on US 27 in North Lansing. The guardrail has performed well, except for the lap joints which within 10 years showed a most aggressive type of corrosion where fastened to the painted steel support posts. We judged this to be mostly a bi-metallic corrosion accelerated by chloride deicers. This corrosion could be minimized had galvanized or wood posts been used. The second was installed on I 296 (US 131) in Grand Rapids in 1962; a bigger installation, about a mile long. At the 1969 inspection, it showed almost none of the lap joint deterioration, though the same painted steel posts were used as in Lansing. The reason for this difference in behavior is not known, though use of a different aluminum alloy is suspected.

Figure 12. Aluminum guardrail in median of I 296 in Grand Rapids shows expansion and bulging in the heat of summer, breaking fastening bolt on post (September 1969).



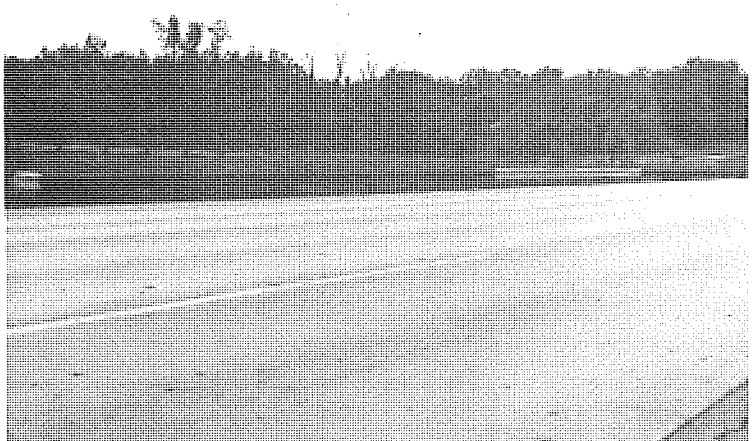


Figure 13. Test unpainted alloy steel guardrail on southbound I 75 north of Pontiac flanked by galvanized rails with four in center being damage replacements. Daytime appearance after 6 years of service (June 1969).

Figure 14. Nighttime appearance of mixed guardrail on I 96 at M 99. End-shoe and curved section (left) are galvanized, 10 straight rails (right) with reflective washers are low-alloy corrosion resistant steel. Curved galvanized section shows two ovate areas on ridges ("Storage Stains" during face down nesting) (July 1965).

A disadvantage of aluminum guardrail is the high thermal coefficient of expansion which causes some strains in the rail (Fig. 12). The guardrail at the former site has mostly been replaced, though it continues in test exposure at the latter site.

b) Aluminum-Coated Steel Guardrail. The Department is evaluating 46 lengths at three locations, installed in 1970, with test rails replacing the originals on three roadways. Two sets of 13 lengths were installed at the John Lodge - I 94 interchange in Detroit, 10 lengths on the US 127 crossing of M 143 in Lansing, and 10 lengths on M 43 east of I 96 in west Lansing. A few newly galvanized rails were installed in the area for comparison. The longitudinal edges of the aluminized rails were raw at the cut. Elcometer thickness readings showed measurement of about 2 mils and about 4 mils for the comparison galvanizing; longitudinal edges coated. Both types of test guardrail were supplied by the same producer.

A recent inspection showed aluminizing to be a slightly darker gray and less apt to protect the cut edges by cathodic action than the galvanizing. A close inspection shows a light brown freckle on the aluminizing; a similar occurrence was noted when evaluating aluminizing on chain-link fencing some years ago, which did not intensify and perhaps diminished with length of exposure. In the latter case, the aluminizing is outlasting the galvanizing, but that is a function of comparative thicknesses. As of today, the guardrail exposures are too recent to give data estimates on ultimate service life.

c) Unpainted Low-Alloy Steel Guardrail (Current Desig. ASTM A606, Type 4). We began evaluating their performance in 1963 on two projects using small footages. The first was installed on I 96 in south Lansing using 10 lengths at the M 99 crossing and six at the US 27 (M 78) crossing. The second was installed later in 1963 on I 75 in north Pontiac using 20 lengths each, on opposite shoulders north of the US 10 crossing.

At a 1969 inspection, the guardrail had a good appearance due to the development of a uniform coating of protective oxide, although at an earlier inspection two locations showed blotchiness apparently due to salt splashes. The lap joints showed no accelerated corrosion. Regarding the durability of the corrosion resistant guardrail, in early 1970 the Department did remove a rail from the original installation for test purposes. The rail was in service exposure for seven years. Specimens showed a tensile stress of 102,000 psi, still well above our 80,000 psi minimum limit. The thickness measurements were still within the tolerance for 12-gage steel. We could not determine the thickness loss, not noticeable visually, since we did not

Figure 15. General view of bridge railing used on Michigan system after mid-1930's. Bridge is on M 46 west of Saginaw built in 1954. Note use of cable guardrail abutting bridge on right.

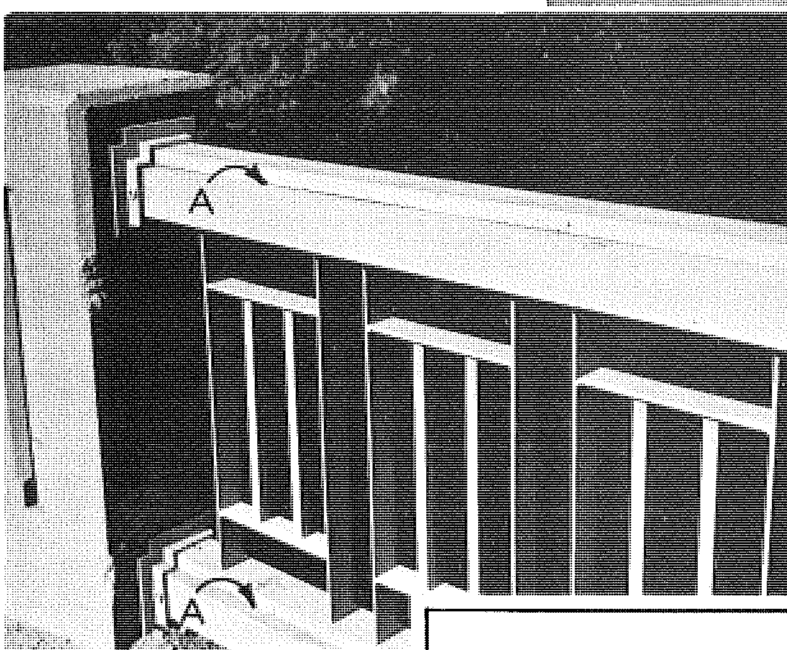
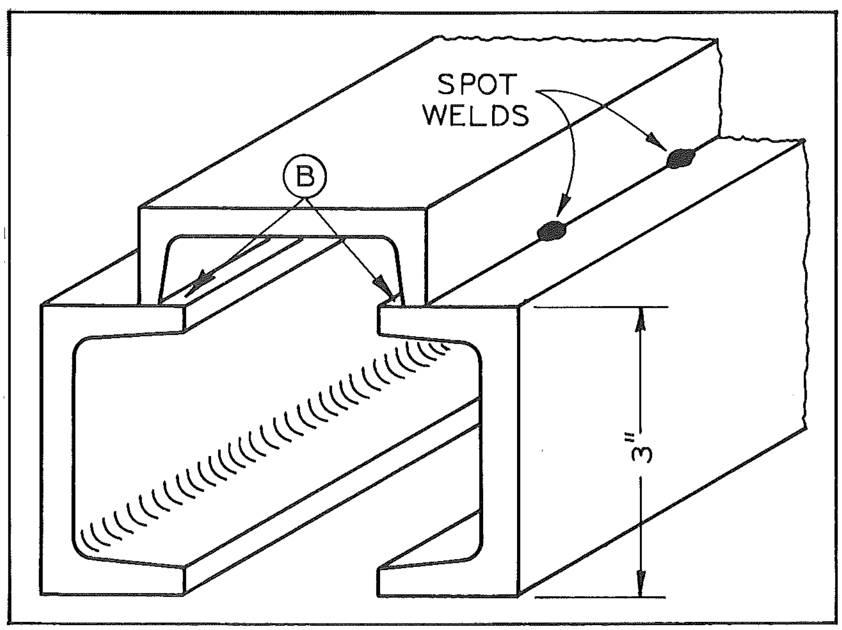



Figure 16. Close-up of above bridge railing, supported by concrete posts. Junction of elements on top and bottom rails (A) was a point of coating weakness (see Fig. 17).

Figure 17. Top and bottom bridge rails are composed of 3 channels spot-welded together. Condensation generally on unpainted inner ledges (B) sometimes seeped through and undercut coating.



have the original thickness measurement. If we estimate a 1/2 mil loss per side per year (one-half that of standard steel) the 12-gage rails will lose about one-fourth of their thickness in 25 years.

Regarding their daytime delineation, inspection personnel rated them as being perhaps more neutral, i.e., providing less striking contrast than the galvanized rail. However, the daytime delineation was rated as satisfactory (Fig. 13). The nighttime delineation was expectantly poorer than that of the galvanized guardrail, though it was significantly improved by using reflective washers, which, incidentally, are also being applied to many galvanized installations (Fig. 14).

On the basis of the above performance, the Department installed about 1.2 miles of the guardrail in the median of US 23 north of Ann Arbor at two locations in the spring of 1970. Satisfied with its early performance, the Department is currently specifying more of the low-alloy steel for guardrail installations.

d) Concrete Median Barrier. The Department began evaluating this type of guardrail in mid-1965 along about a half-mile of I 94 at the DeQuindre crossing in Detroit as replacement rail. Since then, significant mileage has been installed at various locations as replacement and as new guardrail. This type of guardrail was not part of this study, but is noted here for information purposes.

Additional Notes

For some economic and random, though applicable, notes on guardrail see Appendix A.

## BRIDGE RAILINGS

These railings, like the supporting bridge structures on the Michigan highway system, have evolved through several designs utilizing different materials, including wood. However, in the early 1930's the Department began standardizing on a steel balustrade-type railing supported by either concrete or steel posts; subsequently the steel post alternate was dropped. The steel railing was composed of top and bottom rails, plus box-type balusters (Figs. 15 and 16). The top and bottom rails were actually a composite of three structural steel channel sections, tack-welded together to form the top and sides (Fig. 17).

The railing was aesthetically pleasing, formed a reasonably strong barrier, but was difficult and costly to paint and to maintenance repaint. On new construction the specified paint system was the same for the railings as for the bridge steel girders.

The service life of the paint system varied considerably, and with increasing mileage of the bridge railings the frequency of the required repainting began presenting a maintenance problem. The Maintenance Division of the Department issued a summary of some applicable studies in 1963[2].

Appropriate excerpts from the report follow:

> "Approximately 53 miles of this type railing are currently being utilized. Speaking generally, the steel railings called for repainting every three years, after breakdown of the initial paint system. They were not necessarily painted every three years, but this was the cycle which experience indicated as most desirable.
>
> Sandblast cleaning was impractical, considering the openwork design of the railings. Therefore, the steel was cleaned with power-operated and hand brushes and scrapers. Spot priming, and even complete repriming with a top quality red lead primer, was followed by a surface coat of aluminum paint.
>
> Prior to World War II the total cost for repainting these railings was about $1 per linear foot. After the war, as wages and material costs rose sharply, maintenance costs for bridge rail repainting began to run as high as $3 and $4 per foot. One pilot job of railing painting performed in October 1962, primarily for reporting in this paper, and typical in respect to condition of protective coatings, cost $4.45 per linear foot. Some 80 percent of the total cost, of course, was in the cleaning and preparation of the surface before painting.
>
> In 1956 one section of bridge rail was cleaned and hot-dip galvanized to study its corrosion endurance as compared to that of painting. After two years of exposure no deterioration was visible, although paint of similar age would have begun to show considerable signs of failure. Accordingly, the rails of the entire bridge were

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[2] S. M. Cardone, "Galvanizing Reduces Bridge Rail and Guardrail Maintenance in Michigan," HRB Record No. 11, pp. 62-65.

galvanized. A steel fabricator, under contract, removed the railings, trucked them to a hot-dip galvanizer where they were cleaned and galvanized to a 5-mil or 3-oz specification, returned them to the bridge, and reinstalled them. The contractor also erected temporary pipe rails as a safety precaution while the permanent railings were being galvanized.

The cost ($8.50 per ft) was not economical, but analysis of the operation showed many steps which could be taken to lower the costs approximately one-half, as discussed later.

This bridge was inspected periodically during three years to provide performance data (actually 5 years of exposure in the case of the single section of railing that had been galvanized in 1956). Observations throughout this period, when paint would have failed, gave convincing evidence that galvanizing offered excellent service life. No surface deterioration was observed during this period. Consequently, in 1961 galvanization of bridge railings was adopted as a basic maintenance program throughout the State.

Current costs come to $2.25 per foot for the stripping and galvanizing with approximately $3.00 a foot to be added for the operation of removal, trucking, return, and re-erection. Regular highway department crews and trucks are used for this work. Temporary railings are erected during the work. The work is done largely in the colder months of the year when structure maintenance is at a minimum and personnel are most readily available."

Concurrently with above, and prior to the 1961 adoption of galvanizing as a maintenance recoating procedure for the railings, the Laboratory did cooperate in field exposures evaluating the merits of a variety of coatings, as follows.

## Metallizing

One railing on bridge X01 of 19021 (1936) in west Lansing was coated with aluminum in 1955, but inadvertently it was topcoated in 1956 when all the railings (except the one that was galvanized, as noted above) were maintenance repainted. Consequently, exposure data were sketchy. However, all railings covering about 400 lin ft, were metallized with aluminum in 1956 on grade separation S10 of 63022 over I 96 west of Detroit, in new construction. These did not perform commensurate with their cost primarily due to progressive yellowing and breakdown of the organic sealer used in the process, to porosity of the coating, pinhole failures, and to the inability of the coating to stop undercoat leakage at the longitudinal seams of the top and bottom rails (Fig. 17). After about eight years of service exposure the coating was rated unsatisfactory and the railings were maintenance galvanized.

Paint Coatings

The Department evaluated a number of paint systems and cleaning and application procedures on bridge railings in service exposure. Though the tests were generally conducted on existing structures whose railings needed repainting, the results could apply to construction painting or maintenance repainting. The evaluated systems were as follows:

1) A gray, lead-suboxide based paint (allegedly used for protecting many power transmission towers) was brush applied as a spot primer and a complete finish coat in 1957 on railings of B01 of 58071 (1934) on US 25 north of the Ohio border. The structure was over a creek and had four railing sections per side. This was a standard maintenance repainting job where the areas of failure on the previous paint system were hand cleaned and wire brushed before application of spot primer. The proprietary gray paint was substituted for the Department's standard red lead primer and aluminum topcoat combination to check its possible superiority.

2) An amine cured epoxy resin coating system was hot-spray applied in 1957 on a short structure (four railings per side), B01 of 63111 (1936) carrying M 24 over the Clinton River east of Pontiac. The railings were removed, sandblast cleaned on the shoulder of the road, and reinstalled before painting.

3) Several paints including an epoxy, a fish oil-iron oxide combination, a zinc chromate primer and the Department's standard were applied on a 650-ft structure, X01 of 38101 (1949) carrying I 94 over the Grand River and the NYCRR north of Jackson in 1958. This structure received fire damage from an accident involving a gasoline carrier, and the paints on some railings were charred. These were removed, caustic stripped and wire brushed, spray painted and baked at facilities of the nearby State Prison. The other railings were painted in place using the standard maintenance procedure with air-dry paints.

4) A silicone - alkyd aluminum topcoat was substituted in 1959 on the median railings of US 10 over Culver drain, B01 of 09101, east of Midland.

The bridge was three railings long, and two wide in the median. The outside shoulder railings received the standard aluminum topcoat for comparison purposes, on this new construction.

5) Several paints were evaluated in the last of this series after a Department meeting of February 29, 1960. The tests included automotive type systems which could be sprayed on and baked as at auto assembly plants. Hopefully, the tests would lead to a longer coating service life and also year around work for maintenance painting crews. The selected bridge, X01 of 33032 (1952), carried Lansing's Cedar St over the Red Cedar River and RR tracks and was about 950 ft long. The painted railings were eight years old and in need of repainting. Beginning in March 1960 they were removed by maintenance forces, trucked to the Sign Shop facility, sandblasted to varying degrees of cleanliness, and spray painted. If designed for baking, the coatings were baked. The painted railings were reinstalled on the bridge. Most coating systems gave us the desired 4-mil thickness. The primers contained pigments such as iron oxide, red lead, basic lead silico chromate, zinc chromate, and metallic zinc. A variety of primer vehicles was used.

The performance of the test paint coatings varied with some showing minor spot failures especially at the longitudinal junctures in the top and bottom rails within six months after exposure (Fig. 17). Others, like the zinc-rich primed railings showed some spot delamination of the topcoats. The failures increased normally with time of exposure, but the worst oversight of the tests was to neglect maintenance repainting of the supporting steel posts, along with the railings. This proved to be an irking, aesthetic imbalance.

In 1962, after two years of exposure, the Maintenance Division concluded the tests even though the coatings had not reached a terminal stage, and had the railings and posts maintenance galvanized. This followed the 1961 decision to stop maintenance painting of bridge railings and have them galvanized instead.

<u>New Construction</u>

As stated above, a single section of railing was maintenance galvanized in 1956 on a west Lansing bridge. Its excellent performance over the first two years led to extending the evaluation by maintenance galvanizing the remaining 33 sections in 1958. As it turned out that was a most prudent decision, since the railings on the west Lansing bridge galvanized in 1958 now only show minor, incipient spot rusting (failure) after 15 years of service. A 20 to 25 year maintenance-free service life can now be projected for them.

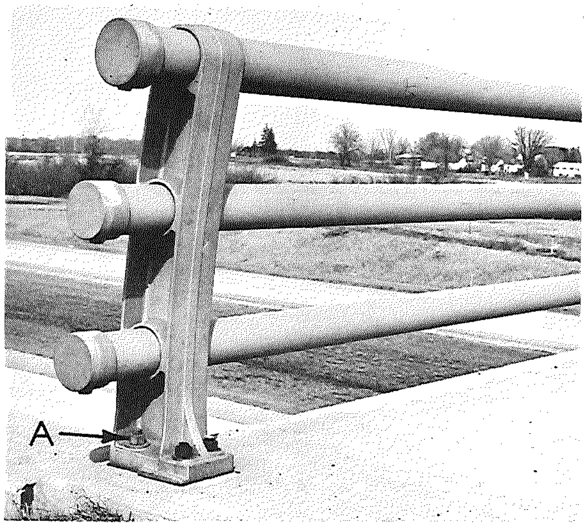



Figure 18. Three-tube all aluminum bridge railing on S01 of 23152 (1961) over I 96 in west Lansing. Aluminized post bolts (A) are being evaluated on the structure.

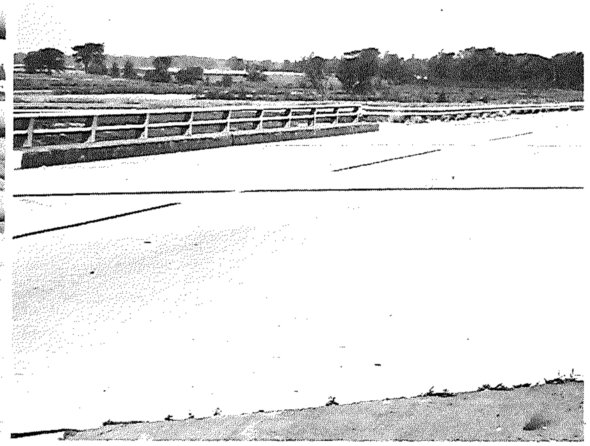


Figure 19. Two-tube all aluminum bridge railing on S07 of 23152 (1962) on I 96 over Canal Rd in southwest Lansing.

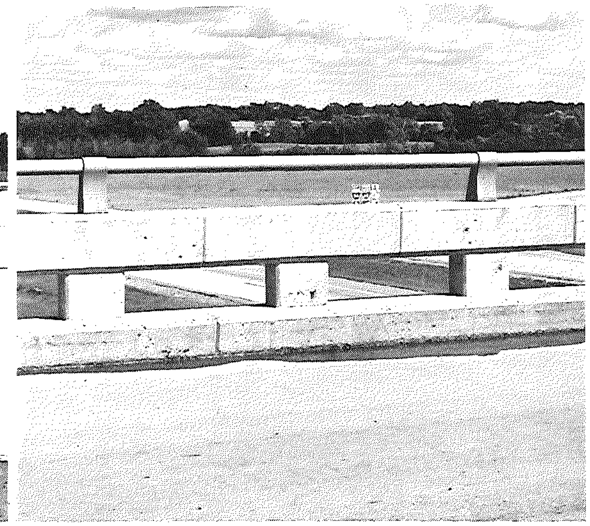


Figure 20. Parapet railing on northbound I 69 over I 94, S14 of 13073 (1968).

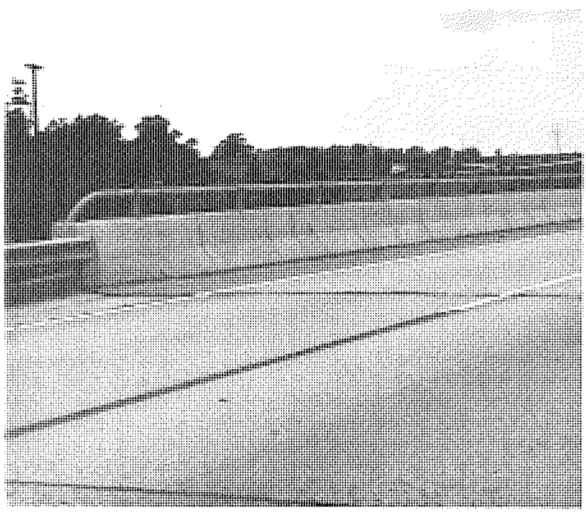
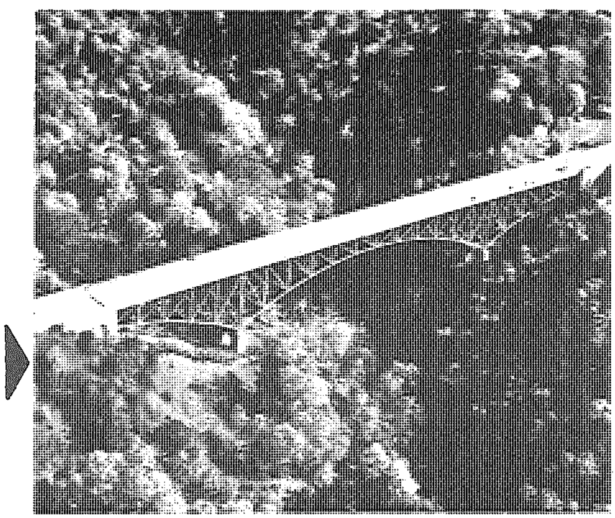


Figure 21. Concrete barrier railing on B02 of 23151 (1962) on I 96 over the Grand River in southwest Lansing. The railing replaced the original of another design in 1969.

Figure 22. US 2 over the Cut River in the Upper Peninsula borders on Lake Michigan, lower right. B01 of 49023 (October 1965).



1) Galvanizing - Noting and enthused over the performance of the single galvanized railing section, the Department in 1958 requested that three bridges in Detroit over I 94 have the railing construction galvanized. These were S11, S16, and X02 of 82024 (1958) in the vicinity of the Packard Motor Company.

The following year, seven more bridges over I 94 in Detroit had their railings construction galvanized. These were east of the above. They were P13, P14, P15, P16, P17, and S18, S19 of 82024 (1959). Another bridge, B01 of 73021 in Saginaw County, was also included in this group.

To our knowledge, these were the first bridge railings to be construction galvanized on our highway system. Since we then had no specific specification covering the galvanizing of bridge railings, they must have been coated on the one then current for beam guardrail, i.e., they could be painted, or galvanized to a pick-up of 2-1/4 oz of zinc/sq ft of railing. Regarding their performance, see Appendix B. In early 1959, the Department issued a specification requiring the construction galvanizing of steel bridge railings of the design shown in Figures 15 and 16, with a pick-up of 2.0 oz of zinc/sq ft of surface. That specification covered a significant percentage of bridge railings on new construction for several more years.

2) Aluminum Alloy - Aluminum railing, identical to design shown in Figures 15 and 16, but utilizing a one-piece extrusion for the top and bottom rails, was test installed on a new bridge, B01 of 41043 over the Grand River east of Grand Rapids in 1957. The bridge was about 480 ft long and utilized concrete support posts for the railings. After the initial performance of the railing was judged satisfactory, the Department formalized a standard specification covering the railing, which was utilized on some new construction for several more years.

3) All Aluminum - In about 1960, the Department began evaluating this type railing consisting of several longitudinal tubes, supported by cast-aluminum posts (Figs. 18 and 19). Comparatively, it was a lower cost railing which was specified on some new construction for about two years.

4) Concrete Parapet - In about 1962, the Department began evaluating a concrete parapet railing, providing greater barrier protection than (3), above. There have been some minor modifications in the design of the railing, with one of the first, on the widening of X01 of 82024 (1962) on I 94 in Detroit, being capped with a single rectangular tube of painted steel. The later modification shown in Figure 20 specifies a single aluminum or galvanized steel tube supported by similar metal posts, except in locations

where sight distance is impaired thereby. This railing has been used on the majority of bridges constructed by the Department in the past 10 years.

5) Concrete Barrier Railing - In about 1969 the Department began evaluating this type as a bridge railing (Fig. 21). It may be capped with a single aluminum or galvanized steel tube rail, as shown in the picture. The railing is being specified increasingly on new construction.

The above chronological review of bridge railings in use on the Michigan highway system shows that the trend was towards designs requiring less coatings maintenance. This trend was in accordance with the Department's Research Project 49 G-50, mentioned earlier, but was given added impetus by the memorandum of October 21, 1958 from the Deputy Commissioner-Engineering directing the Department to concentrate efforts towards this goal.

Accordingly when subject project began in 1964, the Laboratory was cooperating with other Divisions in evaluating the performance of bridge railings then in field exposure. A most pressing assignment dealt with the white rusting problem on galvanizing which surfaced in the spring 1962 on some beam guardrail installations.

However, despite the significant mileage[3] of galvanized bridge railings of the type shown in Figures 15 and 16 which was in service during the period of subject project, no deteriorating attack of white rusting on bridge railings has been reported to us, nor have we noticed any. This has remained a puzzle, since the winter environment at least on the bottom areas is considered tougher (i.e., more de-icing salt is apt to be found in the snow build-up) than in that surrounding the beam guardrail. As an exception, in 1972 we did note a light white rusting on galvanized bridge railings on a stairway alongside and leading below B01 of 49023 to a scenic park at the outlet of Cut River on Lake Michigan (Fig. 22). Since the stairway is not subject to winter snow removal, this guardrail would be encased in snow throughout the winter and later into spring than that on the bridge. And we know that snow encasement is one of the requisites for white rusting of galvanizing since it does not occur in Michigan on highway appurtenances, except in the winter and spring-thaw period.

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[3] About 53 miles, much of which was galvanized.

## BRIDGE STRUCTURAL STEEL (GIRDERS)

The Department had about 2,800 bridges and grade separations on the Michigan highway system in July 1964, when this project was started. The approximate percentage breakdown as to type; grade separation, water, railroad, pedestrian, is: 47, 38, 11, 4, respectively. About 800 of these bridges had concrete structural members, while 2,000 utilized steel girders. Estimating an average of 120 tons of steel per bridge in the latter group and 175 sq ft of surface per ton, one gets $42 \times 10^6$ sq ft of total surface area of bridge girder steel that had to be protected from corrosion.

Incidentally, this value is the same order of magnitude as the surface area of our estimated 1,500[4] miles of steel beam guardrail, $1500 \times 5280 \times 3 = 24 \times 10^6$. The problems of coating the steel beam guardrail and the bridge girders have similarities; and differences. Regarding the latter, advantageously and economically the guardrails can be removed, cleaned, stripped, galvanized and re-installed -- while the bridge girders cannot.

### Construction Painting

Customarily, bridge steel girders have been painted to reduce corrosion, thereby assuring their functionality, and secondarily for aesthetic or appearance reasons.

In 1964, the Department specified that bridge girders be hand cleaned and primed with a red lead-linseed oil paint at the fabricating plant. After bridge construction was completed the girders received a touch-up coat over the mars, followed by an intermediate coat of the red lead paint, tinted brown, then topcoated with an aluminum paint. The three paints yielded a system having a dry film-thickness of about 4 mils. The service life of the paint system was quite variable, but if we estimate an average life of 10 years, the Department would have had to maintenance repaint (2,000/10), or 200 bridges per year. That is more bridges than the Department can manage to paint.

As mentioned earlier, the Department initiated project 49 G-50 in 1949 for the specific purpose of developing more durable paint systems, and one of the objectives was to reduce the annual bridge maintenance repainting work load. In retrospect, as the number of bridges on our highway system began increasing significantly, this was given additional emphasis in the

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[4] Appendix A.

October 1958 directive from the Deputy Commissioner-Engineering. Accordingly, the Laboratory was delegated to conduct laboratory screening tests on a variety of available coatings and to recommend the best performers for additional in-service tests on bridge girder steel[5]. This was done on the following bridges, listed chronologically:

M 78 bridges, east of Lansing - On the basis of screening tests and literature surveys, we did recommend a variety of coatings for field evaluation on two bridges being constructed in 1960 on M 78. The first was a four-span grade separation, S07 of 76023, carrying M 71 over four-lane divided M 78. For test purposes, the bridge was divided on the longitudinal centerline to give two test systems per span for a total of eight. This included hot-dip galvanizing with zinc pick-up of 2.0 oz/sq ft of surface and seven paint systems having a minimum dry film thickness of 5 mils. All paint systems were finish painted with the standard No. 5B aluminum paint.

System 1: the standard Departmental system, on hand cleaned steel, beefed-up to 5 mils thickness by an additional coat of aluminum paint. This was the control system.

System 2: identical to System 1, except for being applied on blastcleaned steel, vinyl-wash primed.

System 3: a zinc chromate primer on blastcleaned steel, vinyl-wash primed.

System 4: a red lead-iron oxide primer on blastcleaned steel, vinyl-wash primed.

System 5: a red lead-epoxy primer on blastcleaned steel, vinyl-wash primed.

System 6: a red lead-alkyd plus phenolic wetting agent primer on blastcleaned steel, vinyl-wash primed.

System 7: a zinc-rich primer (one package) on blastcleaned steel.

System 8: galvanized steel without additional topcoats.

The intermediate coat of each paint system was generally a color modification of that primer. For additional details on the test systems, see Table 2.

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[5] Appendix C consists of one such study, Research Report No. R-696.

The second bridge was several miles west of the above. It was a dual structure, B02 of 76023, carrying divided M 78 over the Shiawassee River. It was three span; with each span of a dual structure utilizing a separate test paint system for a total of six. All systems were applied to a minimum dry-film thickness of 5 mils on blastcleaned steel. System Nos. 1 through 4 had a supplemental coat of vinyl-wash primer before application of the regular primers. All systems were finish coated with aluminum paint.

System 1: utilizing the Departmental specification paints, it was the control system on this structure; identical to No. 2 above, with a color modification of the primer as an intermediate coat.

System 2: a basic lead silico-chromate primer was used, with a color modification of the primer as an intermediate coat.

System 3: an epoxy-ester primer was used, with a color modification of the primer as an intermediate coat.

System 4: an epoxy-ester primer was used, with a proprietary bitumastic black as an intermediate coat.

System 5: a vinyl primer was used, with a proprietary bitumastic black as an intermediate coat.

System 6: a two-package zinc-rich primer was used, with a vinyl-alkyd as an intermediate coat.

The last three were three-coat systems, while the others were four-coat (excluding the vinyl-wash primer). The blastcleaning was "commercial" in accordance with SSPC specification No. 6. Additional details on the test systems are given in Table 2, and supplemented in Figure 23.

US 127 bridges, south of Lansing - The second series of field tests on structural steel paint systems was conducted on three bridges being constructed in 1965 as grade separations on existing four-lane divided US 127, as initially presented in Research Report No. R-602. Three paint systems are under evaluation, each applied on half a structure at two locations. The latter is an effort to neutralize the location variable. The girders on these structures had rounded corners on beam-flange edges in accordance with a new Department specification (Fig. 24).

System 1: the new Department standard to-be, four-coat, 5-mil system on blastcleaned steel. It was the control system.

TABLE 2

DETAILS ON TEST PAINT SYSTEMS ON NEW BRIDGES

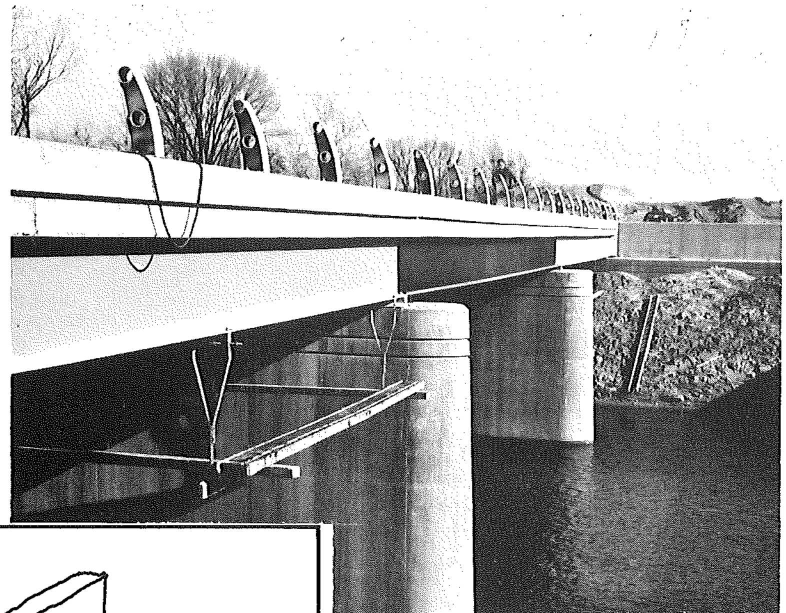
| Bridge No., Location, and Steel Weight | Structure Details | Paint Details | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant Application | | | | | Field Application | | | | | |
| | | Number | Cleaning | Pre-Prime | Primer | Date Primed | Mar Repair | 1st | 2nd | 3rd | Thickness Mils | Date Finished |
| S07 of 76023<br>M 71 over M 78 | 1 - I 36 WF 150 - 35'<br>3 - I 21 WF 68 - 35' | 1 | Hand<br>SSPC - #2 | | #1A Red Lead<br>(MDSHT) | 6/60 | primer or 1st field coat | #2A Red Lead<br>(MDSHT) | #5B Alum leaf-free<br>(MDSHT) | #5B Alum leafing<br>(MDSHT) | 5+ | 11/15/60 |
| 4 spans<br>145T total | 1 - I 36 WF 150 - 35'<br>3 - I 21 WF 68 - 35' | 2 | Blast<br>SSPC - #6 | SSPC-PT-3 | " | 6/60 | " | " | " | " | " | " |
| | 4 - I 36 WF 160 - 83' | 3 | " | " | •G-51 Zn Chromate<br>(California) | 6/60 | " | primer tinted | " | " | " | " |
| | 4 - I 36 WF 160 - 83' | 4 | " | " | SSPC-Paint-3 | 6/60 | " | " | " | " | " | " |
| | 4 - I 36 WF 160 - 83' | 5 | " | " | •G-42 Epoxy Red Lead (California) | 7/60 | " | " | " | " | " | " |
| | 4 - I 36 WF 160 - 83' | 6 | " | " | •2614 Red Lead similar to No. 4 but vehicle is alkyd-phenolic | 7/60 | " | " | " | " | " | " |
| | 1 - I 36 WF 150 - 34'<br>3 - I 21 WF 68 - 34' | 7 | " | | MIL-P-26915 Zn dust, Type I, air-dry | 8/60 | primer or TT-P-641b Type 2 | TT-P-641b Type 2 | " | " | " | " |
| | 1 - I 36 WF 150 - 34'<br>3 - I 21 WF 68 - 34' | 8 | Acid-pickle | | Hot-Dip Galvanize<br>ASTM A-123 | 7/60 | TT-P-641b Type 2<br>2 coats | | | | 3-3/4+ | 10/60 |
| B02 of 76023<br>M 78 over<br>Shiawassee R | 10 - I 33 WF 141 - 60' | 1 | Blast<br>SSPC - #6 | SSPC-PT-3 | •1A Red Lead<br>(MDSHT) | 8/60 | primer or 1st field coat | •2A Red Lead<br>(MDHST) | •5B Alum leaf free<br>(MDSHT) | •5B Alum leafing<br>(MDSHT) | 5+ | 12/60 |
| Divided 3 spans<br>275T total | 10 - I 33 WF 141 - 60' | 2 | " | " | TT-P-615<br>Type 1 | 9/60 | " | primer tinted | " | " | " | " |
| | 10 - I 33 WF 141 - 60' | 3 | " | " | RB-1107 Orange Epoxy Ester<br>(Truscon Co.) | 9/60 | " | " | " | " | " | " |
| | 10 - I 33 WF 141 - 60' | 4 | " | " | " | 9/60 | primer | MIL-C-18480<br>(#270-Koppers) | Alum leafing bleed-free<br>(#800-Kopper's) | | " | " |
| | 10 - I 33 WF 141 - 60' | 5 | " | | V-776 Gray Vinyl<br>(U.S. Engineers) | 9/60 | " | " | " | | " | " |
| | 10 - I 33 WF 141 - 60' | 6 | " | | MIL-P-23236<br>(#11 Carboline) | 9/60 | " | Vinyl-Alkyd<br>(#1230 Carboline) | #5B Alum leafing<br>(MDSHT) | | " | " |
| S01 of 33031<br>Bellevue Rd<br>US 127, 4 spans | 6 - I 30 WF 99 - 30-1/2'<br>6 - I 30 WF 108 - 63-3/4' | 1 | Blast<br>SSPC - #6 | | #1A(1) Red Lead<br>(MDSHT) | 5/65 | primer or 1st field coat | #2A(2) Red Lead<br>(MDSHT) | #3A(1) Gray<br>(MDSHT) | #5B Alum leafing<br>(MDSHT) | 5+ | 7/66 |

# TABLE 2 (Cont.)
## DETAILS ON TEST PAINT SYSTEMS ON NEW BRIDGES

| Bridge No., Location, and Steel Weight | Structure Details | Paint Details | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant Application | | | | | Field Application | | | | | |
| | | Number | Cleaning | Pre-Prime | Primer | Date Primed | Mar Repair | 1st | 2nd | 3rd | Thickness Mils | Date Finished |
| 77T total | 6 - I 30 WF 99 - 30-1/2'<br>6 - I 30 WF 108 - 63-3/4' | 2 | " | | #9 SSPC White Vinyl (2 coats) | 8/65 | 1st field coat | #9 SSPC Gray Vinyl | #8 SSPC Alum Vinyl | | " | " |
| S02 of 33032 Columbia Rd over US 127, 4 spans | 6 - I 30 WF 99 - 36'<br>6 - I 30 WF 99 - 54-1/2' | 1 | " | | as #1 above | | | | | | | " |
| 75T total | 6 - I 30 WF 99 - 33-1/2'<br>6 - I 30 WF 99 - 52-1/2' | 3 | " | | MIL-P-23236 (Rust Ban-191) | 6/65 | primer | SSPC-PT-3 | #8 SSPC Alum Vinyl | | " | " |
| S07 of 38131 US 127 over Territorial Rd | 6 - I 27 WF 84 - 34-1/2'<br>6 - I 27 WF 94 - 41-2/3'<br>6 - I 27 WF 84 - 29-1/2' | 2 | " | | as #2 above | | | | | | | " |
| Divided 3 spans 80T total | 6 - I 27 WF 84 - 34-1/2'<br>6 - I 27 WF 94 - 41-2/3'<br>6 - I 27 WF 84 - 29-1/4' | 3 | " | | as #3 above | | | | | | | " |
| These 5 bridges have hot-dip galvanized expansion bearings and masonry plates | | | | | | | | | | | | |
| S01 of 20016 Military Rd over US 27, 4 spans | 5 - I 36 WF 135 - 37'<br>5 - I 36 WF 150 - 67' | 1 | Blast SSPC - #6 | | #1A(1) Red Lead (MDSHT) | 1/67 | primer or 1st field coat | #2A(2) Red Lead (MDSHT) | #3A(1) Gray (MDSHT) | #4A Green (MDSHT) | 6+ | 9/67 |
| 95T total | 5 - I 36 WF 135 - 37'<br>5 - I 36 WF 150 - 67' | 2 | Blast SSPC - #10 | | MIL-P-26915 (Chem-Zinc) | 1/67 | primer | MIL-E-16501B Vinyl-Alkyd #37 Gray | #4A Green (MDSHT) | | " | " |
| S02 of 20016[1] Fletcher Rd over US 27 (SB), 3 spans 51T total | 5 - I 30 WF 99 - 45'<br>5 - I 30 WF 99 - 44'<br>5 - I 30 WF 124 - 68' | 3 | " | | MIL-P-26915 (Liquid Galvanize)[2] | 2/67 | " | SSPC-PT-3 | #2A(2) Red Lead (MDSHT) | #3A(1) Gray (MDSHT) | " | 10/67 |
| S03 of 20016 Fletcher Rd over US 27 (NB), 3 spans 57T total | 5 - I 30 WF 99 - 44'<br>5 - I 30 WF 99 - 51'<br>5 - I 30 WF 124 - 68' | 4 | " | | MIL-P-26915 (Sealube - ZRC) | 2/67 | " | MIL-E-16051B Vinyl-Alkyd #37 Gray | #3A(1) Gray (MDSHT) | | 5 | 9/67 |
| S03 of 72013[1] Snow Bowl Rd over US 27 (SB) 3 spans 40T total | 5 - I 30 WF 99 - 39'<br>5 - I 30 WF 99 - 37'<br>5 - I 30 WF 108 - 51' | 1 modified | Blast SSPC - #6 | | #1A(1) Red Lead (MDSHT) | 10/66 | " | #3A(1) Gray (MDSHT) | MIL-E-15936B Vinyl-Alkyd #27 Gray | | 6+ | " |
| S04 of 72013[1] Snow Bowl Rd over US 27 (SB), 3 spans, 40T total | 5 - I 30 WF 99 - 39'<br>5 - I 30 WF 99 - 37'<br>5 - I 30 WF 108 - 51' | 2 modified | Blast SSPC - #10 | | MIL-P-26915 (Chem-Zinc) | 11/66 | " | MIL-E-16051B Vinyl-Alkyd #37 Gray | " | | " | 8/67 |

[1] Diaphragms are hot-dip galvanized in accordance with ASTM A-123, except that coating = 3 oz per sq ft.
[2] Intermediate coats were revised from original because pin-point rusting developed in exposed primer.

Figure 23. B02 of 76023 after application of first field coats of Systems 2 (left span), 4 and 6 (November 1960).



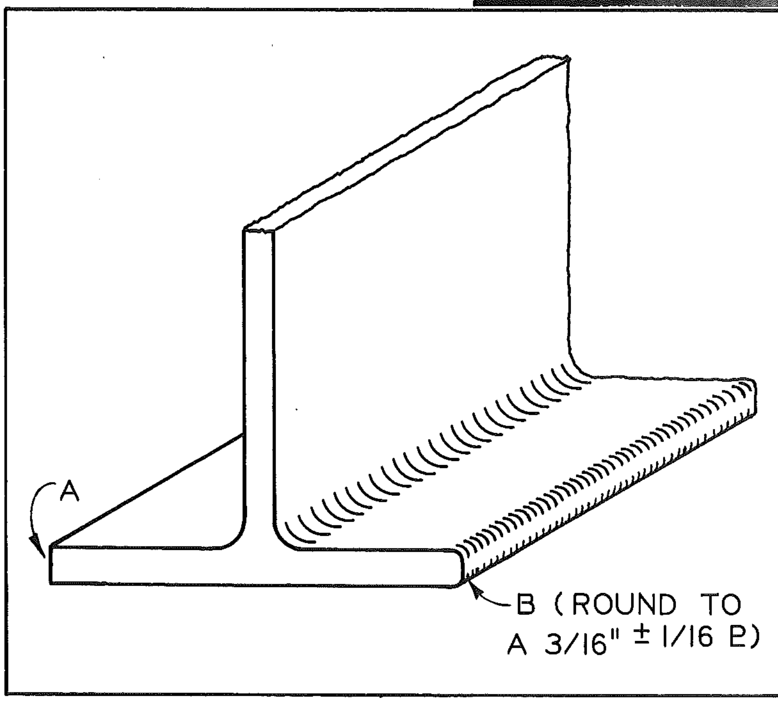
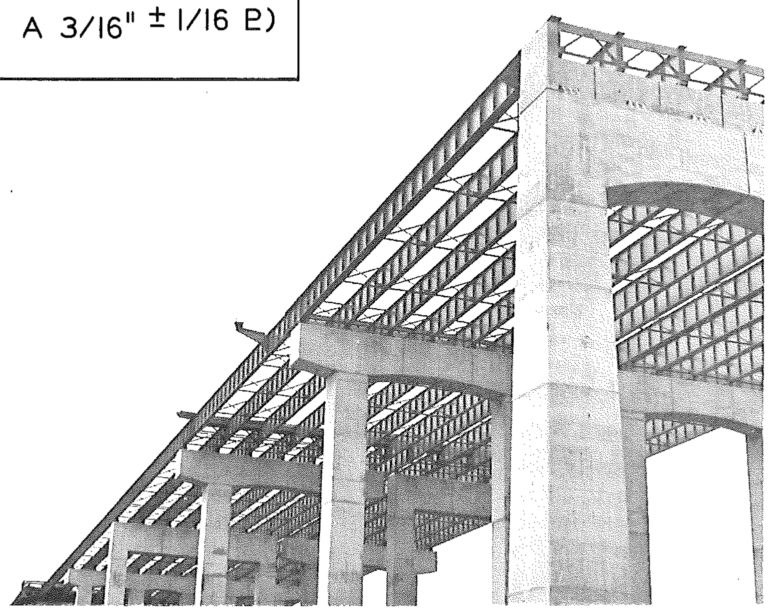



Figure 24. Standard rolled beam girder has square flange edges (A) often upset to a chisel ledge, most difficult to coat to proper thickness by brush. New Department specs required the corners (B) to be rounded, by grinding as shown.

Figure 25. Setting shop primed beams on Rouge River bridge piers no. 40, 41, etc. just north of river piers no. 38 and 39. The biggest beams were 129-in. high. (B01 of 82194, November 1965.)



System 2: a vinyl system on blastcleaned steel.

System 3: a zinc-rich primer, vinyl topcoat system on blastcleaned steel.

Additional details on the test systems on structures, S01 of 33031, etc., are given in Table 2. This shows that the painting stretched out over two seasons. Because of rust-back of some undercoated steel during winter service, some of these had to be removed by blastcleaning before completing the paint systems. This added another variable and complicated the performance study of the paint systems. The expansion joints on these bridges were offset off the piers.

US 27 bridges, south of Grayling - The third series of field tests on structural steel paint systems was conducted on five bridges being constructed in 1967 as grade separations over existing four-lane divided US 27. Actually the bridges consisted of two twin-tandem structures of three spans each, and one standard four-span grade separation. Four different primers are under test exposure, including three one-package zinc-rich primers and the Department's red lead primer as a control. The zinc-rich primers loosely conformed to MIL-P-26915A (USAF) Type 1, Class A specification, which gave good performance in laboratory screening tests. They were topcoated with a vinyl-alkyd paint. Three different finish coats are used on the test structures with details given in Table 2, which shows that all the expansion bearings and masonry plates, and some diaphragms, are hot-dip galvanized. The expansion joints on these bridges are offset off the piers.

I 75 over Rouge River in Detroit, B01 of 82194 - This is an eight-lane, divided structure, 8,626 ft long. It has 106 spans, with beam depths varying from 3 to 11 ft. The structural steel weighs 20,000 tons. All steel was blastcleaned to a SSPC No. 6 (commercial) specification. The painting was divided into two contracts, with the first including application of the standard Department No. 1A(1) red-lead shop primer, field spot priming over the mars, and the No. 2A(2) brown first field coat (Fig. 25). The second contract covered application of the Department's No. 3A(1) gray intermediate and No. 5E blue-gray topcoat. It also included application of an additional "striped" coat on beam-ends under open expansion joints and outside faces of fascia beams using a 1:1 mixture of the two topcoats. The painting extended through October 1968, though the bridge was opened to traffic in December 1967.

Colored Topcoats - On the basis of laboratory screening tests, and because the Department wished to experiment by adding colors to highway structures as a possible deterrent to "driver hypnosis," colored topcoats were substituted for the standard neutral-colored aluminum paint. The specification for the colored topcoats was based on Federal Specification TT-E-529a, "Enamel, Alkyd, Semi-Gloss (Class A - Air Drying)," except that the alkyd was a 23 percent phthalic anhydride type rather than the required 30 percent. The enamel was provided in any of six colors: beige, gray-blue, gray-green, ivory, maroon, and rose. This gave a total of eight topcoats, including the standard aluminum and the secondary standard, No. 4A, foliage green.

In 1963 these were first applied on overpasses over an extension of I 94 south of Port Huron. The structures were S01 through S07 of 72111; requiring the standard three-coat system on hand-cleaned steel. S04 of 50112 used the aluminum for comparison purposes. Subsequently, the colored topcoats were applied on I 94 structures in Macomb County and the John Lodge Freeway extension bridges north of 8-Mile Rd. Later, the colored topcoats were applied on freeway structures in Grand Rapids, Lansing, and other locations; though the two light colors, beige and ivory, were dropped in 1965 as being too stain-prone and were given the No. 5E MDSHT designation. In 1970, we dropped the gray-green and revised the remaining colored topcoat specifications to a more rigid formula, on the basis of field experience. The dry film thickness requirement for the colored topcoats was 1.2 mil vs. 1.0 mil for the standard aluminum.

Construction Painting Alternates

Only a few of these are available to take the place of standard-steel beams. The obvious one is concrete, which the Department has utilized on about 30 percent of its bridge structures (noted earlier) with its performance falling outside the scope of this study. There are two other alternates, as follows:

1) Galvanizing of standard bridge steel had not been specified by roadway authorities in the U.S. primarily because galvanizers did not have dip tanks and accessory equipment large enough to process standard length beams. If a few galvanizers did install such equipment, the economics of transporting bridge steel from a local fabricator to some distant galvanizer and then to the construction site appeared uninviting. Moreover, twenty and even ten years ago, roadway authorities couldn't have fully grasped the problems of maintaining our burgeoning system of structures.

Nevertheless, for evaluation purposes the Department did install; 1) four galvanized 34 ft long beams and accessory diaphragms on a test bridge (coatings) in 1960, as noted earlier[6], and 2) expansion bearings, masonry plates and some diaphragms on five test bridges (coatings) in 1967 also noted above. Their performance is noted later in this report.

For added information, two counties did utilize galvanizing on bridge structures in the last 7 years; 1) in 1966 Ottawa County did on the two-lane, 420-ft bridge over Stearns Bayou (a tributary of Grand River) a few miles southeast of Grand Haven, and 2) Newaygo County in 1971-72 did on a four-span structure over the Muskegon River at Bridgeton.

In addition, the Department and State municipalities have used galvanizing extensively on truss-type pedestrian overpasses, which utilize steel tubing as load bearing members. This is partially covered in Research Report No. R-896.

2) Unpainted, low-alloy steel conforming to ASTM A 588 requirements (initially A 242) was first suggested for bridge beam use in the early 1960's. The Department cooperated in pioneering such end-use nationally on structures carrying M 102 over the John Lodge Freeway in northwest Detroit, which was opened to traffic about November 1964. The structures consisted of reworking existing M 102 (8 Mile Rd) as a crossing over an extension of the freeway. There are four structures involved, S34 of 82112, C1, C2, C3, and C4, utilizing 3,160 tons of low-alloy steel. The longest structure is over 1,800 ft long; it is elevated M 102 carrying through traffic. The shortest is 60 ft long carrying a ramp over another ramp.

The Laboratory cooperated with the steel producer, Bethlehem Steel Corp., in exposing test panels on the bridge, and at a nearby off-road site for reference purposes. The panels were removed to determine the weight loss due to corrosion after one-half, one, two, and four-year's of service. The eight-year (last) panels, will be removed in May 1974. Data obtained to date have been reported[7].

In summary, data and inspections indicate a variable weathering-away loss of steel on the complex of structures. The greatest loss appears to be where the test panels are exposed, over the southbound freeway, where it

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[6] The beams had to be dipped twice, from either end, to effect complete coating, with overlap discernible as shown in Figure 26.

[7] J. C. Zoccola, A. J. Permoda, et al., "Performance of Mayari-R Weathering Steel at Bridges at 8 Mile Rd at Detroit, Michigan," July 1971.


Figure 26. Galvanized 34-ft long beam shows juncture (A) of dipping from either end to complete coating on end span of test bridge. (B) shows field exposure of all specimens of 8 test coatings being evaluated on bridge. (C) is a test painted beam, much longer than galvanized beam. Coatings completed late in 1960 (June 1972).

approaches that of standard steel at a steady rate of almost 1 mil per surface per year. Road dust blown-up by the heavy traffic settles on the overpass beams, having comparatively low clearance, and is not blown-off by the prevailing westerly cross-winds because of an adjacent retaining wall. The road dust accumulation does slough off carrying some steel scale with it, only to reform, but its poultice-like presence appears to increase the weight loss, compared to other areas of this bridge complex. The Department will consider a periodic blowing-off of the accumulations after the last test panels are removed.

Subsequently, and due partially to sharply increasing costs of maintenance repainting of structures, the Department has constructed many bridges of this steel in the Detroit area: I 75 over Fort St, S05 of 82194 in 1967; I 75 under M 102, S10 of 82252 in 1969; and many others on the I 96 extension.

## Maintenance Repainting

In the late 1950's the Department had to give thought to the systematic maintenance repainting of our burgeoning system of bridges. Prior to this, we had used a variety of procedures. Most included spot cleaning and undercoating, followed by an overall application of topcoat. In the Detroit area, the above maintenance repainting procedure was restricted to just the outside face of fascia beams on some structures. Obviously, such piecemeal procedures were inadequate on a system comprising several thousand bridges. Accordingly, the Department decided to evaluate a complete repainting procedure in Detroit in 1962, which was subsequently followed with some revision of specifications, as noted.

1) Two grade separation structures over I 94 on the west outskirts of Detroit, S02 and S03 of 82023 (both built in 1949) carrying Addison and Lonyo St, respectively, were selected for the 1962 tests. The maintenance repainting was done by Wayne County Road Commission personnel, under a work agreement. The work consisted of hand cleaning of all the painted steel, followed by application of the Standard No. 1 red lead primer. This was followed by application of the Standard No. 2 red lead paint, tinted brown, and two coats of No. 5B aluminum paint to give a four-coat system with a dry-film thickness of 5+ mil.

2) In 1963, the tests in Detroit were extended to six grade separations, over I 94, just east of the above. They were built in 1950 and were designated S04 through S09 of 82023 carrying Central, Cecil, Martin, Livernois, Wesson, and Junction St, respectively. All of the deck steel was I-beam, which with accessory steel weighed about 1,430 tons. The maintenance repainting was awarded to the Neumann Co. contractors for an average price of $57.75 per ton. The governing specifications were revised to require blastcleaning to remove all rust and old paint; then followed by application of a four-coat paint system with a dry-film thickness of 5+ mils, as noted above.

3) The maintenance repainting of bridge steel on Detroit freeways continued in 1964 and thereafter, as detailed in Table 3. It shows that the cost of the contract portion of the repainting rose steadily, from $57 per ton in 1964 to $163 per ton in 1970; with part of the rise ascribed to tougher regulations, i.e., a gradual restriction to cleaning and painting steel over traffic lanes to less-busy nighttime hours. The table also shows that Wayne County Road Commission stopped freeway bridge painting in 1968.

By 1965, governing specifications were altered to require substitution of No. 2 MP brown as the second coat and No. 3A gray as the third coat, in the initially shown paint specifications. Both used some basic lead silicochromate pigment in the formulas. In 1968, a colored topcoat was substituted for the previously specified aluminum paint.

TABLE 3
MAINTENANCE REPAINTING OF BRIDGE STRUCTURES IN DETROIT
(1964 through 1970)

| Year | Route | Structure (Construction Date) | | | Beam Weight Tons | Topcoat | Contractor | Bid Dollar/Ton |
|---|---|---|---|---|---|---|---|---|
| 1964 | I 94 | S10 of 82023 | (1951) | 30th | 257 | 5B Alum | Neumann | |
| | | S11 of 82023 | (1953) | Warren | 775 | " | " | |
| | | S12 of 82023 | (1953) | Scotten | 285 | " | " | |
| | | S13 of 82023 | (1953) | Gd. Blvd | 811 | " | " | 56.8 |
| | | S14 of 82023 | (1953) | " | | " | " | |
| | JCL[1] | S10 of 82112 | (1949) | Milwaukee | 93 | " | " | |
| | | S02 of 82112 | (1950) | W. Gd. Blvd | 221 | " | " | |
| | JCL | S16 of 82111 | (1953) | Gd. River | | 5B Alum | WCRC [2] | |
| | | S17 of 82111 | (1952) | Stimson | | " | " | |
| | | S18 of 82111 | (1950) | Forest | | " | " | unknown |
| | | S19 of 82111 | (1950) | Warren | | " | " | |
| 1965 | I 94 | S12 of 82024 | (1955) | Frontenac | 164 | 5B Alum | Geo. Bros. | |
| | | S13 of 82024 | (1957) | Van Dyke | 254 | " | " | |
| | | S14 of 82024 | (1955)[3] | Burns | 154 | Vinyl Alum | " | |
| | | S15 of 82024 | (1957) | McClellan | 284 | 5B Alum | " | |
| | | S02 of 82025 | (1957) | Cadillac | 196 | " | " | 63.2 |
| | | S03 of 82025 | (1957) | French Rd | 162 | " | " | |
| | | P01 of 82025 | (1958) | Garland | 47 | " | " | |
| | | P05 of 82024 | (1957) | Townsend | 35 | " | " | |
| | | P06 of 82024 | (1957) | Seminole | 39 | " | " | |
| | | P07 of 82024 | (1957) | Rohns | 25 | " | " | |
| | I 94 | S22 of 82023 | (1953) | Ramp | | 5B Alum | WCRC | |
| | JCL | S23 of 82023 | (1955) | Ramp | | " | " | |
| | X-ing | S24 of 82023 | (1953) | SB JCL | | " | " | unknown |
| | | S27 of 82023 | (1953) | NB JCL | | " | " | |
| | | S29 of 82023 | (1953) | Ramp | | " | " | |
| 1966 | I 94 | S15 of 82023 | (1953) | 24th | 156 | 5B Alum | Geo. | |
| | | S16 of 82023 | (1954) | Maybury | 185 | " | Kountoupas | |
| | | S17 of 82023 | (1954) | Gd. River | 609 | " | " | |
| | | S18 of 82023 | (1953) | Linwood | 176 | " | " | 86.5 |
| | | S19 of 82023 | (1953) | 14th | 205 | " | " | |
| | | S20 of 82023 | (1953) | 12th | 133 | " | " | |
| | | S21 of 82023 | (1954) | Trumbull | 362 | " | " | |
| | | P05 of 82023 | (1955) | Brooklyn | 88 | " | " | |
| | JCL | S03 of 82112 | (1954) | Pallister | | 5B Alum | WCRC | |
| | | S04 of 82112 | (1954) | Seward | | " | " | |
| | | S05 of 82112 | (1954) | Euclid | | " | " | |
| | | S06 of 82112 | (1954) | Clairmont | | " | " | unknown |
| | | S07 of 82112 | (1954) | Hamilton | | " | " | |
| | | S08 of 82112 | (1955) | Chicago | | " | " | |
| | | P02 of 82112 | (1955) | Pingree | | " | " | |
| | | P03 of 82112 | (1955) | Gladstone | | " | " | |
| 1967 | I 94 | S01 of 82024 | (1954) | Second | 369 | 5B Alum | City | |
| | | S02 of 82024 | (1954) | Cass | 264 | " | Painting | |
| | | S03 of 82024 | (1954) | Woodward | 514 | " | Company | 100 |
| | | S04 of 82024 | (1954) | John R | 172 | " | " | |
| | | S05 of 82024 | (1954) | Brush | 264 | " | " | |
| | | S06 of 82024 | (1955) | Beaubien | 178 | " | " | |

[1] John C. Lodge Freeway
[2] WRCR = Wayne County Road Commission
[3] Received 3-coat vinyl spray-on test system, different than others.

## TABLE 3 (Cont.)
## MAINTENANCE REPAINTING OF BRIDGE STRUCTURES IN DETROIT
## (1964 through 1970)

| Year | Route | Structure (Construction Date) | Beam Weight Tons | Topcoat | Contractor | Bid Dollar/Ton |
|---|---|---|---|---|---|---|
| 1967 | JCL[1] | S11 of 82111 (1958) Fort | | 5B Alum | WCRC[2] | |
| | | S12 of 82111 (1952) Lafayette | | " | " | |
| | | S13 of 82111 (1953) Howard | | " | " | |
| | | S14 of 82111 (1954) Mich-Bagley | | " | " | unknown |
| | | P02 of 82111 (1954) Porter | | " | " | |
| | | P03 of 82111 (1954) Elizabeth | | " | " | |
| 1968 | I 94 | S07 of 82024 (1956) Dubois | 163 | 5E Blue-Gray | City | |
| | | S08 of 82024 (1956) Chene | 178 | " | Painting | |
| | | S09 of 82024 (1955) Gd. Blvd | 303 | " | Company | |
| | | S10 of 82024 (1955) Mt. Elliott | 162 | " | " | |
| | | S11 of 82024 (1958) Concord | 165 | " | " | 116 |
| | | S16 of 82024 (1958) Harper | 172 | " | " | |
| | | P01 of 82024 (1957) J. Campau | 39 | " | " | |
| | | P02 of 82024 (1957) Moran | 33 | " | " | |
| | | P04 of 82024 (1958) Helen | 27 | " | " | |
| | JCL | S09 of 82112 (1955) Calvert | | 5E Maroon | WCRC | |
| | | S10 of 82112 (1955) Webb | | " | " | |
| | | S11 of 82112 (1955) Glendale | | " | " | unknown |
| | | P04 of 82112 (1955) Monterrey | | " | " | |
| | | P05 of 82112 (1955) Highland | | " | " | |
| 1969 | I 94 | S01 of 82025 (1958) Gratiot | 645 | 5E Blue-Gray | Detroit Bldg. | |
| | | S04 of 82025 (1958) SB Conner | 156 | " | Maint. Co. | |
| | | S05 of 82025 (1958) NB Conner | 231 | " | " | |
| | | S06 of 82025 (1958) Barrett | 160 | " | " | 152 |
| | | P02 of 82025 (1958) Springfield | 34 | " | " | |
| | | P03 of 82025 (1958) Malcolm | 43 | " | " | |
| | | X01 of 82025 (1958) D. T. RR | 349 | " | " | |
| | M 153 | S02 of 82081 (1940) Miller Rd | | 4A Green | WCRC | unknown |
| 1970 | JCL | S17 of 82112 (1955) Oakman | 291 | 5E Blue-Gray | Corrosion | |
| | | S18 of 82112 (1957) 12th | 152 | " | Coatings | |
| | | S19 of 82112 (1955) Linwood | 138 | " | Inc. | |
| | | S20 of 82112 (1955) Dexter-Belden | 138 | " | " | |
| | | S21 of 82112 (1955) Livernois | 218 | " | " | |
| | | S22 of 82112 (1955) Greenlawn | 129 | " | " | |
| | | S23 of 82112 (1955) Wyoming | 257 | " | " | 163 |
| | | P09 of 82112 (1956) Log Cabin | 37 | " | " | |
| | | P10 of 82112 (1956) Baylis | 34 | " | " | |
| | | P11 of 82112 (1955) Alden | 56 | " | " | |
| | | P12 of 82112 (1955) Muirland | 32 | " | " | |
| | | P13 of 82112 (1955) Monica | 46 | " | " | |
| | | P14 of 82112 (1955) Tuller | 41 | " | " | |
| | | P15 of 82112 (1955) Northlawn | 52 | " | " | |
| | | P16 of 82112 (1957) Wisconsin | 51 | " | " | |

[1] John C. Lodge Freeway
[2] WRCR = Wayne County Road Commission

Maintenance repainting of Detroit freeway structures continued after 1970, though not listed in the table. The contract bid costs actually decreased slightly from 1970's high, being \$146 in 1971, \$158 in 1972, and \$152 per ton in 1973.

## Maintenance Repainting (Out-State)

Experimentation with the repainting of bridges, out of the Detroit area, was also conducted. The notable ones are listed.

1) B01 of 49023 (1948) carrying US 2 over the Cut River was painted in 1962-64 by a succession of three contractors, with Neumann Co. finishing. The bridge is a somewhat unusual structure and a tourist attraction with the scenic park below overlooking Lake Michigan (Fig. 22). The two end-spans are subject to an abnormal amount of vandalism -- name inscribing and paint damage -- by young tourists. The bridge is 555 ft long, with the deck 147 ft above the river. The structural steel weighs 875 tons and includes many latticed box beams. The applicable specifications called for spot cleaning by mechanical tools, if needed, followed by sandblasting. The spots were then primed with No. 1 red lead, followed by No. 2 MP brown and No. 5B aluminum. All steel was then finish painted with No. 5B aluminum. Before repainting, the gutters and downspouts were removed and plugged since it was noticed that windblown drainage was accelerating the breakdown of the coatings on the significant height of steel below them.

The latter plus a good repainting are contributing to a comparatively good service life of the coating system, as of late 1972. Incidentally, the previous contract repainting was in 1954 with the Department subsequently covering up vandal inscriptions on the end-spans with a coat of No. 5B aluminum paint in the late 1950's. Because of problems with the initial contractor underestimating the amount of spot cleaning and painting required, and the necessary subsequent renegotiations of the contract, the Department has abandoned spot repainting on contract jobs. However, since it is wasteful to remove sound paint from significant areas of bridge steel, the Department may return to contract spot repainting of some selected structures.

2) B01 of 51011 (1933) US 31 over Manistee River in Manistee, and B03 of 51021 (1934) M 55 over Pine River, east of Manistee, were repainted under separate contracts let in 1965 to Dalman Construction Co. The Manistee bascule bridge was finished by October 1, 1965; the Pine River (Cooley) bridge by August 15, 1966.

The governing specifications required complete removal of all rust and old paint by sandblasting to a SSPC No. 10 requirement followed by application of No. 2A brown (faster drying primer), No. 2 MP brown and No. 3A gray undercoats. The topcoat was No. 5B aluminum to yield a 5+ mil dry thickness for the coating system.

The Cooley bridge is a prototype of the Cut River Bridge (Fig. 27). Because of difficulties in estimating the amount of spot painting required on the latter, the Department required complete blastcleaning on the Cooley bridge. Airless spray painting was allowed. The cost of repainting the Cooley bridge came to about $86 per ton of structural steel. Companion maintenance on the bridge included a bituminous overlay of the deck and plugging of mid-deck gutters. The latter was done to prevent localized aggresive corrosion as described on the Cut River bridge.

Figure 27. M 55 over the Pine River is a 3-span structure utilizing mostly latticed members that are difficult to paint. B03 of 51021 (Cooley Bridge) utilizes a design similar to that shown in Figure 22 (July 1972).

3) S09 of 38101 (1949) carrying Elm Rd over I 94, north of Jackson. This is a three-span structure having eight rows of continuous I-beams, weighing about 135 tons. It was repainted in July-August 1964 under contract to Neumann Co. The specifications required complete removal of all rust and old paint by sandblasting followed by spray applications of four coats of vinyl paints. The first double coat was SSPC - paint 9 white, followed by another gray and a white. The final double coat was SSPC-Paint 8 aluminum, to yield a 5-mil dry thickness of coatings.

We noticed some trouble in application of the vinyls; they tended towards a dry, roughish spray, probably because the contractor wished to minimize claims against him for spotting passing autos. The paint system showed early initial minor rusting, which, however, progressed at such a very low rate as to be given a "still satisfactory" rating in 1972 after eight years of service.

4) Electrostatic Spray Painting of Bridge Steel. Spray application should lower the cost of paint application while the electrostatic principle should lower overspray and the spotting of passing autos and give an extra bonus of minimizing thin coating spots.

The Department evaluated the method in the repainting of S02 of 39022 (1956) carrying Lovers' Lane over I 94, south of Kalamazoo. This is a four-span structure, utilizing six rows of I-beams, with the structural steel weighing about 90 tons. The only known painting contractor using this equipment was Decorators and Painters, Inc. of St. Joseph. After delays in preliminaries, the Department issued a negotiated contract to the latter on September 22, 1967. The included specifications called for complete sandblasting and application of two-coats of high-build paints to a dry film thickness of 5 mils. The Department furnished the paints, special modifications of No. 2 MP brown undercoat and No. 3A gray-green topcoat.

The project was beset with difficulties--bad weather, a strike, inability to settle on the right equipment, poor consultation on equipment--so that painting was not completed until October 15, 1968. Most of the painting was finally done with airless-electrostatic spray equipment with which the contractor had no experience. For more particulars see Research Report R-691.

At the end of the tests, we opined that the equipment's electrostatic attraction was outweighed by the force of air currents induced by passing traffic. However, we hoped to again test that type application equipment under more favorable conditions, i.e., a river crossing.

The performance of the coating system is the poorest in any of our tests. In the fall of 1972, after four-years service, the system had deteriorated as much as other test coatings after twice that service. Comparatively low clearance, leading to scraping damage, has contributed to the poor service over the traffic lanes; that was being spot repainted by maintenance personnel in June 1973.

5) S05 of 39022 (1955) Miller Rd over I 94, S06 of 39022 (1955) eastbound I 94 BL over I 94, and S08 of 39022 (1950) Scott Rd over I 94, all in the south Kalamazoo area, were let under contract in July 1970 to the Neumann Co. All were four-span structures, with a total weight of steel of about 375 tons. The governing cleaning and painting specifications were the same as then being used in Detroit, requiring blastcleaning and application of four coats of paint to a 5+ mil dry film thickness. The primer was No. 1-69 red lead, a faster drying revision, while the topcoat on one structure was No. 4-69 green, and No. 9-69 rose on the other two. Because of late in-season letting the painting was not completed until June 1971.

The cost of the painting was just over $100 per ton which is two-thirds of the Detroit cost, due mainly to the fact that there was no restriction on painting during daylight hours.

Regarding the performance; in June 1973 we noted some initial rusting on bottom faces of the lower flanges and on the edges of the lower flanges of the beams on all three bridges, though the Miller Rd bridge was the best. Deck-joint resealing, done at the time of repainting with a two-component polyurethane sealer, was still very good, at least on Miller Rd. The somewhat poorer-than-expected performance of the repainting on the bridges was probably partially due to carry-over into two seasons.

## Test Results

The performance of the experimental paint systems on bridge structural steel was to be followed by periodic inspections. These were made, though not as frequently and thoroughly as we had originally envisioned. Some of the inspections on previously listed bridges follow.

1) M 78 bridges, east of Lansing, applied on new construction in 1960. This was our first set of in-service exposures, conducted under a reasonable test plan, of experimental coatings on girder steel. It involved two bridges several miles apart, utilizing I-beams (Table 2), one a crossing over a divided highway, the other a small river crossing (Fig. 23).

Since this was our first set of field performance tests, a rating system had to evolve with experience and as the exposure progressed. The one-year service inspection showed no noticeable failure in any of the 12 test coating systems, though extraneously caused damage appeared on five systems. Graffiti artists caused minor damage on three systems over abutment slopes, which was to be repaired by us, while Maintenance personnel were to repair damage on System Nos. 3 and 4 of the grade separation bridge apparently caused by some vehicular load not quite clearing the beams. The two-year service inspection showed some initial spot hairline breakdown of most paint coatings along the beam lower flange edge corners; and System Nos. 4 and 5 on the river bridge were showing some darkening due to bleeding of the tar intermediate coat through the aluminum topcoat. This was accompanied by some light alligatoring due apparently to insufficient drying of the tar paint, when applied in cool, fall weather.

The next inspection, after three and one-quarter years of coatings service, was covered by Research Report R-460. The inspection showed; a) no significant worsening of the lower flange edge failures noted previously; b) very noticeable deterioration appeared under leaky deck transverse joints since the sealer had progressively failed in performing its function, especially outside the deck tire tracks; and, c) increased bleeding and alligatoring on System Nos. 4 and 5 of the river bridge, noted previously.

The next inspection, after four and one-half years of coatings' service, was covered by Research Report R-524. Generally, deterioration of the test coatings had been almost dormant in the interim except for progressive failure under leaky transverse joints and the epoxy-red lead primed system on the grade separation bridge showed about eight blister failures on the top of the lower flange of the east fascia beam, apparently because it collects rain and snow and is subject to more rapid thermal changes.

The next inspection, after six years of coatings' service on the grade separation bridge and seven years service on the river bridge, was covered by Research Report R-661. In the interim on the grade separation, the deterioration; a) had progressed moderately on the edges of lower flanges of the beams on all paint systems; b) had progressed under the leaky joints; c) had become greater on hand cleaned than on blastcleaned steel, confined to lower flange areas, on System No. 1 vs. No. 2 utilizing the Department's standard paints; and, d) showed spotty minor white rusting, heavier in the joint area, on the galvanized coating. On the river crossing; a) the bleeding and alligatoring had increased on the two systems utilizing the tar intermediate paint so that they were rated unsatisfactory despite providing good anti-rust protection; b) System No. 3, based on an epoxy-ester primer, was showing initial freckle failure over most of the steel though heaviest in pier areas; and, c) the other three systems Nos. 1, 2, and 6 were better and rated about equal.

The next inspection was made after eleven and one-half years of coatings' service. As mentioned earlier, we had to evolve a rating method as this set of field testing progressed, finally settling on one as shown in Figures 28 and 29, which list the indicated ratings on the grade separation structure. The inspection showed that in the last five-year interim of service the Department's red lead primed systems had deteriorated more than the other paint systems, especially System No. 1 on hand cleaned steel and without the wash primer. They no longer could be rated with the best performers. The best performing paint systems were the two based on primers; a) zinc chromate-alkyd (California specification); and, b) zinc-rich single package proprietary formula. The best performing coating system was the galvanizing.

On the river crossing, the inspection at the eleven and one-half year level showed that Systems No. 1 (Department's red-lead primed), No. 2 (basic lead silico chromate primed), and No. 6 (inorganic zinc-rich primed) were still rated as equally superior, and generally in slightly better condition than paint systems on the grade separation structure. There was less deteriorating effect from leaking transverse deck joints since these appeared to have locked and were allowing little leakage.

2) US 27 bridges, south of Grayling applied on new construction in 1967. This series covered five grade separation bridges on which we were evaluating three different organic zinc-rich primed systems against the Department's standard system and a modification. Galvanizing was also being evaluated on the bearing units and on some diaphragms.

Several complications developed relative to performance rating of the coatings. On System No. 3 (Table 2) the fabricator-applied zinc-rich primer developed a fine, freckle type of rust-back before it was field topcoated, for unknown reasons, and required a revision of topcoat specifications. The cantilevered beam-joints on these bridges do not allow for a free vertical drop of leakage from the deck joints (Fig. 30). It is caught by the beam ends leading to early aggressive deterioration of the coatings in the joint area. Most bridges over southbound US 27 showed varying amounts of clearance damage from high truck loads of Christmas trees coming to market.

The six-year performance ratings made in 1973 are hardly old enough to yield long range ratings, but at that age level they showed the Department's red lead primed systems to be slightly superior to the zinc-rich

| Bridge No. | Highway Rte. No. | Over ~~Under~~ | Facility Crossed | Location | Year Built |
|---|---|---|---|---|---|
| 507 of 76023 | M-71 | | M-78 | DURAND AREA | 1960 |

| No. Spans | Comments on Deck Joints | Leaks in Bridge Deck (Cracks) | Contractor |
|---|---|---|---|
| 4 | N&S PIER, SEALED JOINTS-LEAKING<br>CENTER CONSTRUCTION TYPE - TIGHT | NONE | STOREN |

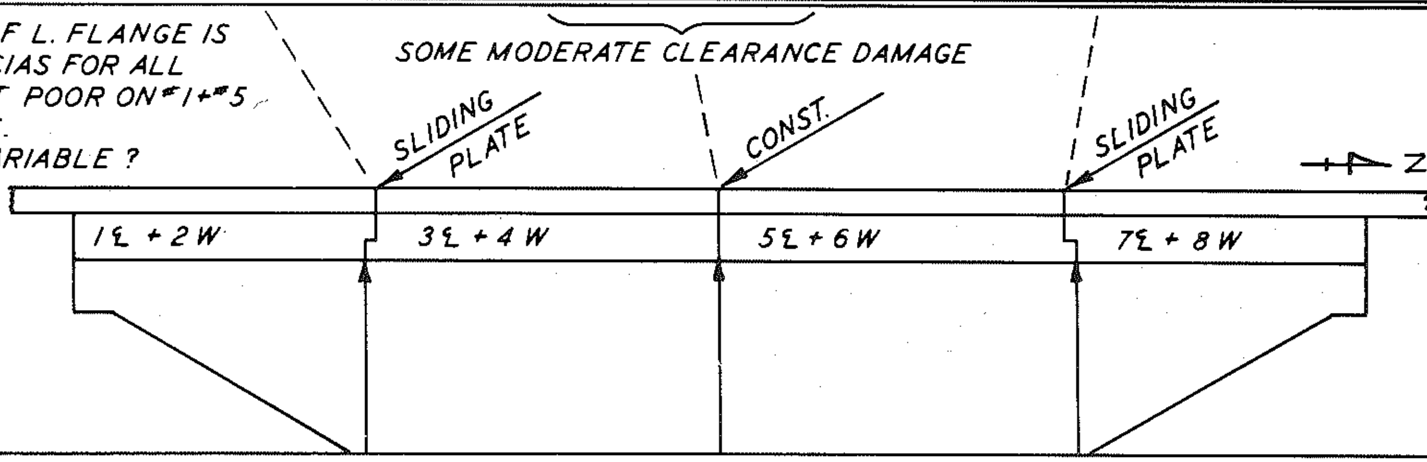
Date: 5 MAY '72 by PA, ARG, SMC — Summary of Deck Condition

SPALLING ON CONCRETE DECK NOTICED PREVIOUSLY NOW REPATCHED WITH CONCRETE. REFLECTION CRACKING OVER REINFORCING, NOW EVIDENT IN PATCHES.

Ratings of Paint Condition*

| | E** | W | | | E | W |
|---|---|---|---|---|---|---|
| Bottom of Lwr Fl | 5 | 6.5 | SLIGHT WORSENING SINCE | SLIGHT WORSENING SINCE | 1+4=9<br>2+3=6 | 1+3=9<br>2+4=7 |
| Bottom of Top Fl | 8 | 8.5 | LAST INSPECTION | LAST INSPECTION. | 9 | 9 |
| Top of Lwr Fl, Fac | 4 | 9 | #3 SHOWS V. LIGHT SPOT | #6 = #4 | 7.5 | 8 |
| Top of Lwr Fl, Int | 7 | 8.5 | RUSTING ON L. FL. EDGES. | #5 INTERIOR - SL. WORSE | 2+3=5<br>4=8 | 3=8<br>2+4=7 |
| Web, Facia | 7.5 | 8.5 | #4 SLIGHTLY MORE EDGE | THAN #6 | 9 | 9 |
| Web, Interior | 8.5 | 8.5 | RUSTING NEAR PIERS & | #5 FASCIA - L. FL. FAILURE | 9 | 9 |
| Joint Area and Diaph | 5 | 6 | OVER TRAFFIC. | | 3-6 | 6-8 |
| Diaphrams - Central | 7 | 8 | | | 9 | 9 |
| | | | RATINGS MADE FROM GROUND | | | |

NOTE: TOP OF L. FLANGE IS OK ON W FASCIAS FOR ALL SYSTEMS BUT POOR ON #1+#5 ON E FASCIAS. LOCATION VARIABLE ?




* RATINGS: 10=PERFECT, 0=COMPLETE FAILURE

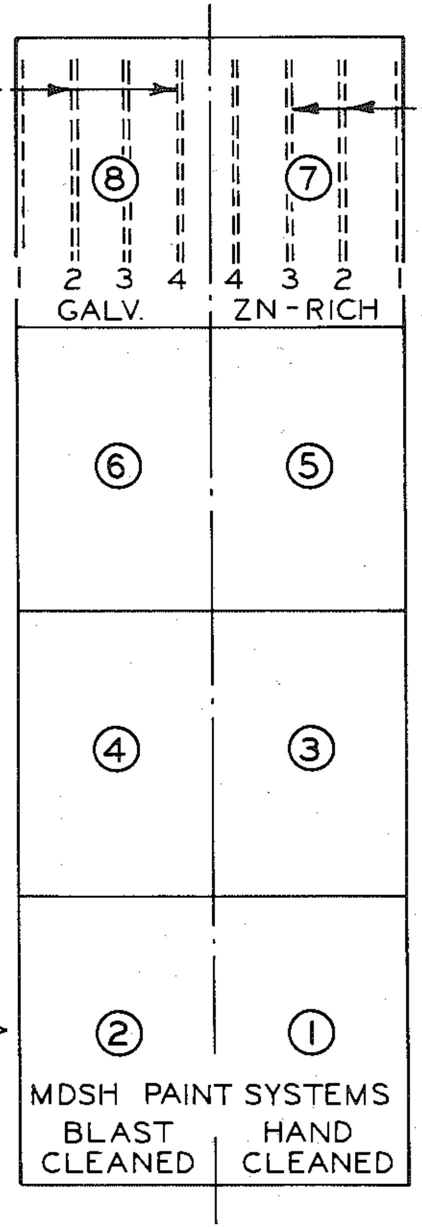
** E = EAST, W = WEST

Figure 28. Performance ratings of test coatings on bridges.

Girders 2 and 4 show a fairly heavy white rusting on lowerflange from joint leakage run-off.

"L" joint design (Fig. 25).


Deterioration is higher during inspection interim than expected, especially because of its off-traffic position.




Girders 2 and 3 show distress from joint leakage run-off on lowerflange which has roughened paint system, but so far left only one red-rust spot.

This inspection:

Deterioration has not worsened much on systems, except on ① and ② as noted below.

Total Appraisal:

⑤ least desirable - epoxy red lead showed earliest failure on fascia lower flange, though interior beam coatings are doing ok.

① next poorest - on hand cleaned steel and without wash primer, using our No. 1A red lead primer.

②, ④, and ⑥ tie for intermediate position. All use red lead primers.

③ and ⑦ are best paint performers, though ⑦ is hurt by leaking joint. Why did California drop ③ ?

Best system - galvanizing. Estimated at its half-life, though also hurt by leaking joint.

This, the standard system (hand cleaned) has worsened the most in 5+ years since last inspection; especially on fascia top of lower flange where several rust areas appeared, and on lowerflanges of interior beams where edge and bottom rusting are noted.

Figure 29. Ratings' Supplement: M 71 bridge over M 78 inspection on May 5, 1972.

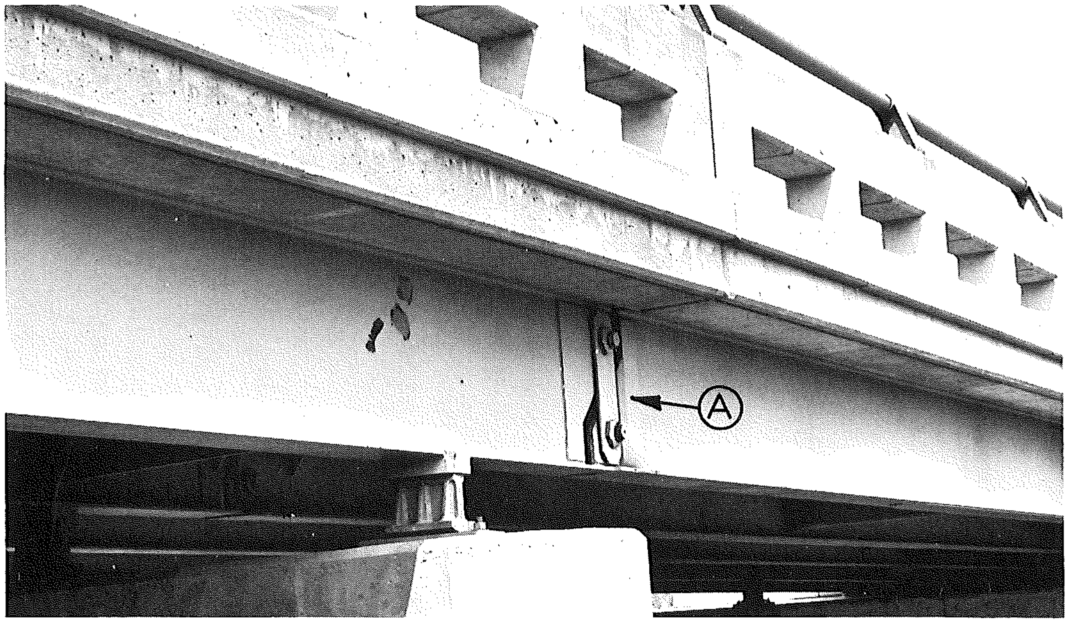



Figure 30. South fascia, west-span on S04 of 72013 shows spots of topcoat peeling off Zinc-Rich primer, over the pier. The cantilever beam-joints configuration (A) catches deck leakage, deteriorating beam coatings (July 1973).

primed systems because of less initial rusting along the lower flanges of the beams. For some reason, the latter are not giving us the cathodic protection, on initial film breaks, that obtained on the first test series using the zinc-rich primers. In addition, the two bridges utilizing zinc-rich primer No. 2 are showing progressive delamination of the field applied vinyl-alkyd second coat indicating a wrong coupling of paints (Fig. 30).

3) Other test coatings on new construction. The performance rating of these coatings will have to be covered in separate Research Reports.

4) Test coating systems applied as maintenance repainting. The first in this series were the Addison and Lonyo grade separations over I 94 in Detroit built in 1949 and repainted in 1962, utilizing a four-coat paint system on hand cleaned steel.

After eleven years of service, a 1973 inspection of the two structures showed the paint systems to be performing comparatively well with the coatings on the Addison structure better than on Lonyo. The former was showing only initial spot failure and rusting, mostly in the lower flange area of the beams while the latter was showing that, plus blister failure, on fascia lower flanges (Fig. 31) and more extensive failures under leaky deck joints.

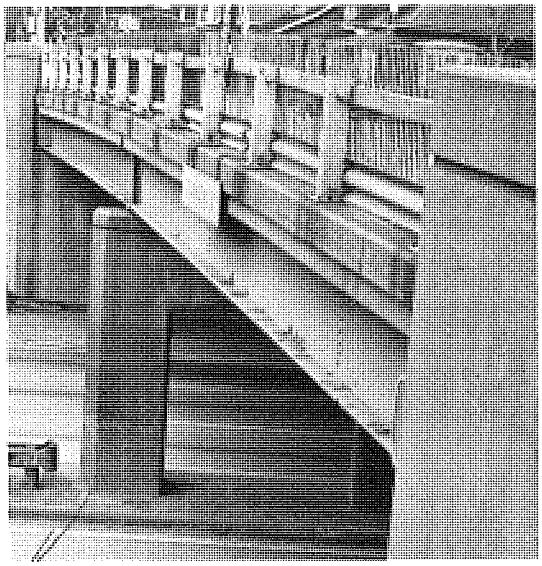


Figure 31. Top of lower flange of fascia beam shows blister and delamination failure 12 years after maintenance repainting. Note barricade at bridge railings while old painted rails are being galvanized (March 1974).

This and the following sets of maintenance repainting of bridges indicates that the same coating system will do as well here, durabilitywise, as on new construction except that any developing distress in the bridge deck or transverse joints that yields leakage will contribute to lowering of the coatings' service life.

5) Other test coating systems applied as maintenance repaintings. A few of these listed previously had accompanying comments relative to their performance. Appraisal of their continuing performance and the performance of others will have to be covered in separate Research Reports.

## CONCLUSIONS AND RECOMMENDATIONS

These are presented to correspond with paragraph identifications listed previously under Project Study.

### Steel Beam Guardrail

1) Good experience on our initial test installations of galvanized beam guardrail on new construction in 1957, and the Department's subsequent decision to require galvanizing of the guardrail on new roadway projects and later as a recoating for formerly painted installations has resulted in considerable savings. The galvanizing, (pre- and hot-dip) has a known and/or estimated service life of 13 to 25 years, while the paint system had a service life of 2 to 3 years, resulting in a conservatively estimated saving of 5¢ per lineal ft per year for the former; or $396,000 per year on our estimated 1,500 miles of guardrail.

2) White Rusting of Galvanizing on Beam Guardrail - Determining the causative mechanism for this premature deterioration in the Michigan roadway environment was a project objective which regrettably was not attained. However, our studies showed that white rusting occurred only during some winters, and at some locations, with encasement in snow or salt-laden snow appearing a requisite. Most frequently, it occurred at installations at bridge pier bases outside the deck area, and on ramps, etc. It is estimated that less than 5 percent of our footage has been affected to varying degrees of intensity. The white rusting occurred almost exclusively the first winter on new installations when the galvanizing had not yet oxidized to develop its own protective coating. Applying a short-lived protective coating, like a chromate conversion type, appeared as an obvious solution. However, we were unable to find a low-cost source for such coating to economically justify application on 100 percent of the footage to protect the random 5 percent that would be affected.

3) Other Developments - Our exposures of test hot-dip aluminized coatings on steel beam guardrail have been of insufficient duration to yield long range performance results. Lately, however, and based on 1963 initial test exposures, the Department is specifying more of the unpainted, low-alloy steel for beam guardrail since it is believed to be more maintenance-free than galvanizing; also, increasing amounts of concrete barrier type is being installed because it is not only more damage resistant but also has safety advantages.

## Bridge Railings

1) Steel Fabrications - The steel balustrade-type bridge railing that the Department adopted as a standard in the mid-1930's was of an architecturally pleasing design that provided a reasonably strong barrier. The railing served as a standard for more than 30 years. Originally, the railings were painted, utilizing the same paint system as specified for the bridge girders. Since the latter were protected by a bridge deck, their coatings' service life was generally greater than on the bridge railings.

As the footage of the railings increased with the increase in the number of bridges on the highway system, the maintenance repainting of the railings about every five years became a bothersome and expensive operation. Consequently, the Department in the mid-1950's began evaluating more durable coatings, including a variety of paint systems and application methods, and metallic coatings.

The latter group included hot-dip galvanizing since it was feasible on the railing panels; about 3 ft high and generally less than 10 ft long. This proved to be a very durable and economical system, adopted as a construction standard in 1958 and as a maintenance recoating standard in 1961. From the initial test exposure in 1956, and from subsequent exposures, we now estimate a 20 to 30 year maintenance-free service life for the galvanized coating on the railings. Since the overall cost on new construction must have been lower for the galvanized than for the painted railings, and since maintenance recoating by galvanizing eliminates at least four repaintings, this decision effects considerable savings to the Department.

For unknown reasons the galvanized bridge railings proved much more immune to white rust deterioration than the galvanized beam guardrail, and consequently were eventually eliminated from this concern in the subject project.

2) Aluminum Alloy Fabrications - A design identical to above, but fabricated of aluminum alloy was specified as railing on some bridges beginning in 1957 and continuing for several years thereafter. The railing was connected to concrete posts. The service life of the aluminum railing should be that of the bridge, though it probably provides a somewhat weaker barrier than the steel railing of identical design.

3) Other Designs - Beginning in about 1960 and continuing for several years thereafter, the Department specified an aluminum railing-post combination on new bridges with the railing consisting of two or three horizontal tubes. Because of somewhat poor barrier characteristics it was superseded by the concrete parapet type, which in turn is giving way to the concrete barrier type. The latter two are generally capped with a single tube of aluminum or galvanized steel.

This recounts the Department's progressive transition in bridge railings to more maintenance-free types and also to those providing improved barrier resistance.

Bridge Structural Steel (Girders)

1) Paint Systems - Under this and prior projects, the Department has been evaluating paints for bridge girders for the specific purpose of developing more durable systems, thereby decreasing maintenance repaintings. The evaluations covered screening of paints via laboratory testing, followed by exposure of the best paints in actual service on bridges. The first well-planned in-service exposures were made in 1960. On one bridge, eight systems are being evaluated, including galvanizing, and the Department's

standard system as a control; six systems, including the Department's as a control, are being evaluated on the other. Recent inspections of above and other later exposures indicate the following tentative conclusions on bridges on our roadways and in the Michigan environment.

a) There are more variables than just paint quality and thickness governing the performance of a paint system on bridge steel, as reviewed in the last paragraph of Appendix B. Consequently, a single test bridge may give misleading information relative to a paint system's value.

b) Painted bridge girders show first distress along the edges of the lower flanges, under leaky deck joints, and the outside top of the lower flange of the fascia beam. These deteriorations progress with exposure at a faster rate than in other areas.

c) A paint system tends to perform better on river crossings than on grade separations over major roadways. On the latter, paint systems tend to deteriorate faster on over-traffic than off-traffic spans, most noticeably in beams' lower flange areas.

d) The unexpected, accelerated mid-age deterioration of our paint system on one of the 1960 test bridges, though it is performing well on the other, raises a question relative to its superiority.

e) The variability of performance of the zinc-rich primed test systems, similar to experience of some others[8], makes us wonder what additional variables are involved affecting their performance. We were surprised to note that some do not provide cathodic protection on initial film breaks on bridge steel, though they do in laboratory Weatherometer exposure. Field tests show that selection of topcoats can be critical to prevent peeling.

f) Our best performing test coating system is the hot-dip galvanizing with an estimated service life of more than 20 years, making us regret not having this information many years ago.

g) Almost all of the preselected, 5-mil thick test paint systems will provide a service life of about 15 years, using the Department's criterion. This is not long enough, however, since the Department's current annual

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[8] W. J. Hart (Oregon Highway) "Zinc Paint?" - Public Roads, Dec. 1973, pp. 54-56; and International Lead Zinc Research Organization - Zinc Research Digest No. 31 - 1973, p. 17.

maintenance repainting work load comes out to 2520/15 = 180 bridges. That is neither inviting nor practical.

h) Our paint system appears to be performing as well on maintenance repaintings as on new construction, except when faced with leakage from a deteriorating deck and/or unsealed joints.

2) Paint System Recommendations - On basis of subject and prior tests, we have or are making the following recommendations:

a) In 1965 to 1970, the Department moderately revised specifications covering the separate paints in our system, to generally obtain improved durability and drying.

b) In 1967, the Department increased the dry-film thickness of our paint system on bridge steel from 4.0 to 5.2 mils by requiring an additional, fourth and intermediate, coat of paint.

c) In 1967, the Department revised cleaning specifications for bridge steel to require SSPC No. 6 commercial blastcleaning rather than the former hand cleaning.

d) In about 1967 on new bridge steel, the Department began requiring the removal of sharp corners on the beam's lower flange by grinding to a 3/16 ± 1/16-in. radius, as shown in Figure 24.

e) In 1968, the Department required hot-dip galvanizing on all steel of bridge bearings not requiring welding to the beams.

f) Since the Department is already using improved bridge-joint sealers (preformed neoprene or reinforced neoprene expansion) on new construction, we hereby recommend that bridge deck joints be resealed prior to maintenance repainting.

Future Work

We are continuing our inspections of the performance of the various coatings in test exposure on highway structures and appurtenances. This includes the unpainted, low-alloy steel. The inspection results will be reported and may require some revision of the aforementioned Conclusions and Recommendations.

APPENDICES

## APPENDIX A

### Random Notes on Steel Beam Guardrail

The following notes are listed because they apply to steel-beam guardrail installations. We make no claim to their super-accuracy. However, values of this type, even though approximations, must be accumulated and reviewed in an economic study.

1) As noted in the report, prior to 1957 the Department used painted steel guardrail and subsequently maintenance painted them. After the 1957 test installations of galvanized guardrail provided initial exposure data, which were most satisfactory, the Department switched to galvanized guardrail on new construction and by the end of 1959 decided to stop future maintenance painting of existing painted installations. A study showed the feasibility of; a) removing the latter; b) shipment to a galvanizing plant for old paint removal, cleaning and galvanizing; and, c) reshipment to site and re-installation. Regarding b) above, four hot-dip galvanizers in Michigan showed interest in bidding on the work. The above was based on a study conducted by the Department's Maintenance Division, with excerpts following:[1]

Cost of Painting vs. Galvanizing - "Originally, maintenance of guardrail consisted of cleaning with hand tools such as wire brushes and scrapers. This was followed by one coat of good red lead spot primer and a topcoat of white paint. Owing to tough exposure, normally guardrail needed repainting about every two years. The cost of repainting guardrail was \$0.40 a lineal ft of face ($1\text{-}1/2 + ft^2$). The cost of galvanizing was about \$0.30 a lineal ft of both faces, with the cost of removing, trucking and replacing adding another \$0.20 a ft. In at least one district, galvanized guardrail were installed on a rotating basis to replace the guardrail being removed for galvanizing, thereby avoiding double handling and the need for temporary protection."

The specified galvanizing for the guardrail was hot-dip, in accordance with ASTM A 123, requiring 2.0 oz/sq ft of surface. The award bid costs per lineal ft of painted rail were as follows: \$0.33 (1961), \$0.25 (1965), \$0.33 (1966), \$0.365 (1971) with the lengths involved varying up to 97,721 ft, the 1963 value.

Since the maintenance repainting had a service life of about two years, while the hot-dip galvanizing has a service life of 13 to 25 years, the economics strongly favor the galvanizing.

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[1] S. M. Cardone, "Galvanizing Reduces Guardrail Maintenance in Michigan," HRB Record No. 11, pp. 62-65.

2) Cost of Galvanizing vs. Unpainted ASTM A 606, Type 4 Guardrail - A recent inquiry to a producer and a review of some bids shows the two types of railings, specified by the Department, to be priced about equally for both the material, and for the installation.

3) Guardrail Mileage and Percentage Replaced Annually Because of Collision Damage - It is estimated that we have 1,500 lineal miles of guardrail installed on the 9,300 miles Michigan Highway system, i.e., one mile of guardrail for every 6-1/5 miles of roadway. The ratio is likely higher on the Interstate system where the median guardrail is double-faced, and often double height.

The guardrail is subject to collision damage requiring replacement of a certain percentage. This used to be scrapped. In a recent Maintenance Division survey, it is estimated that about 4 percent of the total mileage is damaged and replaced yearly. If the Department buys the available, portable straightening equipment, it is estimated that 2/3 of that can be straightened and salvaged while 1/3 is damaged beyond salvaging and will have to be scrapped. A 1968 study in California showed that on freeway median barriers 9.6 percent of the total length of the system was damaged that year[2].

The above is presented to show that metal guardrail, regardless of its inherent durability, faces the probability of a short life due to collision damage. The damage is not exactly random, since some locations are more subject to damage than others.

Nevertheless, the necessity and expense of replacing some metal guardrail each year because of collision damage is one factor in the recent increased use of the bulkier and damage-resistant concrete guardrail.

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[2] Federally coordinated program of research and development in Highway Transportation - Project Statements, April 1972.

## APPENDIX B
Notes on Bridge Railings and Structural Steel

### Bridge Railings

1) Galvanized - The first construction galvanized bridge railings, installed in 1958, were inspected for appearance and found satisfactory; but not checked for thickness of coating, on either the railings or supporting steel posts. When next inspected in the summer of 1972, we were surprised at the poor condition of the galvanized coating, which showed brown rusting over 10 to 15 percent of the surface, i.e., complete loss of galvanizing in those areas. There was noticeable rust staining of the concrete decking beneath. Actually the railings showed almost as much deterioration of the galvanizing as the abutting chain link right-of-way fencing, whose specifications at that time required less than 1.0 oz of zinc per sq ft of surface. We can now only surmise that the bridge railings also had a light coat of galvanizing which went undetected by personnel unfamiliar with a new coating process. The galvanized bridge railings installed on I 94 in Detroit, a year later, show but slightly better performance, apparently for the same reason. These are good examples that galvanizing per se is not necessarily a durable coating; though it is if applied in sufficient thickness.

2) Painted - The above inspections and observations were made while inspecting the condition of paint coatings on steel beams of bridges, in the same general area in Detroit, scheduled for maintenance repainting in 1972 under contract. These covered seven pedestrian and five vehicular overpasses on I 94, also constructed in 1958 and 1959. The condition of the bridge railings on several of the vehicular structures was also noted. Interestingly, the condition of the painted railings on some was about as good as that of the galvanizing on identical railings, referred to above. The still painted railings, of the same age as the galvanizing, were construction painted with a three-coat system; consisting of a red lead primer, color modified red lead intermediate coat, and an aluminum paint topcoat applied on hand cleaned structural steel, in accordance with the then governing specifications covering steel beams and railings. The original paint system thickness was probably about 4 mils. These painted railings provide us with one of the best performing case histories; if one could deduce the causes -- the serviceability of paint coatings could be more consistently improved.

### Structural Steel

As mentioned above, and from other observations of the performance of coatings on structural steel, one often notes a significant variability between coatings, and indeed between the same coating in different areas.

After some thought, we believe the coatings' performance is governed by its adherence to the following basic factors.

1) Clean steel adequately by removing unsound mill scale and dirt
2) Apply a proven primer of the rust-inhibitive type
3) Apply proven topcoats, tough enough for intended service
4) Use professional application methods
5) Apply coatings in sufficient and uniform thickness
6) Prevent rusting of steel between application of coats
7) Apply required thickness in as few coats as possible
8) Tough areas need special protection or design considerations.

We explain the generally good performance of hot-dip galvanizing by observing that it meets the first seven of the above factors.

# APPENDIX C

# PROTECTIVE COATINGS FOR HIGHWAY METALS
Fourth Progress Report: Protective Coatings for Structural Steel

A. J. Permoda
A. R. Gabel

Progress Report on a Highway Planning and Research Investigation
Conducted in Cooperation with
The U. S. Department of Transportation--Bureau of Public Roads

Research Laboratory Section
Testing and Research Division
Research Project 49 G-50(5)
Research Report No. R-696

State of Michigan
Department of State Highways
Lansing, April 1969

PROTECTIVE COATINGS FOR HIGHWAY METALS
Fourth Progress Report

This progress report continues the presentation of data on performance of specification and proprietary structural steel primers and coatings as determined in accelerated laboratory tests. These tests have been adopted by the coatings industry because they permit easy and rapid screening of coatings' quality, even though the results admittedly may not exactly duplicate service performance. This is the sixth series to be tested using coatings of interest to the Department; series one through five having been reported in Research Report Nos. R-260 (July 1956), R-361 (Aug. 1961) and R-508 (July 1965). The last and subject reports have been prepared under an HPR study.

The primers and topcoats under test were accumulated over the period from early 1965 through mid-1968. Forty-six systems, plus three additional replacements, were covered in the series. The laboratory phase of subject evaluations covering panel preparation, equipment exposures, and rating of test systems were conducted from May to December 1968.

Laboratory Test Procedure

The test paint systems were applied on steel panels in two coats, consisting generally of a primer and a topcoat, prior to exposure in laboratory equipment. The panels were flat, 16-gage, hot-rolled steel. They were cleaned by sandblasting prior to coating.

Duplicate panels were made of all systems although some, including all of the "grease type" coatings, were applied on triplicate panels to allow roof exposure of one panel. All panels were edge-sealed with a fast-drying zinc chromate primer. A three week drying period was allowed on all panels except the replacement grease type paints which were put into test exposure after one week's drying time.

The panel, one of each set, selected for test exposure was given a vertical scratch through the coating to the metal while the other panel was used for comparison purposes during the rating of performance. A single test cycle consisted of 200 hours exposure in the Weatherometer (continuous artificial sunlight with a 9 minute water spray interval per hour) followed by 50 hours at 95F in a combination salt spray-humidity cabinet. The coated panels were exposed to seven such cycles for a total exposure of 1400 hours in the Weatherometer and 350 hours in the cabinet. At the conclusion of the laboratory testing, the exposed test panels were photographed with their respective control panels to show the amounts of degradation (Fig. 1) and were also rated visually.

## Performance Ratings

As in the previous reports, in order to assign numerical values to the performance of the coating systems in the tests, observers (F. J. Bashore, A. R. Gabel, and A. J. Permoda) rated the panels on the following three quality factors:

1. Topcoat appearance; taking into consideration fading, chalking, and gloss change.

2. Amount of coating breakdown on the panel face.

3. Extent of rusting and rust creepage at the vertical scratch.

Each factor was rated numerically on a 10 to 0 scale, with 10 denoting perfect condition and 0 complete failure. For convenience, these three ratings were added into a single total indicating the overall merit of the coating system, with the highest total representing the best performing system. These totals are presented in Table 1 as averages for the three observers. Individual averaged factor ratings are also given in the table, as is the relative rank of the test systems, and sources of the coatings.

## Test Results

Of the 46 test systems (listed in Table 1 and shown in Figure 1) 14 were classified as "very good" (defined as having received 24 or more points of a possible 30-point maximum performance rating) and carry the highest potential for possible Department use. They are listed in descending order of rating merit:

### Rank 1 - 27 Points

System 29: Proprietary, one-package, zinc-rich primer and proprietary gray hi-build topcoat. Primer is on field test on Snow Bowl and Military Road structures over I 75 near Houghton Lake.

System 34: Proprietary, three-package, zinc-rich primer and proprietary gray hi-build topcoat.

Rank 2 - 26.3 Points

System 45: Proprietary, two-package, inorganic zinc-rich primer and vinyl-alkyd gray topcoat. Topcoat is on field test on Snow Bowl Road structure over I 75 near Houghton Lake.

Rank 3 - 25.7 Points

System 28: Proprietary, one-package, zinc-rich primer and vinyl-alkyd gray topcoat. (Primer same as System 29, and topcoat same as System 45, above).

System 31: Proprietary, one-package zinc-rich primer and proprietary gray hi-build topcoat. (Topcoat as on Systems 29 and 34, above).

Rank 4 - 25.3 Points

System 30: Proprietary, one-package zinc-rich primer and vinyl-alkyd gray topcoat. (Primer is on field test on M 71 structure over M 78 near Durand).

Rank 5 - 25 Points

System 1: MDSH Nos. 1A (1) red lead primer and No. 5B aluminum-alkyd topcoat (Department and test standard).

System 15: Proprietary lead pigmented white primer and No. 5B aluminum-alkyd topcoat.

System 32: Proprietary lead sub-oxide pigmented gray hi-build primer and vinyl-alkyd gray topcoat.

Rank 6 - 24.3 Points

System 11: MDSH Nos. 1A (2) red lead primer and No. 4A (1) green topcoat.

System 26: Proprietary, one-package, zinc-rich primer and proprietary aluminum topcoat from same source.

System 44: Proprietary, one-package, zinc-rich primer and proprietary, two-package aluminum-epoxy topcoat.

System 46: Proprietary, fast-dry zinc chromate primer and vinyl-alkyd gray topcoat.

Rank 7 - 24 Points

System 4: MDSH Nos. 1A (1) red lead primer and No. 4A (1) green topcoat.

The remaining systems earned poorer ratings and thereby are of less interest to the Department. However, there is one exception--a group of treated hydrocarbon coatings, sometimes called "grease type," which earned poor ratings in much abbreviated exposures and were withdrawn from the accelerated tests (Fig. 2). This behavior was expected since grease coatings, by experience, do not perform well in the Weatherometer. Consequently, these coatings are being evaluated in a much slower way by outdoor exposure on the roof of the Laboratory (Fig. 3). Remarks on their current performance are given in Table 2, which also describes other systems, so exposed. Future inspections will be made and recorded, covering these exposures.

## Discussion of Results

A review of the above listing shows that:

1. Eight of the 14 best performing systems were based on zinc-rich primers, five on lead pigmented primers, and one on a zinc chromate primer. All inhibit corrosion by any of various mechanisms.

2. The top six rating test systems were based on zinc-rich primers, of the 14 mentioned above. Partial reasons for the high ratings are, (a) these primers are high-build coatings yielding greater thickness than standard, (b) they perform well in laboratory tests, i.e. perhaps better than in field tests, and (c) we've learned to marginally improve their performance by proper topcoating.

3. The Department's current paint system of 1A (1) red lead primer and 5B aluminum alkyd topcoat was surpassed in performance by only the zinc-rich primed systems, mentioned above.

4. As pointed out, several other rust inhibiting primed systems performed well in the tests. Three were based on lead pigments or zinc chromate pigments.

5. Regarding topcoats, the Department's Nos. 5A aluminum and 4A (1) green performed well as did a vinyl-alkyd gray (currently under field test because of previous good test performance) and a high-build chlorinated rubber gray. Several other high-build topcoats did not rate up to expectations.

6. The grease-type coatings are being evaluated since they are high-build coatings having potential of being applied in one or two coats to yield a standard 5-mil thickness. They have found some use in the trade, while the new types are being used extensively as autobody undercoaters. They can migrate to seal minor damage breaks. Unfortunately, some do not take direct exposure to sunlight.

## Recommendations

As in previous reports in this series, we recommend that evaluations be continued--via field tests on structural steel--on at least some of the best performing systems in these tests. The selection could by-pass systems already under field test, and could be made on either construction or maintenance-repainting projects.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

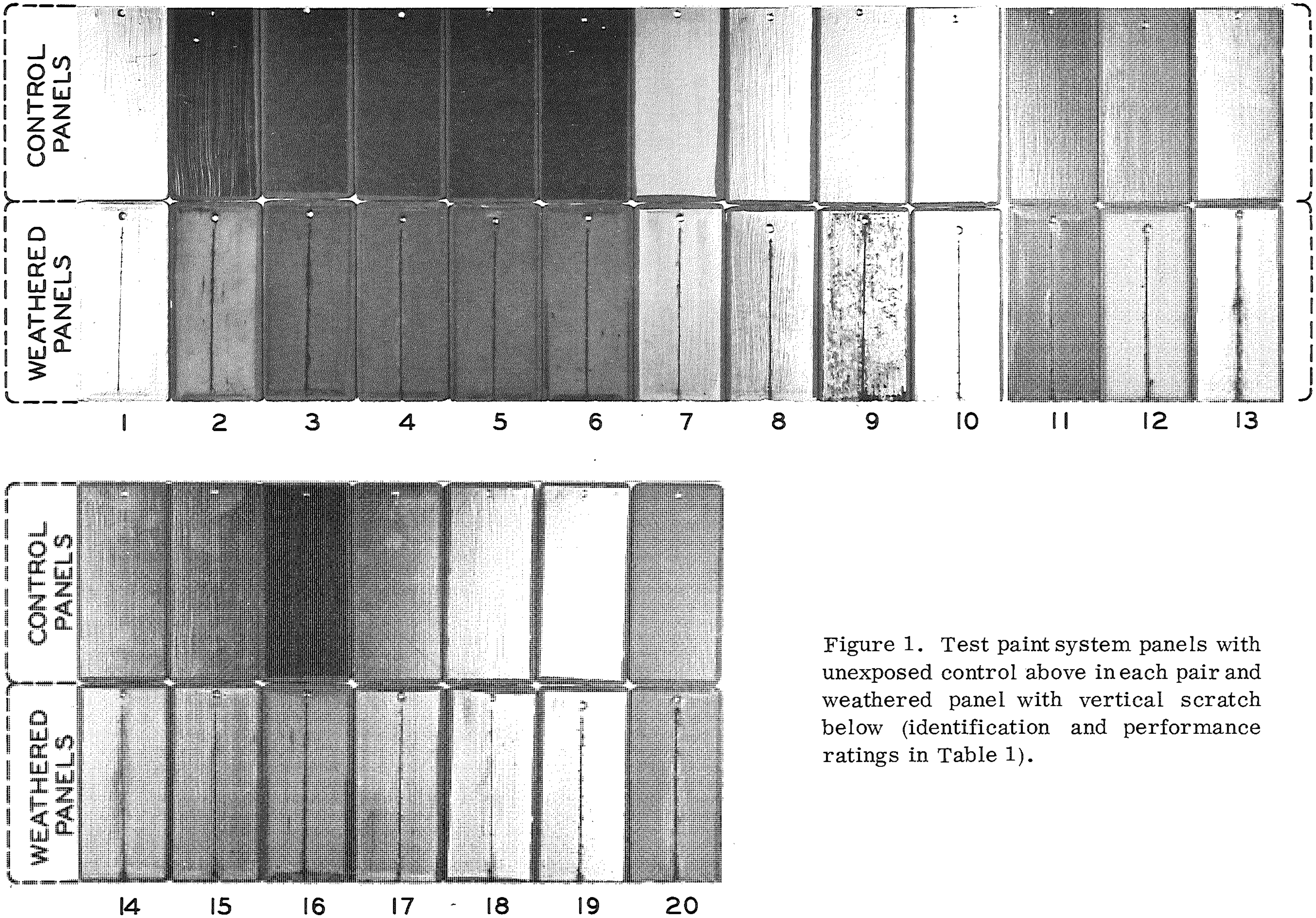


Figure 1. Test paint system panels with unexposed control above in each pair and weathered panel with vertical scratch below (identification and performance ratings in Table 1).

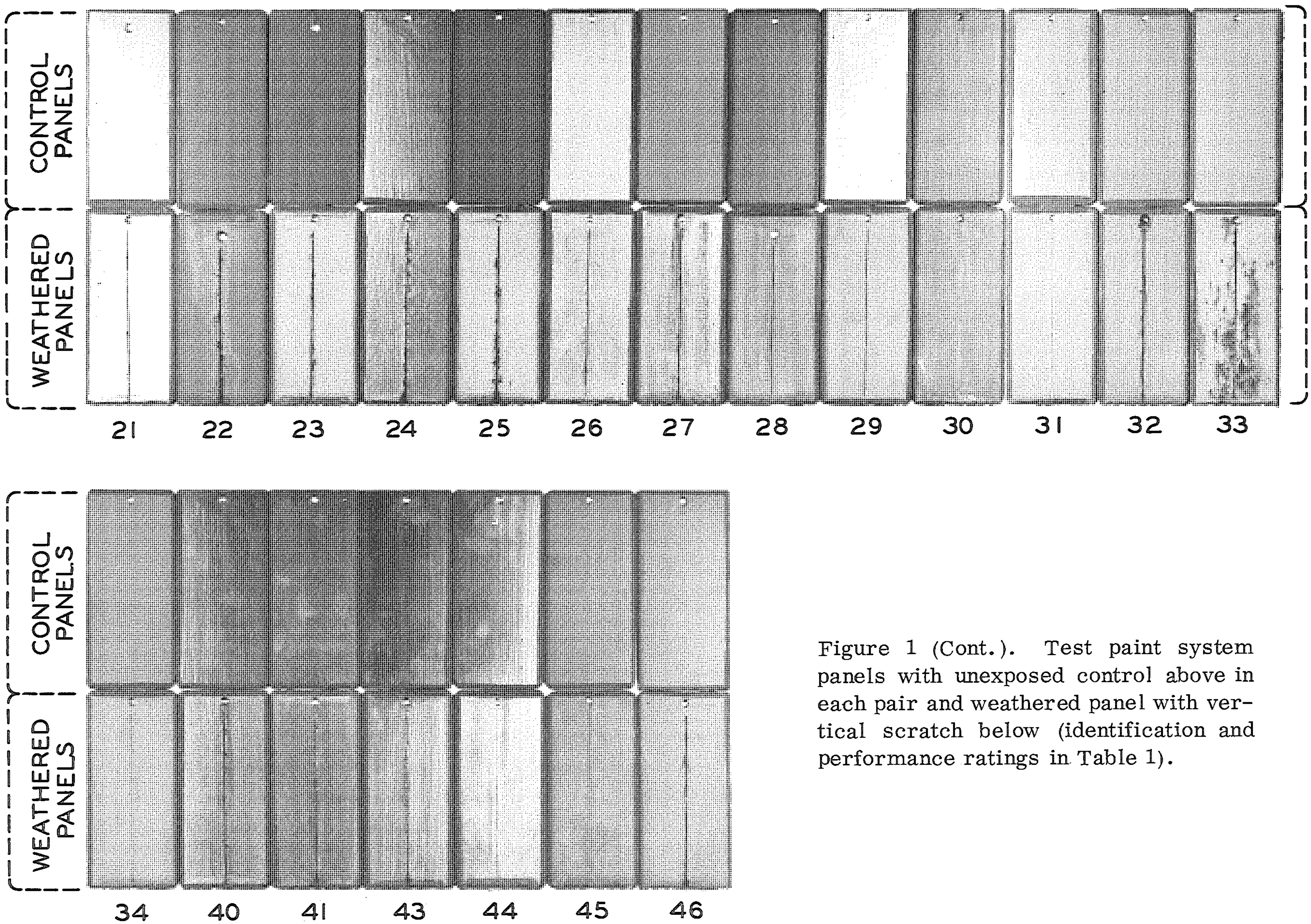


Figure 1 (Cont.). Test paint system panels with unexposed control above in each pair and weathered panel with vertical scratch below (identification and performance ratings in Table 1).

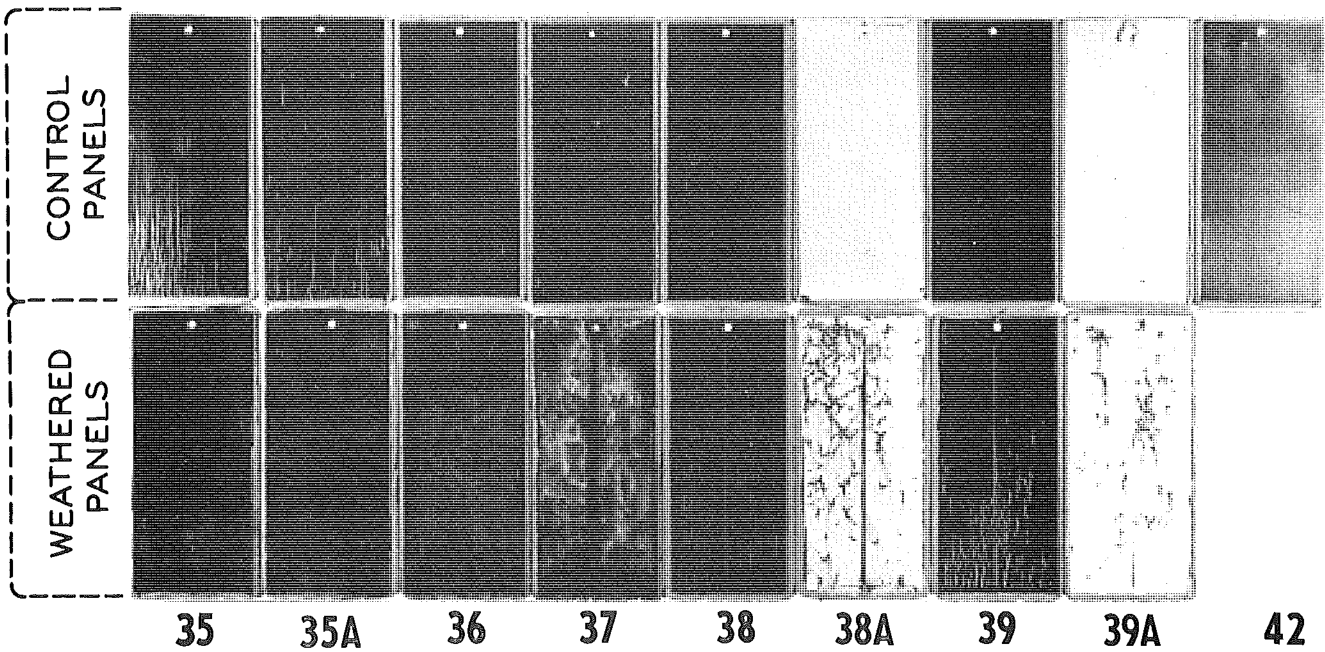


Figure 2. Test "grease type" coated panels with unexposed control, above, and laboratory weathered panel with vertical scratch, below (identification and performance ratings in Table 1).

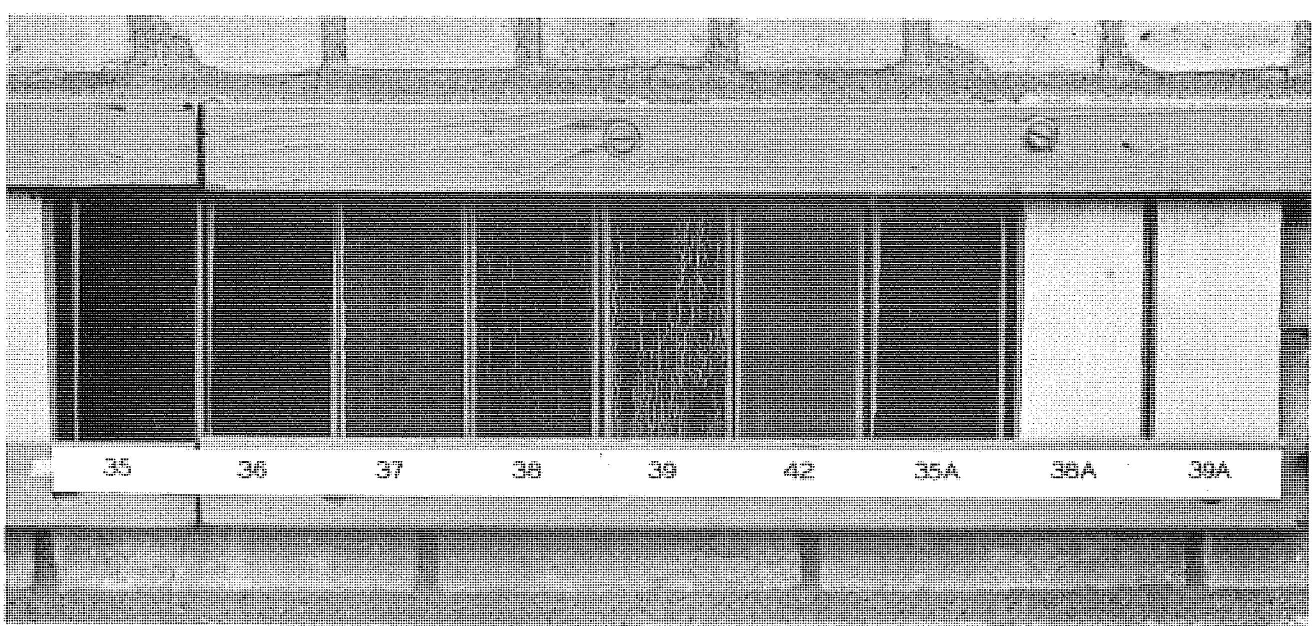


Figure 3. Appearance of test "grease type" coatings on roof exposure, as of February 12, 1969 (identification and performance comments in Table 2).

# TABLE 1
# IDENTIFICATION AND PERFORMANCE OF TEST COATING SYSTEMS
# SERIES 6 COATINGS

| Test System | Identification | Composition | Drying Time, hr | System Thickness, mils | Ratings* | | | | Rank | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Appearance | Face Rusting | Scratch Rusting | Total** | | |
| 1 (b) | Primer: 67 PR-153<br>Topcoat: 60 PR-112 | No. 1A (1) red lead<br>No. 5B alkyd aluminum | 48(c)<br>18(c) | 2.0<br>3.0 | 7.0 | 10.0 | 8.0 | 25.0 | 5 | Standard MDSH system |
| 2 | Primer: 67 PR-153<br>Topcoat: 66 PR-54a | No. 1A (1) red lead<br>No. 4A green | 48<br>9 | 2.0<br>4.5 | 4.7 | 8.0 | 6.6 | 19.3 | 20 | Alternate MDSH system, Topcoat from Hammond Lead |
| 3 | Primer: 67 PR-153<br>Topcoat: 66 PR-54b | No. 1A (1) red lead<br>No. 4A green with P7 | 48<br>7 | 2.0<br>3.0 | 6.7 | 10.0 | 6.0 | 22.7 | 11 | Topcoat from Hammond Lead |
| 4 (b) | Primer: 67 PR-153<br>Topcoat: 67 PR-148 | No. 1A (1) red lead<br>No. 4A (1) green | 48<br>9 | 2.0<br>3.0 | 7.0 | 9.0 | 8.0 | 24.0 | 7 | Topcoat from Nat'l Lead |
| 5 | Primer: 67 PR-153<br>Topcoat: 67 PR-149 | No. 1A (1) red lead<br>No. 4A (1) green | 48<br>9 | 2.0<br>3.5 | 6.0 | 9.7 | 6.6 | 22.3 | 13 | Topcoat from Nat'l Lead |
| 6 | Primer: 67 PR-153<br>Topcoat: 67 PR-150 | No. 1A (1) red lead<br>No. 4A (1) green | 48<br>8 | 2.0<br>3.5 | 5.0 | 9.0 | 6.0 | 20.0 | 18 | Topcoat from Nat'l Lead |
| 7 | Primer: 67 PR-153<br>Topcoat: 67 PR-120 | No. 1A (1) red lead<br>Green aluminum Milthix | 48<br>8 | 2.0<br>3.0 | 7.3 | 9.3 | 6.7 | 23.3 | 9 | Topcoat from Washburn |
| 8 (b) | Primer: 67 PR-153<br>Topcoat: 65 PR-106 | No. 1A (1) red lead<br>Silcone alkyd aluminum | 48<br>1 | 2.0<br>2.5 | 6.7 | 10.0 | 5.3 | 22.0 | 14 | Topcoat from Dow Corning |
| 9 | Primer: 67 PR-153<br>Topcoat: 66 PR-56 | No. 1A (1) red lead<br>Alumanation No. 301 | 48<br>1 | 2.0<br>3.0 | 3.3 | 5.3 | 6.4 | 15.0 | 23 | Topcoat from Republic Metals |
| 10 | Primer: 68 P-6<br>Topcoat: 60 PR-112 | No. 1A (2) red lead<br>No. 5B alkyd aluminum | 24.<br>18 | 1.7<br>2.7 | 6.7 | 8.7 | 5.3 | 20.7 | 16 | Primer from Nat'l Lead |
| 11 (b) | Primer: 68 P-6<br>Topcoat: 67 PR-148 | No. 1A (2) red lead<br>No. 4A (1) green | 24<br>9 | 1.7<br>3.5 | 7.3 | 9.7 | 7.3 | 24.3 | 6 | Both from Nat'l Lead |
| 12 | Primer: 68 P-6<br>Topcoat: 67 PR-118 | No. 1A (2) red lead<br>No. 3A (2) gray-green Hi-Build | 24<br>24 | 1.7<br>4.2 | 5.7 | 9.3 | 5.7 | 20.7 | 16 | Both from Nat'l Lead |
| 13 | Primer: 66 PR-52a<br>Topcoat: 60 PR-112 | No. 2MP (1) brown<br>No. 5B alkyd aluminum | 17<br>18 | 1.2<br>2.2 | 5.7 | 8.7 | 4.3 | 18.7 | 21 | Primer from Hammond Lead |
| 14 | Primer: 66 PR-52b<br>Topcoat: 60 PR-112 | No. 2MP brown with P7<br>No. 5B alkyd aluminum | 17<br>18 | 1.2<br>2.0 | 6.0 | 9.7 | 6.0 | 21.7 | 15 | Primer from Hammond Lead |
| 15 | Primer: 66 PR-53<br>Topcoat: 60 PR-112 | White primer with P7<br>No. 5B alkyd aluminum | 17<br>18 | 2.7<br>3.5 | 7.3 | 9.7 | 8.0 | 25.0 | 5 | Primer from Hammond Lead |
| 16 (b) | Primer: 66 PR-53<br>Topcoat: 68 P-67 | White primer with P 7<br>Hi-Build green | 17<br>6 | 2.7<br>3.7 | 5.7 | 8.3 | 6.7 | 20.7 | 16 | Both from Hammond Lead |
| 17 | Primer: 65 PR-133<br>Topcoat: 60 PR-112 | White primer<br>No. 5B alkyd aluminum | 17<br>18 | 1.7<br>2.5 | 5.7 | 8.7 | 5.3 | 19.7 | 19 | Primer from Eagle-Picher |
| 18 | Primer: 67 PR-117<br>Topcoat: 66 PR-123 | No. 2MP (2) brown<br>Aluminum Milthix | 7<br>6 | 3.0<br>3.9 | 6.7 | 10.0 | 7.0 | 23.7 | 8 | Primer from Nat'l Lead; Topcoat from Washburn |
| 19 | Primer: 67 PR-146<br>Topcoat: 60 PR-112 | TT-P-615d type 3 brown electro.<br>No. 5B alkyd aluminum | 6(c)<br>18 | 1.2<br>2.0 | 5.7 | 10.0 | 5.0 | 20.7 | 16 | Primer from Std., Detroit |
| 20 | Primer: 67 PR-146<br>Topcoat: 67 PR-119 | TT-P-615d type 3 brown electro.<br>Gray Milthix | 6(c)<br>6 | 1.2<br>2.7 | 7.0 | 9.3 | 5.7 | 22.0 | 14 | Primer from Std., Detroit; Topcoat from Washburn |
| 21 | Primer: 66 PR-121<br>Topcoat: 67 PR-120 | M-50 brown Milthix<br>Green aluminum Milthix | 4<br>7 | 2.2<br>3.2 | 6.3 | 10.0 | 6.0 | 22.3 | 13 | Both from Washburn |
| 22 | Primer: 66 PR-121<br>Topcoat: 67 PR-119 | M-50 brown Milthix<br>Gray Milthix | 4<br>6 | 2.2<br>4.5 | 6.3 | 9.0 | 5.0 | 20.3 | 17 | Both from Washburn |
| 23 | Primer: 66 PR-121<br>Topcoat: Whse Stk | M-50 brown Milthix<br>No. 3A (1) gray-green | 4<br>24 | 2.2<br>3.9 | 4.0 | 8.7 | 6.0 | 18.7 | 21 | Primer from Washburn |
| 24 | Primer: 65 PR-151<br>Topcoat: 60 PR-112 | Org. Phosphate & $ZnCrO_4$<br>No. 5B alkyd aluminum | 2<br>18 | 2.5<br>3.2 | 6.3 | 10.0 | 4.4 | 20.7 | 16 | Primer from Lubrizol |

Notes: * Rated on scale from 10 to 0; with 10 = no deterioration and 0 = complete failure.

** Parenthesized ratings in this column indicate early removal from test due to failures. Systems 38 and 39 after 100 hrs., #(35, 38, 39)A after 200 hrs., #35 & 36 after 600 hrs.

(a) Faulty company identification.

(b) Roof exposure; panels vertical, facing East.

(c) Under field test on bridge structures.

## TABLE 1 (Cont.)
## IDENTIFICATION AND PERFORMANCE OF TEST COATING SYSTEMS
## SERIES 6 COATINGS

| Test System | Identification | Composition | Drying Time, hr | System Thickness, mils | Ratings* Appearance | Ratings* Face Rusting | Ratings* Scratch Rusting | Ratings* Total** | Rank | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | Primer: 65 PR-151<br>Topcoat: Whse Stk | Org. Phosphate & $ZnCrO_4$<br>No. 3A (1) gray-green | 2<br>24 | 2.5<br>4.0 | 4.0 | 8.7 | 5.0 | 17.7 | 22 | Primer from Lubrizol |
| 26 | Primer: 68 P-34<br>Topcoat: 68 P-35 | Gal-V-Tal Z-99H (Zinc Rich)<br>Gal-V-Tal I-90 aluminum | 10<br>10 | 1.6<br>2.2 | 6.0 | 10.0 | 8.3 | 24.3 | 6 | Both from United Paint |
| 27 | Primer: 65 PR-124<br>Topcoat: 65 PR-125b | ZRC (Zinc Rich)<br>ZRC Metaz aluminum | 10(c)<br>10 | 2.1<br>2.7 | 5.7 | 7.7 | 7.3 | 20.7 | 16 | Both from Sealube |
| 28 (b) | Primer: 66 PR-116<br>Topcoat: 67 CH-127 | Chem-Zinc (Zinc Rich)<br>MIL-E-16501 vinyl alkyd gray | 10(c)<br>4(c) | 3.0<br>5.0 | 7.3 | 9.0 | 9.4 | 25.7 | 3 | Primer from Truscon;<br>Topcoat from Std., Detroit |
| 29 (b) | Primer: 66 PR-116<br>Topcoat: 68 P-59 | Chem-Zinc (Zinc Rich)<br>Chlor-Rubber, gray Hi-Build | 10(c)<br>4 | 3.2<br>5.0 | 7.7 | 10.0 | 9.3 | 27.0 | 1 | Primer from Truscon;<br>Topcoat from Pittsburg Plate |
| 30 | Primer: 67 PR-155<br>Topcoat: 67 CH-127 | Galvanox (Zinc Rich)<br>MIL-E-16501 vinyl alkyd gray | 10(c)<br>4(c) | 3.5<br>4.2 | 6.7 | 9.0 | 9.6 | 25.3 | 4 | Primer from Wyandotte;<br>Topcoat from Std., Detroit |
| 31 | Primer: 65 PR-134<br>Topcoat: 68 P-59 | Galvicon (Zinc Rich)<br>Chlor-Rubber, gray Hi-Build | 10<br>4 | 3.5<br>4.5 | 7.3 | 8.4 | 10.0 | 25.7 | 3 | Primer from Galvicon;<br>Topcoat from Pittsburg Plate |
| 32 | Primer: 65 PR-130<br>Topcoat: 67 CH-127 | Leadox gray Hi-Build<br>MIL-E-16501 vinyl alkyd gray | 7<br>4(c) | 3.5<br>5.0 | 8.0 | 10.0 | 7.0 | 25.0 | 5 | Primer from Tropical;<br>Topcoat from Std., Detroit |
| 33 | Primer: 65 PR-130<br>Topcoat: 68 P-59 | Leadox gray Hi-Build<br>Chlor-Rubber, gray Hi-Build | 7<br>4 | 3.2<br>4.7 | 3.3 | 4.4 | 7.0 | 14.7 | 24 | Primer from Tropical;<br>Topcoat from Pittsburg Plate |
| 34 | Primer: 68 P-58<br>Topcoat: 68 P-59 | Aquapon 9685 (Zn Rich - 3 comp)<br>Chlor-Rubber, gray Hi-Build | 10<br>4 | 3.0<br>4.0 | 7.7 | 10.0 | 9.3 | 27.0 | 1 | Both from Pittsburg Plate |
| 35 (b) | Primer: 66 PR-60<br>Topcoat: 66 PR-60 | No-Ox-Id 400 Hi-Build black<br>No-Ox-Id 400 Hi-Build black | 36<br>36 | ≅ 5 | 1.7 | 2.7 | 6.3 | (10.7) | -- | Coating from Dearborn Chem. |
| 36 (b) | Primer: 66 PR-60<br>Topcoat: 68 P-7 | No-Ox-Id 400 Hi-Build black<br>Tectyl TL-174 Al black | 36<br>36(a) | ≅ 5 | 1.3 | 0.7 | 2.0 | (4) | -- | Primer from Dearborn Chem;<br>Topcoat from Valvoline |
| 37 (b) | Primer: 65 PR-131<br>Topcoat: 65 PR-131 | Quaker-Coat black<br>Quaker-Coat black | 36<br>36 | ≅ 5 | 0.3 | 1.7 | 4.7 | 6.7 | 25 | Both from Quaker Co. |
| 38 (b) | Primer: 67 PR-142<br>Topcoat: 68 P-7 | Tectyl 506, brown<br>Tectyl TL-174 Al black | 36<br>36(a) | ≅ 4 | 2.3 | 7.0 | 8.7 | (18) | -- | Primer and Topcoat from Valvoline Co. |
| 39 (b) | Primer: 67 PR-141<br>Topcoat: 68 P-7 | Tectyl 127B aluminum<br>Tectyl TL-174 Al black | 36<br>36(a) | ≅ 3 | 3.3 | 7.3 | 8.7 | (19.3) | -- | Primer and topcoat from Valvoline Co. |
| 40 | Primer: 67 PR-117<br>Topcoat: 60 PR-112 | No. 2MP (2) brown<br>No. 5B alkyd aluminum | 7<br>18 | 2.2<br>3.0 | 6.0 | 10.0 | 5.7 | 21.7 | 15 | Primer from Nat'l Lead |
| 41 | Primer: 68 P-6<br>68 P-18<br>Topcoat: 60 PR-112 | No. 1A (2) red lead & additive<br>No. 5B alkyd aluminum | 3<br>18 | 1.5<br>2.3 | 6.3 | 10.0 | 6.7 | 23.0 | 10 | Primer from Nat'l Lead;<br>Additive from Humko |
| 42 (b) | Primer: 67 PR-156 | Kencote 60 brown Hy.Carbon | 36 | .75 | ---- | --- | --- | --- | ---- | Coating from Kendall Refining Co. |
| 43 | Primer: 68 P-6<br>Topcoat: 66 PR-12 | No. 1A (2) red lead<br>Epoxy aluminum (2 comp) | 3<br>3 | 1.7<br>4.5 | 6.7 | 10.0 | 5.7 | 22.4 | 12 | Primer from Nat'l Lead;<br>Topcoat from Truscon |
| 44 | Primer: 68 P-72<br>Topcoat: 66 PR-12 | DMC Zinc Rich (1 pkg)<br>Epoxy aluminum (2 comp) | 1<br>3 | 3.0<br>4.0 | 5.3 | 9.3 | 9.7 | 24.3 | 6 | Primer from DuBois;<br>Topcoat from Truscon |
| 45 | Primer: 68 P-74<br>Topcoat: 67 CH-127 | Av-Tec G-100 (2 comp)<br>MIL-E-16501 vinyl alkyd gray | 12<br>1 | 3.0 (d)<br>3.5 | 7.0 | 10.0 | 9.3 | 26.3 | 2 | Primer from Davtec Co. |
| 46 | Primer: 68 P-82<br>Topcoat: 67 CH-127 | X-200 Chromate primer<br>MIL-E vinyl alkyd gray | 1<br>1 | 2.7<br>4.2 | 8.0 | 10.0 | 6.3 | 24.3 | 6 | Primer from United Paint |
| 35A(b) | Primer: 66 PR-60<br>Topcoat: 66 PR-60 | No-Ox-Id 400 Hi-Build black<br>No-Ox-Id 400 Hi-Build black | 36<br>36 | ≅ 2 | 0.3 | 3.3 | 6.7 | (10.3) | --- | Primer and topcoat from Dearborn Chemical |
| 38A(b) | Primer: 67 PR-142<br>Topcoat: 68 P-113 | Tectyl 506, brown<br>Tectyl TL-127C aluminum | 36<br>36 | ≅ 2-1/2 | 2.3 | 4.3 | 5.4 | (12) | --- | Both from Valvoline Co. |
| 39A(b) | Primer: 67 PR-141<br>Topcoat: 68 P-113 | Tectyl 127B aluminum<br>Tectyl TL-127C aluminum | 36<br>36 | ≅ 2 | 3.0 | 5.3 | 9.0 | (17.3) | --- | Both from Valvoline Co. |

Notes: * Rated on scale from 10 to 0; with 10 = no deterioration and 0 = complete failure.

** Parenthesized ratings in this column indicate early removal from test due to failures. Systems 38 & 39 after 100 hrs., #(35, 38, 39)A after 200 hrs., #35 & 36 after 600 hrs.

(a) Faulty company identification.

(b) Roof exposure; panels vertical, facing East.

(c) Under field test on bridge structures.

(d) Applied in two coats.

TABLE 2
ROOF PERFORMANCE OF TEST COATING SYSTEMS
SERIES 6 COATINGS

| Test System | Identification | Composition | Notes | System Thickness, mils | Performance Comments (as of 2-12-69) |
|---|---|---|---|---|---|
| 1 | Primer: 67 PR-153<br>Topcoat: 60 PR-112 | No. 1A (1) red lead<br>No. 5B aluminum | b | ≅ 3 | very slight dulling |
| 4 | Primer: 67 PR-153<br>Topcoat: 67 PR-148 | No. 1A (1) red lead<br>No. 4A (1) green | b | ≅ 3 | very slight dulling |
| 8 | Primer: 67 PR-153<br>Topcoat: 65 PR-106 | No. 1A (1) red lead<br>Silicone alkyd aluminum | b | ≅ 2-1/2 | slight dulling |
| 11 | Primer: 68 P-6<br>Topcoat: 67 PR-148 | No. 1A (2) red lead<br>No. 4A (1) green | b | ≅ 3-1/2 | very slight dulling |
| 16 | Primer: 66 PR-53<br>Topcoat: 68 P-67 | White primer with P7<br>Hi-build green | b | ≅ 3-1/2 | slight dulling |
| 28 | Primer: 66 PR-116<br>Topcoat: 67 CH-127 | Chem-Zinc (zinc rich)<br>MIL-E-Vinyl alkyd gray | b | ≅ 5 | very slight dulling |
| 29 | Primer: 66 PR-116<br>Topcoat: 68 P-59 | Chem-Zinc (zinc rich)<br>Parlon Hi-build gray | b | ≅ 5 | no dulling |
| GREASE-TYPE COATINGS | | | | | |
| 35 | Primer: 66 PR-60<br>Topcoat: 66 PR-60 | No-Ox-Id 400 black<br>No-Ox-Id 400 black | b | ≅ 5 | medium grain alligatoring |
| 36 | Primer: 66 PR-60<br>Topcoat: 68 P-7 | No-Ox-Id 400 black<br>Tectyl Al-black | a, b | ≅ 5 | fine grain alligatoring |
| 37 | Primer: 65 PR-131<br>Topcoat: 65 PR-131 | Quaker coat black<br>Quaker coat black | | ≅ 5 | slight chalking |
| 38 | Primer: 67 PR-142<br>Topcoat: 68 P-7 | Tectyl 506 brown<br>Tectyl Al-black | a, b | ≅ 4 | checking and cracking |
| 39 | Primer: 67 PR-141<br>Topcoat: 68 P-7 | Tectyl 127B aluminum<br>Tectyl Al-black | a, b | ≅ 3 | checking and cracking |
| 42 | Primer: 67 PR-156 | Kencote 60 brown | b | ≅ 1 | slight bleaching |
| 35A | Primer: 66 PR-60<br>Topcoat: 66 PR-60 | No-Ox-Id 400 black<br>No-Ox-Id 400 black | c | ≅ 2 | medium grain alligatoring |
| 38A | Primer: 67 PR-142<br>Topcoat: 68 P-113 | Tectyl 506 brown<br>Tectyl 127C aluminum | c | ≅ 2-1/2 | good, no dulling |
| 39A | Primer: 67 PR-141<br>Topcoat: 68 P-113 | Tectyl 127B aluminum<br>Tectyl 127C aluminum | c | ≅ 2 | good, no dulling |

Notes: a) Faulty company identification
b) Exposed June 12, 1968
c) Exposed September 25, 1968.