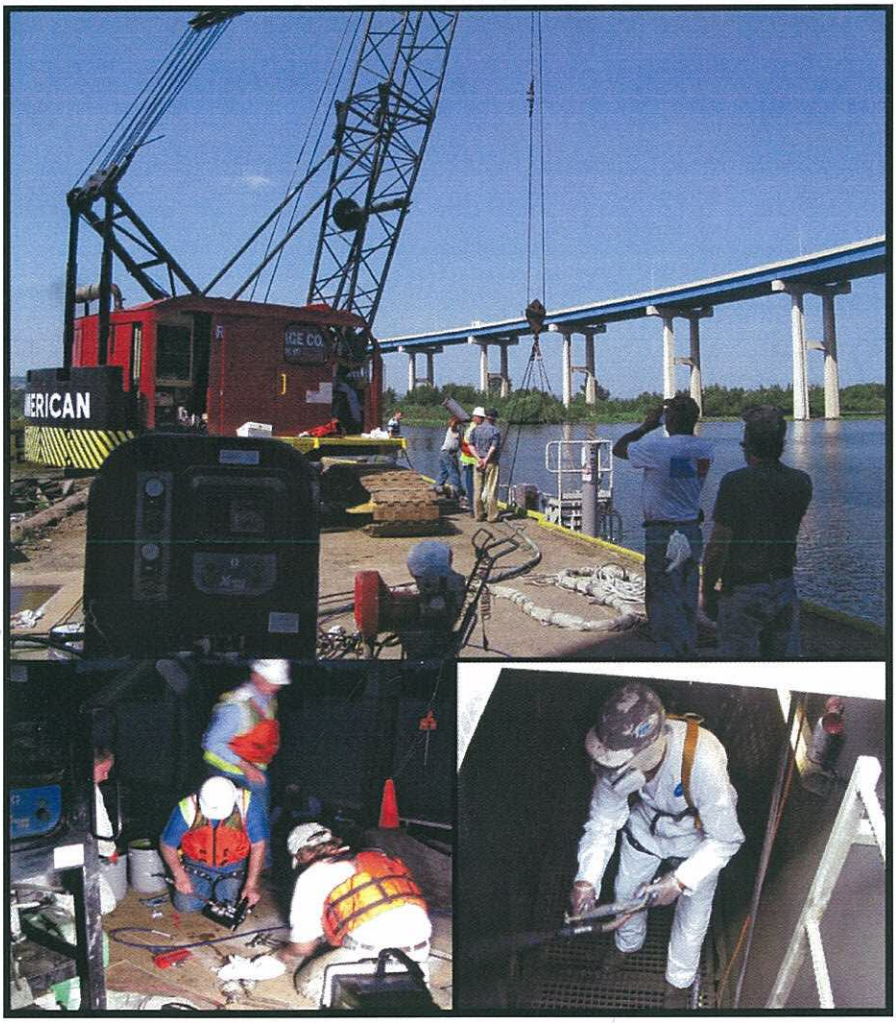
Cofferdam Applied Coating Trial

Prepared for the City of Superior, Wisconsin



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Cofferdam Applied Coating Trial
AMI Project 081127

Prepared for the City of Superior, Wisconsin
October 20, 2009

Contents

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Trial Overview

In the natural harbor shared by Duluth, Minnesota and Superior, Wisconsin structural steel is being lost to corrosion at a rate much greater than what is experienced at other fresh water ports. Various chemical, biological, and electrolytic factors are being investigated to find the factor or factors that are contributing to this accelerated corrosion. The problem was first discovered in 1998, since then research has indicated that the increased corrosion started in the late 1970's. With the amount of steel lost in that time some structural members require immediate repairs or replacement to allow for the continued use of the structures. For much of the 13 miles of unprotected steel structures in the harbor, prompt action is needed to prevent to the corrosion from compromising the integrity of the structures.

Since most of the current working docks have structural sheet pilings that make up the dock walls a cofferdam applied coatings may protect the steel from corrosion. Cofferdams allow for the structural steel to be exposed, cleaned, repaired, and prepped by enclosing a section of the wall and allowing pumps to dewater that section. This technique provides a dry and well prepared surface for the application of the protective coating.

One of the difficulties experienced in the Duluth /Superior harbor is that the coatings are susceptible to damage from the thick ice that breaks up and moves around due to ship traffic or currents. The ice has the ability to exert massive amounts of force on small areas of the coating and this can cause areas of the coating to chip off or wear down and ultimately lead to the premature failure of the coating.

So far the data collected on how coatings hold up to these conditions has come from several full scale coating projects as well as studies in which coated pieces of steel were mounted at various locations in the harbor. These samples were generally prepared and coated in a shop allowing for excellent surface preparation and long cure times. This study was designed to monitor how different coatings hold up when applied in imperfect conditions and with short cure times, and also to see how a larger sample held up to the ice impact and abrasion. Eight commercially available coatings were selected to participate in the trial. Each coating was applied to an area approximately 8ft wide extending from 2 feet above the waterline to 10ft below, allowing two coatings to be applied during each cofferdam setup.

The site selected for the trial is on the North-East corner of the Cenex-Harvest States Dock in Superior, Wisconsin. The site was chosen because the sheet pile there was installed in the 1970's and has the type of severe pitting seen throughout the harbor, and there was no major structural damage that would hamper the trial. This area is also on a point that is exposed to ship traffic and ice movement, making it an ideal place to test the abrasion and impact resistance of the coatings.

Picture 1: The location of the coating trial at the end of the Cenex Harvest States dock.

Sheet Pile Repair and Preparation

Roen Salvage Company was contracted to supply the cofferdam, interlock sealing, and initial cleaning. The cofferdam supplied sealed quickly to the wall and allowed for rapid dewatering and use. Upon dewatering the cofferdam, water leaks were seen at most of the sheet pile interlocks. On interlocks with less severe leaks, hydraulic cement was used to stop the flow of water. In some of these locations the water could not be fully stopped and the hydraulic cement would remain damp to the touch and in a few areas water drips were still present.

Picture 2: Hydraulic cement sealing an interlock, some damp spots are visible.

On interlocks with active water flow after the application of hydraulic cement, thin steel bars or angle were welded over the interlocks. Water leaking through the

interlocks was channeled down the gap created by welded steel and discharged below the line where the coatings were applied. This left the surrounding wall dry and provided a surface at the interlocks that could be coated.

Picture 3: Angle iron used to seal an interlock.

The areas where the water could not be fully stopped may be susceptible to premature failure of the coating. These areas were marked on sketches of the wall surface and photographs were taken that covered all areas of the wall before a coating was applied. This documentation will allow us to determine if coating failures found in future inspections may have been due to imperfect application conditions.

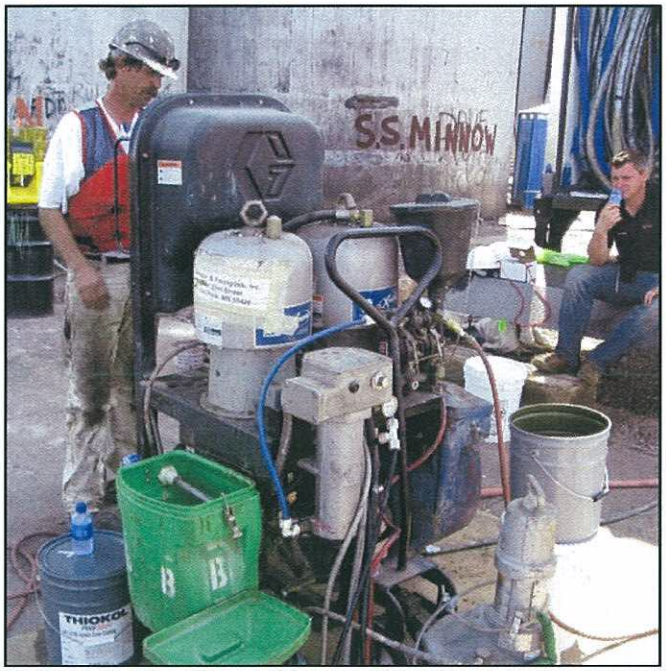
The final preparation for the sheet pile was performed by the coating contractor Swanson & Youngdale, and involved grit blasting surfaces to a SPEC. 10 - Near White Metal finish. Before coating Swanson & Youngdale measured the surface profile with Press-O-Film testers to insure a minimum blast profile of 3 mils, and a representative for each coating was given a chance to inspect the surface before the coating was applied.

Finally, atmospheric and surface conditions were measured to insure that the steel temperature was adequately above the dew point to allow for proper curing of the coatings. The air temperature, surface temperature, relative humidity, dew point, and general weather conditions were all recorded.

Application

Coatings were applied by Swanson and Youngdale. A variety of equipment was utilized for the applications, depending on the coating manufactures' recommendations. For single component coatings, or coatings that could be mixed and then applied a simple airless sprayer was used. Coatings that were supplied as two components and that could not be simply mixed before being sprayed were applied with either a Graco Xtreme Mix pump or from a truck mounted Graco Reactor pump. Ecologiq E-Shield was applied using a unique spray system developed specifically for the product.

The airless sprayer was the simplest system and took the least amount of time to set up and clean. The Graco Xtreme Mix pump experienced several problems with its mix valve and also took a considerable amount of time to start up after a new product was put into it. The Graco Reactor pump worked well during the trial but experienced one problem at the beginning of an application that lead to a lengthy clean up of the wall before the work could continue. The pump supplied by Ecologiq appeared to work without any problems. No preheating was required and the metering was mechanically built into the pump resulting in a simple system not susceptible to problems.



Picture 4: The Graco Xtreme Mix Pump being prepared for an application.

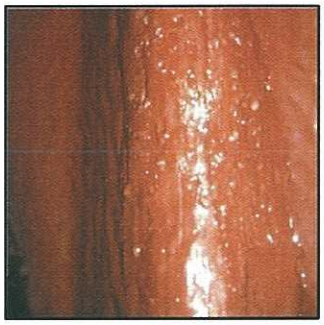
Products

Eight different commercially available coatings with apparent abrasion and impact resistance were applied during the trial. A brief description of each of the coatings properties and initial observations during the application follows.

Ceilcote Interzone 954

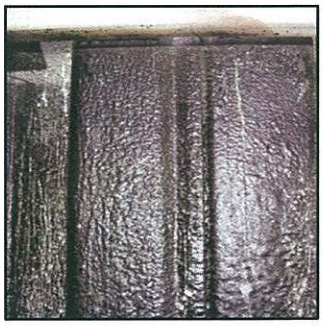
Interzone 954 is a high solid modified epoxy that is supplied in two parts. The parts were mixed 4 to 1 in a standard paint pail with a drill mounted mixer and then sprayed on using a standard airless spray system. Two passes were needed to get the recommended wet film thickness of 25 mils. The coating sprayed easily and there were no issues with the equipment during this application. The product set quickly and can be immersed in water in as little as 15 minutes after application.

AquaPure HR



AquaPure HR is a modified epoxy based coating. It was applied using the Graco Xtreme Mix rig. The coating sprayed nicely but a malfunction with the spray equipment led to considerable delays during the application. The coating was sprayed to an average dry film thickness of 24 mils in two passes. The application took 25 minutes and the coating was allowed to cure 4 hours before re-immersion.

Ecologiq E-shield



Ecologiq E-shield is an elastomeric membrane that is available with anti-fouling agents specifically designed to decrease the amount of zebra mussels that attach to the surface. This product is unique in that it is designed to remain very flexible. The two component coating was applied using a relatively simple arrangement of two piston pumps driven off of a single motor each with separate lines leading to a custom spray gun. This coating sprayed to 54 mils in 45 minutes and cured for 18 hours before re-immersion.

Biocoatings Marine Vinyl Coating

Biocoating supplied a marine vinyl coating for this test. This product is a solvent based, VOC free product. The application of this product went very well and it can be applied with either an air or airless sprayer. The product dried within seconds allowing for multiple passes in a short amount of time. Three passes were used to deliver a 9.1 mil average coating thickness in 30 minutes. A cure time of 15 hours before re-immersion was specified for this product.

Thiokol LPE 5100

Thiokol is a high solids high build type epoxy coating. It was sprayed on in one coat to an average dry film thickness of 46 mils. The Graco Xtreme Mix pump was used and the whole application took about 12 minutes. There were no equipment or other issues while applying this coating. The coating produced a hard dry surface within ten minutes and could be re-immersed within 15 minutes.

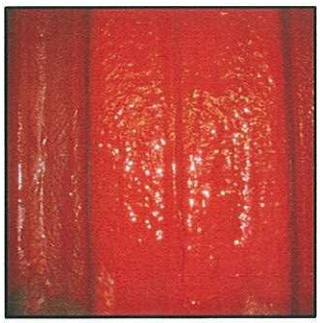
Acotec Humidur

Humidur is a solvent free modified epoxy based coating. It was applied using the Graco Xtreme Mix pump. Prior to being sprayed on some of the coating was mixed and applied manually over the interlocks and areas requiring extra protection. The material sprayed well but there was a malfunction of spray equipment during the application. The final dry film thickness of the test sample was 31 mils. The application of the Humidur took 30 minutes not counting the time for the sprayer malfunction. The coating was left to cure for one hour before re-immersion.

Sherwin Williams Envirolastic AR200HD

Envirolastic AR200HD Polyurea is a two part system designed for abrasion and tear resistance. The coating was applied with the Graco Reactor Pump. The coating sets up almost instantly, allowing the coating to reach an average dry film thickness of 140 mils in three passes of about 30 to 40 mils. The application of this coating took 45 minutes and the product can be re-immersed in 1-2 hours.

Versaflex FSS50DM



This coating is very similar to the Envirolastic AR200HD from Sherwin Williams, although the bright orange color of the Versaflex product made the application in the limited light environment of the cofferdam easier. The color also allowed the applicator to easily identify pinholes and holidays. The application went well other than a delay caused by an equipment malfunction resulting in only one of the two components being applied at the beginning of the application. The component needed to be cleared off the wall before the application could resume to prevent the coating from blistering.

Product Summary Table

Product Information	Description	Application Time	Average Dry Film Thickness	Re-Immersion Time
Ceilcote Interzone 954	Flake Filled Epoxy	30 min.	25 mils	30 min
Marine Coatings LLC Aquapure HR	Modified Epoxy	25 min.	24 mils	2 hours
Ecologiq	Elastomeric Polymer with anti-fouling	45 min.	54 mils	17 hours
Biocoatings Marine Vinyl Coating	Marine Vinyl Coating	30 min.	9.1 mils	15 hours
Thikol LPE 5100	High build epoxy	12 min.	46 mils	1 hour
Acotec Humidur	Polyamine cured epoxy	30 min.	31 mils	1 hour
Sherwin Williams AR200HD	High build polyurea epoxy	45 min.	140 mils	1-2hr
Versaflex FSS50DM	High build polyurea epoxy	40 min.	140 mils	2-3hr

Conclusion

All of the coatings were successfully applied during the trial. Most of the difficulties encountered during the trial were due to issues with sealing the interlocks on the sheet pile and breakdowns of the application equipment.

Most of the issues with the equipment were due to the cleanings and set up required for each new product. Fewer problems are generally experienced on a full scale project when the equipment is set up for just one product.

The difficulties with sealing the interlocks at the test site were not solved during this trial. Several products and techniques were utilized but different measures with faster installation times may be required for a full scale application of coating.

AMI's Engineer dive team will inspect the test areas in the spring of 2010 to look for damage caused by the ice movements in the harbor and determine each coatings overall condition. Coating thickness measurements will be taken to determine if any considerable loss of coating has taken place. The information gathered during the application will allow us to determine if any coating failures observed are due to poor adhesion to the surface or problems sealing the interlocks.

This and future inspections will show which of the coating technologies withstand the harbor ice conditions. These observations in conjunction with other considerations such as cost, ease of application, cure times, ect. will allow the determination of which coatings are more suitable candidates for future full scale cofferdam-applied systems.

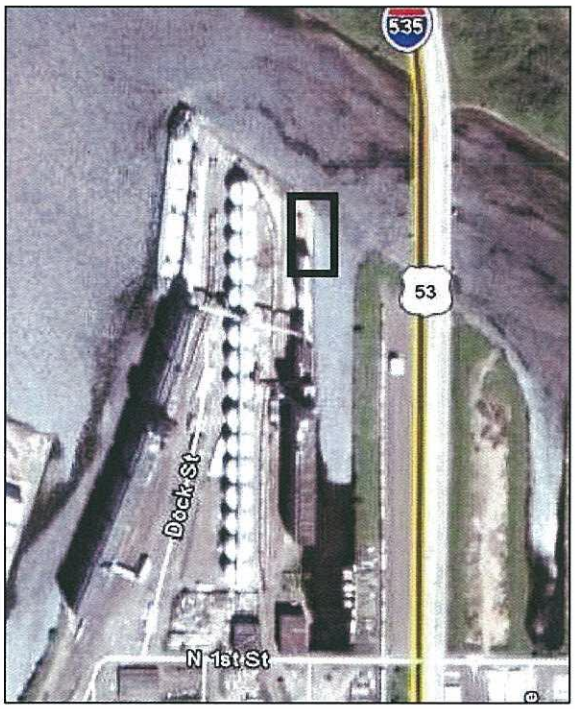
Respectfully Submitted,

Adam Marksteiner, EIT
Mechanical Engineer

Reviewed By,

Chad W. Scott, P.E.
Principal

APPENDIX A Drawings



CENEX HARVEST STATES DOCK
SUPERIOR, WISCONSIN

BOLLARDS

1
2 SECTION A
BIOCOATINGS – MARINE VINYL COATING
3
4 SECTION B
ECOLOGIQ – E-SHIELD
5
COFFERDAM SETUP 2

6
7 SECTION C
CEILCOTE – ENERZONE 954
8
9 SECTION D
AQUAPURE
10
COFFERDAM SETUP 1

11
12 THIS SECTION SKIPPED DUE TO MISALIGNED PILINGS
13
14
15 SECTION E
SHERWIN WILLIAMS – ENVIROLASTIC AR200HD
16
COFFERDAM SETUP 4

17
18 SECTION F
VERSAFLEX
19
20 SECTION G
THIOKOL – LPE-5100
21
COFFERDAM SETUP 3

22
23 SECTION H
ACOTEC – HUMIDUR
24

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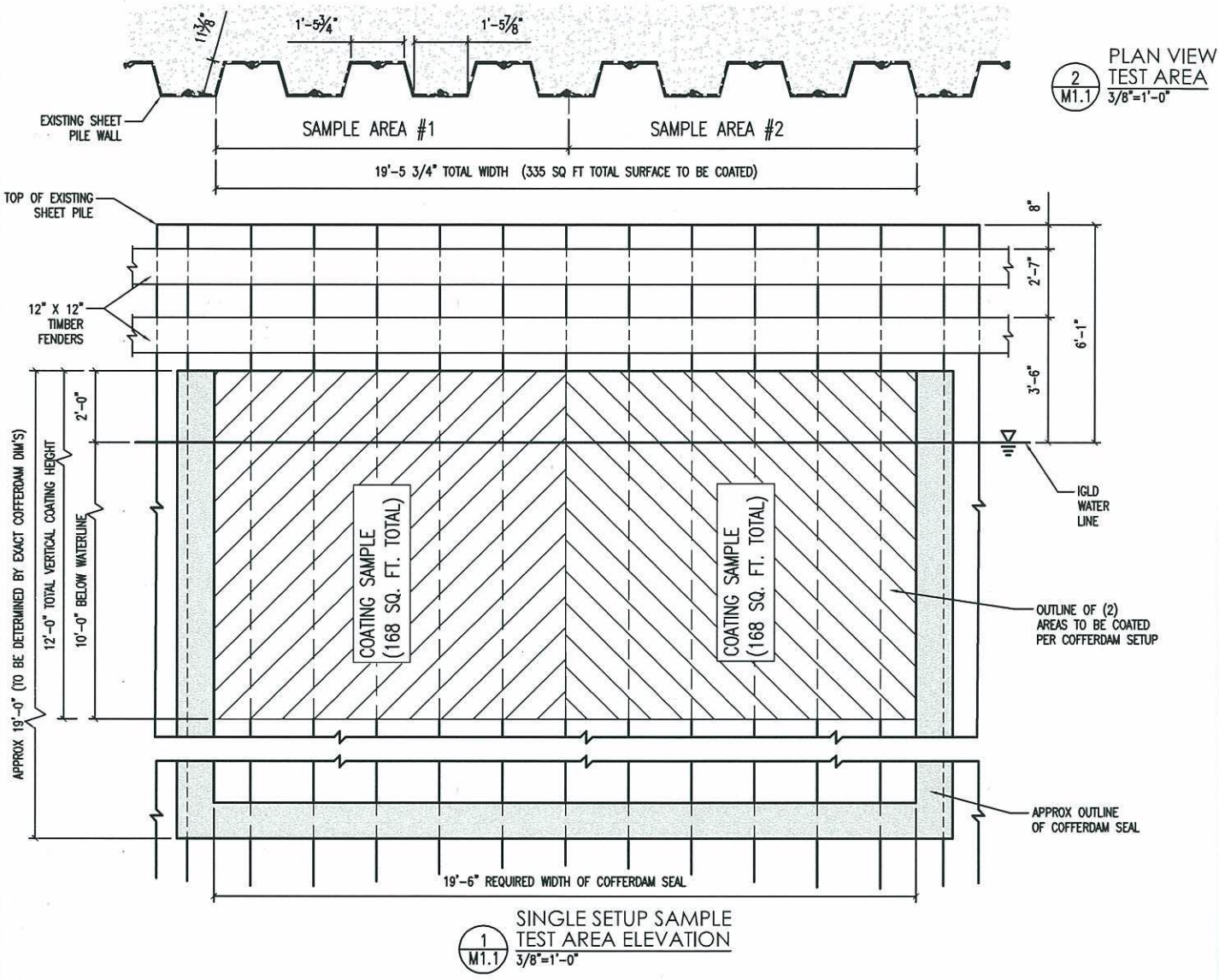
COFFERDAM APPLIED COATING TRIAL
CENEX HARVEST STATES DOCK

APPLICATION MAP

JOB No: 081127
DATE: 10/20/2009
DRAWN BY: ADM

SHEET: S1.0



2 / M1.1 PLAN VIEW TEST AREA 3/8"=1'-0"

1 / M1.1 SINGLE SETUP SAMPLE TEST AREA ELEVATION 3/8"=1'-0"

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COFFERDAM APPLIED
COATING TRIAL
CENEX HARVEST STATES DOCK

TYPICAL INSTALLATION
ELEVATION VIEW

JOB No: 081127
DATE: 10/20/2009
DRAWN BY: ADM

SHEET: S1.1

APPENDIX B Application Notes

Coating: Biocoatings - Marine Vinyl Coating
Date: 8/12/2009
Position: A
Application Equipment: Airless Sprayer (this was the first time they used an airless sprayer with this product, normally had been using a air compressor/HVLP setup)

	Start	Finish
Time:	5:15 PM	5:45 PM
Air Temp. :	75	80
Humidity:	56%	57%
Dew Point:	58	54

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	80

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several. See photos.

Application Notes:	Applied in multiple passes 2/3 mils per pass. Dries in seconds, too fast to get a wet film thickness. Applicator found it very easy to put on.

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	7.2	6.8	7.1	11.1	7.8	8.00
Top	8.3	8.8	10.2	6.7	11.8	9.16
Middle	8.3	18	12.3	9	13	12.12
Middle	10.3	13.1	7.4	6.4	8.5	9.14
Bottom	13	17	9.3	7	10	11.26
Bottom	14	7	9.8	5.5	6.7	8.60

Mean	9.71
Std. Dev.	3.14

Max	18.00
Min	5.50

Coating: Ecologiq - E-Shield
Date: 8/10/2009
Position: B
Application Equipment: Product specific pump

	Start	Finish
Time:	7:45 PM	8:00 PM
Air Temp. :	75	80
Humidity:	56%	57%
Dew Point:	58	54

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	80

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several. See photos.

Application Notes:	Average WFT - 7-9 mils.

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	65	42	71	34	38	50.00
Top	78	71	43	32	49	54.60
Middle	40	76	55	41	29	48.20
Middle	34	32	48	62	67	48.60
Bottom	78	59	74	33	47	58.20
Bottom	64	75	54	76	68	67.40

Mean	54.50
Std. Dev.	16.65

Max	78.00
Min	29.00

Coating: Ceilcote - Enerzone 954
Date: 8/10/2009
Position: C
Application Equipment: Airless Sprayer

	Start	Finish
Time:	7:45pm	8:00pm
Air Temp. :	75	78
Humidity:	83%	56%
Dew Point:	70	54

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	75

Surface Profile:	3 mils

Surface Condition Notes:	Some damp spots. See photos.

Application Notes:	Average WFT - 10-15 mils. Applied in 2 coats.

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	23	34	28	34	36	31.00
Top	31	27	20	22	18	23.60
Middle	36	21	32	28	21	27.60
Bottom	17	26	22	30	24	23.80
Bottom	21	23	31	22	19	23.20

Mean	25.84
Std. Dev.	5.82

Max	36.00
Min	17.00

Coating: Aquapure
Date: 8/11/2009
Position: D
Application Equipment: Grayco X-treme Mix Pump Sprayer

	Start	Finish
Time:	10:30 AM	1:00 PM
Air Temp. :	78	75
Humidity:	60%	81%
Dew Point:	63	65

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	80

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several spots. See photos.

Application Notes:	Average WFT - 10-15 mils. Applied in 2 coats. Sprayer broke down for a few hours in the middle of application

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	19	28	22	31	23	24.60
Top	24	32	26	28	21	26.20
Middle	27	23	38	21	29	27.60
Middle	15	24	31	27	37	26.80
Bottom	18	21	24	31	24	23.60
Bottom						

Mean	25.76
Std. Dev.	5.60

Max	38.00
Min	15.00

Coating: Sherwin Williams Envirolastic AR200HD
Date: 8/14/2009
Position: E
Application Equipment: Grayco Reactor Pump

	Start	Finish
Time:	2:00 PM	2:45 PM
Air Temp. :	75	75
Humidity:	81%	81%
Dew Point:	65	65

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	73	78

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Hydraulic cement is a bit crumbly in several. See photos.

Application Notes:	Average WFT - 30 mils

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top						
Top	Measurements taken during application result in DFT of 130-150 mils.					
Top						
Top						

Mean	
Std. Dev.	

Max	
Min	

Coating: Versaflex
Date: 8/14/2009
Position: F
Application Equipment: Grayco Reactor Pump

	Start	Finish
Time:	5:00 PM	5:45 PM
Air Temp. :	75	75
Humidity:	81%	81%
Dew Point:	65	65

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	73	75

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several. See photos.

Application Notes:	Average WFT - 30-40 mils per pass

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top						
Top	Measurements taken during application result in DFT of 130-150 mils.					
Middle						
Middle						
Bottom						
Bottom						

Mean	
Std. Dev.	

Max	
Min	

Coating: Thiokol LPE-5100
Date: 8/13/2009
Position: G
Application Equipment: Grayco X-treme Mix Pump

	Start	Finish
Time:	6:53pm	7:05pm
Air Temp. :	78	78
Humidity:	72%	72%
Dew Point:	69	69

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	75

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several. See photos.

Application Notes:	Average WFT - 45-60 mils

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	41	46	37	33	36	38.60
Top	58	43	60	39	44	48.80
Top	48	55	67	31	44	49.00
Top	51	62	39	47	53	50.40

Mean	46.70
Std. Dev.	10.01

Max	67.00
Min	31.00

Coating: Acotec Humidur
Date: 8/13/2009
Position: H
Application Equipment: Grayco X-treme Mix Pump

	Start	Finish
Time:	7:17pm	9:21pm
Air Temp. :	78	
Humidity:	72%	
Dew Point:	69	

Weather Conditions
Clear and Sunny

	Top	Bottom
Steel Temp.	75	75

Surface Profile:	3 mils

Surface Condition Notes:	Interlocks still damp in several spots. Wet to touch and a bit crumbly in several. See photos.

Application Notes:	Average WFT - 30 mils

Dry Film Thickness Measurements

Area	Spot Reading					Average
	1	2	3	4	5	
Top	24	28	38	40	34	32.80
Top	33	34	21	24	23	27.00
Top	32	25	27	33	38	31.00
Top	41	40	25	27	21	30.80

Mean	30.40
Std. Dev.	6.71

Max	41.00
Min	21.00