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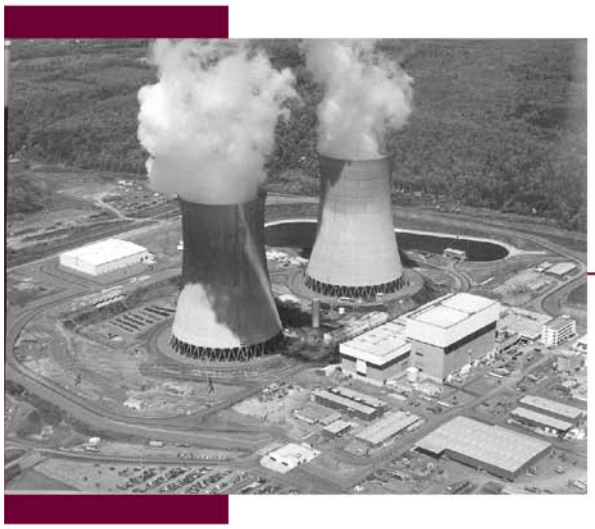
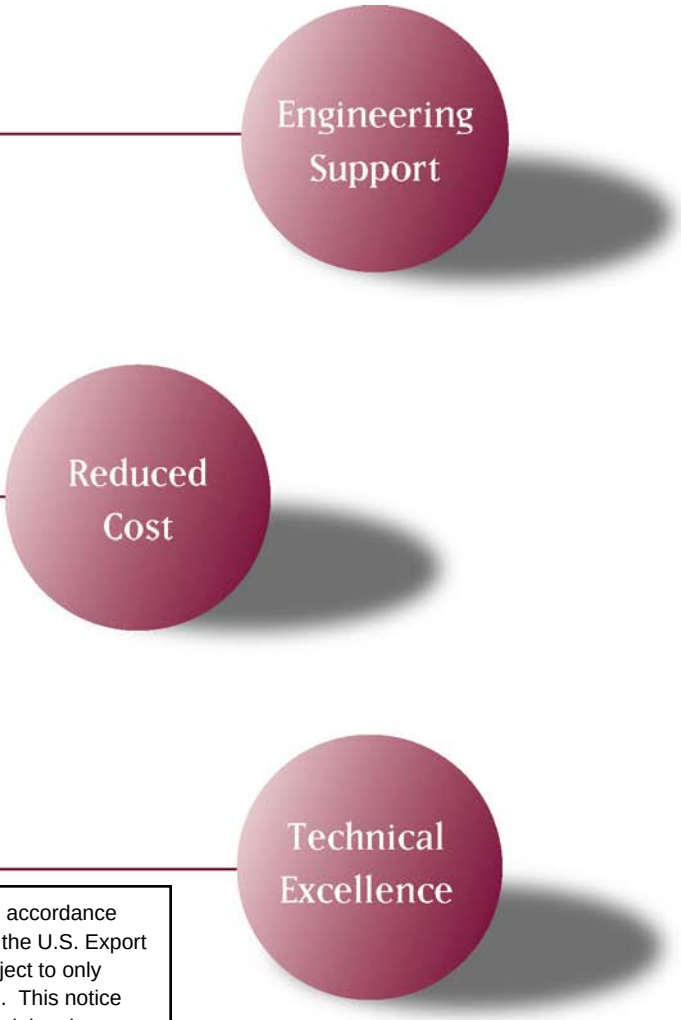
Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings





Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings

1014883

Final Report, August 2007

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PRODUCT DESCRIPTION

The nuclear industry has experienced instances of degradation of the protective coating systems applied inside reactor containment (nuclear Coating Service Level 1 coatings). These areas have become a concern to the industry, but the industry does not have a thoroughly documented history of the degradation or its causes. In response, the Electric Power Research Institute (EPRI) is conducting research to gain an understanding of the coating degradation and to evaluate the effects of aging on the qualified coatings used inside containment. This report is one product of that research.

Results and Findings

EPRI and the Nuclear Utilities Coating Council (NUCC) initiated a program in 2005 to evaluate coating failures and the potential influence of aging. Task 3 of the EPRI/NUCC program collected coating adhesion data for coating systems to provide a baseline correlation to original qualification and to provide confirmatory support for ASTM coating inspection methods that rely upon visual inspection as an initial step.

Coating adhesion test data were collected at four sites:

- San Onofre Nuclear Generation Station (SONGS) Unit 3
- Waterford Unit 3
- McGuire Unit 1
- Oconee Unit 2

Review of the adhesion test data confirms that aged, visually intact, design-basis-accident-(DBA-) qualified coatings (from various manufacturers) that exhibit no visual anomalies (that is, no flaking, peeling, chipping, blistering, etc.) continue to exhibit system pull-off adhesion at or in excess of the originally specified (ANSI N5.12 and ASTM D5144) minimum value of 200 psi.

Challenges and Objectives

In a letter dated January 16, 2006, the U.S. Nuclear Regulatory Commission (USNRC) staff expressed concerns regarding the adequacy of the current industry method for assessment of qualified coatings within containment. In this letter, the staff presented potential resolution paths for the treatment of qualified coatings in relation to Generic Safety Issue 191, Assessment of Debris Accumulation on PWR Sump Pump Performance, the most severe was: “Assume all coatings inside of containment (qualified and unqualified) fail under LOCA (loss of coolant accident) conditions and become available for transport to the sump.” The objective of this EPRI project was to collect coating adhesion data for coating systems applied in the containments of

operating U.S. nuclear power plants to provide confirmatory support for ASTM coating inspection methods that rely upon visual inspection as an initial step.

Applications, Value, and Use

This report will be of value to nuclear power plant engineering personnel with responsibility for the inspection and maintenance of the coatings inside the containment building of nuclear power plants. The report will also be of value to nuclear power plant engineering personnel with responsibility for the resolution of Generic Safety Issue 191.

EPRI Perspective

In all instances, aged DBA-qualified/acceptable coatings with no visual anomalies (from various manufacturers) tested at the four volunteer plants exhibited system pull-off adhesion at or in excess of the originally specified (ANSI N5.12-1972) minimum value of 200 psi when tested using an Elcometer pull-off adhesion tester.

Based on this testing, it is concluded that the containment coatings monitoring approach contained in ASTM D5163, as implemented by licensees, and endorsed by USNRC in RG 1.54 Rev.1 and NUREG 1801 Volume 2, Appendix XI.S8, is valid.

Approach

EPRI Plant Support Engineering (PSE) was approached by utility representatives of the NUCC for assistance in documenting the magnitude and nature of degradation seen for qualified coatings within containment. A task group composed of utility coating engineers, consultants, contractors, and EPRI staff collaborated in developing the Evaluation of Coating Failures and the Potential Influence of Aging Project (also known as the Coating Aging Project).

The project was designed with the following phases:

Task 1: Coatings Degradation Utility Survey

Task 2: Coatings Degradation Research

Task 3: Containment Coatings Adhesion Testing

Task 4: Coatings Aging Research

Task 5: Long-Term Performance Integrity of Inorganic Coatings

Task 6: Overall Summary

This report documents Task 3, the Containment Coatings Adhesion Testing.

Keywords

Adhesion
Coatings
Design basis accident (DBA)
Emergency core cooling system (ECCS)
Pressurized water reactor (PWR)

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Testing Team:

Jon Cavallo	Corrosion Control Consultants and Labs, Inc.
Daniel Cox	Southern California Edison
Garth Dolderer	Florida Power & Light

Volunteer Plants:

SONGS Unit 3	Southern California Edison
Waterford Unit 3	Entergy
McGuire Unit 1	Duke Energy Carolinas
Oconee Unit 2	Duke Energy Carolinas

NUCC:

Daniel Cox, *Utility Chair*	Southern California Edison
Kenneth S. Isley III, *Utility Co-Chair*	Duke Energy Carolinas

Dedication

This report is dedicated to Kenneth Saunders Isley III, 53, of Charlotte, North Carolina, who passed away May 10, 2007. Ken was born July 25, 1953, in Wake County, to Anne Johnston Isley and the late Kenneth S. Isley Jr. He graduated from NC State University in 1975 and worked as a Senior Engineer for Duke Energy for over 32 years.

Ken served as the NUCC Co-Chair of the Evaluation of Coating Failures and the Potential Influence of Aging Project. He was our friend, associate, and fellow engineer. We will miss him.

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1
INTRODUCTION

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that Coating Service Level I protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System After a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," as well as anticipated responses to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," reinforce this periodic inspection requirement. Licensees typically follow ASTM D5163, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coatings in an Operating Nuclear Power Plant, as a guideline to conduct containment coatings condition assessment activities. ASTM D5163 has been endorsed by the U.S. Nuclear Regulatory Commission (USNRC) in Regulatory Guide (RG) 1.54 Rev.1 and NUREG 1801 (the GALL Report).

The Electric Power Research Institute (EPRI) and the Nuclear Utilities Coating Council (NUCC) are conducting a project entitled, "Evaluation of Coating Failures and the Potential Influence of Aging." Task 3 of the project involves adhesion testing of visually intact, design-basis-accident-(DBA-) qualified (acceptable, in the case of Oconee Unit 2) coatings on concrete and steel containment substrates at four operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement: "that containment coatings exhibit 200 lbs minimum adhesion when measured using an Elcometer adhesion tester" (see ANSI N5.12-1972, Section 6.4).[1]

[1] The Elcometer Model 106 Adhesion Tester used in the testing reported herein and available up to 40 years ago reads out in "pounds per square inch" rather than "pounds." The reference to adhesion in units of "pounds" in Section 6.4 of ANSI N5.12-1972 is erroneous; the units of adhesion should have been stated as "pounds per square inch" as measured by the Elcometer adhesion tester.

2
DEFINITIONS AND KEY CONCEPTS

2.1 Definitions

acceptable coating system – A safety-related coating system for which a suitability-for-application review that meets the plant licensing basis has been completed and for which there is reasonable assurance that, when properly applied and maintained, the coating will not detach under normal or accident conditions.

Coating Service Level I – A term used to describe areas inside the reactor containment where coating failure could adversely affect the operation of post-accident fluid systems and, thereby, prevent safe shutdown (from ASTM D5144-00).

DBA qualified coating system – A coating system used inside the reactor containment that can be attested to having passed the required laboratory testing, including irradiation and simulated design basis accident (DBA), and has adequate quality documentation to support its use as DBA qualified (from ASTM D5144-00). Most plants use RG 1.54, Rev. 0 or ANSI N101.2 as their licensing basis for coatings inside containment.

2.2 Key Concepts

coating selection – ANSI N5.9-1967 (later superseded by ANSI N5.12-1974) provided a standard by which coating systems for nuclear power facilities could be compared and selected using reproducible tests. Adhesion testing, which measures adhesion of the primer coat to the substrate, inter-coat adhesion, and cohesion within each coat, was one of those physical tests. Adhesion testing per ANSI N5.12-1974 provided an acceptance adhesion test value of “200 lbs” minimum measured using an Elcometer pull-off adhesion tester.

evaluating adhesion by knife – ASTM D6677-01 - Standard Test Method for Evaluating Adhesion by Knife. This ASTM standard provides a procedure for performing an X-cut in the coating and using a knife tip to pry up the coating from the intersection point. The amount of coating that is removed is used to rate adhesion.

pull-off adhesion testing – The pull-off adhesion test method is defined by ASTM D4541-02 – “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.” This ASTM standard provides a procedure for determining the pull-off strength (adhesion) of a coating applied to a rigid substrate. The test device measures the force applied perpendicular to the substrate surface that a coating can bear without suffering adhesive failure, up to the capacity of the test device.

Elcometer Model 106 Pull-Off Adhesion Tester – The Elcometer Model 106 pull-off adhesion tester is a fixed-alignment portable tester comprised of a detachable aluminum loading fixture. The detachable loading fixture, called a *dolly,* has a flat base with diameter of 20 mm (~3/4 in.), which is adhered to the coated surface by the use of a high-strength adhesive. The detachable loading fixture is connected to the tester by a notched grip. Load is applied to the aluminum fixture by rotating a hand wheel on the tester.

3
NUCLEAR POWER AND ASSOCIATED COATING SYSTEMS

Four pressurized water reactor (PWR) nuclear power plants volunteered to be involved in the containment coatings adhesion testing task. At each plant, the coatings representative conducted a review of the plant coating documentation to identify DBA-qualified/acceptable coating systems on steel and concrete substrates by coating manufacturer's name, product names, and product numbers. Two types of test areas were identified: 1) visually intact coatings, and 2) visually intact coatings adjacent to degraded or previously repaired coatings. The volunteer plants and associated DBA-qualified/acceptable coating systems are listed here:

- San Onofre Nuclear Generation Station (SONGS) Unit 3 (coating work performed circa 1980–1983)
  - Steel substrate coating system – Two coats of Mobil 78-W-3
  - Concrete substrate coating system – Mobil 46-X-29 surfacer with Mobil 84-W-9 topcoat on floors and equipment pads; Mobil 84-V-2 thin film sealer on walls
- Waterford Unit 3 (coating work performed circa 1982–1984)
  - Steel substrate coating system – Carboline Carbo Zinc 11 primer with Carboline Phenoline 305 topcoat on the containment liner; Ameron Dimetcote D-6 primer with Ameron Amercoat 90 topcoat on structural steel. Ameron Amerlock 400 NT used as a repair coating on the containment liner.
  - Concrete substrate coating system – Ameron 110AA surfacer with Ameron Amercoat 66 topcoat on floors and walls
- McGuire Unit 1 (coating work performed circa 1975–1976)
  - Steel substrate coating system – Mobil MobilZinc 7 primer, Mobil 89 (13-F-12) Hi Build Epoxy topcoat
  - Concrete substrate coating system – Mobil 46-X-29 surfacer with Mobil 76 Hi Solids Epoxy topcoat on floors; Mobil 46-X-29 surfacer with Mobil 89 (13-F-12) Hi Build Epoxy topcoat on walls
- 3.4 Oconee Unit 2 (coating work performed circa 1969)
  - Steel substrate coating system - Carboline Carbo Zinc 11 primer with Carboline Phenoline 305 topcoat
  - Concrete substrate coating system – Carboline 195 surfacer with Carboline Phenoline 305 topcoat on walls, Carboline 2011S surfacer with Carboline Phenoline 305 topcoat on floors

4
ADHESION TEST PROCEDURE

The steps of the adhesion test procedure are:

1. Perform a documentation review at each volunteer plant to identify areas of DBA-qualified/acceptable coatings on steel and concrete substrates.
2. Perform a general visual inspection of selected areas of DBA-qualified/acceptable coatings on steel and concrete substrates according to ASTM D5163-05a. Coated test areas include visually sound coatings and visually sound coatings adjacent to visually degraded coatings.
3. Document each selected test area (including photography).
4. At each test area, perform all of the following:
    a. Dry film thickness testing as stated in SSPC-PA 2, ASTM D4138-94 (re-approved 2000), and/or ASTM D6132-04 as appropriate
    b. Adhesion testing according to ASTM D4541-02
    c. Adhesion testing according to ASTM D6677-01

Adhesion Data Collection Procedure, Revision 2, dated December 11, 2006, is included in this report as Appendix A.

5
RESULTS OF TESTING

The containment coatings adhesion test data collected at the four volunteer plants are summarized in Tables 5-1, 5-2, 5-3, and 5-4. At each test area, three pull-off adhesion tests and three knife adhesion tests were performed, designated A, B, and C. Values for knife adhesion tests are shown in parentheses ( ) and are dimensionless. Each table references the respective figures where photographs of the testing areas are included.

Table 5-1
Adhesion Test Results on Visually Sound Coatings – Songs Unit 3

Test Area Type* (Test Area Number)	Coating System	Data Test A	Data Test B	Data Test C	Figure Number
Sound structural steel (1A, 1B, 1C)	78-W-3	>1000 psi (8)	700 psi (10)	>1000 psi (10)	5-1
Sound concrete wall (2A, 2B, 2C)	84-V-2	500 psi (10)	500 psi (10)	>1000 psi (10)	5-2
Degraded concrete wall	84-V-2	None identified			N/A
Degraded structural steel (3A, 3B, 3C)	78-W-3	300 (No knife cut)	300 (8)	250 (8)	5-3
Sound concrete floor (4A, 4B, 4C)	46-X-29/84-W-9	300 psi (10)	300 psi (10)	700 psi (10)	5-4
Degraded concrete floor	46-X-29/84-W-9	None identified			N/A
Sound steel liner (5A, 5B, 5C)	78-W-3	500 psi (10)	500 psi (10)	>1000 psi (10)	5-5
Degraded steel liner	78-W-3	None identified			N/A

***** A degraded Test Area Type refers to a sound coating adjacent to a visually degraded coating.

1 psi = 6.9 kPa

Table 5-2
Adhesion Test Results on Visually Sound Coatings – Waterford Unit 3

Test Area Type* (Test Area Number)	Coating System	Data Test A	Data Test B	Data Test C	Figure Number
Sound steel liner (1A, 1B, 1C)	CZ-11/305	290 psi (10)	330 psi (10)	310 psi (10)	5-6
Sound concrete wall (2A, 2B, 2C)	110AA/66	400 psi (10)	550 psi (8)	320 psi (8)	5-7
Degraded concrete wall	110AA/66	None identified			N/A
Sound concrete floor	110AA/66	Not tested. Same system as walls.			N/A
Degraded concrete floor	110AA/66	None identified			N/A
Sound structural steel (3A, 3B, 3C)	D-6/90	>1000 psi (8)	625 psi (6)	410 psi (4)	5-8
Degraded structural steel	D-6/90	None identified			N/A
Degraded steel liner (repair) (4A, 4B, 4C)	400NT	600 psi (10)	750 psi (10)	700 psi (10)	5-9
Degraded steel liner (5A, 5B, 5C)	CZ-11/305	300 psi (8)	200 psi (6)	200 psi (4)	5-10

***** A degraded Test Area Type refers to a sound coating adjacent to a visually degraded coating.

1 psi = 6.9 kPa

Table 5-3
Adhesion Test Results on Visually Sound Coatings – McGuire Unit 1

Test Area Type* (Test Area Number)	Coating System	Data Test A	Data Test B	Data Test C	Figure Number
Sound concrete floor (1A, 1B, 1C)	46-X-29/76	>1000 psi (10)	300 psi (10)	400 psi (8)	5-11
Degraded concrete floor (2A, 2B, 2C)	46-X-29/76	200 psi (6)	200 psi (6)	200 psi (6)	5-12
Sound concrete wall (3A, 3B, 3C)	46-X-29/89	500 psi (10)	200 psi (10)	300 psi (10)	5-13
Degraded concrete wall (4A, 4B, 4C)	46-X-29/89	400 psi (10)	400 psi (10)	400 psi (10)	5-14
Sound structural steel	MZ-7/89	Not tested, Same system as liner.			N/A
Degraded structural steel	MZ-7/89	None Identified			N/A
Sound steel liner (5A, 5B, 5C)	MZ-7/89	700 psi (10)	>1000 psi (10)	800 psi (10)	5-15
Degraded steel liner (6A, 6B, 6C)	MZ-7/89	600 psi (10)	700 psi (8)	500 psi (10)	5-16

***** A degraded Test Area Type refers to a sound coating adjacent to a visually degraded coating.

1 psi = 6.9 kPa

Table 5-4
Adhesion Test Results on Visually Sound Coatings – Oconee Unit 2

Test Area Type* (Test Area Number)	Coating System	Data Test A	Data Test B	Data Test C	Figure Number
Sound concrete wall (1A, 1B, 1C)	195/305	300 psi (6)	290 psi (6)	410 psi (6)	5-17
Degraded concrete wall (2A, 2B, 2C)	195/305	410 psi (8)	270 psi (6)	380 psi (6)	5-18
Sound concrete floor (3A, 3B, 3C)	2011S/305	200 psi (4)	320 psi (4)	250 psi (8)	5-19
Degraded concrete floor	2011S/305	**			N/A
Sound steel liner (4A, 4B, 4C)	CZ11/305	370 psi (10)	600 psi (10)	440 psi (10)	5-20
Degraded steel liner (5A, 5B, 5C)	CZ11/305	400 psi (10)	840 psi (10)	450 psi (10)	5-21
Sound structural steel	CZ11/305	Not tested, Same system as liner.			N/A
Degraded structural steel	CZ11/305	None identified			N/A

***** A degraded Test Area Type refers to a sound coating adjacent to a visually degraded coating.

****** Floors at all elevations exhibited mechanical impact damage only. No other coating failure types were observed; therefore, no adhesion testing of degraded concrete floor coating was performed.

1 psi = 6.9 kPa

Data sheets for containment coatings adhesion testing collected at the four volunteer plants are included in this report as Appendices B, C, D, and E.

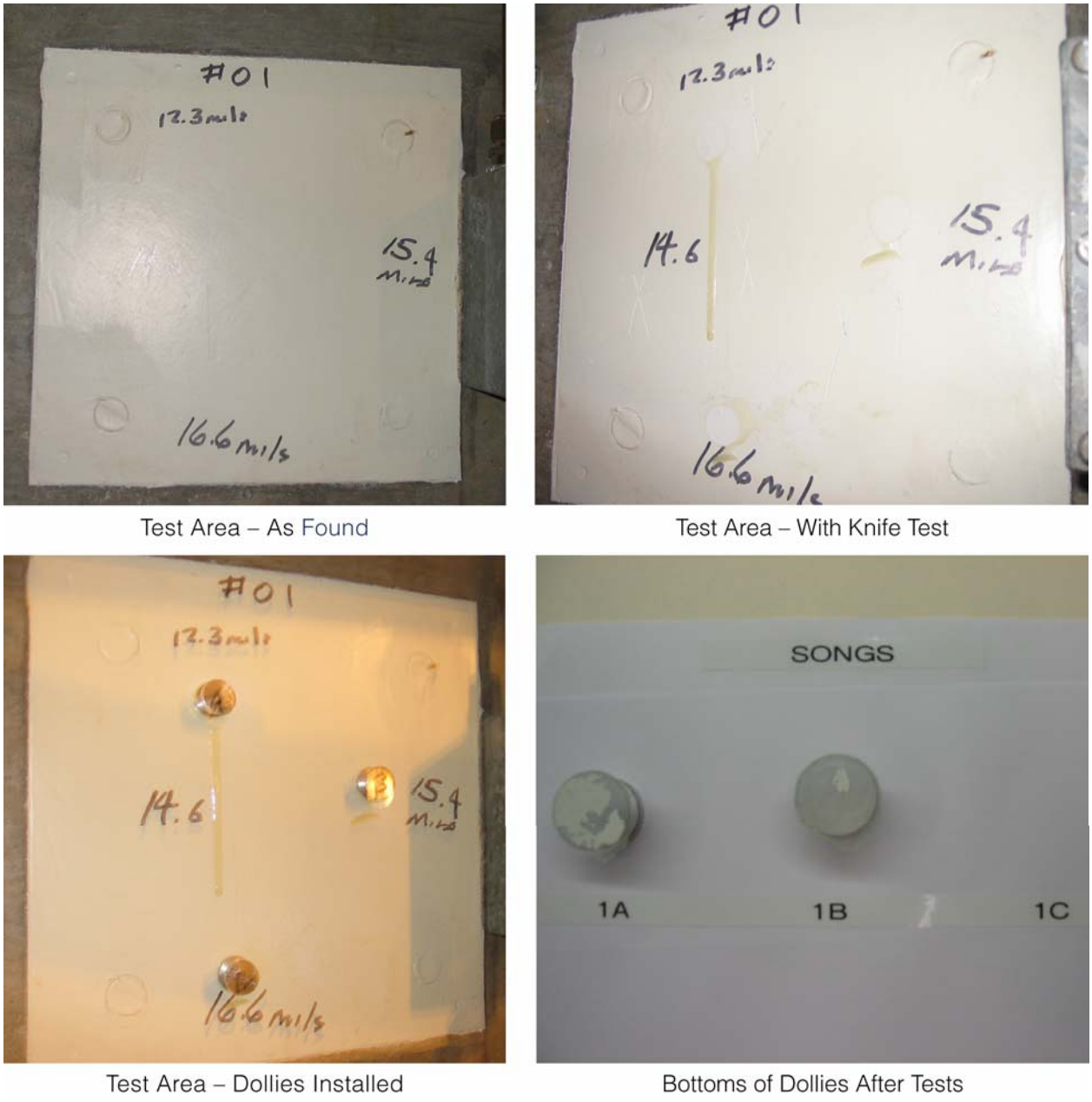


Figure 5-1
SONGs Adhesion Test Areas 1A, 1B, 1C – Sound Structural Steel

Note: Dolly 1C was accidentally dropped into an area from which it was not retrievable; consequently, the dolly was not available for the photo.

Test Area – As Found

Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-2
SONGs Adhesion Test Areas 2A, 2B, 2C – Sound Concrete Wall

Figure 5-3
SONGs Adhesion Test Areas 3A, 3B, 3C – Degraded Structural Steel

Test Area – As Found with Dollies Installed

Test Area – Dollies pulled With Knife Test

Bottoms of Dollies After Tests

Figure 5-4
SONGs Adhesion Test Areas 4A, 4B, 4C – Sound Concrete Floor

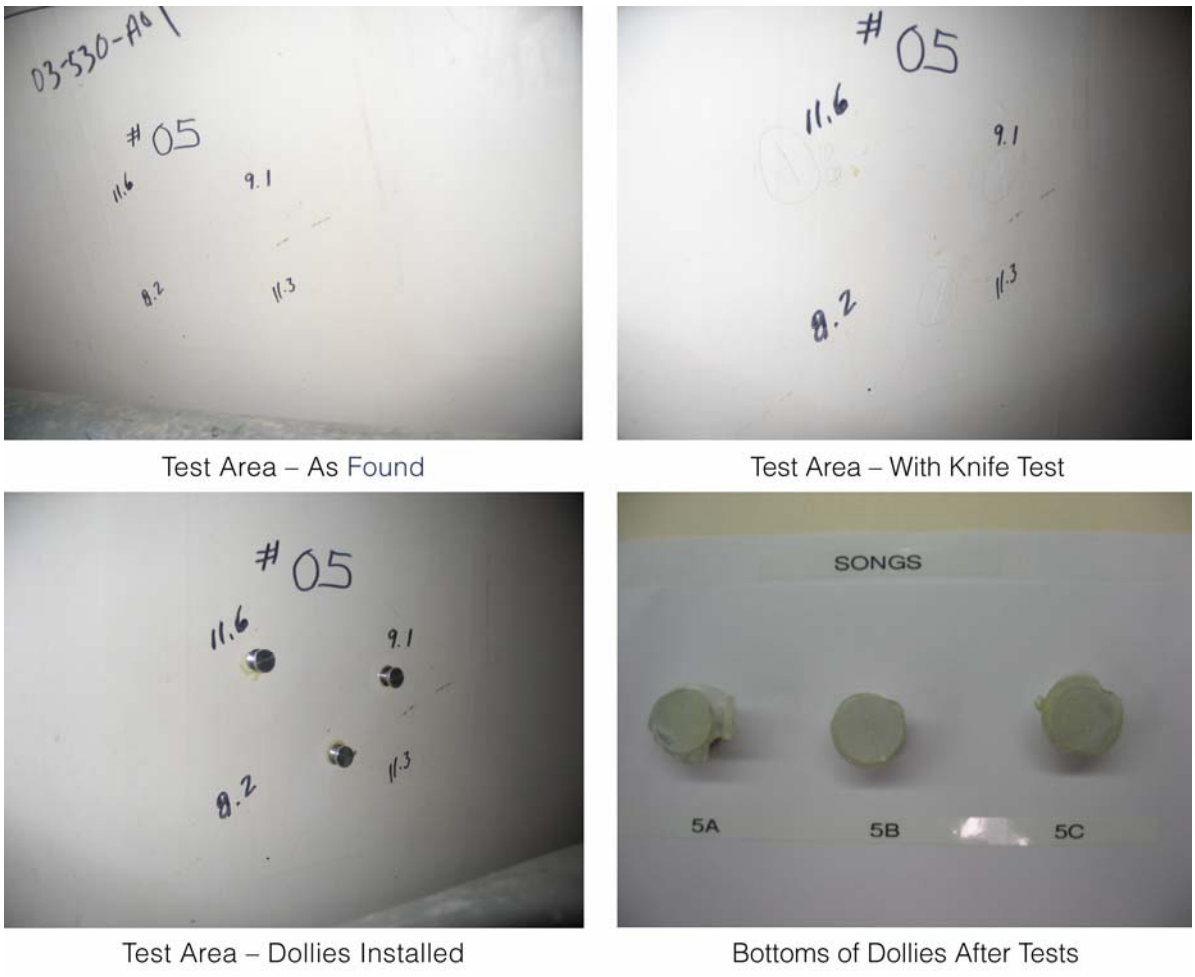
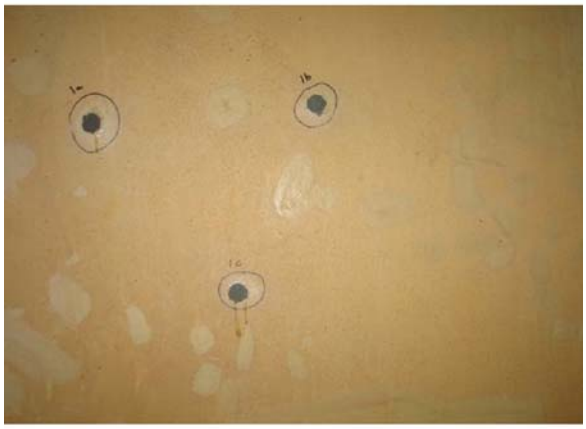


Figure 5-5
SONGs Adhesion Test Areas 5A, 5B, 5C – Sound Steel Liner

Test Area – As Found with Dollies Installed



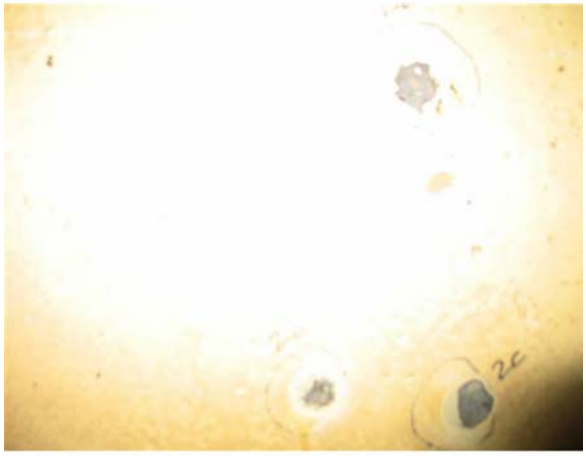
Test Area – Dollies Removed

Bottoms of Dollies After Tests

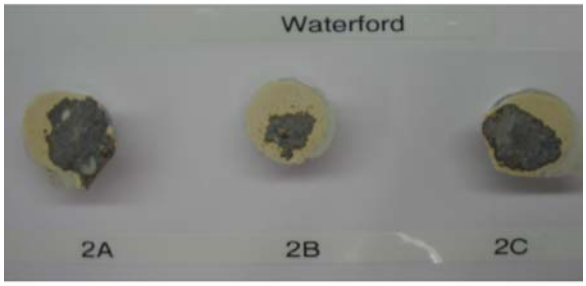
Figure 5-6
Waterford Adhesion Test Areas 1A, 1B, 1C – Sound Steel Liner

Note: Dolly 1B was accidentally dropped into an area from which it was not retrievable; consequently, the dolly was not available for the photo.

Test Area – As Found with Dollies Installed



Test Area – Dollies Removed

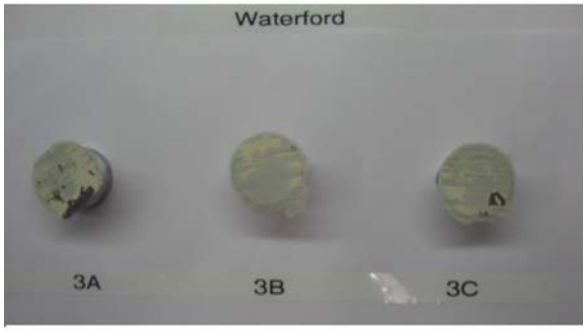


Bottoms of Dollies After Tests

Figure 5-7
Waterford Adhesion Test Areas 2A, 2B, 2C – Sound Concrete Wall

Test Area – As Found with Dollies Installed

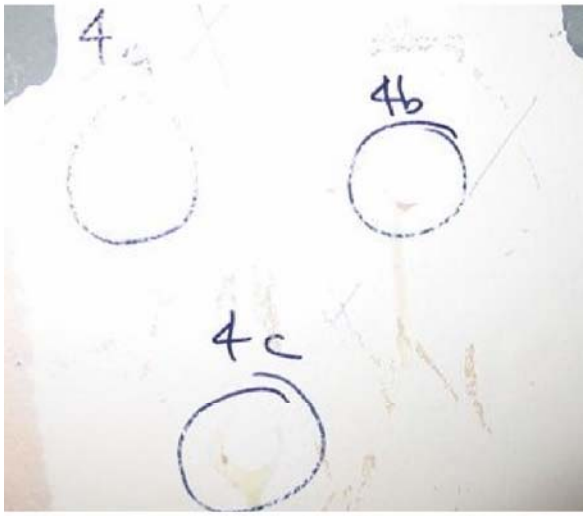
Test Area – Dollies Removed



Bottoms of Dollies After Tests

Figure 5-8
Waterford Adhesion Test Areas 3A, 3B, 3C – Sound Structural Steel

Test Area – As Found with Dollies Installed

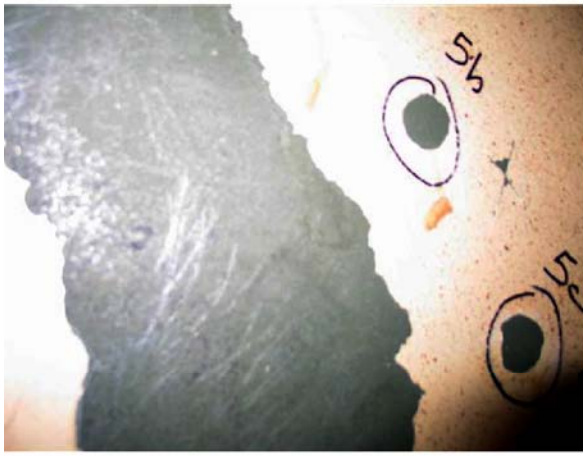


Test Area – Dollies Removed

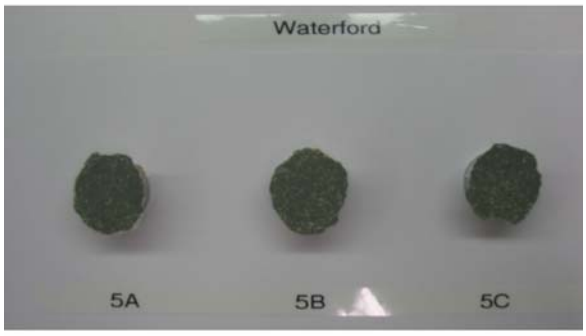
Bottoms of Dollies After Tests

Figure 5-9
Waterford Adhesion Test Areas 4A, 4B, 4C – Degraded Steel Liner

Test Area – As Found with Dollies Installed



Test Area – Dollies Removed



Bottoms of Dollies After Tests

Figure 5-10
Waterford Adhesion Test Areas 5A, 5B, 5C – Degraded Steel Liner

Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-11
McGuire Adhesion Test Areas 1A, 1B, 1C – Sound Concrete Floor

Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-12
McGuire Adhesion Test Areas 2A, 2B, 2C – Degraded Concrete Floor

Test Area – As Found

Test Area – Dollies Installed

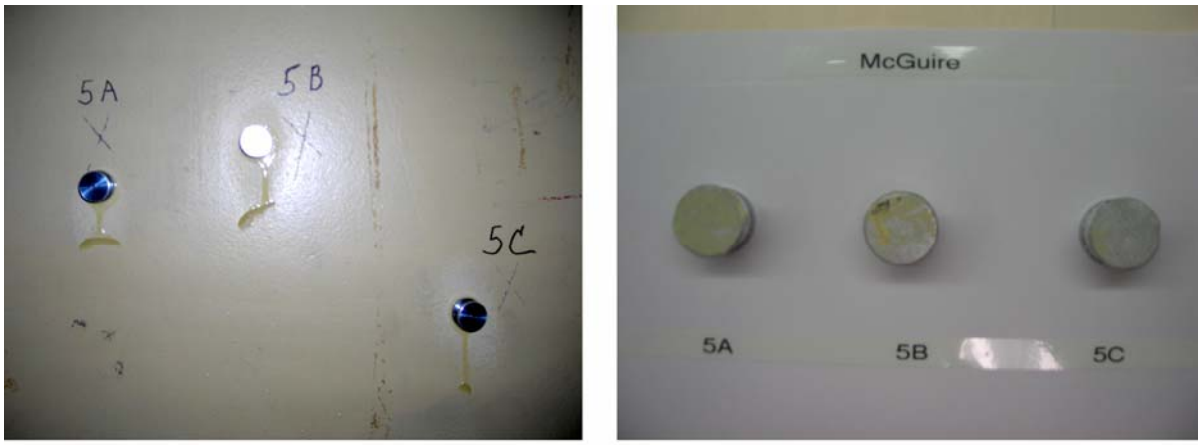
Bottoms of Dollies After Tests

Figure 5-13
McGuire Adhesion Test Areas 3A, 3B, 3C – Sound Concrete Wall

Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-14
McGuire Adhesion Test Areas 4A, 4B, 4C – Degraded Concrete Wall



Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-15
McGuire Adhesion Test Areas 5A, 5B, 5C – Sound Steel Liner

Test Area – Dollies Installed

Bottoms of Dollies After Tests

Figure 5-16
McGuire Adhesion Test Areas 6A, 6B, 6C – Degraded Steel Liner

Test Area – As Found

Test Area – With Dollies Removed & Knife Test

Bottoms of Dollies After Tests

Figure 5-17
Oconee Adhesion Test Areas 1A, 1B, 1C – Sound Concrete Wall

Test Area – As Found

Test Area – With Dollies Removed & Knife Test

Bottoms of Dollies After Tests

Figure 5-18
Oconee Adhesion Test Areas 2A, 2B, 2C – Degraded Concrete Wall

Test Area – As Found

Test Area – With Dollies Removed & Knife Test

Bottoms of Dollies After Tests

Figure 5-19
Oconee Adhesion Test Areas 3A, 3B, 3C – Sound Concrete Floor

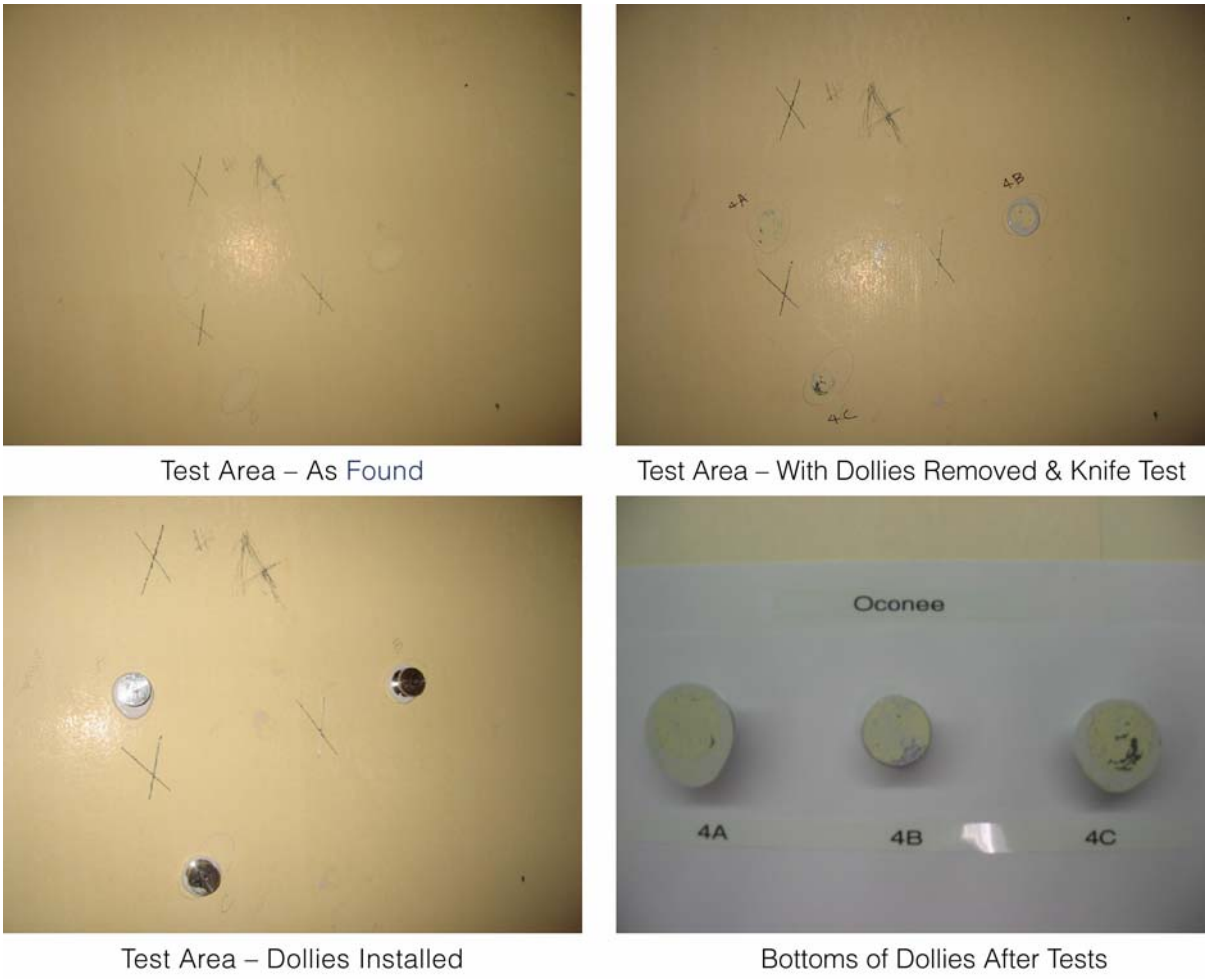


Figure 5-20
Oconee Adhesion Test Areas 4A, 4B, 4C – Sound Steel Liner

Test Area – As Found

Test Area – With Dollies Removed & Knife Test

Bottoms of Dollies After Tests

Figure 5-21
Oconee Adhesion Test Areas 5A, 5B, 5C – Degraded Steel Liner

6
CONCLUSIONS

When tested using an Elcometer pull-off adhesion tester[2], aged DBA-qualified/acceptable coatings (with no visual anomalies) from various manufacturers tested at the four volunteer plants in all instances exhibited system pull-off adhesion at or in excess of the originally specified (ANSI N5.12-1972) minimum value of 200 psi.

Based on this testing, it is concluded that the containment coatings monitoring approach contained in ASTM D5163, as implemented by licensees, and endorsed by the USNRC in RG 1.54 Rev.1 and NUREG 1801 Volume 2, Appendix XI.S8, is valid.

[2] Based upon the results of the adhesion testing, it is apparent that no direct numerical correlation between pull-off adhesion values and knife adhesion values exists. This is because pull-off adhesions testing subjects the coating film to tensile stress, whereas the knife adhesion test subjects the coating film to shear/peel stress. The testers were able to conclude that the knife adhesion test was easy to execute in the containment environment and provided reproducible results. Additionally, lower values of knife adhesion tests usually corresponded with lower values of pull-off adhesion testing.

7
REFERENCES

ASTM D4541-02 - Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5163-05a - Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6677-01 - Standard Test Method for Evaluating Adhesion by Knife.

ANSI N5.12-1972 - Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities

A
ADHESION DATA COLLECTION PROCEDURE

EPRI Task

Evaluation of Coating Failures and the Potential Influence of Aging Project

Adhesion Data Collection Procedure

Revision 2, dated December 11, 2006

Revision Record

Revision 0	-	Original Issue
Revision 1	-	The data tables were revised to present all data (DFT, adhesion, dolly evaluation, knife cut) together for a given coating system. A table was generated for each system and substrate (sound steel coating, degraded steel coating, sound concrete coating, and degraded concrete coating).
Revision 2	-	The data tables were revised to add coating system numbers to ensure adequate tracking of the coating system to the sample locations. Also, additional entries were added to the tables for logging multiple systems at a given plan. The signatures were deleted after Table A-1 because they are redundant to the final verification signatures. Tables were renumbered to correct the duplication of Table A-1 numbering.

A.1 Executive Summary and Procedure Purpose

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, as well as anticipated responses to Generic Letter 2004-02, reinforce this periodic inspection requirement**.**

As part of its review of the nuclear industry practices related to containment coatings condition assessment, the U.S. Nuclear Regulatory Commission has requested data confirming that aged DBA-qualified coatings in operating nuclear power plants will not fail during normal and accident conditions. In response to this request for data, EPRI/NUCC (Nuclear Utilities Coating Council) has initiated the Coatings Aging Task Group. The task goal is "Evaluation of Coating Failures and the Potential Influence of Aging." This task has two major phases: Phase I to collect and analyze coating failure data, and Phase II to research the effects of aging on coating polymers and systems. The results of these two phases will be documented in a series of Level I reports.

As part of the Coatings Aging Task Group Phase I effort, adhesion data will be collected and evaluated by a team of three industry coatings experts on concrete and steel containment coatings at a representative sample of operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement that containment coatings exhibit 200 lbs minimum adhesion when tested with an Elcometer adhesion tester (see ANSI N5.12, Section 6.4).

The results of the adhesion data collection effort will be published as part of an EPRI Level I report containing the following general headings:

- Introduction
- Key Concepts and Definitions
- Identification of the Plants and Coating Types
- Discussion of Data Collection Method and Procedure
- Discussion of Results of the Data Collected
- Discussion of the Correlation between Pull-Off and Knife Adhesion Testing
- Evaluation of Results and Observations
- Conclusions and Recommendations
- Appendix of All Data Collected

This procedure details the steps that will be followed in collecting the coating adhesion data.

A.2 References

ANSI N5.12 – 1972, Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities

ASTM D4138-94 (Reapproved 2001), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D4541-02, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants

ASTM D5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6132-04, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage

ASTM D6677-05, Standard Test Method for Evaluating Adhesion by Knife

SSPC-PA 2 May 1, 2004, Paint Application Specification No. 2, Measurement of Dry Coating Thickness with Magnetic Gages

A.3 Equipment/Apparatus

Elcometer 106, Pull-Off Adhesion Gage, Scale 2

DeFelsko PosiTector 6000 Coating Thickness Gage for Metal Substrates

Tooke Paint Inspection Gage

Digital camera

Flashlight

Utility knife

12-inch (30.5 cm) metal ruler/straight edge

A.4 Selection of Coating Systems and Data Collection Locations

Note: A completed copy of this procedure with all tables below filled out and signed by the coatings data collection team members will be prepared for each plant included in the survey.

1. Perform a documentation review to identify the plant's coating system(s) by manufacturer and product number. Record the coating system data on Table A-1.
2. Identify areas of concrete substrate and areas of steel substrates that are coated with documented, DBA-qualified coating systems.

Table A-1
Coating System Data

Plant & Unit			
Dates of Coatings Work			
Substrate	**1st Coat Manufacturer**	**2nd Coat Manufacturer**	**3rd Coat Manufacturer**
System Number	**Product #**	**Product #**	**Product #**
Concrete			
Concrete			
Concrete			
Steel			
Steel			
Steel			

Note: For additional coating systems at one plant, complete as many tables as necessary.

A.5 Coating Condition Assessment

1. Perform a general visual coating assessment of the selected areas using the general guidance of ASTM D5163-05a (see items 2 and 3 below).
2. For steel substrate areas:

    2.1 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

        2.1.1 Document the area with photographs.

        2.1.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.1.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

        2.1.4 Attach a dolly at three “spots” for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer’s instructions.

        2.1.5 At the remaining three “spots,” perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

    2.2 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

        2.2.1 Document the area with photographs.

        2.2.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.2.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

2.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

2.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3. For concrete substrate areas:

3.1 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

3.1.1 Document the area with photographs.

3.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3.2 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

3.2.1 Document the area with photographs.

3.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

A.6 Data Recording

1. Record in Tables A-2, A-3, A-4, and A-5, respectively, the dry film thickness results collected in accordance with 2.1.3, 2.2.3, 3.1.3, and 3.2.3 (in Section A.5 above).

Note: For multiple coating systems at one plant, complete as many tables as necessary to collect all required data.

2. Record in Tables A-2, A-3, A-4, and A-5, respectively, the pull-off adhesion results collected in accordance with 2.1.4, 2.2.4, 3.1.4, and 3.2.4 (in Section A.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.
3. Examine each of the dollies used in the pull-off test (see 2.1.4, 2.2.4, 3.1.4, and 3.2.4 in Section A.5 above), and evaluate each dolly according to ASTM D4541-02 Section 8. Record the results in Tables A-2, A-3, A-4, and A-5, respectively.
4. Record in Tables A-2, A-3, A-4, and A-5, respectively, the knife adhesion results collected in accordance with 2.1.5, 2.2.5, 3.1.5, and 3.2.5 (in Section A.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.

Table A-2
Concrete Substrate Sound Coating

Plant & Unit		**Dates**	
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#			
System Application/Use			
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			
System #/Sample ID#			
System Application/Use			
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			

Table A-3
Concrete Substrate Surrounding Degraded

Plant & Unit		**Dates**			
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**		
System #/Sample ID#					
System Application/Use					
Describe Degraded Area, Type, Size, Etc.					
DFT Readings (mils)					
ASTM D4541-02, Elcometer Pull-Off Results (psig)					
Elcometer Pull-Off Dolly Evaluation					
ASTM D6677-05, Adhesion by Knife Results					
System #/Sample ID#					
System Application/Use					
Describe Degraded Area, Type, Size, Etc.					
DFT Readings (mils)					
ASTM D4541-02, Elcometer Pull-Off Results (psig)					
Elcometer Pull-Off Dolly Evaluation					
ASTM D6677-05, Adhesion by Knife Results					

Table A-4
Steel Substrate Sound Coating

Plant & Unit		**Dates**			
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**		
System #/Sample ID#					
System Application/Use					
DFT Readings (mils)					
ASTM D4541-02, Elcometer Pull-Off Results (psig)					
Elcometer Pull-Off Dolly Evaluation					
ASTM D6677-05, Adhesion by Knife Results					
System #/Sample ID#					
System Application/Use					
DFT Readings (mils)					
ASTM D4541-02, Elcometer Pull-Off Results (psig)					
Elcometer Pull-Off Dolly Evaluation					
ASTM D6677-05, Adhesion by Knife Results					

Table A-5
Steel Substrate Surrounding Degraded

Plant & Unit		Dates	
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**
System #/Sample ID#			
System Application/Use			
Describe Degraded Area, Type, Size, Etc.			
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			
System #/Sample ID#			
System Application/Use			
Describe Degraded Area, Type, Size, Etc.			
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			

B
ADHESION DATA COLLECTION PROCEDURE DATA - SONGS

EPRI Task

Evaluation of Coating Failures and the Potential Influence of Aging

San Onofre Nuclear Generation Station (SONGS)

Adhesion Data Collection Procedure

Revision 2, dated December 11, 2006

Revision Record

Revision 0	-	Original Issue
Revision 1	-	The data tables were revised to present all data (DFT, adhesion, dolly evaluation, knife cut) together for a given coating system. A table was generated for each system and substrate (sound steel coating, degraded steel coating, sound concrete coating, and degraded concrete coating).
Revision 2	-	The data tables were revised to add coating system numbers to ensure adequate tracking of the coating system to the sample locations. Also, additional entries were added to the tables for logging multiple systems at a given plan. The signatures were deleted after Table B-1 because they are redundant to the final verification signatures. Tables were renumbered to correct the duplication of Table B-1 numbering.

B.1 Executive Summary and Procedure Purpose

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, as well as anticipated responses to Generic Letter 2004-02, reinforce this periodic inspection requirement**.**

As part of its review of the nuclear industry practices related to containment coatings condition assessment, the U.S. Nuclear Regulatory Commission has requested data confirming that aged DBA-qualified coatings in operating nuclear power plants will not fail during normal and accident conditions. In response to this request for data, EPRI/NUCC (Nuclear Utilities Coating Council) has initiated the Coatings Aging Task Group. The task goal is "Evaluation of Coating Failures and the Potential Influence of Aging." This task has two major phases: Phase I to collect and analyze coating failure data, and Phase II to research the effects of aging on coating polymers and systems. The results of these two phases will be documented in a series of Level I reports.

As part of the Coatings Aging Task Group Phase I effort, adhesion data will be collected and evaluated by a team of three industry coatings experts on concrete and steel containment coatings at a representative sample of operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement that containment coatings exhibit 200 lbs minimum adhesion when tested with an Elcometer adhesion tester (see ANSI N5.12, Section 6.4).

The results of the adhesion data collection effort will be published as part of an EPRI Level I report containing the following general headings:

- Introduction
- Key Concepts and Definitions
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- Evaluation of Results and Observations
- Conclusions and Recommendations
- Appendix of All Data Collected

This procedure details the steps that will be followed in collecting the coating adhesion data.

B.2 References

ANSI N5.12 – 1972, Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities

ASTM D4138-94 (Reapproved 2001), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D4541-02, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants

ASTM D5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6132-04, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage

ASTM D6677-05, Standard Test Method for Evaluating Adhesion by Knife

ASTM D7234-05 Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers

SSPC-PA 2 May 1, 2004, Paint Application Specification No. 2, Measurement of Dry Coating Thickness with Magnetic Gages

B.3 Equipment/Apparatus

Elcometer 106, Pull-Off Adhesion Gage, Scale 2

Elcometer 106/6, Coatings on Concrete Adhesion Tester

DeFelsko PosiTector 6000 Coating Thickness Gage for Metal Substrates

Tooke Paint Inspection Gage

Digital camera

Flashlight

Utility knife

12-inch (30.5 cm) metal ruler/straight edge

B.4 Selection of Coating Systems and Data Collection Locations

Note: A completed copy of this procedure with all tables below filled out and signed by the coatings data collection team members will be prepared for each plant included in the survey.

1. Perform a documentation review to identify the plant's coating system(s) by manufacturer and product number. Record the coating system data in Table B-1.
2. Identify areas of concrete substrate and areas of steel substrates that are coated with documented, DBA-qualified coating systems.

Table B-1
Coating System Data

Plant & Unit	**San Onofre Nuclear Generating Station (SONGS), Unit #3**		
Dates of Coatings Work	CIRCA 1980-1983	CIRCA 1980-1983	NA
Substrate	**1st Coat Manufacturer**	**2nd Coat Manufacturer**	**3rd Coat Manufacturer**
System Number	**Product #**	**Product #**	**Product #**
Concrete	Mobil	Mobil	NA
#4	46-X-29	84-W-9	NA
Concrete	Mobil	NA	NA
#2	84-V-2	NA	NA
Concrete	NA	NA	NA
NA	NA	NA	NA
Steel	Mobil	Mobil	NA
#1	78-W-3	78-W-3	NA
Steel	Mobil	Mobil	NA
#3	78-W-3	78-W-3	NA
Steel	Mobil	Mobil	NA
#5	78-W-3	78-W-3	NA

Note: For additional coating systems at one plant, complete as many tables as necessary.

B.5 Coating Condition Assessment

1. Perform a general visual coating assessment of the selected areas using the general guidance of ASTM D5163-05a (see items 2 and 3 below).
2. For steel substrate areas:

    2.1 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

        2.1.1 Document the area with photographs.

        2.1.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.1.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

        2.1.4 Attach a dolly at three “spots” for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer’s instructions.

        2.1.5 At the remaining three “spots,” perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

    2.2 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

        2.2.1 Document the area with photographs.

        2.2.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.2.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

2.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing per ASTM D4541-02 and the test device manufacturer's instructions.

2.2.5 At the remaining three "spots," perform knife adhesion testing per ASTM D6677-05. Document the area with photographs and record the results.

3. For concrete substrate areas:

3.1 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

4.3.1.1 Document the area with photographs.

3.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3.2 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

3.2.1 Document the area with photographs.

3.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

B.6 Data Recording

1. Record in Tables B-2, B-3, B-4, and B-5, respectively, the dry film thickness results collected in accordance with 2.1.3, 2.2.3, 3.1.3, and 3.2.3 (in Section B.5 above).

Note: For multiple coating systems at one plant, complete as many tables as necessary to collect all required data.

2. Record in Tables B-2, B-3, B-4, and B-5, respectively, the pull-off adhesion results collected in accordance with 2.1.4, 2.2.4, 3.1.4, and 3.2.4 (in Section B.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.
3. Examine each of the dollies used in the pull-off test (see 2.1.4, 2.2.4, 3.1.4, and 3.2.4 in Section B.5 above), and evaluate each dolly according to ASTM D4541-02 Section 8. Record the results in Tables B-2, B-3, B-4, and B-5, respectively.
4. Record in Tables B-2, B-3, B-4, and B-5, respectively, the knife adhesion results collected in accordance with 1.2.5, 2.2.5, 3.1.5, and 3.2.5 (in Section B.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.

Table B-2
Concrete Substrate Sound Coating

Plant & Unit	**SONGS 3**	**Dates**	**November 15-16, 2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	4*	4B	4C
System Application/Use	Original concrete floor and equipment pad coating system		
DFT Readings (mils)	7	7	7
ASTM D4541-02, Elcometer Pull-Off Results (psig)	300	300	700
Elcometer Pull-Off Dolly Evaluation	100% glue failure	100% glue failure	100% glue failure
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	2*	2B	2C
System Application/Use	Concrete curing sealer applied to vertical walls of the bioshield		
DFT Readings (mils)	1.5**	1.5**	1.5**
ASTM D4541-02, Elcometer Pull-Off Results (psig)	500	500	>1000
Elcometer Pull-Off Dolly Evaluation	60% substrate failure 40% glue failure	10% substrate failure 90% glue failure	90% substrate failure 10% glue failure
ASTM D6677-05, Adhesion by Knife Results	10	10	10

***** System 2 DBA-qualification paper work is not available. There is reasonable assurance that it is DBA qualified based on the original design specs and DBA qualifications of essentially identical sealers manufactured by Carboline and Keeler& Long during the same timeframe.

****** System 2 estimated DFT due to very thin coating and the Tooke Gauge did not provide a clean cut as a result.

Table B-3
Concrete Substrate Surrounding Degraded

Plant & Unit	**SONGS 3**	**Dates**	**November 15-16, 2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	No degraded concrete coating system identified		
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	No degraded concrete coating system identified		
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			

Table B-4
Steel Substrate Sound Coating

Plant & Unit	**SONGS 3**	**Dates**	**November 15-16, 2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	1A	1B	1C
System Application/Use	Original structural steel and embed coating system		
DFT Readings (mils)	12.3	15.4	16.6
ASTM D4541-02, Elcometer Pull-Off Results (psig)	>1000	700	>1000
Elcometer Pull-Off Dolly Evaluation	No failure	5% cohesive failure 95% glue failure	No failure*****
ASTM D6677-05, Adhesion by Knife Results	8	10	10
System #/Sample ID#	5A	5B	5C
System Application/Use	Original liner plate coating system		
DFT Readings (mils)	11.6	9.1	11.3
ASTM D4541-02, Elcometer Pull-Off Results (psig)	500	500	>1000
Elcometer Pull-Off Dolly Evaluation	100% glue failure	100% glue failure	No failure
ASTM D6677-05, Adhesion by Knife Results	10	10	10

***** The dolly was dropped into a high contamination area and was unretrievable.

Table B-5
Steel Substrate Surrounding Degraded

Plant & Unit	**SONGS 3**	**Dates**	**November 15-16, 2006**	
Elcometer Model 106 Adhesion Tester Serial No.		**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**
System #	**Sample ID#**	3A	3B	3C
System Application/Use		Original structural steel coating system		
Describe Degraded Area, Type, Size, Etc.		Heat damage due to proximity to steam line. Degraded area triangular, approximately 0.25 ft x 1 ft x 1.1 ft., A @ 2", B @ 6", C @ 10" from original scraped area		
DFT Readings (mils)		8.7	7.9	7.4
ASTM D4541-02, Elcometer Pull-Off Results (psig)		300	300	250
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation		10% adhesive failure 90% glue failure	1% cohesive failure 99% glue failure	100% glue failure
ASTM D6677-05, Adhesion by Knife Results		Brittle with no “clean” X cut obtained	8	8
System #	**Sample ID#**	NA	NA	NA
System Application/Use		NA		
Describe Degraded Area, Type, Size, Etc.		No degraded concrete coating system identified		
DFT Readings (mils)				
ASTM D4541-02, Elcometer Pull-Off Results (psig)				
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation				
ASTM D6677-05, Adhesion by Knife Results				

C
ADHESION DATA COLLECTION PROCEDURE DATA - WATERFORD

EPRI Task

Evaluation of Coating Failures and the Potential Influence of Aging Project

Waterford 3

Adhesion Data Collection Procedure

Revision 2, dated December 11, 2006

Revision Record

Revision 0	-	Original Issue
Revision 1	-	The data tables were revised to present all data (DFT, adhesion, dolly evaluation, knife cut) together for a given coating system. A table was generated for each system and substrate (sound steel coating, degraded steel coating, sound concrete coating, and degraded concrete coating).
Revision 2	-	The data tables were revised to add coating system numbers to ensure adequate tracking of the coating system to the sample locations. Also, additional entries were added to the tables for logging multiple systems at a given plan. The signatures were deleted after Table C-1 because they are redundant to the final verification signatures. Tables were renumbered to correct the duplication of Table C-1 numbering.

C.1 Executive Summary and Procedure Purpose

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, as well as anticipated responses to Generic Letter 2004-02, reinforce this periodic inspection requirement**.**

As part of its review of the nuclear industry practices related to containment coatings condition assessment, the U.S. Nuclear Regulatory Commission has requested data confirming that aged DBA-qualified coatings in operating nuclear power plants will not fail during normal and accident conditions. In response to this request for data, EPRI/NUCC (Nuclear Utilities Coating Council) has initiated the Coatings Aging Task Group. The task goal is "Evaluation of Coating Failures and the Potential Influence of Aging." This task has two major phases: Phase I to collect and analyze coating failure data, and Phase II to research the effects of aging on coating polymers and systems. The results of these two phases will be documented in a series of Level I reports.

As part of the Coatings Aging Task Group Phase I effort, adhesion data will be collected and evaluated by a team of three industry coatings experts on concrete and steel containment coatings at a representative sample of operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement that containment coatings exhibit 200 lbs minimum adhesion when tested with an Elcometer adhesion tester (see ANSI N5.12, Section 6.4).

The results of the adhesion data collection effort will be published as part of an EPRI Level I report containing the following general headings:

- Introduction
- Key Concepts and Definitions
- Identification of the Plants and Coating Types
- Discussion of Data Collection Method and Procedure
- Discussion of Results of the Data Collected
- Discussion of the Correlation between Pull-off and Knife Adhesion Testing
- Evaluation of Results and Observations
- Conclusions and Recommendations
- Appendix of All Data Collected

This procedure details the steps which will be followed in collecting the coating adhesion data.

C.2 References

ANSI N5.12 – 1972, Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities

ASTM D4138-94 (Reapproved 2001), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D4541-02, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants

ASTM D5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6132-04, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage

ASTM D6677-05, Standard Test Method for Evaluating Adhesion by Knife

ASTM D7234-05 Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers

SSPC-PA 2 May 1, 2004, Paint Application Specification No. 2, Measurement of Dry Coating Thickness with Magnetic Gages

C.3 Equipment/Apparatus

Elcometer 106, Pull-Off Adhesion Gage, Scale 2

Elcometer 106/6, Coatings on Concrete Adhesion Tester

DeFelsko PosiTector 6000 Coating Thickness Gage for Metal Substrates

Tooke Paint Inspection Gage

Digital camera

Flashlight

Utility knife

12-inch (30.5 cm) metal ruler/straight edge

C.4 Selection of Coating Systems and Data Collection Locations

Note: A completed copy of this procedure with all tables below filled out and signed by the coatings data collection team members will be prepared for each plant included in the survey.

1. Perform a documentation review to identify the plant's coating system(s) by manufacturer and product number. Record the coating system data in Table C-1.
2. Identify areas of concrete substrate and areas of steel substrates that are coated with documented, DBA-qualified coating systems.

Table C-1
Coating System Data

Plant & Unit	**Waterford 3**		
Dates of Coatings Work	CIRCA 1982-1984 Repair Coating 2002	CIRCA 1982-1984 Repair Coating 2002	NA
Substrate	**1st Coat Manufacturer**	**2nd Coat Manufacturer**	**3rd Coat Manufacturer**
System Number	**Product #**	**Product #**	**Product #**
Concrete	Ameron	Ameron	NA
#2	110AA Nu-Klad	Amercoat 66	
Concrete	NA	NA	NA
Concrete	NA	NA	NA
Steel	Carboline	Carboline	NA
#1 & #5	CarboZinc 11	Phenoline 305	
Steel	Ameron	Ameron	NA
#3	D-6	Amercoat 90	
Steel	Ameron	Ameron	NA
#4	Amerlock 400NT	Amerlock 400NT	

Note: For additional coating systems at one plant, complete as many tables as necessary.

C.5 Coating Condition Assessment

1. Perform a general visual coating assessment of the selected areas using the general guidance of ASTM D5163-05a (see items 2 and 3 below).
2. For steel substrate areas:

    2.1 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

        2.1.1 Document the area with photographs.

        2.1.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.1.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

        2.1.4 Attach a dolly at three “spots” for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer’s instructions.

        2.1.5 At the remaining three “spots,” perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

    2.2 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

        2.2.1 Document the area with photographs.

        2.2.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.2.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

2.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

2.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3. For concrete substrate areas:

3.1 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

3.1.1 Document the area with photographs.

3.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3.2 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

3.2.1 Document the area with photographs.

3.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

C.6 Data Recording

1. Record in Tables C-2, C-3, C-4, and C-5, respectively, the dry film thickness results collected in accordance with 2.1.3, 2.2.3, 3.1.3, and 3.2.3 (in Section C.5 above).

Note: For multiple coating systems at one plant, complete as many tables as necessary to collect all required data.

2. Record in Tables C-2, C-3, C-4, and C-5, respectively, the pull-off adhesion results collected in accordance with 2.1.4, 2.2.4, 3.1.4, and 3.2.4 (in Section C.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.
3. Examine each of the dollies used in the pull-off test (see 2.1.4, 2.2.4, 3.1.4, and 3.2.4 in Section C.5 above), and evaluate each dolly according to ASTM D4541-02 Section 8. Record the results in Tables C-2, C-3, C-4, and C-5, respectively.
4. Record in Tables C-2, C-3, C-4, and C-5, respectively, the knife adhesion results collected in accordance with 2.1.5, 2.2.5, 3.1.5, and 3.2.5 (in Section C.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.

Table C-2
Concrete Substrate Sound Coating

Plant & Unit	**Waterford 3**	**Dates**	**12/5-6/2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	2A	2B	2C
System Application/Use	Original concrete wall and floor coating system.		
DFT Readings (mils)	15 (top coat)	15 (top coat)	15 (top coat)
ASTM D4541-02, Elcometer Pull-Off Results (psig)	400	550	320
Elcometer Pull-Off Dolly Evaluation	75% concrete 25% surfacer-concrete interface	75% concrete 25% surfacer-concrete interface	75% concrete 25% surfacer-concrete interface
ASTM D6677-05, Adhesion by Knife Results	10	8	8
System #/Sample ID#	NA	NA	NA
System Application/Use			
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			

Table C-3
Concrete Substrate Surrounding Degraded

Plant & Unit	**Waterford 3**	**Dates**	**12/5-6/2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	No degraded concrete coating system identified		
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	No degraded concrete coating system identified		
DFT Readings (mils)			
ASTM D4541-02, Elcometer Pull-Off Results (psig)			
Elcometer Pull-Off Dolly Evaluation			
ASTM D6677-05, Adhesion by Knife Results			

Table C-4
Steel Substrate Sound Coating

Plant & Unit	**Waterford 3**	**Dates**	**12/5-6/2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	1A	1B	1C
System Application/Use	Original steel containment pressure vessel coating system		
DFT Readings (mils)	11.0	12.0	10.6
ASTM D4541-02, Elcometer Pull-Off Results (psig)	290	330	310
Elcometer Pull-Off Dolly Evaluation	100% intracoat failure of IOZ primer	100% intracoat failure of IOZ primer*****	100% intracoat failure of IOZ primer
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	3A	3B	3C
System Application/Use	Original structural steel coating system		
DFT Readings (mils)	5.9	10.4	9.5
ASTM D4541-02, Elcometer Pull-Off Results (psig)	>1000	625	410
Elcometer Pull-Off Dolly Evaluation	No Failure	10% intracoat of topcoat 90% glue failure	20% intracoat of topcoat 5% intracoat of IOZ primer 75% glue failure
ASTM D6677-05, Adhesion by Knife Results	8	6	4

***** The dolly was dropped into a high contamination area and was unretrievable.

Table C-5
Steel Substrate Surrounding Degraded

Plant & Unit	**Waterford 3**	**Dates**	**12/5-6/2006**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**
System #/Sample ID#	4A	4B	4C
System Application/Use	Repair coating on steel containment pressure vessel at failure of CarboZinc11/Phenoline 305		
Describe Degraded Area, Type, Size, Etc.	Peeling area approximately 18" in diameter. Data at 4" from peeled area.		
DFT Readings (mils)	10.5	9.5	8.7
ASTM D4541-02, Elcometer Pull-Off Results (psig)	600	750	700
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation	100% glue failure	100% glue failure	100% glue failure
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	5A	5B	5C
System Application/Use	Original steel containment pressure vessel coating system		
Describe Degraded Area, Type, Size, Etc.	Peeling area approximately 18" in diameter. Data at 4" from peeled area		
DFT Readings (mils)	14.8	12.6	14.3
ASTM D4541-02, Elcometer Pull-Off Results (psig)	300	200	200
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation	100% intracoat failure of IOZ primer	100% intracoat failure of IOZ primer	100% intracoat failure of IOZ primer
ASTM D6677-05, Adhesion by Knife Results	8	6	4

D
ADHESION DATA COLLECTION PROCEDURE DATA - MCGUIRE

EPRI Task

Evaluation of Coating Failures and the Potential Influence of Aging Project

McGuire Nuclear Station Unit 1

Adhesion Data Collection Procedure

Revision 2, dated December 11, 2006

Revision Record

Revision 0 - Original issue

Revision 1 - The data tables were revised to present all data (DFT, adhesion, dolly evaluation, knife cut) together for a given coating system. A table was generated for each system and substrate (sound steel coating, degraded steel coating, sound concrete coating, and degraded concrete coating).

Revision 2 - The data tables were revised to add coating system numbers to ensure adequate tracking of the coating system to the sample locations. Also, additional entries were added to the tables for logging multiple systems at a given plan. The signatures were deleted after Table D-1 because they are redundant to the final verification signatures. Tables were renumbered to correct the duplication of Table D-1 numbering.

D.1 Executive Summary and Procedure Purpose

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, as well as anticipated responses to Generic Letter 2004-02, reinforce this periodic inspection requirement**.**

As part of its review of the nuclear industry practices related to containment coatings condition assessment, the U.S. Nuclear Regulatory Commission has requested data confirming that aged DBA-qualified coatings in operating nuclear power plants will not fail during normal and accident conditions. In response to this request for data, EPRI/NUCC (Nuclear Utilities Coating Council) has initiated the Coatings Aging Task Group. The task goal is "Evaluation of Coating Failures and the Potential Influence of Aging." This task has two major phases: Phase I to collect and analyze coating failure data, and Phase II to research the effects of aging on coating polymers and systems. The results of these two phases will be documented in a series of Level I reports.

As part of the Coatings Aging Task Group Phase I effort, adhesion data will be collected and evaluated by a team of three industry coatings experts on concrete and steel containment coatings at a representative sample of operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement that containment coatings exhibit 200 lbs minimum adhesion when tested with an Elcometer adhesion tester (see ANSI N5.12, Section 6.4).

The results of the adhesion data collection effort will be published as part of an EPRI Level I report containing the following general headings:

- Introduction
- Key Concepts and Definitions
- Identification of the Plants and Coating Types
- Discussion of Data Collection Method and Procedure
- Discussion of Results of the Data Collected
- Discussion of the Correlation between Pull-off and Knife Adhesion Testing
- Evaluation of Results and Observations
- Conclusions and Recommendations
- Appendix of All Data Collected

This procedure details the steps which will be followed in collecting the coating adhesion data.

D.2 References

ANSI N5.12 – 1972, Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities

ASTM D4138-94 (Reapproved 2001), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D4541-02, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants

ASTM D5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6132-04, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage

ASTM D6677-05, Standard Test Method for Evaluating Adhesion by Knife

SSPC-PA 2 May 1, 2004, Paint Application Specification No. 2, Measurement of Dry Coating Thickness with Magnetic Gages

D.3 Equipment/Apparatus

Elcometer 106, Pull-Off Adhesion Gage, Scale 2

DeFelsko PosiTector 6000 Coating Thickness Gage for Metal Substrates

Tooke Paint Inspection Gage

Digital camera

Flashlight

Utility knife

12-inch (30.5 cm) metal ruler/straight edge

D.4 Selection of Coating Systems and Data Collection Locations

Note: A completed copy of this procedure with all tables below filled out and signed by the coatings data collection team members will be prepared for each plant included in the survey.

1. Perform a documentation review to identify the plant's coating system(s) by manufacturer and product number. Record the coating system data in Table D-1.
2. Identify areas of concrete substrate and areas of steel substrates that are coated with documented, DBA-qualified coating systems.

Table D-1
Coating System Data

Plant & Unit	**McGuire Unit 1**		
Dates of Coatings Work	1975-1976	1975-1976	
Substrate	**1st Coat Manufacturer**	**2nd Coat Manufacturer**	**3rd Coat Manufacturer**
System Number	**Product #**	**Product #**	**Product #**
Concrete	Mobil	Mobil	
#1	46-X-29	76 Hi Solids Epoxy	
Concrete	Mobil	Mobil	
#2	46-X-29	76 Hi Solids Epoxy	
Concrete	Mobil	Mobil	
#3	46-X-29	89 Hi Build Epoxy	
Concrete	Mobil	Mobil	
#4	46-X-29	89 Hi Build Epoxy	
Steel	Mobil	Mobil	
#5	MobilZinc 7 13-F-12	89 Hi Build Epoxy	
Steel	Mobil	Mobil	
#6	MobilZinc 7 13-F-12	89 Hi Build Epoxy	

Note: For additional coating systems at one plant, complete as many tables as necessary.

D.5 Coating Condition Assessment

1. Perform a general visual coating assessment of the selected areas using the general guidance of ASTM D5163-05a (see items 2 and 3 below).
2. For steel substrate areas:

    2.1 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

        2.1.1 Document the area with photographs.

        2.1.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.1.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

        2.1.4 Attach a dolly at three “spots” for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer’s instructions.

        2.1.5 At the remaining three “spots,” perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

    2.2 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

        2.2.1 Document the area with photographs.

        2.2.2 Select and mark six “spots” (see SSPC-PA2, Figure A1 for defining “spots”) to perform adhesion testing.

        2.2.3 Perform dry film thickness measurements at each of the six “spots” in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

2.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

2.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3. For concrete substrate areas:

3.1 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

3.1.1 Document the area with photographs.

3.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3.2 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

3.2.1 Document the area with photographs.

3.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

D.6 Data Recording

1. Record in Tables D-2, D-3, D-4, and D-5, respectively, the dry film thickness results collected in accordance with 2.1.3, 2.2.3, 3.1.3, and 3.2.3 (in Section D.5 above).

Note: For multiple coating systems at one plant, complete as many tables as necessary to collect all required data.

2. Record in Tables D-2, D-3, D-4, and D-5, respectively, the pull-off adhesion results collected in accordance with 2.1.4, 2.2.4, 3.1.4, and 3.2.4. For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.
3. Examine each of the dollies used in the pull-off test (see 2.1.4, 2.2.4, 3.1.4, and 3.2.4 in Section D.5 above), and evaluate each dolly according to ASTM D4541-02 Section 8. Record the results in Tables D-2, D-3, D-4, and D-5, respectively.
4. Record in Tables D-2, D-3, D-4, and D-5, respectively, the knife adhesion results collected in accordance with 2.1.5, 2.2.5, 3.1.5, and 3.2.5 (in Section D.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.

Table D-2
Concrete Substrate Sound Coating

Plant & Unit	**McGuire Unit 1**	**Dates**	**March 21-22, 2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	1A	1B	1C
System Application/Use	Concrete floor		
DFT Readings (mils) – Tooke Gage	10 top coat, 5 surfacer	10 top coat, 5 surfacer	10 top coat, 5 surfacer
ASTM D4541-02, Elcometer Pull-Off Results (psig)	>1000	300	400
Elcometer Pull-Off Dolly Evaluation	No failure	100% cohesive failure of surfacer	80% cohesive failure of surfacer, 20% concrete
ASTM D6677-05, Adhesion by Knife Results	10	10	8
System #/Sample ID#	3A	3B	3C
System Application/Use	Concrete wall		
DFT Readings (mils) - Tooke Gage	10 top coat, 5 surfacer	5–10 top coat, 5 surfacer	5–10 top coat, 5 surfacer
ASTM D4541-02, Elcometer Pull-Off Results (psig)	500	200	300
Elcometer Pull-Off Dolly Evaluation	100% concrete	100% concrete	100% concrete
ASTM D6677-05, Adhesion by Knife Results	10	10	10

Table D-3
Concrete Substrate Surrounding Degraded

Plant & Unit	**McGuire Unit 1**	**Dates**	**March 21-22, 2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	2A	2B	2C
System Application/Use	Concrete floor		
Describe Degraded Area, Type, Size, Etc.	Mechanical damage and wear 6-12 square inches, not repaired		
DFT Readings (mils) – Tooke Gage	5–10 top coat, 5–10 surfacer	5–10 top coat, 5–10 surfacer	5–10 top coat, 5–10 surfacer
ASTM D4541-02, Elcometer Pull-Off Results (psig)	200	200	200
Elcometer Pull-Off Dolly Evaluation	90% top coat adhesion 10% surfacer adhesion	90% top coat adhesion 10% surfacer adhesion	90% top coat adhesion 10% surfacer adhesion
ASTM D6677-05, Adhesion by Knife Results	6	6	6
System #/Sample ID#	4A	4B	4C
System Application/Use	Concrete wall		
Describe Degraded Area, Type, Size, Etc.	Mechanical damage and wear 1 square inch, not repaired		
DFT Readings (mils) – Tooke Gage	10 top coat, 5 surfacer	10 top coat, 5 surfacer	10 top coat, 5 surfacer
ASTM D4541-02, Elcometer Pull-Off Results (psig)	400	400	400
Elcometer Pull-Off Dolly Evaluation	80% concrete failure, 20%surfacer adhesion	80% concrete failure, 20%surfacer adhesion	80% concrete failure, 20%surfacer adhesion
ASTM D6677-05, Adhesion by Knife Results	10	10	10

Table D-4
Steel Substrate Sound Coating

Plant & Unit	**McGuire Unit 1**	**Dates**	**March 21-22, 2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**

System #/Sample ID#	5A	5B	5C
System Application/Use	Carbon steel liner plate		
DFT Readings (mils)	11	9	10
ASTM D4541-02, Elcometer Pull-Off Results (psig)	700	>1000	800
Elcometer Pull-Off Dolly Evaluation	100% glue	No failure	100% glue
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
DFT Readings (mils)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Results (psig)	NA	NA	NA
Elcometer Pull-Off Dolly Evaluation	NA	NA	NA
ASTM D6677-05, Adhesion by Knife Results	NA	NA	NA

Table D-5
Steel Substrate Surrounding Degraded

Plant & Unit	**McGuire Unit 1**	**Dates**	**March 21-22, 2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - PosiTector Model 6000 Serial No.**	**601812**
System #/Sample ID#	6A	6B	6C
System Application/Use	Carbon steel liner plate		
Describe Degraded Area, Type, Size, Etc.	Small areas 2-3 square inches		
DFT Readings (mils)	12	12	12
ASTM D4541-02, Elcometer Pull-Off Results (psig)	600	700	500
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation	100% glue failure	100% glue failure	85% glue failure, 15% top coat cohesive failure
ASTM D6677-05, Adhesion by Knife Results	10	8	10
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	NA		
DFT Readings (mils)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Results (psig)	NA	NA	NA
Elcometer Pull-Off Dolly Evaluation	NA	NA	NA
ASTM D6677-05, Adhesion by Knife Results	NA	NA	NA

E
ADHESION DATA COLLECTION PROCEDURE DATA - OCONEE

EPRI Task

Evaluation of Coating Failures and the Potential Influence of Aging

Oconee Nuclear Station Unit 2

Adhesion Data Collection Procedure

Revision 2, dated December 11, 2006

Revision Record

Revision 0 - Original issue

Revision 1 - The data tables were revised to present all data (DFT, adhesion, dolly evaluation, knife cut) together for a given coating system. A table was generated for each system and substrate (sound steel coating, degraded steel coating, sound concrete coating, and degraded concrete coating).

Revision 2 - The data tables were revised to add coating system numbers to ensure adequate tracking of the coating system to the sample locations. Also, additional entries were added to the tables for logging multiple systems at a given plan. The signatures were deleted after Table E-1 because they are redundant to the final verification signatures. Tables were renumbered to correct the duplication of Table E-1 numbering.

E.1 Executive Summary and Procedure Purpose

U.S. nuclear power plants were originally designed to be in service for 40 years. Recently, many plants have been granted, or have applied for, license extensions to permit operation for a total of 60 years. To ensure that protective coatings within reactor containments continue to perform satisfactorily throughout the life of the plant, periodic condition assessments must be performed. Licensee responses to GL 98-04, as well as anticipated responses to Generic Letter 2004-02, reinforce this periodic inspection requirement**.**

As part of its review of the nuclear industry practices related to containment coatings condition assessment, the U.S. Nuclear Regulatory Commission has requested data confirming that aged DBA-qualified coatings in operating nuclear power plants will not fail during normal and accident conditions. In response to this request for data, EPRI/NUCC (Nuclear Utilities Coating Council) has initiated the Coatings Aging Task Group. The task goal is "Evaluation of Coating Failures and the Potential Influence of Aging." This task has two major phases: Phase I to collect and analyze coating failure data, and Phase II to research the effects of aging on coating polymers and systems. The results of these two phases will be documented in a series of Level I reports.

As part of the Coatings Aging Task Group Phase I effort, adhesion data will be collected and evaluated by a team of three industry coatings experts on concrete and steel containment coatings at a representative sample of operating nuclear power plants. The resultant data will be compared to the original DBA-qualification screening requirement that containment coatings exhibit 200 lbs minimum adhesion when tested with an Elcometer adhesion tester (see ANSI N5.12, Section 6.4).

The results of the adhesion data collection effort will be published as part of an EPRI Level I report containing the following general headings:

- Introduction
- Key Concepts and Definitions
- Identification of the Plants and Coating Types
- Discussion of Data Collection Method and Procedure
- Discussion of Results of the Data Collected
- Discussion of the Correlation between Pull-off and Knife Adhesion Testing
- Evaluation of Results and Observations
- Conclusions and Recommendations
- Appendix of All Data Collected

This procedure details the steps which will be followed in collecting the coating adhesion data.

E.2 References

ANSI N5.12 – 1972, Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities

ASTM D4138-94 (Reapproved 2001), Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means

ASTM D4541-02, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants

ASTM D5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant

ASTM D6132-04, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage

ASTM D6677-05, Standard Test Method for Evaluating Adhesion by Knife

SSPC-PA 2 May 1, 2004, Paint Application Specification No. 2, Measurement of Dry Coating Thickness with Magnetic Gages

E.3 Equipment/Apparatus

Elcometer 106, Pull-Off Adhesion Gage, Scale 2

DeFelsko PosiTector 6000 Coating Thickness Gage for Metal Substrates

Tooke Paint Inspection Gage

Digital camera

Flashlight

Utility knife

12-inch (30.5 cm) metal ruler/straight edge

E.4 Selection of Coating Systems and Data Collection Locations

Note: A completed copy of this procedure with all tables below filled out and signed by the coatings data collection team members will be prepared for each plant included in the survey.

1. Perform a documentation review to identify the plant's coating system(s) by manufacturer and product number. Record the coating system data on Table E-1.
2. Identify areas of concrete substrate and areas of steel substrates that are coated with documented, DBA-qualified coating systems.

Table E-1
Coating System Data

Plant & Unit	**Oconee Nuclear Station Unit 2**		
Dates of Coatings Work	Circa 1969	Circa 1969	N/A
Substrate	**1st Coat Manufacturer**	**2nd Coat Manufacturer**	**3rd Coat Manufacturer**
System Number	**Product #**	**Product #**	**Product #**
Concrete	Carboline	Carboline	N/A
1	195	Phenoline 305	
Concrete	Carboline	Carboline	N/A
2	195	Phenoline 305	
Concrete	Carboline	Carboline	N/A
3	2011S*** Needs Validation	Phenoline 305	
Steel	Carboline	Carboline	N/A
4	Cz11	Phenoline 305	
Steel	Carboline	Carboline	N/A
5	Cz11	Phenoline 305	
Steel	N/A	N/A	N/A
	N/A	N/A	N/A

Note: For additional coating systems at one plant, complete as many tables as necessary.

E.5 Coating Condition Assessment

1. Perform a general visual coating assessment of the selected areas using the general guidance of ASTM D5163-05a (see items 2 and 3 below).
2. For steel substrate areas:

    2.1 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

        2.1.1 Document the area with photographs.

        2.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

        2.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

        2.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

        2.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

    2.2 Select a suitable steel substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

        2.2.1 Document the area **with** photographs.

        2.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

        2.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

2.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

2.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3. For concrete substrate areas:

3.1 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually sound and intact coating for adhesion testing.

3.1.1 Document the area with photographs.

3.1.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.1.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.1.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull-off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.1.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

3.2 Select a suitable concrete substrate area that has been identified by the plant licensee as DBA-qualified and exhibits visually degraded coating for performance of adhesion testing adjacent to the degraded coating area.

3.2.1 Document the area with photographs.

3.2.2 Select and mark six "spots" (see SSPC-PA2, Figure A1 for defining "spots") to perform adhesion testing.

3.2.3 Perform dry film thickness measurements at each of the six "spots" in accordance with SSPC-PA 2, ASTM D4138-94 (Reapproved 2001) and/or ASTM D6132-04 as appropriate.

3.2.4 Attach a dolly at three "spots" for adhesion pull testing. Conduct pull off adhesion testing in accordance with ASTM D4541-02 and the test device manufacturer's instructions.

3.2.5 At the remaining three "spots," perform knife adhesion testing in accordance with ASTM D6677-05. Document the area with photographs, and record the results.

E.6 Data Recording

1. Record in Tables E-2, E-3, E-4, and E-5, respectively, the dry film thickness results collected in accordance with 2.1.3, 2.2.3, 3.1.3, and 3.2.3 (in Section E.5 above).

Note: For multiple coating systems at one plant, complete as many tables as necessary to collect all required data.

2. Record in Tables E-2, E-3, E-4, and E-5, respectively, the pull-off adhesion results collected in accordance with 2.1.4, 2.2.4, 3.1.4, and 3.2.4 (in Section E.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.
3. Examine each of the dollies used in the pull-off test (see 2.1.4, 2.2.4, 3.1.4, and 3.2.4 in Section E.5 above), and evaluate each dolly according to ASTM D4541-02 Section 8. Record the results in Tables E-2, E-3, E-4, and E-5, respectively.
4. Record in Tables E-2, E-3, E-4, and E-5, respectively, the knife adhesion results collected in accordance with 2.1.5, 2.2.5, 3.1.5, and 3.2.5 (in Section E.5 above). For degraded areas where the coating is scraped back to sound areas, describe the type of degradation, the size of the remediated area, and any other relevant information.

Table E-2
Concrete Substrate Sound Coating

Plant & Unit	**ONS 2**	**Dates**	**5/9–10/2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT – Tooke Gauge**	**Serial No. N/A**

System #/Sample ID#	1A	1B	1C
System Application/Use	'D'ring wall outside 3rd floor		
DFT Readings (mils) Surfacer/Topcoat	10/5	10/5	10/5
ASTM D4541-02, Elcometer Pull-Off Results (psig)	300	290	410
Elcometer Pull-Off Dolly Evaluation	100% intracoat failure	100% intracoat failure	100% intracoat failure
ASTM D6677-05, Adhesion by Knife Results	6	6	6
System #/Sample ID#	3A	3B	3C
System Application/Use	Basement floor under landing for elevator		
DFT Readings (mils) surfacer/topcoat	12/7	12/7	12/7
ASTM D4541-02, Elcometer Pull-Off Results (psig)	200	320	250
Elcometer Pull-Off Dolly Evaluation	100% cohesive failure of surfacer	100% cohesive failure of surfacer	100% cohesive failure of surfacer
ASTM D6677-05, Adhesion by Knife Results	4	4	8

Table E-3
Concrete Substrate Surrounding Degraded

Plant & Unit	**ONS 2**	**Dates**	**5/9-10/2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT – Tooke Gauge**	**Serial No. N/A**

System #/Sample ID#	2A	2B	2C
System Application/Use	'D'Ring wall outside 3rd floor		
Describe Degraded Area, Type, Size, Etc.	Delamination, cracking, peeling of topcoat from surfacer		
DFT Readings (mils) surfacer/topcoat	15/5	15/5	15/5
ASTM D4541-02, Elcometer Pull-Off Results (psig)	410	270	380
Elcometer Pull-Off Dolly Evaluation	60% failure of concrete 40% intracoat failure	100% intracoat failure	15% failure of concrete 85% intracoat failure
ASTM D6677-05, Adhesion by Knife Results	8	6	6
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	NA		
DFT Readings (mils)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Results (psig)	NA	NA	NA
Elcometer Pull-Off Dolly Evaluation	NA	NA	NA
ASTM D6677-05, Adhesion by Knife Results	NA	NA	NA

Table E-4
Steel Substrate Sound Coating

Plant & Unit	**ONS 2**	**Dates**	**5/9-10/2007**
Elcometer Model 106 Adhesion Tester Serial No.	**AH2010**	**DFT - Quanix 2000**	**Serial No. 140671**

System #/Sample ID#	4A	4B	4C
System Application/Use	Liner plate 3rd floor stairwell		
DFT Readings (mils)	6.8	7.3	7.2
ASTM D4541-02, Elcometer Pull-Off Results (psig)	370	600	440
Elcometer Pull-Off Dolly Evaluation	100% cohesive failure of topcoat	100% cohesive failure of topcoat	75% cohesive failure of topcoat, 25% cohesive failure of primer
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
DFT Readings (mils)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Results (psig)	NA	NA	NA
Elcometer Pull-Off Dolly Evaluation	NA	NA	NA
ASTM D6677-05, Adhesion by Knife Results	NA	NA	NA

Table E-5
Steel Substrate Surrounding Degraded

Plant & Unit	ONS 2	Dates	5/9-10/2007
Elcometer Model 106 Adhesion Tester Serial No.	AH2010	DFT - QuanixSerial No.	601812
System #/Sample ID#	5A	5B	5C
System Application/Use	Liner plate 3rd floor stairwell		
Describe Degraded Area, Type, Size, Etc.	Delamination, cracking, peeling of topcoat from primer		
DFT Readings (mils)	6.4	6.1	6.1
ASTM D4541-02, Elcometer Pull-Off Results (psig)	400	840	450
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation	90% cohesive failure of primer, 10% cohesive failure of topcoat	75% cohesive failure of primer, 25% cohesive failure	40% cohesive failure of primer, 60% cohesive failure
ASTM D6677-05, Adhesion by Knife Results	10	10	10
System #/Sample ID#	NA	NA	NA
System Application/Use	NA		
Describe Degraded Area, Type, Size, Etc.	NA		
DFT Readings (mils)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Results (psig)	NA	NA	NA
ASTM D4541-02, Elcometer Pull-Off Dolly Evaluation	NA	NA	NA
ASTM D6677-05, Adhesion by Knife Results	NA	NA	NA

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