1. Report No. SPR-PL-PR-1(31) Project 12323 D	2. Gov. Accession No.	3. Recipient=s Catalog No.
4. Title and Subtitle ALTERNATE PAINT SYSTEMS FOR OVERCOATING		5. Report Date: October, 2000 6. Performing Organization Code
7. Author(s) Gary L. Tinklenberg		8. Performing Organization Report No.
9. Performing Organization Name and Address CORROSION CONTROL CONSULTANTS & LABS, INC. 4403 DONKER CT SE KENTWOOD, MICHIGAN 49512-4054		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR-PL-PR-1(31)
12. Sponsoring Agency Name and Address The State of New Hampshire Department of Transportation John O. Morton Building 1 Hazen Drive, P.O. Box 483 Concord, N.H. 03302-0483		13. Type of Report and Period Covered Research Project June, 1994 to September, 1999 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the New Hampshire Department of Transportation and the U.S. Department of Transportation, 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 New Hampshire Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification or regulation.

16. Abstract

This research project was undertaken to test various generic types of currently available paint systems over existing coatings used on bridges. After acquiring the products, fifteen different paint systems were applied according to manufacturer instructions on beams removed from highway bridges and set up in a New Hampshire Dot maintenance yard. The five types of generic systems included alkyds, moisture-cure urethanes, epoxies, acrylics, and a calcium sulfonate system. These were compared to a control - a traditional lead-based paint system. The application data and climatic conditions were recorded as well as dry film thickness measurements. The exposed beams were observed for a period of four years, periodically rated and photographed. The periodic inspections included documentation of the type and extent of failure. The study resulted in nine basic conclusions regarding the tested paint systems. One conclusion is the fact that whenever an existing paint is overcoated, some failure must be expected and therefore periodic repairs will be necessary. The experimental exposures in this study also led the researchers to conclude that a three-coat moisture-cure urethane system can best be recommended for use over surfaces hand tool cleaned in a manner typical of field use.

17. Key Words: testing program; generic paint systems; surface preparation; overcoating; field inspections; condition ratings			18. Distribution Statement No Restrictions. This document is available to the public through the national Technical Information Service (NTIS), Springfield, Virginia, 22161
19. Security Classif. (Of this report)	20. Security Classif. (Of this page)	21. No. of Pages	22. Price

ALTERNATE PAINT SYSTEMS
FOR OVERCOATING

SPR-PL-PR-1(31)
PROJECT 12323 D
(Formerly Project 94-10, X2727)

Research Project Conducted by
Gary L. Tinklenberg
CORROSION CONTROL CONSULTANTS & LABS, INC.
KENTWOOD, MICHIGAN

Prepared in cooperation with
the New Hampshire Department of Transportation
and the U.S. Department of Transportation,
Federal Highway Administration.

October, 2000

ALTERNATE PAINT SYSTEMS FOR OVERCOATING
SPR-PL-PR-1(31)
PROJECT 12323 D
(Formerly Project 94-10, X2727)

FIGURES

APPENDICES

A EVALUATION SUMMARY

1. System Application Data
2. System Condition Ratings
3. System Representative Photos

B TABLE OF SYSTEMS, PANEL RATINGS, AND AVERAGE RATINGS

C SYSTEM DATA

1. List of Systems with Panel Designations
2. Field Test Panel Location Map
3. Method for Salt Spray Applications

D DRY FILM THICKNESS DATA

1. DFT Summary Chart: Actual DFT v Theoretical DFT
2. DFT Tables

Executive Summary

New Hampshire DOT contracted with Corrosion Control Consultants & Labs, Inc. (CCC&L) to test various generic types of paint systems over existing coatings used on bridges. As part of the research project, CCC&L placed 15 different paint systems on four randomly selected areas or panels, on a series of beams in a New Hampshire DOT Maintenance Yard. All steel surfaces were prepared by hand tool cleaning in a manner typical of field use.

There were five basic generic types of coatings: Alkyds (the traditional resin type used by many highway departments), moisture-cure urethanes, epoxies, acrylics and a calcium sulfonate. All five of these were compared to the very traditional lead-based paint used from 1950 to 1980 and, in some cases into the1980s, by various highway departments. The paint systems were evaluated for four years. Many are still doing very well.

The basic conclusions of the study are:

1. When overcoating an existing paint system it should be assumed that some areas will fail quite rapidly and will require repair after two to three years to obtain maximum effectiveness of the entire system.

2. The lead-based paint was and is a very good topcoat system for existing steel bridges.

3. Moisture-cure urethanes are at least as good as the red lead systems and in some cases slightly better.

4. Alkyds are varied in performance when compared to the Lead-based Alkyd formulation.

5. Epoxies tend to place sufficient stress on the existing system to cause the original primer to delaminate. One epoxy system that was based on a flexible epoxy primer was essentially equal to the control.

6. Acrylics (generally waterborne systems) performed satisfactorily on the painted surfaces but on rusted areas failed within the first two years.

7. The Calcium Sulfonate coating remained soft and tacky for up to two years. Although the system performs well from a corrosion protection viewpoint, it became quite dirty and therefore was judged to be aesthetically unacceptable.

8. The measurement of dry film thicknesses with magnetic or electronic DFT gages is of very little, if any, value on over-coating projects. This is due to the highly variable thickness of the existing paint or corrosion products and the extreme difficulty of measuring in the exact same spot once subsequent coats have been applied.

9. Based on this experimental exposure, the best system that can be recommended is a three-coat moisture-cure urethane system.

INTRODUCTION

New Hampshire, like many other states, has experienced problems related to lead paint removal and containment, which have placed increased demands on their bridge maintenance programs. Keeping bridges in good condition while keeping costs under control has prompted maintenance departments to look at the overcoating of existing paints rather than complete removal of a coating. Systems that can be applied with minimal surface preparation and provide adequate, long-term performance in various environments, are an alternative to complete removal. To date, no system had been established as a superior performer. NHDOT recognized a need to test and evaluate the various systems available for overcoating to determine the compatibility and performance of each system under real conditions.

In June 1994, Corrosion Control Consultants & Labs, Inc. (CCC&L) was engaged by the State of New Hampshire, Department of Transportation (NHDOT), to render professional services to research and evaluate various paint systems used for overcoating existing painted steel structures. (SPR Project 12323 D, Alternate Paint Systems for Overcoating; Formerly Project 94-10, X2727) To that end, CCC&L's Principal Investigator, Gary Tinklenberg, visited the proposed test site and provided recommendations related to setting up the testing facility to ensure a meaningful and unbiased evaluation of selected paint systems. Beams at the test site and those selected at other locations were examined and tested to determine existing condition relative to the proposed research. Prior to beginning the testing program, representatives from CCC&L met with Department personnel to discuss current and past NHDOT maintenance coating practices.

It should be noted that the schedule for the original proposal called for a three-year evaluation period, with the first anniversary inspection to be conducted in April 1995, and the final inspection in August 1997. During the course of the testing program, it was mutually determined that NHDOT's best interests would be better served by extending the evaluation period for an additional period of time; thus the final field inspection was concluded in April, 1999.

SOLICITATION AND SELECTION OF CANDIDATE PAINT SYSTEMS

New Hampshire DOT has over-coated numerous lead-based, alkyd-coated bridges with a lead-free vinyl system. This system met their needs very well. However, the vinyl systems are not VOC-compliant. New Hampshire DOT needs an overcoating system that will adhere to the existing vinyl and is VOC-compliant.

CCC&L, with input from New Hampshire DOT, contacted coatings manufacturers to collect information regarding the various generic systems currently available and to solicit participation in the proposed testing program. A pre-requisite for being selected as a candidate system was VOC content that did not exceed limits imposed by recent state and environmental regulations. Systems could not exceed the VOC limit of 3.5 pounds per gallon. Other criteria to be considered were tolerance of environmental conditions, degree of surface preparation recommended by the manufacturer, life expectancy of the coating system, future maintenance that may be required. The objective for the project was to obtain the best and most cost-effective system available.

In early 1995, CCC&L and New Hampshire DOT personnel met to select the fifteen systems that would be tested in the program. The selected systems, the reasons for its inclusion in the program, and source of products follow. It should be noted that the systems are presented in no particular order. They are listed as discussed and entered in the original database.

SYSTEM 1. Generic Class: Alkyd

Generic Type:	Long-Oil Zinc-Containing Alkyd (Tower Paint) (Two coats)
Reason For Use:	The system is very tolerant of poorly prepared surfaces. Seals existing paint while at the same time results in very little stress on the existing coating due to the very low solvent content and the very, very long dry times. (VOC was typically less than 1 pound per gallon. The selected product was 0.5 pounds per

	gallon.)
Products:	Numerous products from various manufacturers
Source:	Various manufacturers make this type of system. A local manufacturer's product was selected.

SYSTEM 2. Generic Class: Moisture-Cure Urethane

Generic Type:	Moisture-Cure Urethane Primer / Aliphatic Urethane Topcoat
Reason for Use:	This type of system generally involves mild solvents; displays exceptional adhesion and penetration characteristics.
Products:	There are a number of manufacturers of this type of system and other major manufacturers are starting to market this type of coating. This two-coat system was selected since it had a micaceous iron oxide primer and a typical urethane topcoat.
Source:	See above.

System 3. Generic Class: Calcium Sulfonate

Generic Type:	Calcium Sulfonate (SACI) - Drying Type
Reason For Use:	In CCC&L's independent laboratory tests, it has been clearly demonstrated that Calcium Sulfonates perform well over rust. Both the non-drying (grease type) and drying version from various companies have been tested. Over rust, even acid-contaminated rust, in high humidity conditions, they performed better than epoxies and acrylics.
Products:	There are a number of manufacturers that produce essentially the same formulations.
Source:	A licensed manufacturer.

SYSTEM 4. Generic Class: Moisture-Cure Urethane

Generic Type:	Moisture-Cure Urethane Aluminum Primer / High-build Micaceous Iron Oxide Moisture-Cure Urethane Intermediate / Moisture-Cure Urethane Topcoat
Reason For Use:	This was a commonly used, all moisture-cured urethane system.
Products:	Various manufacturers produce similar generic systems
Source:	Large national manufacturer

SYSTEM 5. Generic Class: Acrylic

Generic Type:	Formula Spec Water-base Acrylic (CalTrans)
Reason For Use:	This system would have an advantage for NHDOT in that it could be specified on a formula basis.
Products:	State Spec - Waterborne System
Source:	California Manufacturer

SYSTEM 6. Generic Class: Epoxy

Generic Type:	Epoxy/Polysiloxane
Reason for Use:	This is a new system that utilizes the latest in coating technology. In 1995, these systems were quite expensive but should be affordable at the end of the testing period. They are said to be easy to apply and have outstanding UV resistance. CCC&L's independent testing confirms both of these claims. A major disadvantage is that it is a two-component product that would require mixing. However, if performance is superior, the extra effort required by this product may be justified.
Products:	Epoxy Primer / Polysiloxane Topcoat
Source:	National Manufacturer

SYSTEM 7. Generic Class: Alkyd Lead-Based

Generic Type:	Alkyd Lead-Based
Reason for use:	Control - Most of the systems that have been used throughout the United States from 1950 to the mid-seventies have been alkyd lead-based systems. For this reason they have a long history of documented performance. Including this system in the program will provide a well-documented benchmark to which all systems can be compared.
Products:	The best source for these products is from contractors or State DOTs which have some old material in storage, since very few, if any, manufacturers make lead-based products
Source:	Maine DOT

SYSTEM 8. Generic Class: Moisture-Cure Urethane

Generic Type:	Zinc-Rich Moisture-Cure Urethane / Moisture-Cure Urethane Mastic Intermediate / Moisture-Cure Topcoat
Reason For Use:	Premium System - It was reported that this system would give good to better protection to the bare steel areas due to its thicker application film thickness and the use of metallic zinc in the primer.
Products:	Various manufacturers produce similar generic systems
Source:	Large national manufacturer

SYSTEM 9. Generic Class: Acrylic

Generic Type:	Waterborne Wash Primer / Waterborne Acrylic / Waterborne Acrylic
Reason For Use:	Wash Primers are known to enhance adhesion. Waterborne products in general should have the least effect on the solvent-sensitive vinyl that will be over-coated. Acrylics are one-component, easy-to-handle products that make them ideal for maintenance painting operations. Small amounts can be removed from containers and the containers resealed. Storage is easy since most paint storage regulations are not concerned with waterborne systems; however, products must not be allowed to freeze. This system is VOC-compliant. Waterborne acrylics should put very little stress on the existing coating. Aged vinyl paints should tolerate the waterborne type well.
Products:	Numerous manufacturers make systems of this nature
Source:	National manufacturer.

SYSTEM 10. Generic Class: Acrylic

Generic Type:	Waterborne Acrylic / Waterborne Acrylic / Waterborne Acrylic
Reason for use:	Waterborne products in general should have the least effect on the solvent-sensitive vinyl that will be over-coated. Acrylics are one-component, easy-to-handle products that make them ideal for maintenance painting operations. Small amounts can be removed from containers and the containers resealed. Storage is easy since most paint storage regulations are not concerned with waterborne systems; however, products must not be allowed to freeze. This system is VOC-compliant. This system will be formulated by the

	leading manufacturer of acrylic resins. It will be their best formulation regardless of cost.
Products:	Custom Made Experimental products
Source:	A leading manufacturer of waterborne acrylic resins manufactured a small amount of the products.

SYSTEM 11. Generic Class: Alkyd

Generic Type:	Alkyd (Low VOC) with Rust-Inhibitive Pigment
Reason for Use:	A pigment supplier believes that performance of overcoats can be enhanced by the use of rust-inhibitive pigments.
Products:	Formula specification paint supplied by a pigment manufacturer.
Source:	Local paint manufacturer.

SYSTEM 12. Generic Class: Moisture-Cure Urethane

Generic Type:	Zinc-Rich Moisture-Cure Urethane / Aliphatic Urethane Topcoat
Reason For Use:	Premium System - It was reported that this system would give good to better protection to the bare steel areas due to its thicker application film thickness and the use of metallic zinc in the primer. The use of an aliphatic urethane topcoat should improve weatherability.
Products:	Various manufacturers produce similar generic systems
Source:	Large national manufacturer

SYSTEM 13. Generic Class: Alkyd

Generic Type:	ZHP (Zinc-Hydroxy-Phosphite) Alkyd - New Hampshire System
Reason for use:	Control - New Hampshire DOT has used this system.
Products:	Formula Specification
Source:	Purchased from local manufacturer

SYSTEM 14. Generic Class: Epoxy

Generic Type:	Surface-Tolerant Epoxy Mastic / Urethane Intermediate / Urethane Topcoat
Reason For use:	It is generally believed that systems that are flexible with mild solvents should perform satisfactorily over existing coatings. This epoxy system was formulated to utilize the mildest solvent available (and then at a high solids level to minimize the amount of solvent) and cure to a flexible film. The intermediate coat and the topcoat

	were urethane to maintain the flexibility and minimize the stress on the original primer.
Products:	There are very few epoxy products that remain flexible.
Source:	A leading manufacturer markets a system which claims to remain flexible.

SYSTEM 15. Generic Class: Epoxy

Generic Type:	100% Solids Epoxy Primer and Urethane Topcoat
Reason For Use:	These systems are known to seal edges of existing paint. Its penetration properties are excellent. It is easy to apply with inexpensive disposable equipment. The products require a topcoat.
Products:	Several manufacturers have this system.
Source:	Leading manufacturer

SELECTION OF BEAMS AND LAYOUT OF TESTING FACILITY

The proposed test site was located on State property in Newfields, New Hampshire. During a pre-project meeting and site visit with NHDOT representatives, it was determined that beams for the testing facility would be selected from Bridge Maintenance stockpiles at the test site. All the beams chosen came from the same structure; all had consistent characteristics. In general, the beams were typical of many existing bridges in New Hampshire. The existing paint was well-adhered to a generally tight mill-scale-coated surface. The topcoat was a vinyl.

Testing Facility

The test rack or facility consisted of a series of painted steel members oriented to provide a consistent exposure to the elements. Ten beams were set up - five were completely open to exposure to the weather; five were covered to simulate exposures beneath a bridge deck. The beams were numbered from 1 to 10: beams 1 through 5 were “sheltered” - those positioned under the simulated bridge deck; beams 6 through 10 were “fully exposed” - those positioned to obtain an open exposure. Between each of the test areas, there was an unpainted 4-inch strip. It is interesting to note that at the conclusion of the testing, the rust build-up and depth of pitting was much greater in the “sheltered” area than in the “fully exposed” area. A video and photographs were taken to document the original condition of the beams prior to any surface preparation.

SURFACE PREPARATION

On one side of each member, the bottom four inches of the web together with a 2-inch portion of the top of the bottom flange were blasted to remove all mill scale and paint. Back sides of members were not blasted. The blasted beams were allowed to rust for about four weeks prior to hand tool cleaning and application of the test paints. All sides were power water-washed by New Hampshire DOT personnel.

CCC&L technicians, along with and under the direct supervision of the Principal Investigator, performed SSPC-SP-2 Hand Tool Cleaning prior to application of the paint systems. Prior to hand tool cleaning, any visible oil or grease (there was only one small spot), were removed from the surfaces of the test beams by solvent wiping. Surfaces were then scraped to remove loose paint and loose rust. Wire brushes were used to further prepare the surface for coating application. Surfaces were wiped with a dry rag to remove any accumulated dust and dirt. Dry Film Thicknesses (DFTs) of the prepared surface were taken and recorded. A table of DFTs is included in Appendix B. Video documentation was conducted during portions of the surface prep activities.

COATING SYSTEM APPLICATION

Application Sites

Specified spaces for coating system application were designated on the beams, allocating two sheltered sites, front and back of the beam, and two fully exposed sites, front and back of the beam, for each system. Therefore, sites designated as “A” and “B” may be considered as random duplicates-sheltered; and sites designated as “C” and “D” are random duplicates-fully exposed. The number of application sites and locations were chosen to help offset the possibility that any one system might be located on an “inferior” section of steel or on a part of the beam that received a more unfavorable exposure as regards the long term performance of a coating. For example, a generic coating system of 100% Solids Epoxy Urethane had the following designated sites: Beam #2 / Location #12 / Site A **and** Beam #3 / Location#1 / Site B **and** Beam #6 / Location #1 / Site C **and** Beam #9 / Location #5 / Site D. A listing of the designated sites for each applied generic system and the Sample Location Map are located in Appendix C. The size of each application location is approximately 4 feet along the length of the beam. The web measurement of the beams is 36 inches. Application sites were separated by a space of approximately four inches.

Coating Application

Between May 31, 1995, and June 5, 1995, the Principal Investigator and a Senior Technician applied the selected coating systems using brushes and rollers, strictly following manufacturers’ instructions for such applications. Two additional senior technicians documented the application process, recording the number and type of coats applied for each system. Weather conditions, wet film thickness, drying time and dry film thicknesses were measured and recorded. Some parameters were recorded and commented on only if unusual conditions existed or problems were encountered during application of the coat or system.

The following information and application conditions were documented for each coating system:

Manufacturer’s Name
Coating Name and Batch Number
Thinner - ounces per gallon if thinner was used
Date of Application; Time of Day
Ambient Temperature; Steel Temperature
Humidity; Wind Speed
Wet Film Thickness

Comments were recorded along with the application data, if deemed pertinent to the research, and are included in the Evaluation Summary Documents contained in Appendix A.

The following components of the beam were included in the cleaning process and in the application of the coating systems. The components are named, beginning at the top flange and wrapping around the beam from front to back.

Bottom of Top Flange
South Web
Top of Bottom Flange
Bottom of Bottom Flange
Top of Bottom Flange
North Web
Bottom of Top Flange

Dry film thicknesses were recorded during the entire process of coating application. (DFTs) were recorded as Data After Prep; Data After Primer; Data After Intermediate (if an intermediate coat was required); Data After Topcoat. The DFT after Prep and DFT after Topcoat are reported in the Evaluation Summary Documents for each System, Appendix A. (All DFTs are included in the table contained in Appendix D.) Video documentation was conducted periodically during the application of various coating systems.

Each panel was scribed along the left edge of the web in a vertical line approximately 2/3 the distance from the bottom to the top flange.

ACCELERATED CORROSION-INDUCING ACTIVITIES (SALT-SPRAY)

CCC&L provided a written procedure for wetting the beams with salt-spray to the Bridge Maintenance Division of the NH DOT. CCC&L also supplied a two-gallon garden sprayer and 18 pre-measured packets of salt to provide a 1% salt solution for each application. Accelerated corrosion-inducing salt spray was applied to the beams of the testing facility beginning in December, 1995, and approximately every other week for the next 12 weeks of the exposure period. The second and third series of applications were scheduled to begin in December, 1996 and 1997, for a total of 18 applications during the entire exposure period.

INSPECTIONS

Inspections to assess coating system conditions were conducted on 6/27/96 and 3/25/97 by Jon Cavallo, Vice-President from CCC&L's office in Eliot, Maine, and on 4/19/99 by Gary Tinklenberg. A numerical system incorporating ASTM rust ratings was developed for rating the coating systems and is included in this report as Figure 1. Photo documentation of each panel was performed to show the progression of corrosion or the lack of deterioration of a system. Comments appropriate to each panel were recorded along with numerical ratings and were entered to a cumulative database record. Appendix A contains the Evaluation Summary documents for the panels. Each coating system that was applied is reported as: System Application Data; System Condition Ratings; and System Representative Photos. The system reports are presented generically as System 1, System 2, System 3, etc. Periodic inspection photographs selected for the individual reports include a photo of the test panel after surface preparation; after application of the topcoat; the one-year inspection; the four-year inspection. Photographs included in this report are almost exclusively of the front side of the panel. Back side photos were included where conditions on the back side were significantly different from the front side or unusual as compared to other systems.

Appendix B contains a Table of Panel Conditions Ratings and Front/Back/General Averages. Appendix C is a collection of System Data such as a list of the generic systems and their site designations, depicting where each panel of the tested systems was located on the "test rack". Appendix D is the record of Dry Film Thickness (DFT) measurements. A summary chart is included, comparing actual DFT with theoretical DFT. Raw data is contained in the Dry Film Thickness tables.

PANEL CONDITION RATING CRITERIA

Rating	Condition Description
10	No failures
9	Slight discoloration; runs; sags; wrinkles; isolated rusting; rust staining; isolated edge failure
8	Edge failure > 1 foot in length; pin-point rusting
7	Slight delamination @ edges of scribe; and/or ASTM rust rating 8-9 in previously rusted areas
6	Isolated delamination < 12 sq inches; and/or ASTM rust rating 6-7 in previously rusted areas
5	Isolated delamination < 36 sq inches; and/or ASTM rust rating 5 in previously rusted areas
4	Cracking/delamination > 36 sq inches; and/or ASTM rust rating 4 in previously rusted areas
3	Spontaneous delamination < 144 sq inches; and/or ASTM rust rating 3 in previously rusted areas
2	Spontaneous delamination < 2 sq feet; and/or ASTM rust rating 2 in previously rusted areas
1	Spontaneous delamination > 3 sq feet; and/or ASTM rust rating 1 in previously rusted areas

Note: Panels are generally 3' x 4'

Figure 1.

CONCLUSIONS and Discussion

There were five basic generic classes of coatings: Alkyds (the traditional resin type used by many highway departments), moisture-cure urethanes, epoxies, acrylics and a calcium sulfonate. All five of these were compared to the very traditional lead-based paint used during the ‘50s, ‘60s, ‘70s and, in some cases ‘80s, by various highway departments. The paint systems were evaluated for four years. Many are still doing very well.

Since a listing of the conclusions is contained in the Executive Summary, this section will list the conclusion and discuss each of them. The basic conclusions of the study are listed and discussed below.

1. When over-coating an existing paint system it should be assumed that some areas will fail quite rapidly and will require repair after two to three years to obtain maximum effectiveness of the entire system.

There were two methods used to determine the effects of stress on the existing coating. First of all, the amount of delaminating paint over the entire area was evaluated; and second, the delamination that occurred along the scribe was evaluated. It is obvious from the data in Appendix B, “Table of Systems, Panel Ratings, and Averages”, that most of the systems had at least one of the eight panels (front and back on the four locations) that had a significant delamination not associated with the scribed area. The existing paint in some areas had sufficient adhesion to withstand the rigors of power washing and hand tool cleaning but insufficient adhesion to withstand the stress placed on the system by any of the generic classes of coatings. From this information we conclude that all systems place some stress on the existing coating. It is impossible to find all areas of poor adhesion utilizing the methods selected by NHDOT. (It should be noted that it may be possible to locate these areas using a much more aggressive power washing method, such as 5000 PSI water with a 0-degree rotary nozzle, assuring that every square inch of the surface is power washed.) Therefore, some failure should be expected, regardless of the type of overcoat system applied. Once these failed areas are repaired, the maximum service life of the overcoating system should be achieved.

The adhesion in the scribed areas appears to be more consistent and the amount of scribe undercut does correlate to the generic type of coating. This information was relied upon for conclusions and will be discussed in more detail with each of those conclusions.

2. The lead-based paint was and is a very good topcoat system for existing steel bridges.

The biggest reason that the lead-based paint did not rate at the highest level on most panels was due to some application problems that resulted in some runs and sags. As noted in the body of the text, the paint was provided from the stores of a highway department. (They where happy to be rid of it.) CCC&L received no paperwork and could not determine the age of the paint. The application problems and their effect on the rating may simply have been the result of a very old batch of paint. The basic lead silico chromate formulation is the control in this experiment.

3. Moisture-cure urethanes are generally as good as the alkyd lead-based systems and in some cases slightly better.

In general the three-coat urethane systems did very well. The two-coat systems rated somewhat lower, mostly as a result of their poorer performance in the previously rusted areas. A thicker film build over rust did enhance performance. Figure 2 is a comparison of the various urethane systems to the control. It should be noted that in this comparison graph and all others, the worst test panel from each set of eight (four locations, front and back) was deleted and the remaining seven panels averaged. In almost every case, the worst panel rating was the result of a delamination of the original primer. We believe that a system should not be down-graded based on one unusual data point caused by a loosely adherent existing coating. If however, there were numerous panels that had a delamination problem, it is more likely that the paint system had an effect on the adhesion of the original system. If there was no panel that delaminated, all eight values were used in the average rating.

4. Non-Lead Alkyds varied considerably when compared to the red lead formulations.

In the four years of the evaluation period, one of the three alkyds - a very slow-drying long oil variety - performed equal to the Control; the other two were not as good as the Control. This is clearly demonstrated in Figure 3. The only concern was System 13 - The New Hampshire Zinc-Hydroxy Phosphite System. This system appears to be deteriorating at a significant rate between the third and fourth rating. The slope of this line is not encouraging.

5. Epoxies tend to place sufficient stress on the existing system to cause the original primer to delaminate. One epoxy system that was based on a flexible epoxy primer performed essentially the same as the Control.

The epoxies, where they did not delaminate, generally looked very good, but it was clear, based on the scribed areas, that epoxies placed the most stress on the existing paint. System 14 utilized a “flexible” resin in the primer and was noticeably better (and equal to the Control) than the other epoxy systems tested. The performance of the 100% epoxy system was disappointing in that these systems are touted for their performance over existing coatings; yet in four years it was one of the worst of the solvent-borne systems. (Figure 4.)

6. **Acrylics (generally water-based systems) performed satisfactorily on the painted surfaces but on rusted areas failed within the first two years.**

The acrylics were the biggest disappointment in the study. See Figure 5. If they could have been utilized only over sound, existing coating, they would have performed quite well. However, once the previously rusted areas were considered, the group as a whole performed the worst of all coatings. Simply put, there was not enough resistance to flash rusting and/or contamination below the coating for acrylics to perform well in the test. Since it is our belief that on any re-coating project, there are bound to be some areas of rust, and these areas must be protected, we cannot recommend acrylics at this time. If a system were found which utilizes a solvent-borne spot primer for rusted areas, it is probable that the performance of acrylic systems would be greatly enhanced. This would allow the obvious advantages of acrylics - water clean-up, one component materials, easy application - to be fully utilized.

7. **The Calcium Sulfonate coating remained soft and tacky for up to two years. It became quite dirty and therefore was judged to be aesthetically unacceptable.**

The idea that calcium sulfonate systems place very little stress on the existing paint system was obvious in this study. However, it did not appear that the paint sealed the edges of the existing paint as well as other harder solvent-borne systems. Additionally the dirt accumulation on the soft, tacky surface of the coating could not be overlooked. If the rating system had accounted for appearance only, this system would have been significantly impacted, and then severely. Since the exposure was in a maintenance yard with no traffic below the beams, it can only be assumed that on a “real world” bridge, the dirt accumulation problem would be further exacerbated. For these reasons it is clear that the calcium sulfonate system as tested cannot be recommended for use. If the system had utilized a topcoat that does not have such an affinity for dirt collection, it is probable that the results would be much different. (See Figure 3-included in chart with alkyds.)

8. **The measurement of dry film thicknesses with magnetic or electronic DFT gages is of very little, if any, value on over-coating projects. This is due to the highly variable thickness of the existing paint or corrosion products and the extreme difficulty of measuring in the exact same spot once subsequent coats have been applied.**

Although a complete statistical analysis of all the dry film thickness measurements was beyond the scope of this study, it is clear from even a cursory review, that the predicted applied DFTs were often not achieved and in many cases were not even close. This is due to the high degree of variability in the existing coating. Often the variability is greater than the applied DFT of the applied coating. In addition to this problem, once the primers were applied, it was not readily apparent whether the previous measurement was on a painted or rusted area of the measured component. Thus there were times that the application of the paint resulted in a substantial decrease in measured DFT. It should be noted that a statistical analysis could yet be done, since all measurements are supplied in Appendix D. However, included at the end of this Appendix are several tables derived from the data of some of the systems which demonstrate the large variations from the expected DFT.

Based on these measurements and their lack of dependability, it is clear that other methods are needed to determine whether the proper amount of paint has been applied. Calculating coverage and careful attention to applied wet film thickness is recommended. Inspectors or foremen must be made aware that they must keep careful record of the gallons of paint used and the square footage of the area covered. Since these systems are applied by brush and roller, these calculated dry film thicknesses will generate a reasonable approximation of applied DFT if application technique is consistent.

9. **Based on this experimental exposure, the best system that can be recommended is a three-coat moisture-cure urethane system.**

This type of system gave constantly good performance in both rusted and non-rusted areas. At the same time, it seals edges of existing paint very well. There were insufficient comparable systems from different manufacturers to determine if any particular products are better than any others. It is also clear that the addition of metallic zinc did not appear to have significant impact on performance. The worst performing system in this class was one that contained metallic zinc.

Figure 2. COMPARE PERIODIC PANEL AVERAGES (FR/BK) of MOISTURE-CURE URETHANE SYSTEMS to PANELS AVERAGES of CONTROL

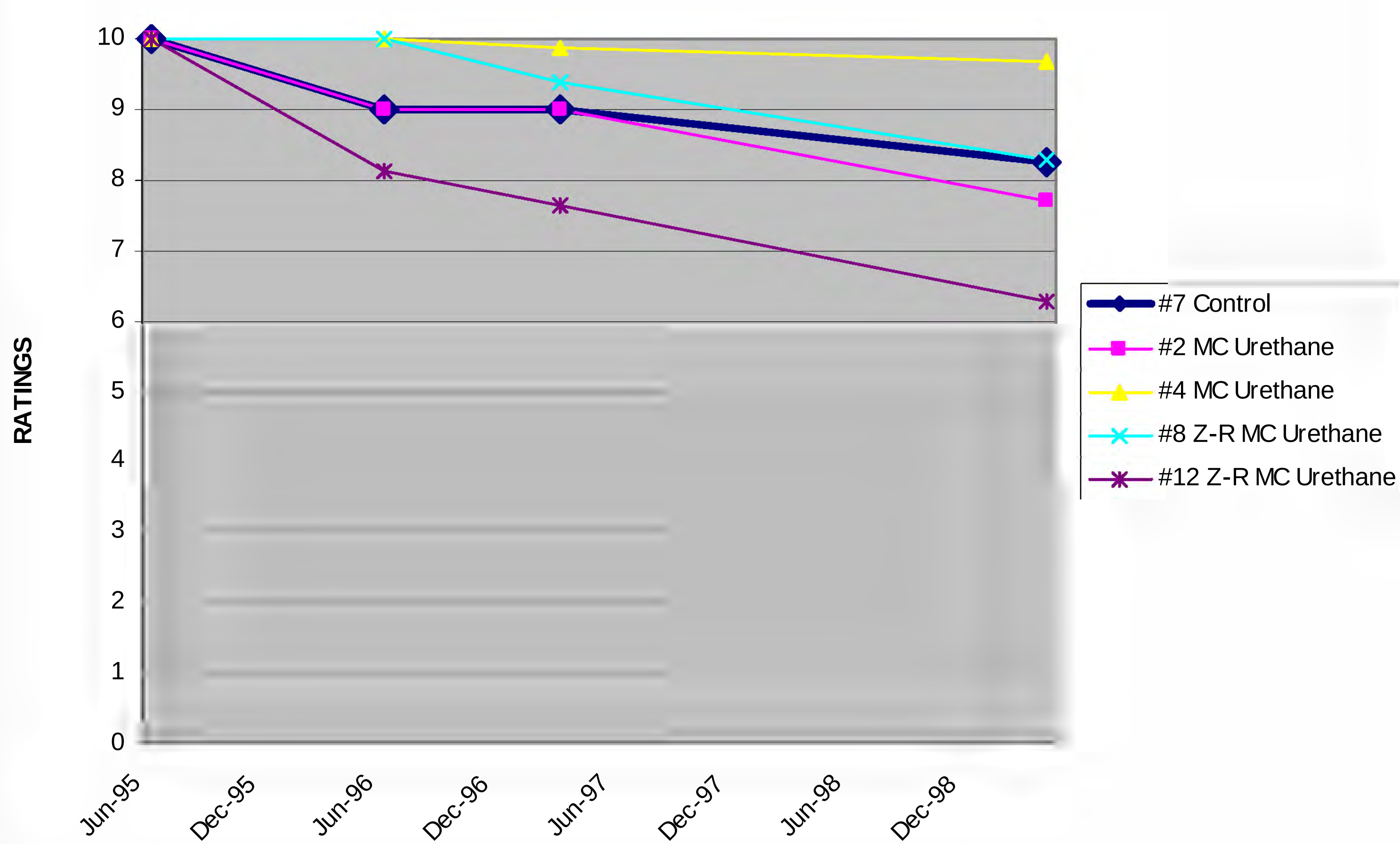

Figure 3. COMPARE PERIODIC PANEL AVERAGES (FR/BK) of ALKYDS & CALCIUM SULFONATE to PANEL AVERAGES of CONTROL

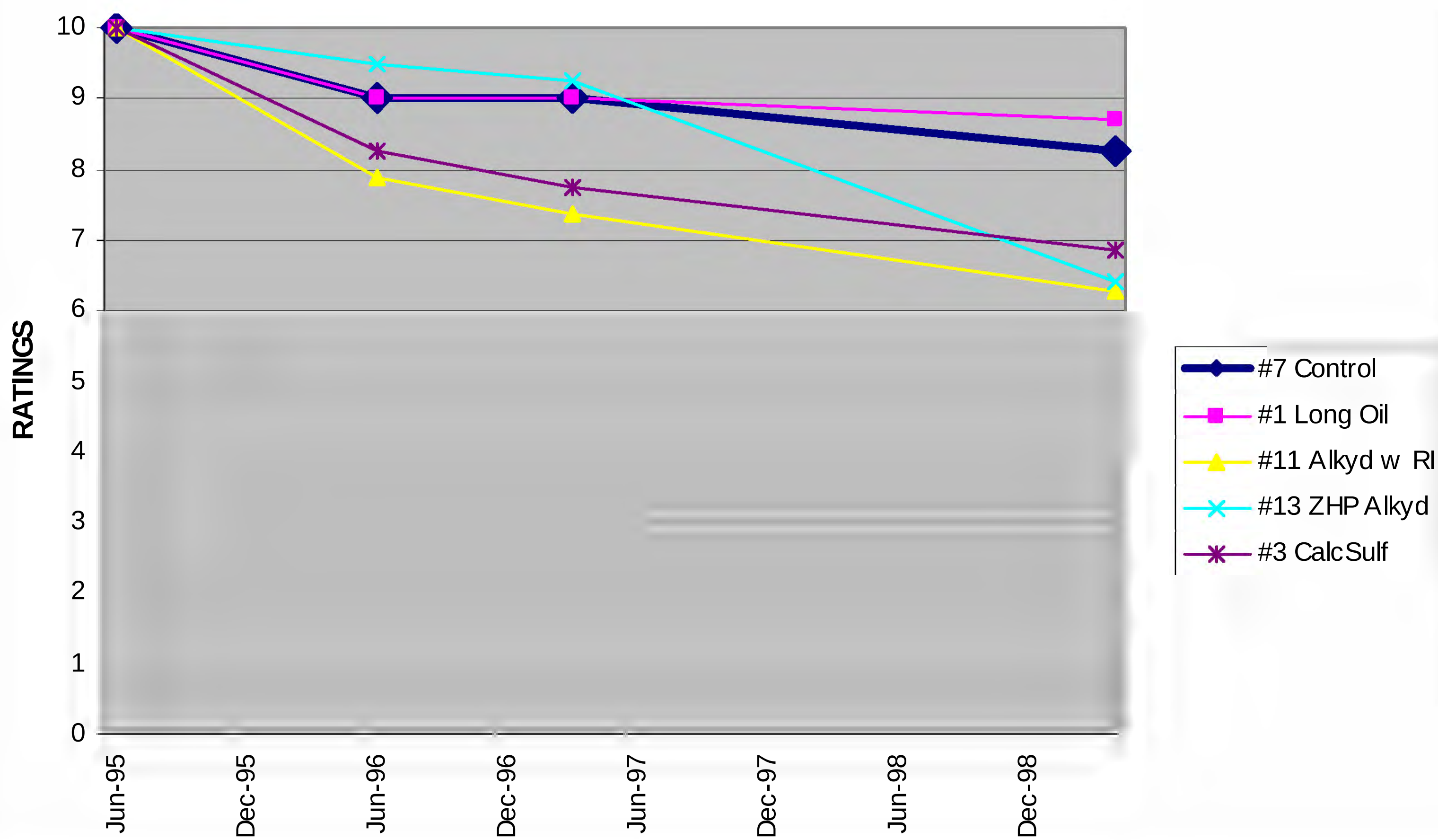

Figure 4. COMPARE PERIODIC PANEL AVERAGES (FR/BK) of EPOXIES to PANEL AVERAGES OF CONTROL

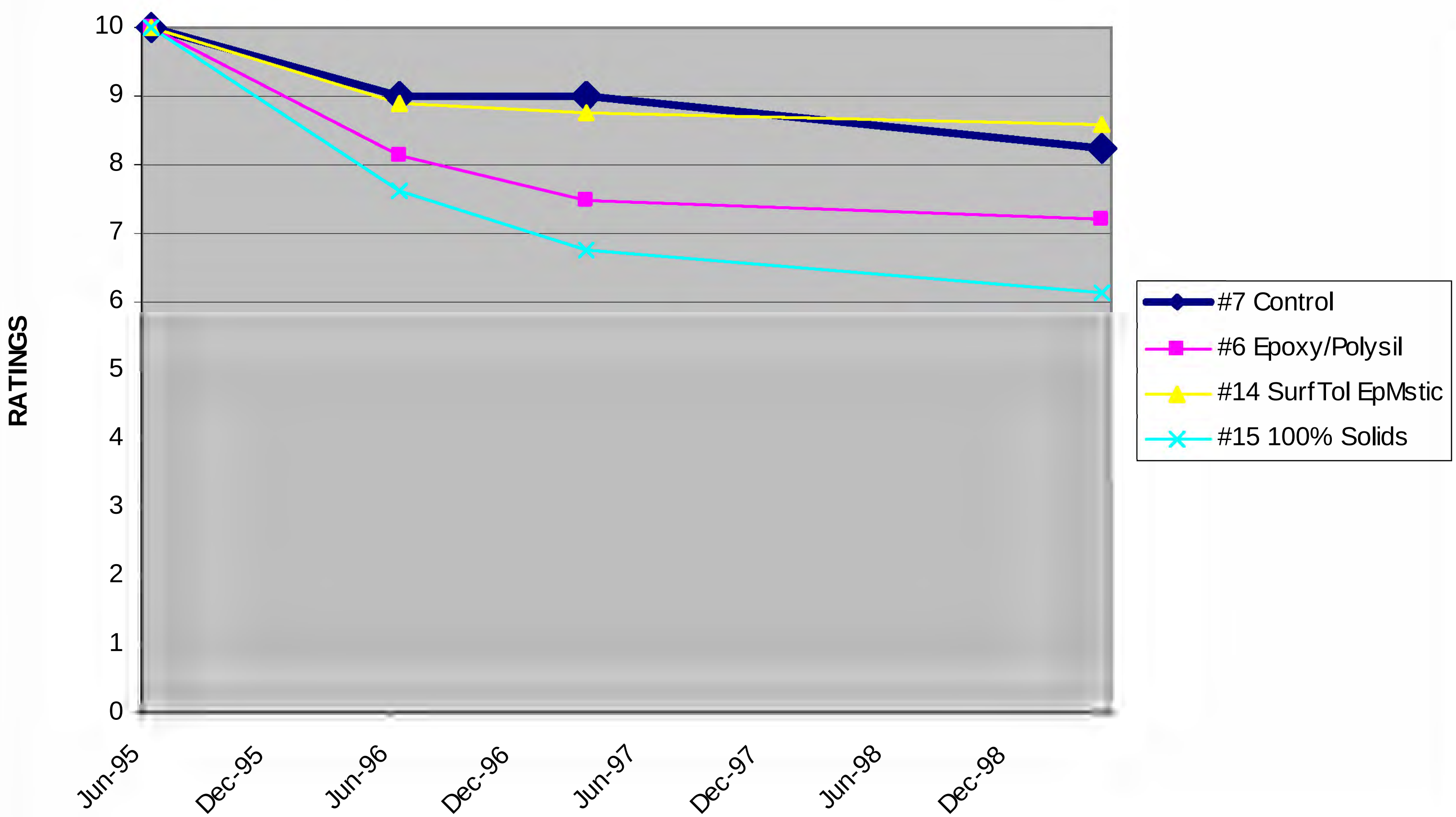

Figure 5. COMPARE PERIODIC PANEL AVERAGES (FR/BK) of ACRYLICS to PANEL AVERAGES of CONTROL

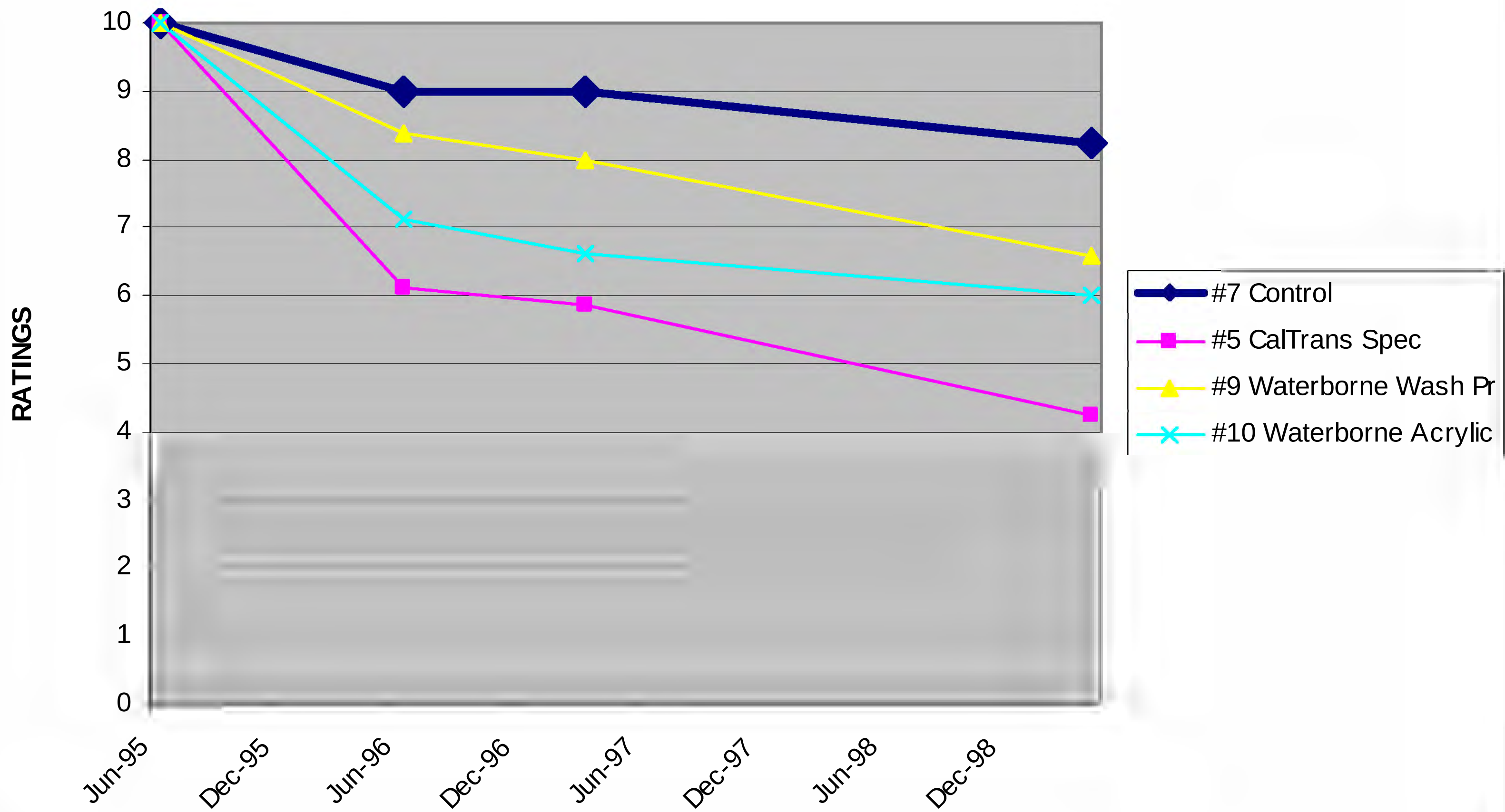

Figure 6. PERIODIC AVERAGES ALL PANELS (Fr/Bk) COMPARED TO CONTROL