1394

EVALUATION OF MINIMUM SURFACE PREPARATION COATINGS FOR BRIDGE PAINTING

MDOT
Michigan Department of Transportation

CONSTRUCTION AND TECHNOLOGY DIVISION

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16. Abstract

This report evaluates the value of coating over existing red lead systems with Minimal Surface Preparation (MSP). To evaluate the benefits of MSP, the department painted three bridges using this method. We also tested twenty-five paint systems to determine which ones worked best when applied over MSP surfaces. This report shows the results of the field applications and then shows the results of our lab tests of the different products. The five best performers in the overall lab rating were three-coat systems, which included two of the moisture cure urethane sealers, one aluminum-filled moisture cure urethane, one zinc-filled moisture cure urethane and one epoxy mastic system. The four systems that performed the best in the lab when applied directly to chloride contaminated and rusted, bare steel panels, and power tool cleaned to SSPC-C, included three three-coat zinc-filled moisture cure urethane systems and one two-coat aluminum-filled epoxy mastic system. Only one of the tested systems, a three-coat zinc-filled moisture cure urethane, performed well over both the existing red lead system and bare steel. The same system did not perform well in the weather cycle, which includes freeze-thaw cycles. If MSP systems are to be used, they should only be used on structures where the existing coating was applied over a abrasive blasted surface and the areas of coating failure do not exceed 10 percent of the total surface area of the structure. Painting after MSP is known to be a less durable paint system. In the field, the three systems tested on Michigan structures all showed corrosion after only three years.

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MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT

EVALUATION OF MINIMUM SURFACE PREPARATION COATINGS FOR BRIDGE PAINTING

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Construction and Technology Division
Research Project 94 G-0304
Research Report R-1394

Lansing, May 2001

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INTRODUCTION

In 1994, research project 94 G-304 was initiated to evaluate the value of coating over existing red lead systems with Minimal Surface Preparation (MSP). The Michigan Department of Transportation (MDOT) wanted an alternate method for maintaining Michigan's steel bridges. The intent of MSP, is to only remove the loose coating and corrosion, while leaving the intact existing red lead paint. This method was thought to be beneficial since many bridges have isolated paint failure and corrosion problems, typically beneath bridge deck expansion joints. Minimal Surface Preparation eliminates the need for abrasive blast cleaning and the required negative pressure containment.

To understand the benefits of MSP, we first must understand our standard paint system. The quality and durability of any paint system is directly related to proper surface preparation and application of the coating. Our standard paint system involves blast-cleaning the surface to a near-white finish. Then, a three-coat system composed of an organic zinc-rich primer, intermediate coat and urethane top coat paint is applied. The expected life of our standard paint system is 30 years. During blast-cleaning in the field, the contractor must provide negative pressure containment to protect the environment and the workers as required by the Environmental Protection Agency, Occupational Health Services Agency and Michigan's Department of Environmental Quality (DEQ). The negative pressure containment typically used on MDOT jobs takes time to set up and is not movable. The typical enclosure is in place for four to five days. Total time for painting consists of one to two days for erection of the containment, one day to blast-clean and prime coat the cleaned steel, another day each to apply the intermediate and topcoats.

Minimal Surface Preparation is not a well defined procedure, it can include power tool cleaning such as needle gun, grinder, or power wire brush. Although MSP eliminates the need for abrasive blast cleaning and the required negative pressure containment that goes along with it, the contractor must still contain and recover the generated waste materials from the hand or power tool cleaning and the pressure washing of the structure. The containment for hand and power tool and vacuum blasting needs to extend beyond the horizontal limits of the structure. Typically, tarpaulins are laid out on the ground or beneath the area being worked on to catch waste from the hand and power tool cleaning. The tarpaulins need to extend beyond the beam's bottom flange (similar to the space needed for blast cleaning) far enough to enable access to the bottom surface of the beam. For the wet cleaning operation, the containment is needed to control the mist and collection of the water. This is usually done by using tarpaulins and plastic sheets to funnel the water and mist into containers. The water must be filtered to remove any lead particulate and the water stream tested for leachable lead which could classify it as a hazardous waste. The contractor is still responsible for the design of the enclosure and method of containing and recovering the generated waste materials.

When they were first fabricated and erected, most of Michigan's red lead coated structures did not have the mill scale removed prior to being painted. The smoothness of mill scale is not conducive to allowing a good mechanical bond between itself and a primer. Applying additional coating thickness to an existing coating applied over mill scale increases the potential for adhesion failure between the mill scale and the existing red lead coating.

To evaluate the benefits of MSP, the department painted three bridges using MSP. We also tested several paint systems in the lab to determine which ones worked best when applied over MSP surfaces. The intent was to place the best performers on a Qualified Products List (QPL) for overcoat systems over a minimally prepared surface. This report shows the results of the field applications and then shows the results of our lab tests of the different products.

FIELD APPLICATIONS

Structure Number P01 of 25085 - Pedestrian Bridge over I-69 in Flint

The pedestrian bridge is an eight span structure coated with a red lead alkyd system. The structural steel was fifteen percent corroded, with the east fascia beam being worse than the west fascia beam. In July of 1995, MDOT's Construction and Technology Division and Maintenance Division worked jointly to clean and coat the north half of the structure using MSP. The coating system used was a two-coat moisture cure urethane. The new coating started lifting the existing red lead coating around all of the repair areas after only six months (see Figures 1 and 2). After five years, the paint system has completely failed (see Figures 3 and 4).

Figure 1- P01 of 25085 after six months

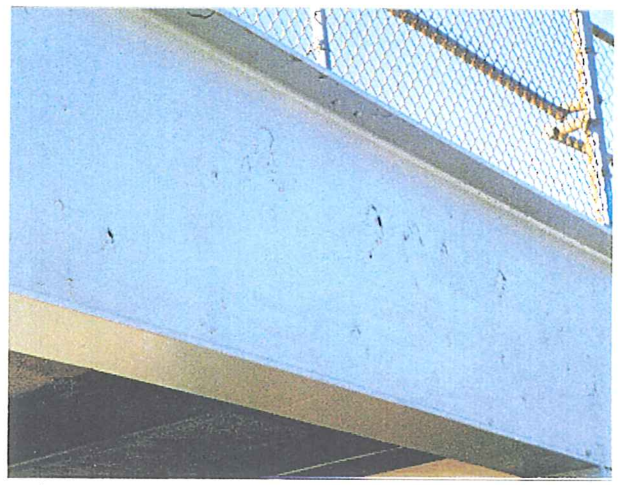

Figure 2 - P01 of 25085 after six months (Close up of lifting coating)

Figure 3 - after 5 years

Figure 4- after 5 years (Close up of lifting coating)

Structure Number S05 of 63022 - Wixom Road over I-96

In November 1996, a second structure was coated with a MSP system. The original coating on the structure was a red lead alkyd system. The structure has four spans and the structural steel was 40 percent corroded. The steel of the structure was so badly corroded that three beams in span one were replaced prior to the coating (see Figure 5). Spans 2, 3 and 4 were power tool cleaned, while span one was brush blasted. The contractor was allowed to brush blast Span 1 in lieu of power tool cleaning, because an excessive amount of power tool cleaning that would have been required to prepare the span sufficiently. Spans 1 and 2 were coated with a three-coat urethane coating system with the primer being an aluminum urethane filled moisture cure. Spans 3 and 4 were coated with a three-coat zinc rich moisture cure primer system. The MSP system started failing after only 12 months of service. Figures 6 through 10 show the amount of corrosion after 4-1/2 years.

Figure 5 - Pier 1 of S05 of 63022 prior to coating

Figure 6 - Beam G @ Pier 1 after 4 1/2 years

Figure 7 - East Fascia over pier 1 after 4 1/2 years

Figure 8 - West fascia over pier 1 after 4 1/2 years

Figure 9 - Over WB traffic lanes after 4 1/2 years

Figure 10 - Close up over WB traffic lanes after 4 1/2 years

<u>Structure Number R01 of 33032 - Business Loop I-96 over Grand Truck Railroad and the Red Cedar River</u>

In August of 1997, the contractor worked on the minimal surface preparation of this structure. R01 of 33032 is a 15 span structure carrying traffic over South Street, the Red Cedar river and the GTW CR railroad in Lansing. The structure had less than 10 percent failure of the existing red lead alkyd coating system. The span adjacent to the railroad was abrasive blasted and coated using the department's standard three coat system. The areas coated using MSP were the outside face and bottom flange of the fascia beams in Spans 1 through 5 (the west fascia beam only) and Spans 14 and 15 (both fascia beams). These areas were power tool cleaned (see Figure 11) and overcoated with a three coat moisture cure urethane system with a zinc-rich primer. After three years, the coating system looks good over the existing red lead coating. However, the overcoating is not performing well over the previously corroded areas, mostly along the web and bottom flange interface (see Figures 12-14).

Figure 11 - Cedar St fascia after power tool cleaning

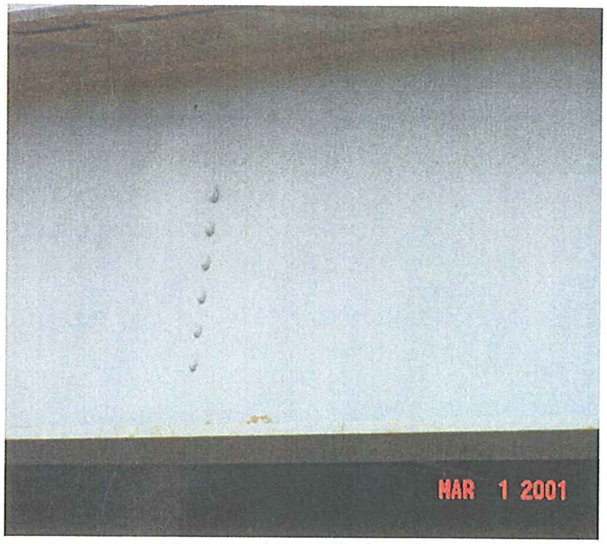

Figure 12 - Cedar St fascia after 40 months

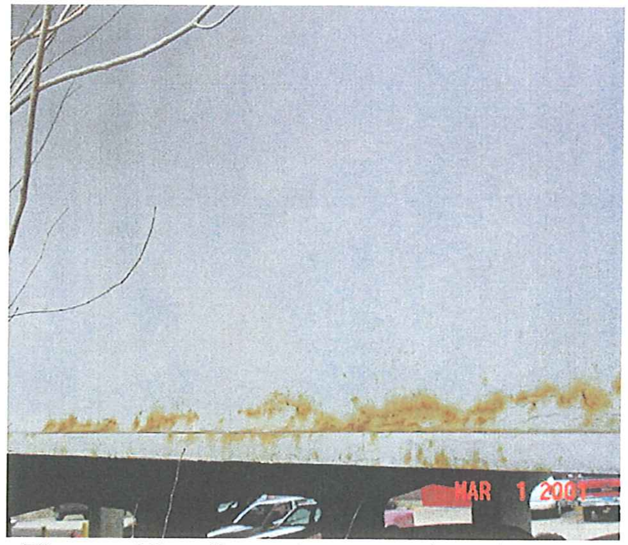

Figure 13 - Corrosion on web and bottom flange of east fascia of span 1 after 40 months

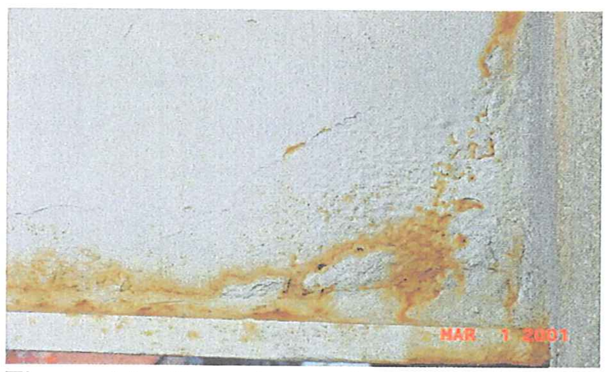

Figure 14 - Corrosion on the east fascia beam at the abutment of span 1 after 40 months

__Laboratory Testing of Overcoat Systems to be Used over MSP__

In June of 1998, paint manufacturers were asked to submit samples of coating systems that they would recommend to be applied over minimally prepared surfaces. They were informed the products were to be applied over a 25+ year old four coat red lead system. Twenty-five different systems were submitted and evaluated. Each system is shown in Table 1. Seventeen of the twenty-five were three-coat systems and the remaining eight were two-coat. Five of the three-coat systems used an aluminum-filled moisture cure urethane as the primer and four of the three-coat systems used a zinc-filled moisture cure urethane as the primer. Four of the three-coat systems used moisture cure urethane sealers as primers and another two used epoxy sealers as the primer. The remaining two three-coat systems were epoxy mastics, one of which was aluminum filled. The eight two-coat systems used epoxies for the primer, six used epoxy mastics, four of which were aluminum-filled. One used a 100 percent solids epoxy sealer and another used a multi-purpose epoxy as the primer.

Each coating system was applied to test panels, which were 3/8 inch by 3 inch by 6 inch pieces of steel cut from the diaphragms of a twenty-five-year-old red lead coated steel structure. The steel had been coated with No.1A red-lead oil paint that was shop applied directly over existing mill scale. The second coat, No.2A brown red-lead oil paint and the finish coat, No. 5B aluminum paint, were field applied after erection.

Each system also had an additional test panel put into the salt fog and the envirotest. The two additional panels were made up of 1/4 inch by 3 inch by 6 inch, A-36 hot rolled steel, which were preconditioned by blast cleaning to remove mill scale and then exposed to salt fog (ASTM -B117) for 400 hours. All panels were solvent washed (SSPC-SP1) and power wire brush cleaned (SSPC-SP3) (See Figures 15 and 16) prior to the application of the tested systems.

Figure 15 - Painting system applied over mill scale, power tool cleaned by power wire brush.

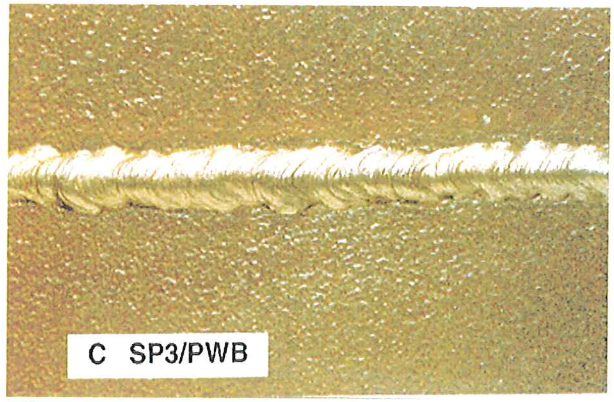

Figure 16 - Rusted surface with minor pits, power tool cleaned by power wire brush.

Each system was evaluated for *Performance* and *Ease of Application*. The test procedure used was the same procedure that is used to determine which products are to be placed on the Department's standard paint system Qualified Products List. The *Performance* evaluation consisted of five tests; salt fog, ultraviolet light, 100 percent humidity, weather cycle, and Envirotest. *Ease of Application* included mixing, spraying, sagging of the paint, and settling of the paint. The panels are evaluated and given an overall rating which is weighted to 80 percent of the *Performance* rating and 20 percent of the *Ease of Application* rating. The following section discusses in more detail the test procedures and the rating system.

Performance Evaluation

As mentioned above, the *Performance* evaluation consists of five tests; salt fog, ultraviolet light, 100 percent humidity, weather cycle, and Envirotest. Each test is described below:

Salt Fog - The salt fog test makes up 20 percent of the *Performance* evaluation rating. The test is done according to ASTM B-117. The duration of the test is 5,000 hours, and the panels are evaluated every 1,000 hours to give five separate evaluations. For each evaluation, a panel is rated on a scale of one to ten, with one being the worst rating and ten the best. Each evaluation is weighted as follows: 1,000 hours - 5 percent, 2,000 hours - 12.5 percent, 3,000 hours - 17.5 percent, 4,000 hours - 25 percent, and 5,000 hours - 40 percent.

Ultraviolet Condensation - The Ultraviolet Condensation test makes up 20 percent of the *Performance* evaluation rating. The test is done according to ASTM G-53. The duration of the test is 5000 hours, and the panels are evaluated every 1000 hours to give five separate evaluations. For each evaluation, a panel is rated on a scale of one to ten, with one being the worst rating and ten the best. Each evaluation is weighted as follows: 1,000 hours - 5 percent, 2,000 hours - 12.5 percent, 3,000 hours - 17.5 percent, 4,000 hours - 25 percent, and 5,000 hours - 40 percent.

100 Percent Humidity - The 100 Percent Humidity test makes up 10 percent of the *Performance* evaluation rating. The duration of the test is 6,000 hours, and the panels are evaluated every 1,200 hours to give five separate evaluations. For each evaluation, a panel is rated on a scale of one to ten, with one being the worst rating and ten the best. Each evaluation is weighted as follows: 1,200 hours - 5 percent, 2,400 hours - 12.5 percent, 3,600 hours - 17.5 percent, 4,800 hours - 25 percent, and 6,000 hours - 40 percent.

Weather Cycle - The Weather Cycle test makes up 20 percent of the *Performance* evaluation rating. The Weather Cycle test consists of a combination of freeze/thaw, ultraviolet condensation, and salt fog. A panel is placed vertical in a pan half filled with distilled water. For each cycle, the panels experience five freeze/thaw cycles, consisting of temperatures of minus 20° F and 120° F, 200 hours in the Ultraviolet Condensation and 50 hours in the salt fog. The duration of the test is ten cycles and the panels are evaluated after every two cycles. For each evaluation, a panel is rated on a scale of one to ten, with one being the worst rating and ten the best. Each evaluation is weighted as follows: 2 cycles - 5 percent, 4 cycles - 12.5 percent, 6 cycles - 17.5 percent, 8 cycles - 25 percent, and 10 cycles - 40 percent.

Envirotest - The Envirotest makes up 30 percent of the *Performance* evaluation rating. The Envirotest is a chamber with a paddle wheel configuration that makes a complete revolution every four hours. The top of the chamber is heated to 120 degrees F and contains an ultraviolet light source. The bottom contains enough 3 percent sodium chloride solution to submerge the panels for eighty minutes each rotation. The duration of the test is 5,000 hours, and the panels are evaluated every 1,000 hours to give five separate evaluations. For each evaluation, a panel is rated on a scale of one to ten, with one being the worst rating and ten the best. Each evaluation is weighted as follows: 1,000 hours - 5 percent, 2,000 hours - 12.5 percent, 3,000 hours - 17.5 percent, 4,000 hours - 25 percent, and 5,000 hours - 40 percent.

Ease of Application

The *Ease of Application* evaluation consists of four items; mixing, spraying, sagging, and settling of each coating product. During the mixing and application of each product, they are evaluated on a scale of one to ten, with one being the worst, and ten being the best. The *Ease of Application* rating is a weighted average of the individual tests, 20 percent given to ease of mixing, 40 percent given to spray characteristics, 30 percent given to sagging, and 10 percent given to settling of the paint.

Results - Accelerated Testing

The five best performers in the overall rating were three-coat systems, which included two of the moisture cure urethane sealers (9816 and 9820), one aluminum-filled moisture cure urethane (9801), one zinc-filled moisture cure urethane (9815) and an epoxy mastic system (9810). The four systems that preformed the best when applied directly to chloride contaminated and rusted, bare steel panels, and power tool cleaned to SSPC-C SP3/PWB (Shown in Figures 15, and 16), included system 9815, and two other three-coat zinc-filled moisture cure urethane systems (9804 and 9805) and one two-coat aluminum-filled epoxy mastic system (9811). The next tier of performers included four three-coat systems, one aluminum-filled moisture cure urethane (9801), one zinc-filled moisture cure urethane (9806), one moisture cure urethane sealer (9824) and an epoxy mastic (9810). The seven top performers in the weather cycle, included three three-coat moisture cure urethane sealers (9816, 9820 and 9821), one three-coat aluminum-filled moisture cure urethane (9801), two three-coat epoxy mastic systems (9809 and 9810), and a two-coat epoxy mastic system (9822). Only one of the tested systems performed well over both the existing red-lead system and bare steel. The same system did not perform well in the weather cycle which includes freeze-thaw cycles. Table 1 shows the generic products of each tested system. Figures 17-19 show how the systems performed overall, over bare steel, and in the weather cycle, respectively.

CONCLUSIONS

Of the three structures prepared using MSP, only structure number R01 of 33032 was a good example of a candidate for a MSP coating system. An industry criterion for determining when a structure should be abrasive blasted is when the existing coating is 20 percent failed. The existing coating system on structures P01 of 25085 and S05 of 63022 were poor choices because the original surface of both structures had corrosion over at least 20 percent of their surface. All three structures have some degree of failure after only three years. Due to the fact that MSP involves applying coatings over a less than ideal surface preparation, painting after MSP is a less durable paint system. Most of Michigan's red lead coated structures, when fabricated, did not have the mill scale removed prior to being painted. Applying additional coating thickness to an existing coating applied over mill scale, greatly increases the potential for adhesion failure between the mill scale and the existing red lead coating. After evaluating these systems, a more appropriate way to utilize a MSP system would be to apply the first two coats to the power tool cleaned areas of steel and coat the entire structure with the top coat. This could lessen the potential for adhesion failure between the steel and red-lead coating. Minimal Surface Preparation systems should not be applied to structures that still have mill scale. A Federal Highway Report *Coating and Corrosion Costs of Highway Structural Steel*, FHWA-RD-79-121, March 1980, shows the rate of deterioration for a lead alkyd system over mill scale varies considerably depending on the structure's environment. Curves derived by trial and error, show that the deterioration is roughly exponential. The study shows that significant cost savings can be achieved by repainting the structure when it is still in an early stage of corrosion. If MSP systems are to be utilized, they should only be applied to structures where the existing coating is in sound condition with less than 10 percent of the structure requiring surface preparation.

RECOMMENDATIONS

MDOT should not adopt a policy of using MSP coating systems. Only one of the tested systems performed well in the accelerated testing over both the existing red-lead system and the chloride contaminated bare steel. The system's performance was questionable in the weather cycle which includes freeze-thaw cycles. In field trials, the three systems tested all showed significant corrosion after only three years. The majority of Michigan's structures coated with a red lead coating system have mill scale underneath the coating system which is a prelude to coating failure. MDOT's 1967 Standard Specification book was the first to require sandblasting prior to the application of the shop applied red lead coating. Structures built before 1967 did not have the mill scale removed unless they were repainted in the field prior to 1980. A large number of new steel structures built from 1967 to 1980 were constructed of uncoated A-588 steel. If MSP systems are to be used, they should only be used on structures where the existing coating was applied over a abrasive blasted surface and the areas of coating failure do not exceed 10 percent of the total surface area of the structure.

1998-99 Systems

System #	Primer	Intermediate	Topcoat
9801	MC-Aluminum (Moisture Cure Urethane -Aluminum Filled)	Moisture Cure (MC) Urethane	MC Urethane
9802	MC-Aluminum	Epoxy	Urethane
9803	MC-Aluminum	MC Urethane	MC Urethane
9804	MC-Zn (Moisture Cure Urethane -Zinc Rich)	Epoxy	Urethane
9805	MC-Zn	MC Urethane	MC Urethane
9806	MC-Zn	MC Urethane	MC Urethane
9807	100% Epoxy Sealer	Epoxy Mastic	Urethane
9808	Epoxy		Urethane
9809	Epoxy Mastic Aluminum	Epoxy	Urethane
9810	Epoxy Mastic	Epoxy Mastic	Urethane
9811	Epoxy Mastic Aluminum		Epoxy Mastic Aluminum
9812	Epoxy Mastic Aluminum		Calcium Sulfonate
9813	100% Epoxy Sealer		Urethane
9814	Epoxy Mastic Aluminum		Urethane
9815	MC-Zn	MC Urethane	MC Urethane
9816	Urethane-Sealer	MC Urethane	MC Urethane
9817	Urethane-Sealer	Urethane-Sealer	MC Urethane
9818	MC-Aluminum	Urethane	Urethane
9819	100% Epoxy Sealer	Epoxy	Urethane
9820	Urethane-Sealer	Epoxy	Urethane
9821	Urethane-Sealer	MC Urethane	Urethane
9822	Epoxy Mastic		Urethane
9823	Epoxy Mastic		Urethane
9824	MC-Aluminum	MC-Aluminum	Urethane
9825	Epoxy Mastic Aluminum		Urethane

TABLE 1

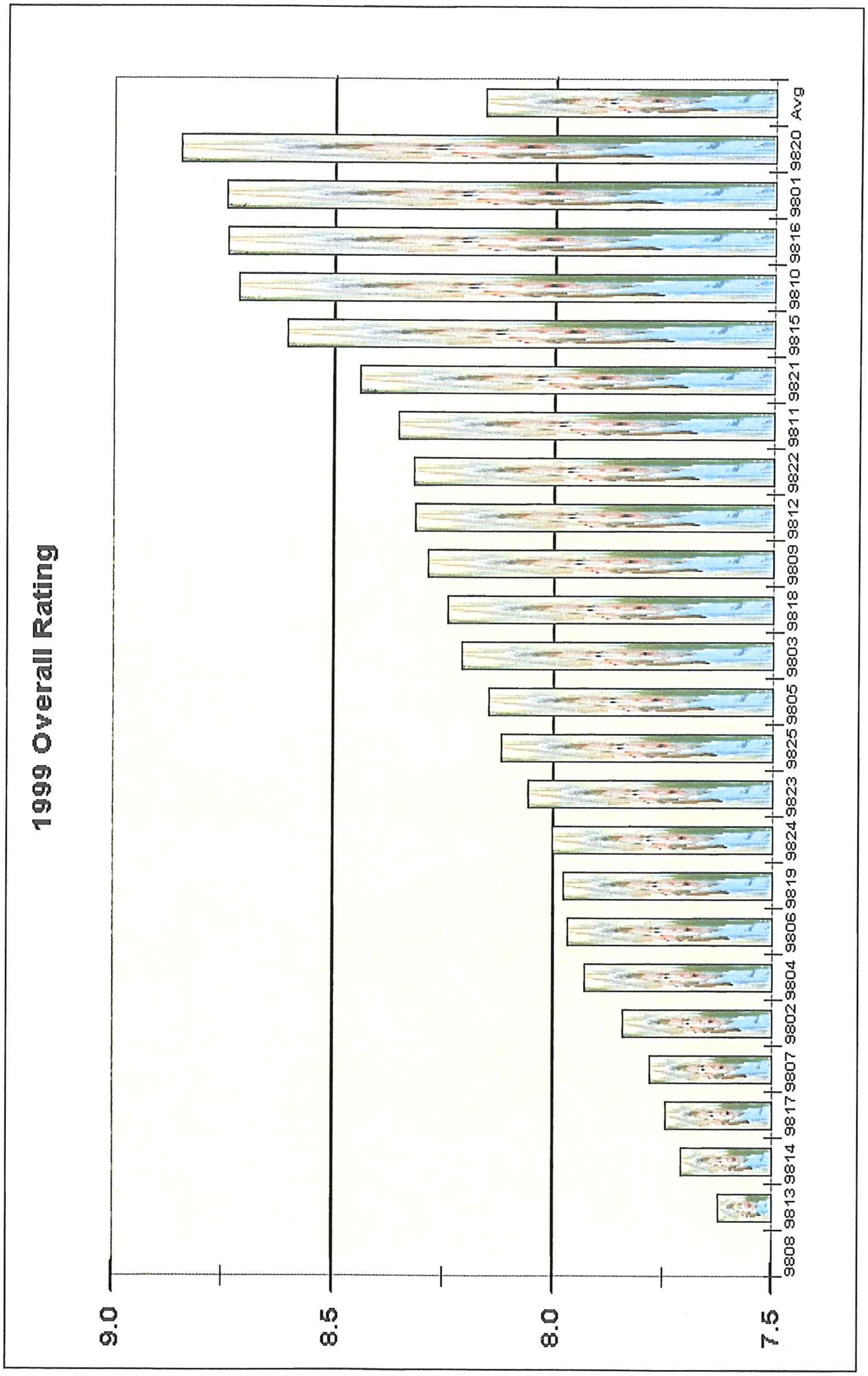
1999 Overall Rating
9.0
8.5
8.0
7.5
9808 9813 9814 9817 9807 9802 9804 9806 9819 9824 9823 9825 9805 9803 9818 9809 9812 9822 9811 9821 9815 9810 9816 9801 9820 Avg

FIGURE 17

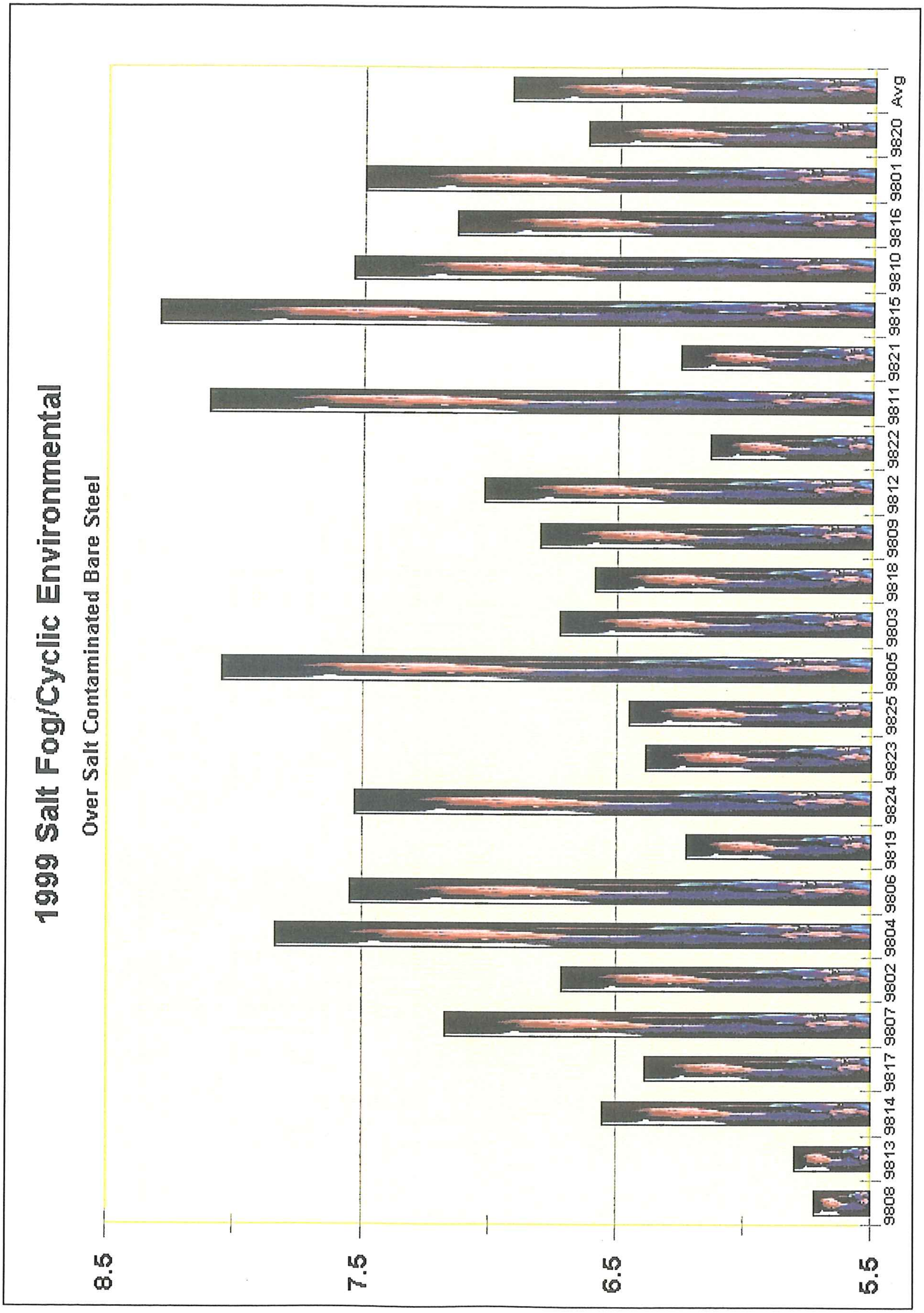
1999 Salt Fog/Cyclic Environmental
Over Salt Contaminated Bare Steel
8.5
7.5
6.5
5.5
9808 9813 9814 9817 9807 9802 9804 9806 9819 9824 9823 9825 9805 9803 9818 9809 9812 9822 9811 9821 9815 9810 9816 9801 9820 Avg

FIGURE 18

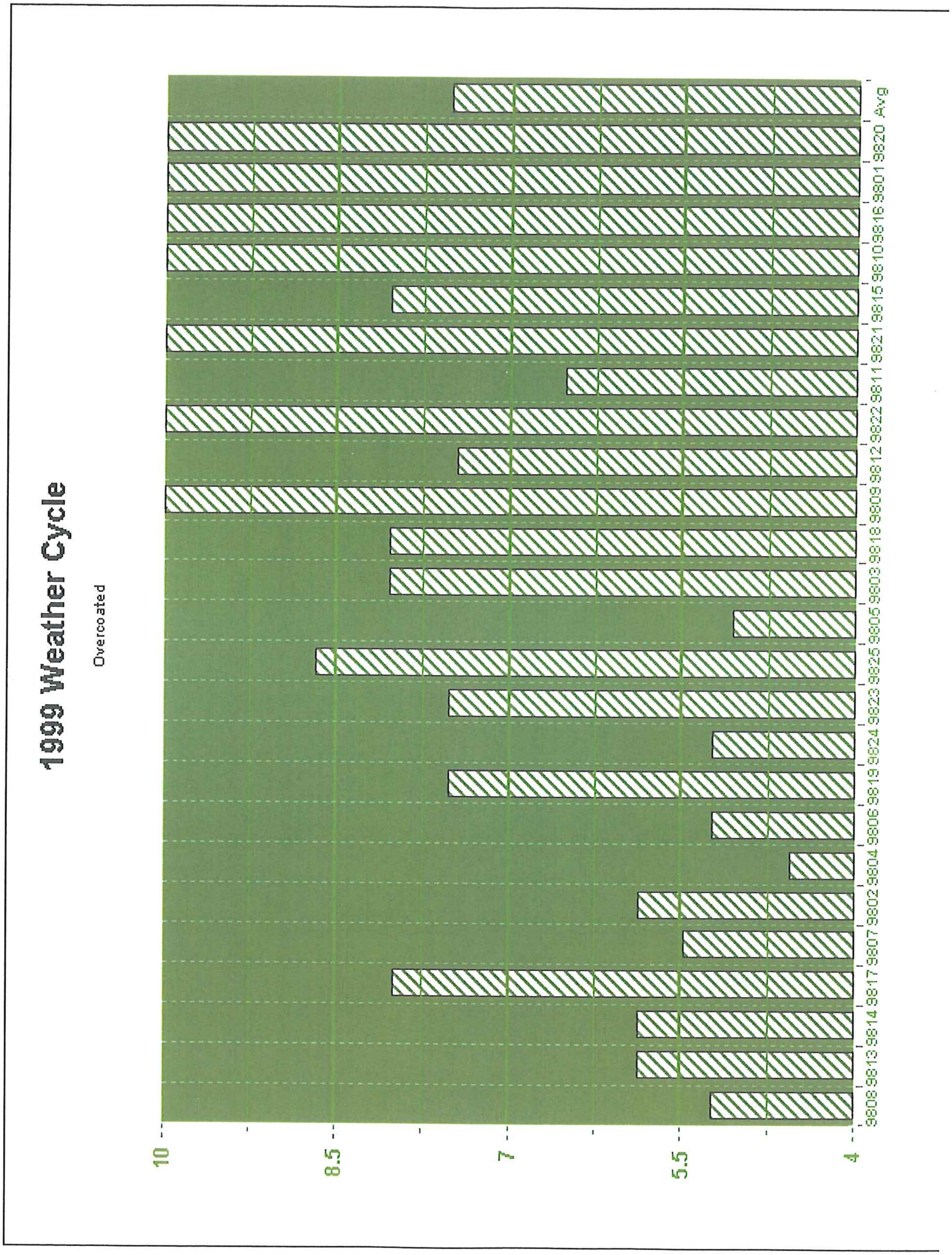
1999 Weather Cycle
Overcoated
10
8.5
7
5.5
4
9808 9813 9814 9817 9807 9802 9804 9806 9819 9824 9823 9825 9805 9803 9818 9809 9812 9822 9811 9821 9815 9810 9816 9801 9820 Avg

FIGURE 19