INDUSTRY COATINGS PIRT REPORT NO. IC99-02

PWR Containment Coatings Research Program
Phenomena Identification and Ranking Tables (PIRT's)

by

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June 16, 2000

ADAMS Accession Number ML003733475

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Executive Summary

The United States Nuclear Regulatory Commission (NRC) has sponsored the formation of a Phenomena Identification and Ranking Table (PIRT) panel to identify and rank phenomena and process associated with the failure of protective coatings (paints) qualified for use inside pressurized water reactor (PWR) containment buildings. For the purposes of the PIRT, failure of a coating is defined as the detachment of the coating from the surface to which it was applied. The PIRT's documented herein will be used to support decision making regarding analytical, experimental, and modeling efforts related to the study of qualified coatings used inside PWR containments and their failure.

The current NRC research program is focused on the post-accident behavior of qualified coating systems used inside containment. Qualified coatings are those coatings that have undergone design basis accident (DBA) testing and have been demonstrated to remain on the surface to which they were initially applied. Therefore, qualified coatings are typically not considered as a source of post-accident debris.

However, ongoing indications from industry suggest that there are failures of qualified coatings under normal service conditions. Hence, the NRC has undertaken a research program to study coating performance from a materials science perspective.

The PIRT development process facilitates the structured collection and documentation of informed (expert) judgement with respect to phenomena identification and ranking. The quality and accuracy of a PIRT are directly related to the expertise of the panel members and the technical database available to the panel. For this PIRT activity, a modest database of experimental and technical results existed to support the PIRT effort. A vita for each member of the PIRT panel is presented in Appendix A.

There are a number of PWR containment types, including large dry, subatmospheric, and ice condenser designs. In addition, there are a number of qualified coating types that are used inside containment. An essential element of the PIRT process is that the panel focuses on a specific containment design, accident scenario, and coating type for a given PIRT. Once the initial PIRT is completed, other coatings types can be considered for the same containment design and scenario. Also, using the same coating, other containment designs and / or scenarios can be considered. These additional PIRT would build on the initial PIRT.

For this effort, the panel identified the base configuration as a Westinghouse four-loop PWR with a large, dry containment. The panel selected a double-ended cold-leg large-break LOCA for the baseline scenario.

The event scenario was divided into five time phases;

- ❑ Phase 1: Normal operation
- ❑ Phase 2: 0 - 40 Seconds After Initiation of LOCA
- ❑ Phase 3: 40 Seconds - 30 Minutes After Initiation of LOCA
- ❑ Phase 4: 30 Minutes - 2 Hours After Initiation of LOCA
- ❑ Phase 5: > 2 Hours After Initiation of LOCA

Each phase was characterized with respect to physical conditions, important phenomena and processes, and equipment operation.

The panel identified a primary evaluation criteria for judging the relative importance of the phenomena and processes to the failure of qualified coatings used inside containment. The primary evaluation criteria was the coating remaining attached to the surface to which it was applied. Each phenomena or process identified by the panel was ranked relative to its importance with respect to its affect on the ability of the coating being considered to remain attached to the surface of application. Highly ranked phenomena and processes were judged to have a dominant impact with respect to the primary evaluation criteria. Medium-ranked phenomena and processes were judged to have a moderate impact with respect to the primary evaluation criteria. Low-ranked phenomena were processes were judged to have a small impact with respect to the primary evaluation criteria.

A total of five (5) coatings systems were subjected to the PIRT process by the panel. These coating systems were judged by the panel members to be those most commonly used as qualified coating systems inside PWR containments. The phenomena and processes ranked as high relative to the primary evaluation criteria varied somewhat with the type of coating considered. The detailed results of the panel's identification and ranking efforts are tabulate and presented in Section 4 of this document. The rationale for the rankings are given in Appendix C.

Acknowledgements

Several organizations and individuals were most support of the PIRT panel efforts. Although the PIRT panel maintained an independent and separate perspective, the panel acknowledges help received from:

- ❑ Aleck Serkiz of the NRC's Office of Nuclear Regulatory Research, for his help in facilitating the panel's understanding of needs, as well as providing invaluable assistance and support in each of the panel's meetings.

- ❑ Natraj C. Iyer, Poh-Sang Lam, Robert Sindelar, Eric Skidmore, and Philip Zapp of the Savannah River Technology Center, for their help in facilitating the panel's understanding of the experimental and developmental work being performed by their organization in support of extending the knowledge base for coatings performance and failure mechanisms from a materials science perspective.

- ❑ The Westinghouse Owners Group and the Westinghouse Electric Company, LLC, for their support in the compilation and production of this final report.

Nomenclature

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DBA	Design Basis Accident
ECCS	Emergency Core Cooling System
EPRI	Electric Power Research Institute
GSI	Generic Safety Issue
LOCA	Loss of Coolant Accident
NA	Not Applicable
NEI	Nuclear Energy Institute
NPP	Nuclear Power Plant
NRC	United States Nuclear Regulatory Commission
PIRT	Phenomena Importance Ranking Table
PWR	Pressurized Water Reactor
SRTC	Savannah River Technical Center
SSC	Systems, Structures and Components
SSPC	Steel Structures Painting Council
USI	Unresolved Safety Issue

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1. INTRODUCTION

The United States Nuclear Regulatory Commission (NRC) has commissioned the formation of a Phenomena Identification and Ranking Table (PIRT) panel to identify and rank the phenomena and processes associated with Pressurized Water Reactor (PWR) containment coating failure mechanisms, failed coating debris characteristics and time to failure in normal operating and accident conditions. This report collects and documents the findings of the Industry Coatings PIRT panel.

The report is organized into four sections and contains five supporting appendices. Section 1, Introduction, summarizes the issues associated with PWR containment coatings failure, provides and overview of the PIRT process, identifies the members of the PWR containment coatings PIRT panel, and identifies the objectives of the PWR containment coatings PIRT effort. Section 2, PIRT preliminaries, describes elements of the PIRT process, as applied to the PWR containment coatings failure issue, that precede the identification and ranking of phenomena and processes. Section 3, Data Bases, documents the elements of the experimental and analytical database reviewed and used by the Industry Coating PIRT Panel members in support of the phenomena identification and ranking process. Section 4, Coating System PIRT's, contains the PIRT's for PWR containment coating failure for each of the five phases into which the accident scenario was partitioned, namely normal operation for full plant life (40 to 60 years) followed by medium to large break LOCA, 0 to 40 seconds after LOCA initiation, 40 seconds to 30 minutes after LOCA initiation, 30 minutes to 2 hours after LOCA initiation, and >2 hours after LOCA initiation. Brief experience summaries for each Panel member are provided in Appendix A, phenomena descriptions for the Industry Coatings PIRT are contained in Appendix B, and the ranking rationales for the Industry Coatings PIRT are contained in Appendix C.

Although not directly related to the PIRT process itself, application guides for inorganic zinc and epoxy coatings are included as Appendices D and E, respectively, for background information.

1.1 Background

10 CFR 50.46[1-1], "Acceptance Criteria of Emergency Core Cooling Systems for Light Water Nuclear Reactors" requires all light water reactors to provide an emergency core cooling system (ECCS) that is designed to meet five criteria. One of these criteria specifies the requirement for maintenance of long-term cooling. The specific criterion is 10 CFR 50.46(b)(5), which states, "After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radio-activity of the core."

The issue of degradation of long-term cooling by debris transport and deposition was considered during the early 1980's through efforts associated with Unresolved Safety Issue (USI) A-43. The resolution of USI A-43 was documented in NRC Generic Letter 85-22[1-2] and NRC Regulatory Guide 1.82 Revision 1[1-3]. Subsequent incidents involving foreign and domestic Boiling Water Reactor (BWR) ECCS strainer blockages prompted the issuance of NRC Bulletin 96-03[1-4] and NRC Regulatory Guide 1.82, Revision 2[1-5]. Corrective actions were required in BWR plants that could not certify sufficient core cooling.

On July 14, 1998, NRC Generic Letter 98-04[1-6], "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." Among other sources of containment debris, Generic Letter 98-04 expressed concern that containment coatings had failed during normal plant and might also fail in plant accident conditions, thus creating debris which might adversely impact ECCS operation.

The insights developed from the BWR strainer blockage evaluation has prompted the NRC to reassess debris blockage of PWR sumps to determine if there is a need for further actions to be taken for PWR's beyond the original resolution of USI A-43. This reassessment is contained in the scope of Generic Safety Issue (GSI)-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance"[1-7]. In support of this effort, the subject of PWR containment coatings as a contributing source of debris is being reviewed both analytically and experimentally by a NRC research project.

1.2 PIRT Panel Members

The Industry Coatings PIRT panel members were recommended by industry sources and approved by the NRC. The selected individuals provide extensive expertise concerning coating failure mechanisms, failed coating debris characteristics and time to failure of containment coating systems.

The Industry Coatings PIRT Panel members are:

- ❑ Jon R. Cavallo, P.E., Corrosion Control Consultants and Labs, Inc., Panel Chairman
- ❑ Timothy S. Andreychek, Westinghouse Electric Company, LLC
- ❑ Jan Bostelman, P.E., ITS Corporation
- ❑ Dr. Brent Boyack, P.E., Los Alamos National Laboratory
- ❑ Garth Dolderer, Florida Power and Light Corporation
- ❑ David Long, retired (formerly of Keeler & Long, Inc.)

Brief experience summaries for each panel member are contained in Appendix A.

1.3 PIRT Overview

The PIRT process has evolved from its initial development and application1to its description as a generalized process. After development, a PIRT can be used to support several important decision-making processes. For example, the information obtained through the application of the PIRT process can be used to support definition of requirements for related experiments and/or analytical tools. Because importance ranking is a fundamental element of the PIRT process, requirements can be prioritized with respect to their contributions to the reactor phenomenological response to the accident scenario. Because it is neither cost effective nor required to assess and examine all the parameters and models in a best-estimate code (or supporting experiment) in a uniform fashion, the methodology focuses on those processes and phenomena that dominate the transient behavior, although all plausible effects are considered. This screening of plausible phenomena, to determine those which dominate the plant response, ensures a sufficient and efficient analysis. PIRTs are not computer code-specific; that is, PIRTs are applicable to the scenario and plant design regardless of which code may be chosen to perform the subsequent safety analysis.

A typical application of the PIRT process is conceptually described as follows. The PIRT process focuses on phenomena/processes that are important to the particular scenario, or class of transients, in the specified nuclear power plant (NPP), i.e., those that drive events. Plausible physical phenomena and processes, and their associated system components are identified. From a modeling perspective, phenomena/processes important to a plant response to an accident scenario can be grouped in two separate categories: 1) higher level system interactions (integral) between components/subsystems and 2) those local to (within) a component/subsystem. The identification of plausible phenomena is focused toward component organization, but experience has indicated it can be most helpful to relate the phenomena to higher level integral system processes. Time can often be saved when it can be demonstrated that a higher level integral system process is of low importance during a specific time phase. A subsequent and equally important step is the partitioning o the plant into components/subsystems. This latter step is a significant aid in organizing and ranking phenomena/processes. The phenomena/processes are then ranked with respect to their influence on the primary evaluation criteria, to establish PIRTs. Primary evaluation criteria (or criterion) are normally based on regulatory safety requirements such as those related to restrictions in fuel rods (peak clad temperature, hydrogen generation, etc.) and/or containment operation (peak pressure, emergency core cooling system performance, etc.). The rank of a phenomenon or process is a measure of its relative influence on the primary criteria (criterion). The identification and ranking are justified and documented.

The relative importance of phenomena is time dependent as an accident progresses. Thus, it is convenient to partition accident scenarios into time phases in which the dominant phenomena/processes remain essentially constant; each phase is separately investigated. The

processes and phenomena associated with each component are examined, as are the inter-relations between the components. Cause and effect are differentiated. The processes and phenomena and their respective importance (rank) are judged by examination of experimental data, code simulations related to the plant and scenario, and the collective expertise and experience of the evaluation team. Independent techniques to accomplish the ranking include expert opinion, subjective decision making methods (such as the Analytical Hierarchy Process), and selected calculations. The final product of application of the PIRT process is a set of tables (PIRTs) documenting the ranks (relative importance) of phenomena and processes, by transient phase and by system component. Supplemental products include descriptions of the ranking scales, phenomena and processes definitions, evaluation criteria, and the technical rationales for each rank. In the context of the PIRT process application to PWR containment coatings failures, the primary elements of interest are described in Section 2. The PIRTs resulting from this specific application are documented in Section 4.

1.4 PIRT Objectives

The objectives of the Industry Coatings PIRT panel are:

1. To identify coatings systems applied to steel and concrete substrates in PWR containments to be considered for the PIRT process,

2. To identify phenomena and processes for coatings applied inside PWR containments, and,

3. To rank those phenomena and processes with respect to their importance to coating failures.

The PIRT's developed by the Industry Coatings PIRT panel are documented for use in future NRC sponsored analytical, experimental and modeling efforts conducted as part of the GSI-191 study, particularly the Nuclear Power Plant Coatings Program being conducted by Savannah River Technology Center.

1.5 References

1-1 10 CFR 50.46, "Acceptance Criteria of Emergency Core Cooling Systems for Light Water Nuclear Reactors" revised as of January 1, 1995

1-2 United States Nuclear Regulatory Commission Generic Letter 85-22, "Potential For Loss of Post LOCA Recirculation Capability Due to Insulation Debris Blockage." December 3, 1985

1-3 United Sates Nuclear Regulatory Commission Regulatory Guide 1.82 Revision 1, "Water Sources for Long Term Recirculation Cooling Following a Loss-of-Coolant Accident"

1-4 United States Nuclear Regulatory Commission Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors"

1-5 United States Nuclear Regulatory Commission Regulatory Guide 1.82, Revision 2, "Water Sources for Long Term Recirculation Cooling Following a Loss-of-Coolant Accident"

1-6 United States Nuclear Regulatory Commission Generic Letter 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."

1-7 Generic Safety Issue (GSI)-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance"

2.0 PIRT PRELIMINARIES

Several important preliminary steps must be completed in advance of the identification and ranking efforts of the PIRT process. The PIRT objective was defined and documented in Section 1.4. During the PIRT development process, each PIRT is developed for a specific coating system and scenario. The scenario, in turn, is considered plant specific to a plant design. This is done because the both the occurrence of the phenomena and processes and the importance of the phenomena and processes are specific to the scenario (and hence, plant design) and the coating system being considered. After considering other coating systems and scenarios, it may be possible for the PIRT panel to certify that the PIRT presented here have broader applicability.

The coatings considered by the PIRT panel was limited to those coatings historically used as qualified coatings inside containment. A discussion of coatings systems qualified for use inside containment is given in Section 2.1. A description of coating system components, used to evaluate coating system performance by type of application, is given in Section 2.2. The plant scenario selected for the PWR containment coatings PIRT effort is discussed in Section 2.3. Acknowledging that a phenomena or process may not have the same impact on a coating over the full duration of a scenario, the phases of the specific scenario used for the PIRT development are discussed in Section 2.4. The PIRT panel performs the ranking of the phenomena and processes relative to a primary evaluation criterion. Therefore, it is important to explicitly define this criterion, which is done in Section 2.5. The ranking scale agreed to by the PIRT panel members was also agreed to and is explicitly defined in Section 2.6. Finally, several figures are provided to illustrate and aid in the understanding of the phenomena and processes identified by the PIRT panel.

2.1 Generic Qualified Coatings Systems for PWR Containments

The Industry Coatings PIRT Panel members initially drew from the panel's collective experience and reviewed EPRI Report TR-106160, "Coatings Handbook for Nuclear Power Plants" to identify various qualified coatings systems which have been applied to the interior surfaces of PWR containment structures, systems and components (SSC's). Two major considerations accounted for by the panel in selecting coating systems for which a PIRT would be constructed were:

1. The frequency with which that system was considered to be generally used inside containments, and,
2. The volume that a coating system was considered to be generally used inside containment.

After compilation of the panel's listing, eight generic qualified coatings systems were identified

for consideration by the panel. Subsequent to identifying these eight systems, information collected by the containment survey containment conducted by the Nuclear Energy Institute was used to identify a ninth qualified coating system to be considered by the PIRT Panel.

The nine qualified coating systems identified and considered by this PIRT Panel are:

1. Steel substrate, inorganic zinc primer, epoxy phenolic topcoat,
2. Steel substrate, epoxy phenolic primer, epoxy phenolic topcoat,
3. Steel substrate, inorganic zinc primer, epoxy topcoat,
4. Steel substrate, epoxy primer, epoxy topcoat,
5. Concrete substrate, surfacer, epoxy phenolic topcoat,
6. Concrete substrate, surfacer, epoxy topcoat,
7. Concrete substrate, epoxy phenolic primer, epoxy phenolic topcoat,
8. Concrete substrate, epoxy primer, epoxy topcoat, and,
9. Steel substrate, untopcoated inorganic zinc primer (added per the NEI survey)

PIRT's for systems (1), (4), (6), (8) and (9) are included in this report.

2.2 Coating System Components

To enable development of the individual PIRT's, the Industry Coatings PIRT Panel partitioned the qualified coating systems into components as follows:

STEEL SUBSTRATE COATED WITH A PRIMER AND A TOPCOAT	CONCRETE SUBSTRATE COATED WITH A SURFACER AND A TOPCOAT
Steel Substrate ❑ Substrate ❑ Substrate/Primer Interface ❑ Primer ❑ Primer/Topcoat Interface ❑ Topcoat	Concrete Substrate ❑ Substrate ❑ Substrate/Surfacer Interface ❑ Surfacer ❑ Surfacer/Topcoat Interface ❑ Topcoat

STEEL SUBSTRATE COATED ONLY WITH A PRIMER	CONCRETE SUBSTRATE COATED WITH A PRIMER AND A TOPCOAT
Steel Substrate ❏ Substrate ❏ Substrate/Primer Interface ❏ Primer	Concrete Substrate ❏ Substrate ❏ Substrate/Primer Interface ❏ Primer ❏ Primer/Topcoat Interface ❏ Topcoat

2.3 Accident Scenario

The Industry Coatings PIRT Panel discussed a number of accident scenarios postulated for occurrence in PWR plants and their potential effects on containment SSC coating systems and the generation of coating debris which could transport to PWR containment sump(s). The following coating failure scenario was selected by the panel for use in its subsequent deliberations:

1. Normal plant operation, including outages, for 40 years (potentially longer due to plant life extension),

2. Mechanical damage (see Figures 2.3.a., 2.3.b., and 2.3.c. for illustration of incipient and developed defects in coatings on concrete and steel substrates),

3. Chemical damage (from plant process fluid leakage and overspray/leakage of decontamination chemicals),

4. Normal plant operation for 40 years (potentially longer due to plant life extension) followed by a large LOCA without jet impingement (note: small break LOCA was not considered because containment spray is not initiated and thus significant coating debris transport to the sump(s) is not probable).

Scenarios 1, 2, 3, and 4 above may occur independently or synergistically to cause coating failure.

The Industry Coatings PIRT Panel excluded jet impingement due to LOCA from its deliberations

as industry test experience indicates that none of the coating systems applied to PWR SSC's will survive direct steam impingement.

2.4 Scenario Phases

To develop the requisite PIRT's, the Industry Coatings PIRT Panel partitioned the coating failure scenario into convenient time phases. These phases, outlined below, are based on conditions associated with a Westinghouse 4-loop PWR with a dry ambient containment.

PHASE 1: Normal Operation Followed by LOCA, No Jet Impingement

(-) Time	Coating System Installation
	- Surface Preparation
	- Coating Application
	- Curing
	Integrated Leak Rate Testing (ILRT)
T = 0	Start of Power Operations
T = 40 years	Medium / Large Break LOCA Occurs (T could be 60 years in the case of plant life extension)

PHASE 2: 0 to 40 Seconds After Start of LOCA

PHASE 3: 40 Seconds to 30 Minutes After Start of LOCA

PHASE 4: 30 Minutes to 2 Hours After Start of LOCA

PHASE 5: Greater Than 2 Hours After Start of LOCA

A discussion of the phenomena associated with each of the event phases identified above is contained in Appendix B to this report.

2.5 Primary Evaluation Criterion

The primary evaluation criterion, or parameter of interest, considered by the Industry Coatings PIRT Panel concerning coatings on PWR Containment SSC's is:

> "Will the coating system completely detach from the surface to which it is applied?"

2.6 Phenomena Ranking Scale

PIRT's historically developed for complex hierarchical, multi-leveled scenarios have traditionally utilized a labor-intensive Analytical Hierarchy Process ranking methodology. The Industry Coatings PIRT Panel decided to use a simplified ranking scale as described below because of the relatively simplistic nature of containment coatings PIRT's.

Ranking Scales

High - Phenomena has a dominant impact on the primary parameter of interest. Phenomena will be explicitly considered in the implementation of the Savannah River Technical Center (SRTC) Research Program

Medium - Phenomena has a moderate influence on the primary parameter of interest. Phenomena will also be considered in the implementation of the SRTC Research Program

Low - Phenomena has a small effect on the primary parameter of interest. Phenomena will also be considered in the implementation of the SRTC Research Program, to the extent possible

2.7 Figures

As the PIRT's were developed, the panel found it beneficial to construct several figures to illustrate the failure mechanisms associated with various substrates and coatings systems. These figures are included in this report for the benefit of the reader.

Figure 2.7-(a): Illustration of Coating Defects, Steel Substrate

Figure 2.7-(b): Illustration of Coating Defects, Concrete Substrate

Figure 2.7-(c): Illustration of Coating Defects, Concrete Substrate

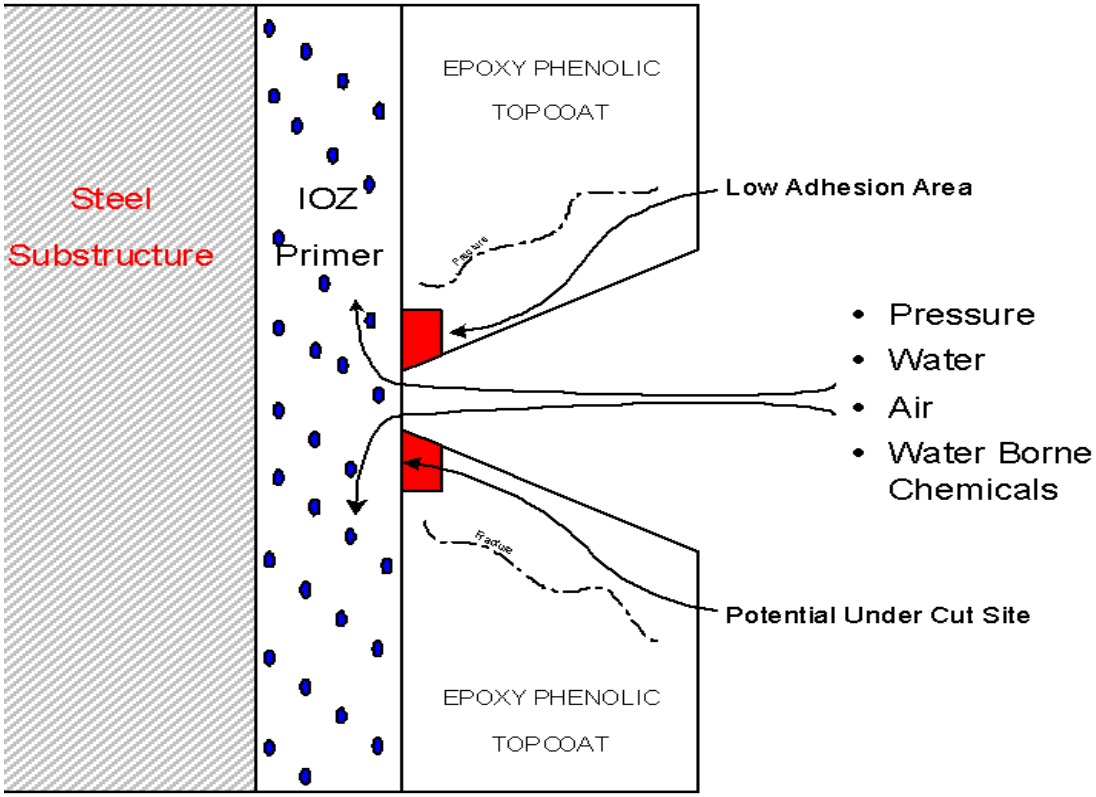

Figure 2.7-(a): Illustration of Coatings Defects; Steel Substrate

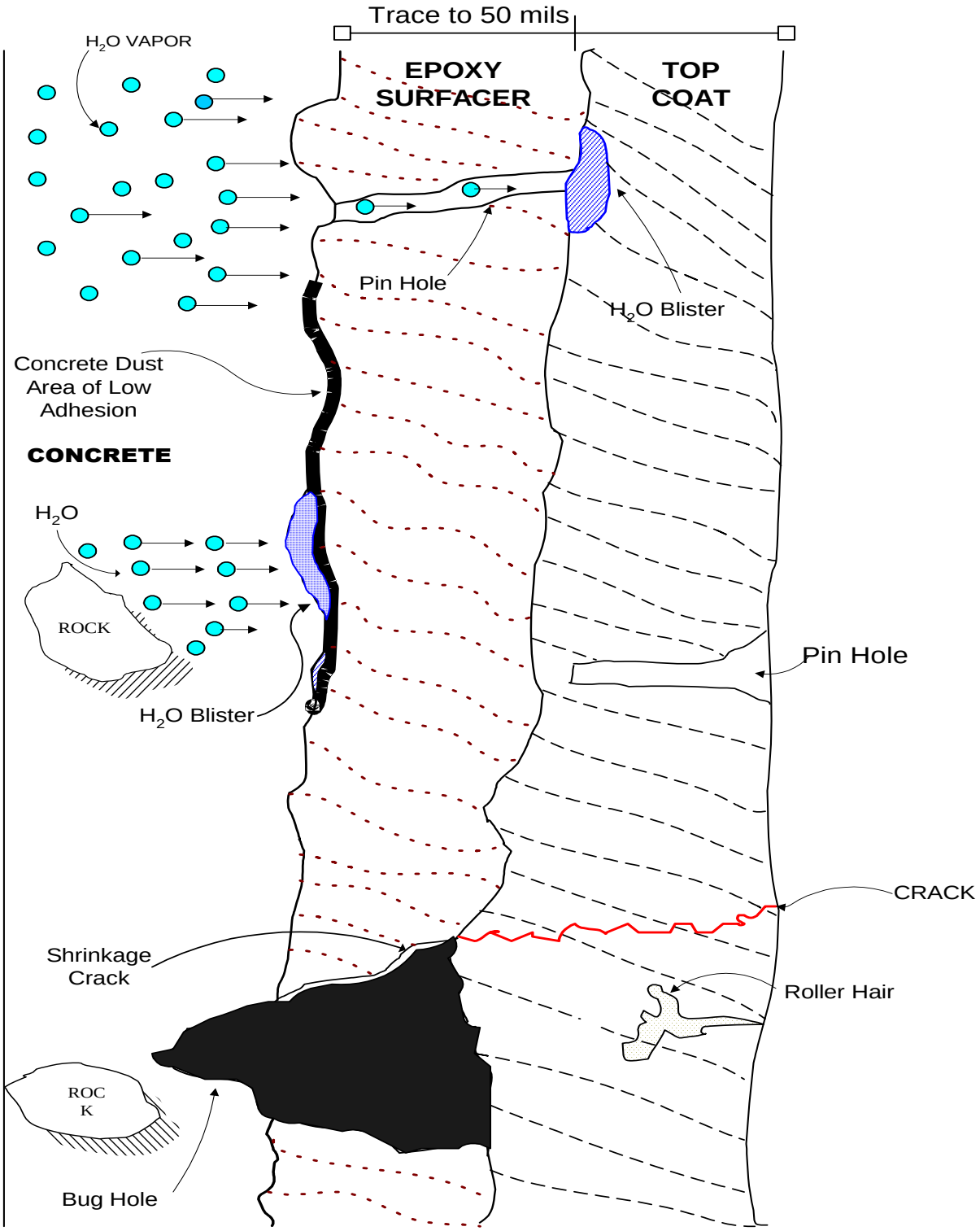

Figure 2.7-(b): Illustration of Coating Defects, Concrete Substrate

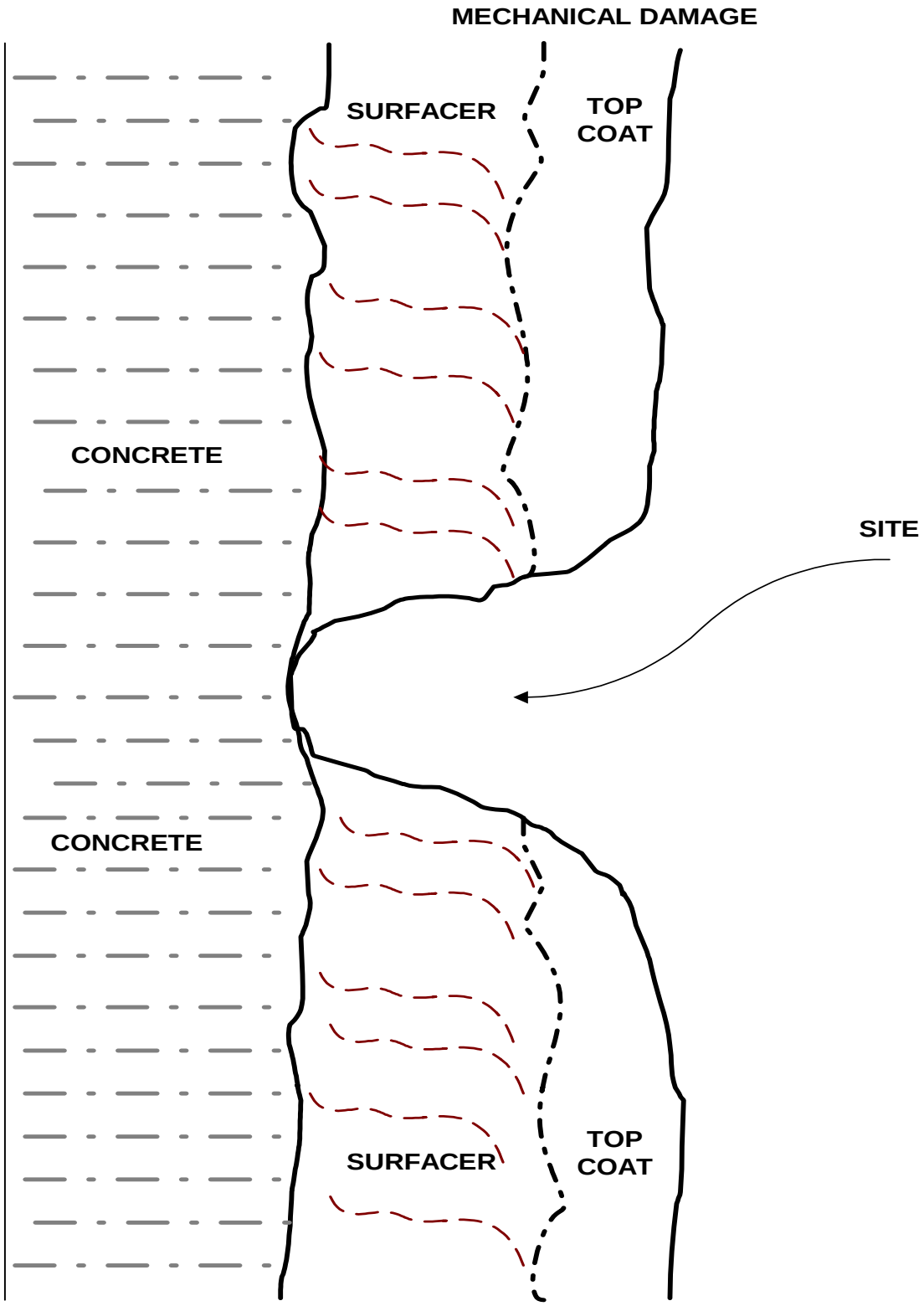

Figure 2.7-(c): Illustration of Coating Defects, Concrete Substrate

3.0 DATA BASES

Although identification and ranking of processes and phenomena rely heavily on the expertise of the PIRT panel, both of these efforts proceed best when information databases are available to and used by the PIRT panel in the formulation of their judgements. Listed below are the sources of information available to and used by the PIRT panel in the effort documented herein.

3.1 Experimental, Analytical, Emperical Databases

The Industry Coatings PIRT Panel identified various experimental, analytical and empirical data bases applicable to the PIRT effort. These data bases are:

- ANSI N101.2-1972, "Protective Coatings (Paints) for Light-Water Nuclear Reactor Containment Facilities"
- ASTM D3911, "Test method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions"
- EPRI Report TR-106160, "Coatings Handbook for Nuclear Power Plants"
- EPRI Report TR-109937, "Guideline on Nuclear Safety-Related Coatings
- DBA testing performed for coatings used inside containment (pre-ANSI N101.2) provided by various utilities and coatings manufacturers
- DBA testing performed for coatings used inside containment (post-ANSI N101.2) provided by various utilities and coatings manufacturers
- DBA testing performed for coatings used inside containment (ASTM D3911) provided by various utilities and coatings manufacturers
- Coatings research data provided by Savannah River Technical Center
- Various industry data, containment coating condition walkdown data, industry sponsored environmental qualification data
- Data provided in NRC Generic Letter 98-04
- Nuclear Energy Institute (NEI) Sump Design Survey Results

4.0 COATING SYSTEM PIRT's

PIRT tables for five (5) coatings systems are presented in this section. As identified in Section 2.4, "Scenario Phases," a postulated large break LOCA event was segregated into five (5) phases. PIRT tables are presented for each phase of the postulated event for each coating system.

These PIRTs represent the informed judgement of the PIRT panel members regarding both the process and phenomena that are expected to occur during the event and the relative importance of those processes and phenomena. The importance of each process and phenomena was evaluated relative to the primary evaluation criteria defined in Section 2.5:

> "Will the coating system completely detach from the surface to which it is applied?"

4.1 Table Structure

The structure of the PIRT tables is:

- Column 1 - Phase of the event.
- Column 2 - Component of the coating system; for example, the substrate.
- Column 3 - Higher level process or phenomena with that is associated with the component at that phase of the event.
- Column 4 - Process or phenomena relative importance rank. The ranking scheme is identified in Section 2.6.
- Column 5 - Definition of the process or phenomena being ranked.

4.2 Applicability of PIRTs to Other Containments

A postulated LOCA for a Westinghouse 4-loop PWR with a dry ambient containment was used as the basis for defining the scenario. However, the scenario appears to be representative of PWR designs with dry ambient containments. Thus, it is expected that the processes and phenomena identified in the tables given in this section are generally applicable to all dry containments.

There are two significant differences in the phenomena associated with the postulated LOCA event for ice condenser containments compared to a dry containment. First, the bulk containment pressure associated with an ice condenser plant is nominally about 1/3 the peak value predicted for a dry containment. Second, the water pool on the ice condenser containment floor builds to greater depths more quickly than is the case for dry containments. Thus, a greater volume of coatings in the lower regions of an ice condenser containment are submerged earlier in the scenario than for a dry containment. It is expected that these changes would have a small effect on the relative ranking of the processes and phenomena for an ice condenser.

Thus, the PIRT tables presented here may be used as a tool to support plant specific decision-making about either the capabilities of analytical tools or details of experimental test programs, providing the focus of the decision is on identified processes and phenomena. However, if decisions are to be made based on the relative ranking of phenomena, it is recommended that a mini-PIRT activity be conducted to ensure either the rankings apply to the specific facility, or revised rankings specific to the facility of interest are generated.

4.3 Applicability of PIRTs to Other Coating Systems

Processes and phenomena have been identified for the five (5) specific coatings systems considered under this effort. Many of these phenomena are common to the performance of other coating systems. However, there may be other processes or phenomena, unique to a coating system, that have not be identified because they are not applicable to with coating systems considered under this effort. Similarly, the processes and phenomena identified for the coatings systems included under the current effort may not be applicable to other coating systems.

Thus, it is suggested that caution be exercised in the application of the current PIRTs to other coating systems. Rather, it is recommended that a PIRT activity be convened and the current PIRT tables be utilized as a base upon which to construct a coating-specific PIRT table for the selected scenario.

INDUSTRY COATINGS PIRT TABLE 4.1

Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat

Table 4.1-1:	Normal Operation
Table 4.1-2:	0 - 40 Seconds After Initiation of LOCA
Table 4.1-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table 4.1-4	30 Minutes - 2 Hours After Initiation of LOCA
Table 4.1-5	> 2 Hours After Initiation of LOCA

INDUSTRY COATING PIRT TABLE 4.1-1: NORMAL OPERATION

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 1 Normal Operation	Substrate (Steel)	Expansion/contraction	Low	Pressure/temperature induced expansion/contraction of liner plate
	Substrate/Primer Interface	Differential expansion/contraction	Low	Differing rates between substrate and primer
	Primer (Inorganic Zinc)	Expansion/contraction Differential expansion/contraction stresses Oxidation Film splitting Environmental exposure Minor coating anomalies	Low Low Low Medium Low Medium	Pressure/temperature induced expansion/contraction within primer Differing rates between filler and binder Semi-permeable membrane permits migration of moisture and air (oxygen) Cohesive failure within the zinc film; zinc fails in shear, epoxy pulls zinc apart Heat, brittleness, breaking of bonds Result from normal application process
	Primer/Topcoat Interface	Differential expansion/contraction	Medium	Differing rates between primer and topcoat
	Topcoat (Epoxy Phenolic)	Expansion/contraction Environmental exposure Discoloration Mechanical damage Minor coating anomalies	Medium High Low Medium Low	Pressure/temperature induced expansion/contraction Changes in properties over time Polymer chemical changes Normal wear and tear Result from normal application process

INDUSTRY COATING PIRT TABLE 4.1-2: 0-40 SECONDS AFTER INITIATION OF LOCA

Coating Description: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 2 0-40 Seconds (Outside Zone of Influence)	Substrate (Steel)	Expansion Temperature gradient Increased radiation exposure	Low Low Low	Temperature increases due to energy releases expansion Pressure expansion is greater Primary coolant released to containment environment
	Substrate/primer Interface	Differential expansion/contraction	Low	Pressure/temperature induced contraction at liner plate
	Primer (Inorganic Zinc)	Expansion/contraction Differential expansion/contraction stresses Film splitting Temperature gradient Increased radiation exposure Diffusion rate of air/water Minor coating anomalies Environmental exposure Chemical, air, moisture intrusion	Low Low Medium Low Low Low High Low Low	Pressure/temperature induced expansion/contraction within primer Differing rates between filler and binder Cohesive failure within the zinc film; zinc fails in shear, epoxy pulls zinc apart Bulk thermal stresses Primary coolant released to containment environment Increases concentration of air/water Result from normal application process Heat, brittleness, breaking of bonds Mechanical damage sites from phase 1
	Primer/topcoat Interface	Differential expansion/contraction Diffusion rate of air/water	High Low	Differing rates between primer and topcoat Increased concentration of air/water
	Topcoat (Epoxy Phenolic)	Expansion/contraction Temperature gradient Diffusion rate of air/water Increased radiation exposure Condensation (cold wall) Mechanical damage	High Low Low Low Low Low	Pressure/temperature induced expansion/contraction Thermal stresses Increased concentration of air/water Primary coolant adjacent to structure Heating the wall with condensed steam DBA-generated flying debris

INDUSTRY COATING PIRT TABLE 4.1-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

Coating Description: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 3 40 Sec - 30 Min (Outside Zone of Influence)	Substrate (Steel)	Contraction Temperature gradient Increased radiation exposure	Low Low Low	Containment pressure decreasing Temperature increases due to energy releases expansion Pressure expansion is greater
	Substrate/primer Interface	Differential contraction	Low	Pressure/temperature induced contraction at liner plate
	Primer (Inorganic Zinc)	Contraction Differential contraction stresses Film splitting Temperature gradient Increased radiation exposure Diffusion rate of air/water Chemical attack Minor coating anomalies	Low Low Medium Low Low Medium Low Medium	Pressure/temperature induced contraction within primer Differing rates between filler and binder Cohesive failure within the zinc film; zinc fails in shear, epoxy pulls zinc apart Bulk thermal stresses Primary coolant released to containment environment Increases concentration of air/water From boric acid at locations of topcoat mechanical damage Result from normal application process
	Primer/topcoat Interface	Differential contraction Diffusion rate of air/water	High High	Differing rates between primer and topcoat Increased concentration of air/water
	Topcoat (Epoxy Phenolic)	Contraction Temperature gradient Diffusion rate of air/water Increased radiation exposure Condensation (cold wall) Wash down of surfaces	High Low Low Low Low Low	Pressure/temperature induced contraction at liner plate Thermal stresses Increased concentration of air/water Primary coolant and noble gases adjacent to structure Heating the wall with condensed steam Water films from containment spray

INDUSTRY COATING PIRT TABLE 4.1-4: 30 MINUTES - 2 HOURS. AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 4 30 min - 2 hrs (outside Zone of Influence)	Substrate (Steel)	Contraction Temperature gradient Increased radiation exposure	Low Low Low	Containment pressure increase Temperature increases due to energy releases expansion
	Substrate/Primer Interface	Differential contraction	Low	Pressure/temperature induced contraction at liner plate
	Primer (Inorganic Zinc)	Contraction Differential contraction stresses Film splitting Temperature gradient Increased radiation exposure Diffusion rate of air/water above pool surface Chemical attack Minor coating anomalies Moisture and air intrusion through damage sites Water intrusion below pool surface	Low Low Medium Low Low Medium Medium Medium Medium Low	Pressure/temperature induced contraction within primer Differing rates between filler and binder Cohesive failure within the zinc film; Zinc fails in shear, epoxy pulls zinc apart Bulk thermal stresses Failure due radiation exposure Increase in pressure, humidity drives moisture into primer Boric acid attack at locations of topcoat mechanical damage Areas of mechanical damage and/or minor coating anomalies In topcoat at areas of mechanical damage and/or minor coating anomalies Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer/Topcoat Interface	Differential contraction Diffusion rate of air/water	Low High	Differing rates between substrate, primer and coating Increased concentration of air/water

INDUSTRY COATING PIRT TABLE 4.1-4: 30 MINUTES - 2 HOURS. AFTER INITIATION OF LOCA

	Topcoat (Epoxy Phenolic)	Contraction	Low	Pressure/temperature induced contraction at liner plate
		Temperature gradient	Low	Thermal stresses
		Diffusion of air/water	Low	Increased concentration of air/water
		Increased radiation exposure	Low	Primary coolant adjacent to structure
		Condensation (cold wall)	Low	Heating the wall with condensed steam
		Wash down of surfaces	Low	Water films from containment spray
		Immersion to pool surface	Low	Coatings submersed in coolant pool on containment floor

INDUSTRY COATINGS PIRT TABLE 4.1-5: >2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 5 **2 hrs - end** **(outside Zone of Influence)**	Substrate (Steel)	Contraction Temperature gradient Increased radiation exposure	Low Low Low	Containment pressure decrease due to cooling of containment Temperature changes associated with containment cooling Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential contraction	Low	Pressure/temperature induced contraction at liner plate
	Primer (Inorganic Zinc)	Contraction Differential contraction stresses Film splitting Temperature gradient Increased radiation exposure Diffusion of air/water Chemical attack Minor coating anomalies Moisture and air intrusion through damage sites Water intrusion below pool surface	Low Low Medium Low Low High Low High High Medium	Pressure/temperature induced contraction in primer Differing rates between substrate, primer and coating Cohesive failure within the zinc film; zinc fails in shear, epoxy pulls zinc apart Bulk thermal stresses Primary coolant adjacent to structure Increases concentration of air/water From boric acid at locations of topcoat mechanical damage Topcoat imperfections at areas of mechanical damage and/or application variations Ingress at areas of mechanical damage and/or minor coating anomalies in topcoat Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer/Topcoat Interface	Differential contraction Diffusion of air/water	Low High	Differing rates between primer and topcoat Increased concentration of air/water

INDUSTRY COATINGS PIRT TABLE 4.1-5: >2 HOURS AFTER INITIATION OF LOCA

	Topcoat (Epoxy Phenolic)	Contraction	Low	Pressure/temperature induced contraction at liner plate
		Temperature gradient	Low	Thermal stresses
		Diffusion of air/water	Medium	Increased concentration of air/water
		Increased radiation exposure	Low	Primary coolant adjacent to structure
		Condensation (cold wall)	Low	Heating the wall with condensed steam
		Chemical attack	Low	Reaction to changing pH of recirculating sump water
		Immersion to pool surface	Medium	Coatings submersed in coolant pool on containment floor

INDUSTRY COATINGS PIRT TABLE 4.2

Concrete Substrate, Surfacer, Epoxy Topcoat

Table 4.2-1:	Normal Operation
Table 4.2-2:	0 - 40 Seconds After Initiation of LOCA
Table 4.2-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table 4.2-4	30 Minutes - 2 Hours After Initiation of LOCA
Table 4.2-5	> 2 Hours After Initiation of LOCA

INDUSTRY COATING PIRT TABLE 4.2-1: NORMAL OPERATION

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 1 Normal Operation	Substrate (Concrete)	Outgassing / vapor expansion	High	Phase 1 vapor migration through concrete damage from ILRT
		Pressure gradients from ILRT's	Medium	Experience from Phase 1 ILRT shows coatings have come off from rapid depressurizations
		Temperature gradients	Low	Temperature changes due to normal operations
		Compression / expansion	Low	Pressure changes due to normal operation
		Increased radiation exposure	Low	Radiation damage due to normal operations
	Substrate/surfacer Interface	Calcium carbonate buildup	Medium	Potential pure vapor long term
		Differential expansion and contraction	Low	Differential growth due to changes in pressure, temperature
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	High	Vapor collection under surface
	Surfacer	Bulk movement	Low	Expansion of concrete due to temperature changes
		Environmental exposure	Medium	Exposure to heat over time
		Small coating anomalies	High	Variations in coating due to application
		Cracking	Low	Not observed from experience; not considered likely
		Chemical exposure	Low	Top coat protects the surfacer
		Water diffusion (from concrete)	Low	Not by bulk diffusion; can occur through pathways through top coat
		Mechanical damage	Low	Damage from wear normal wear and tear
		Water intrusion from pool	Na	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Small gradients during normal operation
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Through pathways through top coat
		Increased radiation exposure	Low	Radiation damage associated with normal operations

INDUSTRY COATING PIRT TABLE 4.2-1: NORMAL OPERATION

	Surfacer/Topcoat Interface	Differential expansion and contraction	Low	No difference in relative thermal expansion coefficients of the topcoat and surfacer
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	High	Vapor collection under the top coat
	Topcoat (Epoxy)	Bulk movement	Low	No movement; thermal expansion of concrete is small
		Temperature gradient	Low	Does not have an effect on top coat
		Increased radiation exposure	Low	Low; based on test data
		Diffusion air/water	Low	Small vapor transmissivity rate
		Coating anomalies	High	Pathways for air and water buildup
		Environmental exposure	High	Lots of exposure to heat over time
		Chemical attack	Low	Formulated to withstand chemicals
		Cracking	Low	Based on walkdowns of containments/drywells, etc.
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Condensation / cold wall	Low	Coating formulated to resist cold wall effects
		Immersion in pool	NA	Soaking of coatings in coolant; not in this phase
		Washdown	NA	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.2-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 2 0-40 Seconds (outside Zone of Influence)	Substrate (Concrete)	Outgassing / vapor expansion	High	Phase 2 vapor migration through concrete damage
		Pressure gradients	High	Loading due to rapid pressure changes
		Temperature gradients	Low	Would not degrade concrete
		Compression / expansion	Low	No evidence of significant impact
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/surfacer Interface	Calcium carbonate buildup	Low	Potential pure vapor long term
		Differential expansion/contraction	Low	Surfacer designed to withstand expansion/contraction
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	High	Vapor collection between substrate and surfacer
	Surfacer	Bulk movement	Low	Movement of surfacer due to thermal expansion
		Environmental exposure	Low	Exposure to heat over time
		Minor coating anomalies	High	Perturbations in coating due to application process
		Cracking	Low	Not observed from experience; not considered likely
		Chemical exposure	Low	Interaction of surfacer with chemicals in environment
		Water diffusion (from concrete)	Low	Bulk diffusion through pathways through top coat
		Mechanical damage	Low	Damage due to impact loading
		Water intrusion from pool	NA	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Transient heat up of surfacer
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Air and water migration through pathways through top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Surfacer/topcoat Interface	Differential expansion/contraction	Low	Difference in relative thermal expansion of the topcoat and surfacer
		Blistering/delamination	High	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under the top coat

INDUSTRY COATING PIRT TABLE 4.2-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

	Topcoat (Epoxy)	Bulk movement	Low	No movement; thermal expansion of concrete is small
		Temperature gradient	Low	Does not have an effect on top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Small vapor transmissivity rate
		Coating anomalies	High	Pathways for air and water buildup
		Environmental exposure	Low	Lots of exposure to heat over time
		Chemical attack	Low	Formulated to withstand chemicals
		Cracking	Low	Based on walkdowns of containments/drywells, etc.
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Condensation / cold wall	Low	Coating formulated to resist cold wall effects
		Immersion in pool	NA	NA for this phase of event
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.2-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 3 40 Sec - 30 Min (outside Zone of Influence)	Substrate (concrete)	Outgassing / vapor expansion	High	Vapor migration through concrete damage
		Pressure gradients	High	Experience from Phase 1 ILRT shows coatings have come off from rapid depressurizations
		Temperature gradients	Low	Would not degrade concrete
		Compression / expansion	Low	No evidence of significant impact
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Surfacer Interface	Calcium carbonate buildup	Low	Potential pure vapor long term
		Differential expansion/contraction	Low	Surfacer designed to withstand expansion/contraction
		Blistering/delamination	High	Pressure and thermal loading changes
		Vapor buildup	High	Vapor collection under surface
	Surfacer	Bulk movement	Low	Thermal expansion of concrete
		Environmental exposure	Low	Lot of exposure over time to heat
		Coating anomalies	High	Pathway for vapor transmission
		Cracking	Low	Not observed from experience; not considered likely
		Chemical exposure	Low	Top coat protects the surfacer
		Water diffusion (from concrete)	Low	Migration of water through pathways in top coat
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Water intrusion from pool	NA	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Low, does not affect the surfacer
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Low, only through pathways through top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Surfacer/Topcoat interface	Differential expansion/contraction	Low	No difference in relative thermal expansion coefficients of the topcoat and surfacer
		Blistering/delamination	High	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under the top coat

INDUSTRY COATING PIRT TABLE 4.2-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Bulk movement	Low	No movement; thermal expansion of concrete is small
		Temperature gradient	Low	Does not have an effect on top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Small vapor transmissivity rate
		Coating anomalies	High	Pathways for air and water buildup
		Environmental exposure	Low	Lots of exposure to heat over time
		Chemical attack	Low	Formulated to withstand chemicals
		Cracking	Low	Based on walkdowns of containments/drywells, etc.
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Condensation / cold wall	Low	Coating formulated to resist cold wall effects
		Immersion in pool	NA	NA for this phase of event
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.2-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 4 30 min - 2 hrs (outside Zone of Influence)	Substrate (Concrete)	Outgassing / vapor expansion	Medium	Vapor migration through concrete
		Pressure gradients	Low	Delamination due to rapid pressure changes
		Temperature gradients	Low	Response to changes in containment environment temperature
		Compression / expansion	Low	No evidence of significant impact
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Surfacer Interface	Calcium carbonate buildup	Low	Potential pure vapor long term
		Differential expansion and contraction	Low	Surfacer designed to withstand expansion/contraction
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	Medium	Vapor collection under surface
	Surfacer	Bulk movement	Low	Movement of surfacer due to temperature changes
		Environmental exposure	Low	Exposure over time to heat
		Coating anomalies	Medium	Variation in finish due to application process
		Cracking	Low	Not observed from experience; not considered likely
		Chemical exposure	Low	Top coat protects the surfacer
		Water diffusion (from concrete)	Low	Migration can occur through pathways through top coat
		Mechanical damage	Low	Degradation of coating due to normal wear and tear
		Water intrusion from pool	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Low, does not affect the surfacer
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Low, only through pathways through top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Surfacer/Topcoat Interface	Differential expansion/contraction	Low	No difference in relative thermal expansion coefficients of the topcoat and surfacer
		Blistering/delamination	High	
		Vapor buildup	Medium	Vapor collection under the top coat

INDUSTRY COATING PIRT TABLE 4.2-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Bulk movement	Low	No movement; thermal expansion of concrete is small
		Temperature gradient	Low	Does not have an effect on top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Small vapor transmissivity rate
		Coating anomalies	Medium	Pathways for air and water buildup
		Environmental exposure	Low	Lots of exposure to heat over time
		Chemical attack	Low	Formulated to withstand chemicals
		Cracking	Low	Break in coating surface due to tension in coating
		Mechanical damage	Low	Local coating failure due to impact loading
		Condensation / cold wall	Low	Liquid infusion into coating due to cold walls
		Immersion in pool	Low	Submergence of coatings in coolant in lower containment
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.2-5: >2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 5 2 hrs - end (outside Zone of Influence)	Substrate (concrete)	Outgassing / vapor expansion	Medium	Vapor migration through concrete damage from ILRT
		Pressure gradients from ILRT's	Low	Experience from Phase 1 ILRT shows coatings have come off from rapid depressurizations
		Temperature gradients	Low	Thermal response to containment transient
		Compression / expansion	Low	No evidence of significant impact
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Surfacer Interface	Calcium carbonate buildup	Medium	Potential pure vapor long term
		Differential expansion/contraction	Low	Surfacer designed to withstand expansion/contraction
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	Medium	Vapor collection under surface
	Surfacer	Bulk movement	Low	Thermal expansion of concrete
		Environmental exposure	Medium	Lot of exposure over time to heat
		Coating anomalies	Medium	Pathway for vapor transmission
		Cracking	Low	Not observed from experience; not considered likely
		Chemical exposure	Low	Top coat protects the surfacer
		Water diffusion (from concrete)	Low	Not by bulk diffusion; can occur through pathways through top coat
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Water intrusion from pool	Medium	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Low, does not affect the surfacer
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Low, only through pathways through top coat
		Increased radiation exposure	Low	Low; based on test data
	Surfacer/Topcoat Interface	Differential expansion/contraction	Low	No difference in relative thermal expansion coefficients of the topcoat and surfacer
		Blistering/delamination	High	Pressure and thermal loading
		Vapor buildup	Medium	Vapor collection under the top coat

INDUSTRY COATING PIRT TABLE 4.2-5: >2 HOURS AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Bulk movement	Low	No movement; thermal expansion of concrete is small
		Temperature gradient	Low	Does not have an effect on top coat
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Small vapor transmissivity rate
		Coating anomalies	Medium	Pathways for air and water buildup
		Environmental exposure	Medium	Lots of exposure to heat over time
		Chemical attack	Low	Formulated to withstand chemicals
		Cracking	Low	Based on walkdowns of containments/drywells, etc.
		Mechanical damage	Low	Does not affect bulk coating integrity; low priority
		Condensation / cold wall	Low	Coating formulated to resist cold wall effects
		Immersion in pool	Medium	Increased importance due to time in this phase of event
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATINGS PIRT TABLE 4.3

Steel Substrate, Epoxy Primer, Epoxy Topcoat

Table 4.3-1:	Normal Operation
Table 4.3-2:	0 - 40 Seconds After Initiation of LOCA
Table 4.3-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table 4.3-4	30 Minutes - 2 Hours After Initiation of LOCA
Table 4.3-5	> 2 Hours After Initiation of LOCA

INDUSTRY COATING PIRT TABLE 4.3-1: NORMAL OPERATION

COATING DESCRIPTION: Steel Substrate, Epoxy Primer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 1 **Normal Operation**	Substrate (steel)	Expansion and contraction	Low	Liner plate response to changes in containment pressure and temperature due to normal operation and ILRT's.
		Increased radiation exposure	Low	Neutron fluence generated due to operations.
	Substrate/Primer Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion between substrate and primer.
		Cold wall effect	Low	Condensation of water from warmer, humid atmosphere to surfaces of cooler steel structures.
		Oxidation	Low	Chemical interaction of moisture and air at the surface of the substrate (substrate/primer interface).
	Primer (epoxy)	Expansion and contraction	Low	Primer response to changes in containment pressure and temperature due to normal operation and ILRT's.
		Oxidation	Low	Chemical interaction of moisture, air and the primer coat.
		Environmental exposure	High	Exposure to ambient conditions (heat) during operations.
		Minor coating anomalies	Low	Results from normal application process.
		Mechanical damage	High	Damage due to dropped equipment.
		Increased radiation exposure	Low	Neutron fluence generated due to operations.
	Primer/Topcoat Interface	Differential expansion and contraction	Low	Differing rates between primer and topcoat
		Air, water and chemical intrusion	Low	Changes in concentration of air/water
		Blistering and delamination	High	Breaking of bonds between primer and topcoat.

INDUSTRY COATING PIRT TABLE 4.3-1: NORMAL OPERATION

	Topcoat (epoxy)	Expansion and contraction	Low	Topcoat response to changes in containment pressure and temperature due to normal operation and ILRT's.
		Oxidation	Low	Chemical interaction of moisture, air and the primer coat.
		Environmental exposure	High	Exposure to ambient conditions (heat) during operations.
		Discoloration	Low	Polymer chemical changes.
		Minor coating anomalies	Low	Results from normal application process.
		Mechanical damage	High	Damage due to dropped equipment.
		Increased radiation exposure	Low	Neutron fluence generated due to operations.

INDUSTRY COATING PIRT TABLE 4.3-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Epoxy Primer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 2 0-40 Seconds (outside Zone of Influence)	Substrate (steel)	Expansion	Low	Containment pressurization and thermal expansion.
		Temperature gradient	Low	Conduction from surface through base metal.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion between substrate and primer.
		Cold wall effect	Low	Condensation of water from warmer, humid atmosphere to surfaces of cooler steel structures.
		Oxidation	Low	Chemical interaction of moisture and air at the surface of the substrate (substrate/primer interface).
		Blistering and delamination	High	Breaking of bonds between primer and substrate.
	Primer (Epoxy)	Expansion and contraction	Low	Primer response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the primer coat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Low	Results from normal application process.
		Mechanical damage	Low	Damage due to LOCA generated debris.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion	Low	Increase in concentration at damage sights.
	Primer/Topcoat Interface	Differential expansion and contraction	Low	Differing rates between primer and topcoat
		Air, water and chemical intrusion	Low	Increased concentration of air/water
		Blistering and delamination	High	Breaking of bonds between primer and topcoat.

INDUSTRY COATING PIRT TABLE 4.3-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Expansion and contraction	Medium	Topcoat response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the topcoat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Low	Results from normal application process.
		Mechanical damage	Low	Damage due to LOCA generated debris.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion	Low	Increase in concentration at damage sights.
		Cold wall effects	Low	Condensation of water from warmer, humid atmosphere to surface of cooler coating.
		Chemical attack	Low	Reaction to water-bourne chemicals.

INDUSTRY COATING PIRT TABLE 4.3-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Epoxy Primer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 3 **40 Sec - 30 Min** **(outside Zone of Influence)**	Substrate (steel)	Expansion Temperature gradient Increased radiation exposure	Low Low Low	Containment pressurization and thermal expansion. Conduction from surface through base metal. Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential expansion and contraction Cold wall effect Oxidation Blistering and delamination	Low Low High High	Different coefficients of thermal expansion between substrate and primer. Condensation of water from warmer, humid atmosphere to surfaces of cooler steel structures. Chemical interaction of moisture and air at the surface of the substrate (substrate/primer interface). Breaking of bonds between primer and substrate.
	Primer (Epoxy)	Expansion and contraction Oxidation Environmental exposure Minor coating anomalies Mechanical damage Increased radiation exposure Temperature gradient Air, water and chemical diffusion Air, water and chemical intrusion ● Above pool ● Below pool Chemical attack	Low Low Medium Low Low Low Low Low Medium Low Low	Primer response to changes in containment pressure and temperature due to LOCA. Chemical interaction of moisture, air and the primer coat. Exposure to ambient conditions (heat) during LOCA. Results from normal application process. Damage due to LOCA generated debris. Radiation damage due to increased radioactivity from event Response to changing heat transfer at coating surface. Increase in containment pressure. Increase in concentration at damage sights. Increase in concentration at damage sights. Reaction to water-bourne chemicals.
	Primer/Topcoat Interface	Differential expansion and contraction Air, water and chemical intrusion Blistering and delamination	Low Low High	Differing rates between primer and topcoat Increased concentration of air/water Breaking of bonds between primer and topcoat.

INDUSTRY COATING PIRT TABLE 4.3-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Expansion and contraction	Low	Topcoat response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the topcoat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Medium	Results from normal application process.
		Mechanical damage	Low	Damage due to dropped equipment.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion		
		• Above pool	Medium	Increase in concentration at damage sights.
		• Below pool	Low	Increase in concentration at damage sights.
		Cold wall effects	Low	Condensation of water from warmer, humid atmosphere to surface of cooler coating.
		Chemical Attack	Low	Reaction to water-bourne chemicals.

INDUSTRY COATING PIRT TABLE 4.4-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 4 **30 min - 2 hrs** **(outside Zone of Influence)**	Substrate (steel)	Expansion	Low	Containment pressurization and thermal expansion.
		Temperature gradient	Low	Conduction from surface through base metal.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion between substrate and primer.
		Cold wall effect	Low	Condensation of water from warmer, humid atmosphere to surfaces of cooler steel structures.
		Oxidation	High	Chemical interaction of moisture and air at the surface of the substrate (substrate/primer interface).
		Blistering and delamination	High	Breaking of bonds between primer and substrate.
	Primer (epoxy)	Expansion and contraction	Low	Primer response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the primer coat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Low	Results from normal application process.
		Mechanical damage	Low	Damage due to LOCA generated debris.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion		
		• Above pool	Medium	Increase in concentration at damage sights.
		• Below pool	Low	Increase in concentration at damage sights.
		Chemical attack	Low	Reaction to water-bourne chemicals.
	Primer/Topcoat Interface	Differential expansion and contraction	Low	Differing rates between primer and topcoat
		Air, water and chemical intrusion	Low	Increased concentration of air/water
		Blistering and delamination	High	Breaking of bonds between primer and topcoat.

INDUSTRY COATING PIRT TABLE 4.4-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

	Topcoat (epoxy)	Expansion and contraction	Low	Topcoat response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the topcoat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Medium	Results from normal application process.
		Mechanical damage	Low	Damage due to LOCA generated debris.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion		
		• Above pool	Medium	Increase in concentration at damage sights.
		• Below pool	Low	Increase in concentration at damage sights.
		Cold wall effects	Low	Condensation of water from warmer, humid atmosphere to surface of cooler coating.
		Chemical attack	Low	Reaction to water-bourne chemicals.

INDUSTRY COATINGS PIRT TABLE 4.4-5: >2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 5 **2 hrs - end** **(outside Zone of Influence)**	Substrate (steel)	Expansion Temperature gradient Increased radiation exposure	Low Low Low	Containment pressurization and thermal expansion. Conduction from surface through base metal. Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential expansion and contraction Cold wall effect Oxidation Blistering and delamination	Low Low High High	Different coefficients of thermal expansion between substrate and primer. Condensation of water from warmer, humid atmosphere to surfaces of cooler steel structures. Chemical interaction of moisture at the surface of the substrate (substrate/primer interface). Breaking of bonds between primer and substrate.
	Primer (epoxy)	Expansion and contraction Oxidation Environmental exposure Minor coating anomalies Mechanical damage Increased radiation exposure Temperature gradient Air, water and chemical diffusion Air, water and chemical intrusion ● Above pool ● Below pool Chemical attack	Low Low High High Low Low Low Medium High High Low	Primer response to changes in containment pressure and temperature due to LOCA. Chemical interaction of moisture, air and the primer coat. Exposure to ambient conditions (heat) during LOCA. Results from normal application process. Damage due to LOCA generated debris. Radiation damage due to increased radioactivity from event Response to changing heat transfer at coating surface. Increase in containment pressure. Increase in concentration at damage sights. Increase in concentration at damage sights. Reaction to water-bourne chemicals.
	Primer/Topcoat Interface	Differential expansion and contraction Air, water and chemical intrusion Blistering and delamination	Low Low High	Differing rates between primer and topcoat Increased concentration of air/water Breaking of bonds between primer and topcoat.

	Topcoat (epoxy)	Expansion and contraction	Low	Topcoat response to changes in containment pressure and temperature due to LOCA.
		Oxidation	Low	Chemical interaction of moisture, air and the topcoat.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	Medium	Results from normal application process.
		Mechanical damage	Low	Damage due to LOCA generated debris.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Temperature gradient	Low	Response to changing heat transfer at coating surface.
		Air, water and chemical diffusion	Low	Increase in containment pressure.
		Air, water and chemical intrusion		
		• Above pool	Medium	Increase in concentration at damage sights.
		• Below pool	High	Increase in concentration at damage sights.
		Cold wall effects	Low	Condensation of water from warmer, humid atmosphere to surface of cooler coating.
		Chemical attack	Medium	Reaction to water-bourne chemicals.

INDUSTRY COATINGS PIRT TABLE 4.4

Concrete Substrate, Epoxy Primer, Epoxy Topcoat

Table 4.4-1: Normal Operation

Table 4.4-2: 0 - 40 Seconds After Initiation of LOCA

Table 4.4-3: 40 Seconds - 30 Minutes After Initiation of LOCA

Table 4.4-4: 30 Minutes - 2 Hours After Initiation of LOCA

Table 4.4-5: > 2 Hours After Initiation of LOCA

INDUSTRY COATING PIRT TABLE 4.4-1: NORMAL OPERATION

COATING DESCRIPTION: Concrete Substrate, Epoxy Primer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 1 **Normal Operation**	Substrate (concrete)	Outgassing / vapor expansion	High	Vapor migration through concrete damage from ILRT
		Pressure gradients from ILRT	Medium	Pressurization and depressurization of containment volume
		Temperature gradients	Low	Temperature changes in substrate due to operations
		Compression / expansion	Low	Growth and shrinkage of substrate
		Increased radiation exposure	Low	Neutron fluence generated due to operations
	Substrate/Primer Interface	Calcium carbonate buildup	Medium	Due to long-term vapor migration from concrete.
		Differential expansion and contraction	Medium	Different coefficients of thermal expansion.
		Blistering/delamination	High	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under primer surface.
		Water intrusion/diffusion (from outside the topcoat)	Medium	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer	Bulk movement	Low	Driven by thermal expansion of concrete.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during operations
		Coating anomalies	High	Irregularities in primer coat due to debris, dust trapped in coating at time of application.
		Cracking	Medium	Breaks in primer coat.
		Chemical exposure	Low	Spillage of boric acid solution, etc.
		Water diffusion (from concrete)	Low	Drying of concrete; migration of water to interface.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Water intrusion from pool	NA	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Temperature changes due to operations.
		Water intrusion/diffusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Increased radiation exposure	Low	Neutron fluence generated due to operations.

INDUSTRY COATING PIRT TABLE 4.4-1: NORMAL OPERATION

	Primer/Topcoat Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Low	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under topcoat surface.
		Water intrusion/diffusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Topcoat (epoxy)	Bulk movement	Low	Driven by thermal expansion of concrete.
		Temperature gradient	Low	Temperature changes due to operations.
		Increased radiation exposure	Low	Neutron fluence generated due to operations.
		Diffusion air/water	Low	Through pathways in topcoat and primer
		Minor coating anomalies	High	Irregularities in primer coat due to debris, dust trapped in coating at time of application.
		Environmental exposure	High	Exposure to ambient conditions (heat) during operations
		Chemical attack	Low	Spillage of boric acid solution, etc.
		Cracking	Medium	Breaks in topcoat.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Condensation / cold wall	Low	Surface condensation, migration of water through topcoat.
		Immersion in pool	NA	Submergence in water; not in this phase of the event.
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.4-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 2 0-40 Seconds (outside Zone of Influence)	Substrate (concrete)	Outgassing / vapor expansion	High	Vapor migration through concrete.
		Pressure gradients	High	Pressurization and depressurization of containment volume due to LOCA.
		Temperature gradients	Low	Temperature changes in substrate due to LOCA
		Compression / expansion	Low	Effect of pressurization of substrate due to LOCA.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Calcium carbonate buildup	Low	Due to long-term vapor migration from concrete.
		Differential expansion/contraction	Medium	Different coefficients of thermal expansion.
		Blistering/delamination	High	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under primer surface.
		Water intrusion/diffusion (from Outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer	Bulk movement	Medium	Driven by thermal expansion of concrete.
		Environmental exposure	Low	Exposure to ambient conditions (heat) during LOCA.
		Coating anomalies	High	Irregularities in coating due to debris, dust trapped in coating at time of application.
		Cracking	Medium	Breaks in primer coat.
		Chemical exposure	Low	Spillage of boric acid solution, etc.
		Water diffusion (from concrete)	Low	Drying of concrete; migration of water to interface.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Water intrusion from pool	NA	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Medium	Temperature changes due to LOCA.
		Water/air diffusion (from outside the topcoat)	Low	Through pathways in topcoat and primer
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event

INDUSTRY COATING PIRT TABLE 4.4-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

	Primer/topcoat Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Low	Pressure and thermal loading.
		Vapor buildup	Low	Vapor collection under topcoat surface.
		Water intrusion/infusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Topcoat (epoxy)	Bulk movement	Medium	Driven by thermal expansion of concrete
		Temperature gradient	Medium	Temperature changes due to LOCA
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Through pathways in topcoat
		Coating anomalies	High	Irregularities in primer coat due to debris, dust trapped in coating at time of application
		Environmental exposure	Low	Exposure to ambient conditions (heat) during LOCA.
		Chemical attack	Low	Spillage of boric acid solution, etc.
		Cracking	Medium	Breaks in topcoat
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Condensation / cold wall	Low	Surface condensation, migration of water through topcoat
		Immersion in pool	NA	Submergence in water; not in this phase of the event
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT SUMMARY - TABLE 4.4-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Epoxy Primer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 3 40 Sec - 30 Min (outside Zone of Influence)	Substrate (concrete)	Outgassing / vapor expansion	High	Vapor migration through concrete.
		Pressure gradients	High	Depressurization of containment volume due to LOCA.
		Temperature gradients	Low	Temperature changes in substrate due to LOCA
		Compression / expansion	Low	Effect of pressurization of substrate due to LOCA.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Calcium carbonate buildup	Low	Due to long-term vapor migration from concrete.
		Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Medium	Pressure and thermal loading.
		Vapor buildup	High	Vapor collection under primer surface.
		Water intrusion/diffusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer	Bulk movement	Medium	Driven by thermal expansion of concrete.
		Environmental exposure	Low	Exposure to ambient conditions (heat) during LOCA.
		Minor coating anomalies	High	Irregularities in coating due to debris, dust trapped in coating at time of application.
		Cracking	Medium	Breaks in primer coat.
		Chemical exposure	Low	Spillage of boric acid solution, etc.
		Water diffusion (from concrete)	Low	Drying of concrete; migration of water to interface.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Water intrusion from pool	NA	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Medium	Temperature changes due to LOCA.
		Water/air diffusion (from outside the topcoat)	Low	Through pathways in topcoat and primer
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event

INDUSTRY COATING PIRT SUMMARY - TABLE 4.4-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

	Primer/Topcoat Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Low	Pressure and thermal loading.
		Vapor buildup	Low	Vapor collection under topcoat surface.
		Water intrusion/infusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Topcoat (epoxy)	Bulk movement	Medium	Driven by thermal expansion of concrete.
		Temperature gradient	Medium	Temperature changes due to LOCA.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Through pathways in topcoat
		Minor coating anomalies	High	Irregularities in primer coat due to debris, dust trapped in coating at time of application.
		Environmental exposure	Low	Exposure to ambient conditions (heat) during LOCA.
		Chemical attack	Low	Spillage of boric acid solution, etc.
		Cracking	Medium	Breaks in topcoat.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Condensation / cold wall	Low	Surface condensation, migration of water through topcoat.
		Immersion in pool	NA	Submergence in water; not in this phase of the event.
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.4-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 4 30 min - 2 hrs (outside Zone of Influence)	Substrate (Concrete)	Outgassing / vapor expansion Pressure gradients Temperature gradients Compression / expansion Increased radiation exposure	Medium Low Low Low Low	Vapor migration through concrete. Depressurization of containment volume due to LOCA. Temperature changes in substrate due to LOCA Effect of pressurization of substrate due to LOCA. Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Calcium carbonate buildup Differential expansion and contraction Blistering/delamination Vapor buildup Water intrusion/diffusion (from Outside the primer and topcoat)	Low Low High Medium Low	Due to long-term vapor migration from concrete. Different coefficients of thermal expansion. Pressure and thermal loading. Vapor collection under primer surface. Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Primer	Bulk movement Environmental exposure Coating anomalies Cracking Chemical exposure Water diffusion (from concrete) Mechanical damage Water intrusion from pool Temperature gradient Water/air diffusion (from outside the topcoat) Increased radiation exposure	Low Low Medium Medium Low Low Low Low Low Low Low	Driven by thermal expansion of concrete. Exposure to ambient conditions (heat) during LOCA. Irregularities in coating due to debris, dust trapped in coating at time of application. Breaks in primer coat. Spillage of boric acid solution, etc. Drying of concrete; migration of water to interface. Damage due to dropped equipment, etc. Water migration through topcoat at mechanical damage and minor coating anomaly sites Temperature changes due to LOCA. Through pathways in topcoat and primer Radiation damage due to increased radioactivity from event

INDUSTRY COATING PIRT TABLE 4.4-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

	Primer/Topcoat interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Low	Pressure and thermal loading.
		Vapor buildup	Low	Vapor collection under topcoat surface.
		Water intrusion/infusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Topcoat (epoxy)	Bulk movement	Low	Driven by thermal expansion of concrete.
		Temperature gradient	Low	Temperature changes due to LOCA.
		Increased radiation exposure	Low	Radiation damage due to increased radioactivity from event
		Diffusion air/water	Low	Through pathways in topcoat
		Coating anomalies	Medium	Irregularities in primer coat due to debris, dust trapped in coating at time of application.
		Environmental exposure	Low	Exposure to ambient conditions (heat) during operations
		Chemical attack	Low	Spillage of boric acid solution, etc.
		Cracking	Medium	Breaks in topcoat.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Condensation / cold wall	Low	Surface condensation, migration of water through topcoat.
		Immersion in pool	Low	Submergence in water pool formed on containment floor.
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATING PIRT TABLE 4.4-5: >2 HRS. AFTER INITIATION OF LOCA

COATING DESCRIPTION: Concrete Substrate, Surfacer, Epoxy Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 5 2 hrs - end (outside Zone of Influence)	Substrate (concrete)	Outgassing / vapor expansion	Medium	Vapor migration through concrete.
		Pressure gradients	Low	Depressurization of containment volume due to LOCA.
		Temperature gradients	Low	Temperature changes in substrate due to LOCA
		Compression / expansion	Low	Effect of pressurization of substrate due to LOCA.
		Increased radiation exposure	Low	Neutron fluence generated due to LOCA.
	Substrate/Primer Interface	Calcium carbonate buildup	Medium	Due to long-term vapor migration from concrete.
		Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	High	Pressure and thermal loading.
		Vapor buildup	Medium	Vapor collection under primer surface.
		Water diffusion (from outside the primer and concrete)	Low	Migration through pathways in the topcoat and primer.
	Primer	Bulk movement	Low	Driven by thermal expansion of concrete.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Coating anomalies	Medium	Irregularities in coating due to debris, dust trapped in coating at time of application.
		Cracking	Medium	Breaks in primer coat.
		Chemical exposure	Low	Spillage of boric acid solution, etc.
		Water diffusion (from concrete)	Low	Drying of concrete; migration of water to interface.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Water intrusion from pool	Medium	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Temperature gradient	Low	Temperature changes due to the LOCA.
		Water/air diffusion (from outside the topcoat above submerged level)	Low	Through pathways in topcoat and primer
		Increased radiation exposure	Low	Neutron fluence generated due to LOCA.

	Surfacer/Topcoat Interface	Differential expansion and contraction	Low	Different coefficients of thermal expansion.
		Blistering/delamination	Low	Pressure and thermal loading.
		Vapor buildup	Low	Vapor collection under topcoat surface.
		Water intrusion/infusion (from outside the topcoat)	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
	Topcoat (epoxy)	Bulk movement	Low	Driven by thermal expansion of concrete.
		Temperature gradient	Low	Temperature changes due to LOCA.
		Increased radiation exposure	Low	Neutron fluence generated due to LOCA.
		Diffusion air/water	Low	Through pathways in topcoat.
		Minor coating anomalies	Medium	Irregularities in primer coat due to debris, dust trapped in coating at time of application.
		Environmental exposure	Medium	Exposure to ambient conditions (heat) during LOCA.
		Chemical attack	Low	Spillage of boric acid solution, etc.
		Cracking	Medium	Breaks in topcoat.
		Mechanical damage	Low	Damage due to dropped equipment, etc.
		Condensation / cold wall	Low	Surface condensation, migration of water through topcoat.
		Immersion in pool	Medium	Submergence in water.
		Washdown	Low	Water flow due to containment spray and condensation

INDUSTRY COATINGS PIRT TABLE 4.5

Steel Substrate, Untopcoated Inorganic Zinc Primer

Table 4.5-1:	Normal Operation
Table 4.5-2:	0 - 40 Seconds After Initiation of LOCA
Table 4.5-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table 4.5-4	30 Minutes - 2 Hours After Initiation of LOCA
Table 4.5-5	> 2 Hours After Initiation of LOCA

INDUSTRY COATING PIRT TABLE 4.5-1: NORMAL OPERATION

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 1 Normal Operation	Substrate (Steel)	Expansion/contraction	Low	Movement of substrate due to changes in temperature and pressure
		Chemical attack	Low	Exposure of substrate to various plant chemicals
		Environmental attack	Medium	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Radiation damage	Low	Embrittlement due to neutron exposure
	Substrate/Primer Interface	Differential expansion and contraction	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation	Low	Corrosion of steel substrate and zinc through the zinc
		Cold-wall effect	Low	Condensation of water through the zinc on cool steel
	Primer (Inorganic Zinc)	Expansion/contraction	Low	Movement of primer due to changes in containment temperature, pressure and performing ILRT's
		Differential expansion and contraction stresses	Medium	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation	Medium	Corrosion of the zinc coating
		Environmental attack	Low	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Minor coating anomalies	Low	Inconsistent film properties associated with application
		Pigment/binder ratio	High	Varying concentration of binder and zinc through the thickness of the film
		Erosion	NA	Large areas of unbonded zinc produced during application and not required by specification to be removed
		Radiation damage	Low	Effects of neutron exposure due to plant operations
		Chemical attack	Low	Exposure of zinc coating to various plant chemicals
		Mechanical damage	Low	Minor film damage due to mechanical impact

INDUSTRY COATING PIRT TABLE 4.5-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 2 0-40 Seconds (outside Zone of Influence)	Substrate (Steel)	Expansion	Low	Movement of the substrate due to containment pressurization and heat-up
		Temperature gradient	Low	Development of a through-thickness temperature profile due to LOCA
		Chemical attack	Low	Exposure of substrate to various plant chemicals
		Environmental attack	NA	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential expansion and contraction	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation	Low	Corrosion of steel substrate and zinc through the zinc
		Cold-wall effect	Low	Condensation of water through the zinc on cool steel

INDUSTRY COATING PIRT TABLE 4.5-2: 0 - 40 SECONDS AFTER INITIATION OF LOCA

	Primer (Inorganic Zinc)	Expansion	Low	Movement of primer due to changes in containment temperature and pressure
		Differential expansion and contraction stresses	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Diffusion of air and water	Low	Migration of coolant through zinc film due to concentration gradients
		Oxidation	Low	Corrosion of the zinc coating
		Environmental attack	NA	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Minor coating anomalies	Low	Inconsistent film properties associated with application
		Pigment/binder ratio	Low	Varying concentration of binder and zinc through the thickness of the film
		Erosion	Low	Large areas of unbonded zinc produced during application and not required by specification to be removed
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
		Chemical attack	Low	Exposure of zinc coating to various plant chemicals
		Mechanical damage	Low	Minor film damage due to mechanical impact

INDUSTRY COATING PIRT TABLE 4.5-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 3 40 Sec - 30 Min (outside Zone of Influence)	Substrate (Steel)	Contraction	Low	Movement of the substrate due to containment cool-down and depressurization
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Chemical attack	Low	Exposure of substrate to various plant chemicals Exposure to airborne and waterborne contaminants associated with the plant site environment
		Environmental attack	NA	
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
	Substrate/primer Interface	Differential contraction	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation	Low	Corrosion of steel substrate and zinc through the zinc
		Cold-wall effect	Low	Condensation of water through the zinc on cool steel
	Primer (Inorganic Zinc)	Contraction	Low	Movement of primer due to changes in containment temperature and pressure
		Differential contraction stresses	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Diffusion of air and water	Low	Migration of coolant through zinc film due to concentration gradients
		Oxidation	Low	Corrosion of the zinc coating
		Environmental attack	NA	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Minor coating anomalies	Low	Inconsistent film properties associated with application
		Pigment/binder ratio	Low	Varying concentration of binder and zinc through the thickness of the film
		Erosion	Medium	Action of containment spray to carry away zinc film
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
		Chemical attack	Low	Exposure of zinc coating to various plant chemicals
		Mechanical damage	Low	Minor film damage due to mechanical impact

INDUSTRY COATING PIRT TABLE 4.5-3: 40 SECONDS - 30 MINUTES AFTER INITIATION OF LOCA

INDUSTRY COATING PIRT TABLE 4.5-4: 30 MINUTES - 2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 4 **30 min - 2 hrs** **(outside Zone of Influence)**	Substrate (Steel)	Contraction	Low	Movement of the substrate due to depressurization and cool-down of the containment
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Chemical Attack	Low	Exposure of substrate to various plant chemicals Exposure to airborne and waterborne contaminants associated with the plant site environment
		Environmental attack	NA	
		Radiation Damage	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential contraction	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation above the pool surface	Low	Corrosion of steel substrate and zinc through the zinc
		Oxidation below the pool surface	Low	Corrosion of steel substrate and zinc through the zinc
		Cold-wall effect	Low	Condensation of water through the zinc on cool steel

	Primer (Inorganic Zinc)	Contraction	Low	Movement of primer due to changes in containment temperature and pressure
		Differential contraction stresses	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Diffusion of air and water above pool surface	Low	Migration of coolant through zinc film due to concentration gradients
		Oxidation above pool surface	Medium	Corrosion of the zinc coating
		Oxidation below pool surface	Medium	Corrosion of the zinc coating
		Environmental attack	NA	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Minor coating anomalies	Low	Inconsistent film properties associated with application
		Pigment/binder ratio	Low	Varying concentration of binder and zinc through the thickness of the film
		Erosion	High	Action of containment spray to carry away zinc film
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
		Chemical attack above pool surface	Medium	Exposure of zinc coating to various plant chemicals
		Chemical attach below pool surface	Medium	Exposure of zinc coating to various plant chemicals
		Mechanical damage	Low	Minor film damage due to mechanical impact

INDUSTRY COATINGS PIRT TABLE 4.5-5: >2 HOURS AFTER INITIATION OF LOCA

COATING DESCRIPTION: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat				
	Component	**Processes & Phenomena**	**Rank**	**Definition**
Phase 5 **2 hrs - end** **(outside Zone of Influence)**	Substrate (Steel)	Contraction	Low	Movement of the substrate due to depressurization and cool-down of the containment
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Chemical attack	Low	Exposure of substrate to various plant chemicals Exposure to airborne and waterborne contaminants associated with the plant site environment
		Environmental attack	NA	
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
	Substrate/Primer Interface	Differential contraction	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Oxidation above the pool surface	Low	Corrosion of steel substrate and zinc through the zinc
		Oxidation below the pool surface	Medium	Corrosion of steel substrate and zinc through the zinc
		Cold-wall effect	Low	Condensation of water through the zinc on cool steel

INDUSTRY COATINGS PIRT TABLE 4.5-.5 - >2 HRS. AFTER INITIATION OF LOCA

	Primer (Inorganic Zinc)	Contraction	Low	Movement of primer due to changes in containment temperature and pressure
		Differential contraction stresses	Low	Differential growth due to different thermal expansion coefficients of the substrate and the zinc coating
		Temperature gradient	Low	Development of a through-thickness temperature profile due to mass and energy release inside containment
		Diffusion of air and water above pool surface	Low	Migration of coolant through zinc film due to concentration gradients
		Water intrusion below pool	Low	Water migration through topcoat at mechanical damage and minor coating anomaly sites
		Oxidation above pool surface	Low	Corrosion of the zinc coating
		Oxidation below pool surface	High	Corrosion of the zinc coating
		Environmental attack	NA	Exposure to airborne and waterborne contaminants associated with the plant site environment
		Minor coating anomalies	Low	Inconsistent film properties associated with application
		Pigment/binder ratio	Low	Varying concentration of binder and zinc through the thickness of the film
		Erosion	NA	Action of containment spray to carry away zinc film
		Radiation damage	Low	Radiation damage due to increased radioactivity from event
		Chemical attack above pool surface	Low	Exposure of zinc coating to various plant chemicals
		Chemical attach below pool surface	High	Corrosion of steel substrate and zinc through the zinc
		Mechanical damage	Low	Minor film damage due to mechanical impact

APPENDIX A

Members of the PWR Industry Coatings PIRT Panel

APPENDIX A

MEMBERS OF THE PWR INDUSTRY COATINGS PIRT PANEL

Jon R. Cavallo, P.E.

Jon Cavallo is the Chairman of the Industry Coatings PIRT Panel. He is a Registered Professional Engineer in nine states and holds a Bachelor's Degree in Mechanical Engineering from Northeastern Engineering in Boston, Massachusetts. He also is a certified SSPC Protective Coatings Specialist, holds registration as a Certified Nuclear Coatings Engineer from the National Board of Registration for Nuclear Safety Related Coating Engineers and Specialists, and is certified as an ANSI Level II Coatings Inspector. Active on a number of national technical societies including SSPC, NACE and ASTM, Mr. Cavallo served as Chairman of the Northern New England Chapter of SSPC from 1991 to 1998 and was a Member of the SSPC National Strategic Planning Committee. Mr. Cavallo is now a Vice President of Corrosion Control Consultant & Labs, Inc. and provides corrosion mitigation professional engineering services in surface preparation, protective coatings and linings to a select group of industrial and governmental clients. He also is Vice-Chairman of Sponge-Jet, Inc., located in Eliot, Maine, a company he helped to found which designs and manufactures state-of-the-art surface preparation and decontamination systems.

T. S. Andreychek

Timothy S. Andreychek is an Advanced Technical Engineer with Westinghouse Electric Company, LLC. He obtained his B. S. and M. S. degrees in Mechanical Engineering, and his M. S. in Industrial Engineering from the University of Pittsburgh. Mr. Andreychek has over 27 years experience in the nuclear field, all of it with Westinghouse. He is currently a technical lead in the Containment and Radiological Analysis group. During his tenure with Westinghouse, Mr. Andreychek has been responsible for the conduct of proprietary Emergency Core Cooling System (ECCS) heat transfer tests for pressurized water reactors (PWR's), thermal design and testing of reactor internals for liquid metal reactors, and Loss of Coolant Accident (LOCA) analyses for PWR's. Mr. Andreychek has also worked extensively with Westinghouse's advanced reactor design, the AP600. He was responsible for the design of tests to demonstrate the operability of passive safeguards systems, the reduction and analysis of data from those test, and participated in developing the analysis methodology to demonstrate the performance of the passive containment cooling system for the AP600. Mr. Andreychek also has participated in the performance of Individual Plant Evaluations (IPE's) and Individual Plant External Event Evaluations (IPEEE's).

Jan Bostelman, P.E.

Jan Bostelman holds a B.S. in Chemical Engineering and professional engineer's licenses in several states in metallurgical engineering. Her technical background includes over 19 years of

experience in safety assessments, their application to nuclear reactor systems and analytical modeling, including extensive managerial and technical experience in nuclear fuel design, reactor operations, commercial nuclear safety analyses and commercial nuclear licensing issues. She served on EPRI's advisory committee from 1994-1996 (Materials, Low Level Radioactive Waste, and Fuel Storage/Fuel Reliability/High Level Radioactive Waste). She is trained in numerous vendor thermal hydraulic/transient, source term, containment assessment computer codes, EPA, and commercial CFD codes (FLOW3D). She also has experience in analysis of BWR/PWR LOCA debris generation and subsequent head loss across ECCS strainers for a number of commercial utilities. She has conducted Materials Failures Analysis, and conducts materials research with advanced SEM/EDS/WDS equipment. She has recent graduate work experience in high level waste vitrification, and bioremediation.

Dr. B. E. Boyack

Brent E. Boyack is a Registered Professional Engineer and holds a B.S. and M.S. in Mechanical Engineering from Brigham Young University, and a Ph.D. from Arizona State University. Dr. Boyack has been on the staff of the Los Alamos National Laboratory for 18 years; he is currently the leader of the software development team continuing the development, validation, and application of the Transient Reactor Analysis Code (TRAC). Dr. Boyack has over 30 years experience in the nuclear field. He has been extensively engaged in accident analysis efforts, including design basis and severe accident analyses of light-water, gas-cooled and heavy-water reactors; reactor safety code assessments and applications; safety assessments, preparation of safety evaluation reports; and independent safety reviews. He chaired the MELCOR and CONTAIN independent peer reviews and was a member of the Code Scaling, Applicability and Uncertainty (CSAU) technical program group. He has participated in numerous PIRT panels. He has over 70 journal and conference publications and is an active member of the ANS.

Garth Dolderer

Garth Dolderer has twenty-three years of experience in all phases of the protective coating industry. Projects he has participated in include construction and maintenance of nuclear, fossil, wind and geothermal power plants. His major accountabilities have included the development of protective coating programs, which include technical specifications, material condition programs, contract/labor management, cost and quality control. Mr. Dolderer’s experience includes knowledge of industry standards for protective coatings, thermal spray coatings, brush plating, sealants, adhesives and special linings. Mr. Dolderer is currently a Senior Staff Specialist with Florida Power & Light, responsible all phases of the protective coating program including project management, engineering, contract management and quality control. He is also one of the founders and Chairman of the Nuclear Utilities Coatings Committee (NUCC), a nuclear electric utility focus organization.

David Long

David Long retired in 1998 after a 35 year career in the high performance protective coatings industry. Mr. Long received his B.S. in Chemistry from the University of Louisville in 1963 and performed one year of post-graduate work at the University of Louisville's "Paint Research Institute." He is active in a number of professional and industry organizations, including ANSI, ASTM, NACE and SSPC, and has published several papers related to coatings. Mr. Long participated on the ANSI committees which produced the original standards for nuclear power plant coatings. Prior to his retirement, Mr. Long served in a number of positions at Keeler & Long, Inc., a high-performance coatings manufacturer, including Chemical Director, Vice President of Research and Development, Executive Vice President and, most recently, President and CEO.

APPENDIX B

Phenomena Descriptions of the PWR Industry Coatings PIRT

APPENDIX B

PHENOMENA DESCRIPTIONS OF THE PWR INDUSTRY PIRT

The following scenario is representative of a Westinghouse 4-loop PWR with a large dry containment.

Phase 1: Normal Plant Operations

a. **Pressure Cycles:** 1 atmosphere to approximately 60 psig (corresponds to Integrated Leak Rate Testing) at Time = 0 and approximately every 10 years thereafter

Table C1-2 **Temperature Cycles:** (associated with refueling) - 120 degrees F during normal operations to outside ambient every 18 months, duration approximately 30 - 45 days

Table C1-3 **Humidity Cycles:** (associated with refueling) - 20 percent RH during normal operations to outside ambient (up to 100 percent RH) every 18 months, duration approximately 20 - 45 days

Table C1-4 **Chemical Cycles:** Soluble salts (e.g. chlorides), boric acid, decontamination solutions, grease, oil, solvents

Table C1-5 **Radiation:** Varies with location in containment

Note: Humidity and chemical cycles are included in the PIRT under environmental exposure.

Phase 2: 0 - 40 Seconds After Initiation of LOCA

Containment pressure and temperature peak and begin to decrease, blowdown of reactor coolant system complete at 40 seconds, jet from break ends, increased radiation from exposure due to escaped primary coolant

Phase 3: 40 Seconds - 30 Minutes After Initiation of LOCA

Safety Injection and containment spray initiated from RWST, containment fan coolers operating, pool buildup dynamics, condensation on containment surfaces, boric acid washdown from

containment spray, increase in ionizing radiation, radiation from exposure due to escaped primary coolant

At 30 minutes, full height of water level on containment floor reached, realignment of the Emergency Core Cooling System (ECCS) suction from the refueling water storage tank (RWST) to the containment sump is initiated, containment fan coolers continue to operate

Phase 4: 30 Minutes - 2 Hours After Initiation of LOCA

Recirculation of coolant from the containment sump to the core and to containment spray is established and maintained, flow fields to about the containment floor to the containment sump have been established, containment fan coolers continue to operate, washdown of surfaces due to containment spray, containment pressure and temperature continue to decrease, radiation from exposure due to escaped primary coolant, coatings submerged in the coolant pool on the containment floor are exposed to chemicals in solution (for example, boric acid, sodium hydroxide, and trisodium phosphate)

Phase 5: Greater Than 2 Hours After Initiation of LOCA

Containment spray terminated, recirculation of coolant to core from the containment sump continues to licensing basis (100 hours to 6 months), flow fields to sump decrease due to termination of containment spray, containment fan coolers continue to operate, radiation exposure due to escaped primary coolant

APPENDIX C

Ranking Rationale for PWR Industry Coatings PIRT

APPENDIX C

RANKING RATIONALE FOR PWR INDUSTRY COATINGS PIRT

Contained in this section are the ranking rationale tables for the PIRT tables listed in Section 4. Like the PIRT tables, one ranking rationale table was generated for each phase of the scenario for each coating system. The a total of twenty five (25) ranking rationale tables have been prepared.

The column titles, and the significance of the titles, used in each ranking rationale table are as follows:

Column 1:	Component; substrate, primer, topcoat, and all interfaces in the sequence they occur.
Column 2:	Phenomena; either the phenomena or the process considered.
Column 3:	Rank and Rank Rationale; the ranking given the phenomena or process by the PIRT panel, and the basis for assigning that rank.

The identification of the ranking rationale tables utilized a format similar to that used to identify the PIRT tables. That is, for the five coating systems considered by the Industry Coatings PIRT panel, the associated ranking rationale tables are identified as follows:

C1 Tables: Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat

Table C1-1	Normal Operation
Table C1-2	0 - 40 Seconds After Initiation of LOCA
Table C1-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table C1-4	30 Minutes - 2 Hours After Initiation of LOCA
Table C1-5	> 2 Hours After Initiation of LOCA

C2 Tables: Concrete Substrate, Surfacer, Epoxy Phenolic Topcoat

Table C2-1	Normal Operation
Table C2-2	0 - 40 Seconds After Initiation of LOCA
Table C2-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table C2-4	30 Minutes - 2 Hours After Initiation of LOCA
Table C2-5	> 2 Hours After Initiation of LOCA

C3 Tables: Steel Substrate, Epoxy Primer, Epoxy Topcoat

Table C3-1	Normal Operation
Table C3-2	0 - 40 Seconds After Initiation of LOCA
Table C3-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table C3-4	30 Minutes - 2 Hours After Initiation of LOCA
Table C3-5	> 2 Hours After Initiation of LOCA

C4 Tables: Concrete Substrate, Epoxy Primer, Epoxy Topcoat

Table C4-1	Normal Operation
Table C4-2	0 - 40 Seconds After Initiation of LOCA
Table C4-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table C4-4	30 Minutes - 2 Hours After Initiation of LOCA
Table C4-5	> 2 Hours After Initiation of LOCA

C5 Tables: Steel Substrate, Untopcoated Inorganic Zinc Primer

Table C5-1	Normal Operation
Table C5-2	0 - 40 Seconds After Initiation of LOCA
Table C5-3	40 Seconds - 30 Minutes After Initiation of LOCA
Table C5-4	30 Minutes - 2 Hours After Initiation of LOCA
Table C5-5	> 2 Hours After Initiation of LOCA

Table C1-1 Ranking rationales; Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat; Phase 1, Normal Operation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion/contraction	Low-No effect on steel
Interface Primer/Substrate	Differential expansion/contraction	Low-historically, no failures observed
Primer	Expansion/contraction	Low-historically, no failures observed
	Differential expansion/contraction	Low-panel judgement; film splitting judged higher
	Oxidation	Low-no failures reported to oxidation effects
	Film splitting	Medium-pre-existing conditions such as dry overspray
	Environmental exposure	Low-epoxy phenolic topcoat has low permeability rate
	Minor coating anomalies	Medium-potential precursor to coating failure during transients
	Mechanical Damage	Medium-precursor for pathways of water intrusion, localized impact
Interface Primer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Medium-coefficients of expansion of primer and topcoat different; primer and topcoat hardness different
Phenolic Epoxy Topcoat	Expansion/contraction	Medium-exacerbates conditions for failures
	Environmental exposure	High-polymer material properties change with time, heat and radiation
	Discoloration	Low-industry experience (DBA testing and field observations)
	Mechanical damage	Medium-potential precursor to coating failures during transients
	Minor coating anomalies	Low-not numerous and minor in nature

Table C1-2 Ranking rationales; Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat; Phase 2, 0 - 40 Seconds After initiation of LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion	Low-process just beginning, large heat sink, heat transfer low
	Temperature gradient	Low-gradient not built up yet
	Increased radiation exposure	Low-time limited
Interface Primer/Substrate	Differential expansion/contraction	Low-historically, no failures observed
Primer	Expansion/contraction	Low-historically, no failures observed
	Differential expansion/contraction	Low-panel judgement; film splitting judged higher; historically no failures observed
	Film splitting	Medium-rapid thermal transient on coating system; DBA test results
	Temperature gradient	Low-bulk stresses are low
	Increased radiation exposure	Low-not enough time to damage coating; DBA test results
	Diffusion rate of air/water	Low-low permeability rate of topcoat; not enough time to damage coating
	Environmental exposure	Low-data suggests that inorganic zinc and epoxy phenolic coatings stable
	Minor coating anomalies	High-no available industry data; panel believes important to be addressed in research program
	Chemical, air, moisture intrusion	Low-quantity of minor coating anomalies is small
	Mechanical Damage	Low-type of LOCA generated debris will not significantly damage primer
Interface Primer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-maximum applied external stresses and maximum rate of change of coating stress and stress reversal
	Diffusion rate of air/water	Low-time period is short
Phenolic Epoxy Topcoat	Expansion/contraction	High-coating expands and contracts rapidly with liner; no available industry data
	Temperature gradient	Low-thermal gradient across coating film small
	Diffusion rate of air/water	Low-short time; low permeability rate of topcoat
	Increased radiation exposure	Low-short time; industry DBA test data
	Condensation (cold wall)	Low-low permeability rate of topcoat; short time
	Chemical Attack	Low-not enough time to have chemical attack; epoxy resistant to attack
	Mechanical damage	Low-types of debris will not significantly damage topcoat

Table C1-3 Ranking rationales; Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat; Phase 3, 40 Seconds – 30 Minutes After LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low-no effect on steel
	Temperature gradient	Low-gradient not built up yet
	Increased radiation exposure	Low-time limited
Interface Primer/Substrate	Differential expansion/contraction	Low-industry experience
Primer	Contraction	Low-no failures observed; industry data
	Differential expansion/contraction	Low-panel judgement; film splitting judged higher; historically, no failures observed
	Film splitting	Medium- rapid thermal transient on coating system; DBA test results,; no data available to identify when failure occurs
	Temperature gradient	Low-thermal stresses low
	Increased radiation exposure	Low-industry data; DBA test results
	Diffusion rate of air/water	Medium-topcoat permeability rate; increased exposure time
	Chemical attack	Low-fluid pH 5.5, primer resistant to attack at this pH
	Minor coating anomalies	Medium-shear and tensile stresses present
Interface Primer/Phenolic Epoxy Topcoat	Differential expansion/contraction	High-continued application of stress after T=+40 sec.; no industry data within first 30 minutes
	Diffusion rate of air/water	High-through existing topcoat anomalies
Phenolic Epoxy Topcoat	Contraction	High-topcoat is under stress and moving with substrate
	Temperature gradient	Low-temperature stable; temperature gradient small
	Diffusion rate of air/water	Low-low permeability rate
	Increased radiation exposure	Low-industry data; DBA test data
	Condensation (cold wall)	Low-low delta T (delta = 25 F) across coating
	Chemical Attack	Low-not enough time for chemical attack, topcoat resistant to chemical attack
	Washdown of surfaces	Low-insufficient energy to damage topcoat

Table C1-4 Ranking Rationales; Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat; Phase 4, 30 Minutes - 2 Hours After LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low-no effect on steel
	Temperature gradient	Low-gradient has no effect on coatings
	Increased radiation exposure	Low-time limited
Interface Primer/Substrate	Differential expansion/contraction	Low-industry experience
Primer	Contraction	Low-no failures observed; industry data
	Differential expansion/contraction	Low-panel judgement; film splitting judged higher; historically, no failures observed
	Film splitting	Medium- no data available from existing DBA tests to identify when failure occurs
	Temperature gradient	Low-thermal stresses low
	Increased radiation exposure	Low-industry data; DBA test results
	Diffusion rate of air/water above pool surface	Medium-industry data, longer period for diffusion
	Chemical attack	Medium-industry data, longer period of time
	Minor coating anomalies	Medium-shear and tensile stresses present
	Moisture and air intrusion through damage sites	Medium-isolated areas where water pH may be > 10; industry data, including BWRs
	Water intrusion below pool surface	Low-low permeability rate; industry data
Interface Primer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-transient rate low at this time
	Diffusion rate of air/water	High-pressure and temperature gradients still exist, longer time period
Phenolic Epoxy Topcoat	Contraction	Low-transient rate low
	Temperature gradient	Low-low thermal loading
	Diffusion rate of air/water	Low-low permeability rate
	Increased radiation exposure	Low-industry data; DBA test data
	Condensation (cold wall)	Low-low delta T (< 25 F) across coating
	Washdown of surfaces	Low-insufficient energy to damage topcoat
	Minor Coating Anomalies	High-pathway for water intrusion localized
	Moisture and air intrusion through damage sites	High-pathway for water, chemical intrusion, longer period of time for exposure
	Immersion to pool surface	Low-very low bulk fluid velocity; localized zones of turbulence

Table C1-5 Ranking rationales; Steel Substrate, Inorganic Zinc Primer, Epoxy Phenolic Topcoat; Phase 5, > 2 Hours After initiation of LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low-thermal equilibrium reached in two weeks
	Temperature gradient	Low-thermal equilibrium reached in two weeks
	Increased radiation exposure	Low-steel unaffected
Interface Primer/Substrate	Differential contraction	Low-thermal equilibrium reached
Primer	Contraction	Low-conditions have equilibrated
	Differential contraction	Low-conditions have equilibrated
	Film splitting	Medium-no industry data available for < 24 hour duration
	Temperature gradient	Low-conditions equilibrated
	Increased radiation exposure	Low-industry data; DBA test results
	Diffusion rate of air/water	High-limited industry data; long term exposure, porous primer, electrochemical reactions
	Chemical attack	Low-industry data
	Minor coating anomalies	High-long term exposure
	Moisture and air intrusion through damage sites	High-long term exposure, electrochemical reactions
	Water intrusion below pool surface	Medium-low permeability rate; industry data, but longer exposure
Interface Primer/Phenolic Epoxy Topcoat	Differential contraction	Low-transient rate is low, system in equilibrium
	Diffusion rate of air/water	High-low permeability rate, but long exposure
Phenolic Epoxy Topcoat	Contraction	Low-transient rate low
	Temperature gradient	Low-small delta T
	Diffusion rate of air/water	Medium-low permeability; but long exposure
	Increased radiation exposure	Low-industry data; DBA testing
	Condensation (cold wall)	Low-low delta T (< 25 F) across coating
	Chemical attack	Low-nonaggressive environment
	Minor coating anomalies	High-pathway for long term water intrusion
	Immersion to pool surface	Medium-long term exposure; limited industry data

Table C2-1 Ranking rationales; Concrete Substrate, Surfacer, Epoxy Topcoat; Phase 1, Normal Operation

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact during normal operations.
	Pressure gradient	Medium-Phase 1 ILRTs (Integrated Leak Rate Testing) could have situations when ILRT was depressurized too fast in the past and coatings have been seen to come off from such.
	Temperature gradient	Low-A temperature gradient during normal operation would not be expected to degrade concrete.
	Increased radiation exposure	Low-normal operation radiation exposure does not have significant impact on concrete structure based on known data.
	Outgassing/Vapor Expansion	High-Phase 1 Water vapor migration through concrete (damaged sites) from ILRT.
Interface Surfacer/Substrate	Differential expansion/contraction	Low-Surfacer is designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Medium-there is a potential for buildup of calcium carbonate with long term normal operation at the interface (if not removed before surfacer applied). Unknown what the impact is of calcium carbonate concentration buildup on surfacer.
	Blistering/Delamination.	High-Have seen blistering/delamination during normal operation. Need to examine reasons for this.
	Vapor Buildup	High-Vapor could collect in this interface area (under surfacer) during normal operations.
Surfacer	Bulk movement	Low-During normal operations do not expect movement of surfacer. Thermal expansion of concrete during normal operations is not significant.
	Environmental exposure	Medium-During normal operations have long term exposure of surfacer to thermal conditions.
	Minor coating anomalies	High-During normal operations this could be a pathway for vapor transmission.
	Cracking	Low-Have not seen this from experience during normal operations, therefore, low priority.
	Chemical exposure	Low-During normal operations not an issue since topcoat protects surfacer.
	Water diffusion (from concrete)	Low-During normal operations do not have bulk diffusion through surfacer, but could have it through localized pathways.
	Mechanical damage	Low-During normal operations priority is low, because does not affect the coating integrity.
	Water intrusion from pool	NA, no water intrusion from a pool during normal operations.
	Temperature gradient	Low-during normal operations do not expect a gradient, and does not have an affect on the surfacer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low-During normal operation this can only occur through localized pathways.
	Increased radiation exposure	Low-During normal operation this is not an issue based on experimental data.
Interface Surfacer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-No difference in relative thermal expansion coefficients of the surfacer/topcoat.

	Blistering/Delamination.	High-
	Vapor buildup	High-Vapor could collect under topcoat during normal operations.
Phenolic Epoxy Topcoat	Bulk movement	Low-See Surfacer rationale.
	Temperature gradient	Low-Same as Surfacer.
	Increased radiation exposure	Low-Same as Surfacer.
	Diffusion air/water	Low-The topcoat has a low vapor transmissivity rate.
	Minor coating anomalies	High-During normal operations could serve as pathways for air/water buildup.
	Environmental exposure	High-During normal operations long term exposure to thermal conditions.
	Chemical attack	Low-Topcoat is formulated to withstand chemical attack.
	Cracking	Low-During normal operations have not seen topcoat cracking, based on containment/drywell walkdowns, historical data.
	Mechanical damage	Low-During normal operations does not affect coating integrity.
	Condensation./cold wall	Low-Do not have cold wall affect during normal operations.
	Immersion in pool	NA, do not have pool immersion during normal operations.
	Washdown	Low-do not have washdown impact during normal operations.

Table C2-2 Ranking rationales; Concrete Substrate, Surfacer, Epoxy Topcoat; Phase 2, 0-40 sec. After initiation of LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact in concrete that would impact coating.
	Pressure gradient	High-Have highest pressure gradient acting on concrete surfaces during Phase 2.
	Temperature gradient	Low-Not expected to degrade concrete.
	Increased radiation exposure	Low-No significant impact on concrete structure.
	Outgassing/Vapor Expansion	High-Could have vapor expansion during pressure decrease of LOCA.
Interface Surfacer/Substrate	Differential expansion/contraction	Low-Surfacer designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Low-do not have additional buildup during this Phase.
	Blistering/Delamination.	High-Phase 2 has the maximum thermal loading
	Vapor Buildup	High-Phase 2 has maximum thermal/pressure loading and could cause vapor buildup at interstitial sites.
Surfacer	Bulk movement	Low-no movement of surfacer, thermal expansion of concrete is not significant.
	Environmental exposure	Low-exposure to thermal conditions is short term.
	Minor coating anomalies	High-pathway for vapor transmission.
	Cracking	Low-have not seen it in surfacer.
	Chemical exposure	Low-Topcoat protects surfacer during this Phase.
	Water diffusion (from concrete)	Low-No bulk diffusion through surfacer, but can occur localized through pathways.
	Mechanical damage	Low-Will not impact coating integrity.
	Water intrusion from pool	NA, no pool formation in Phase 2.
	Temperature gradient	Low-Does not impact surfacer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low-Can only occur through localized pathways. Surfacer low diffusivity.
	Increased radiation exposure	Low-Surfacer not subject to damage from radiation exposure, based on test data.
Interface Surfacer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-No difference in relative thermal expansion coefficients of the surfacer/topcoat.
	Blistering/Delamination.	High-
	Vapor buildup	High-Vapor could buildup under topcoat during Phase 2.

Phenolic Epoxy Topcoat	Bulk movement	Low-See Surfacer rationale.
	Temperature gradient	Low-Same as Surfacer.
	Increased radiation exposure	Low-Same as Surfacer.
	Diffusion air/water	Low-Small vapor transmissivity rate, even during Phase 2.
	Minor coating anomalies	High-Pathways for air/water buildup during Phase 2.
	Environmental exposure	Low-No long term exposure to thermal conditions during this phase.
	Chemical attack	Low-Formulated to withstand chemical attack.
	Cracking	Low-Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low-Does not affect coating integrity.
	Condensation./cold wall	Low-Formulation of coating resistant to cold wall affect.
	Immersion in pool	NA, no pool formation in Phase 2.
	Washdown	Low-no washdown during Phase 2.

Table C2-3 Ranking rationales; Concrete Substrate, Surfacer, Epoxy Topcoat; Phase 3, 40 Seconds – 30 Minutes After LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact in concrete.
	Pressure gradient	High-Still at high pressure coming down slowly.
	Temperature gradient	Low-Would not degrade concrete.
	Increased radiation exposure	Low-No significant impact on concrete structure.
	Outgassing/Vapor Expansion	High-Could have outgassing during Phase 3 during depressurization.
Interface Surfacer/Substrate	Differential expansion/contraction	Low-Surfacer designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Low-No buildup on short term process.
	Blistering/Delamination.	High-Phase 3 still coming down in pressure transient.
	Vapor Buildup	High-Vapor still collecting under surfacer during this phase.
Surfacer	Bulk movement	Low-No bulk movement of surfacer. Thermal expansion of concrete is not significant.
	Environmental exposure	Low-No long term thermal exposure during this phase.
	Minor coating anomalies	High-Pathway for vapor transmission during this phase.
	Cracking	Low-Have not seen this, therefore, low priority.
	Chemical exposure	Low-Topcoat still provides protection of surfacer.
	Water diffusion (from concrete)	Low-No bulk diffusion in surfacer, but can occur localized through pathways.
	Mechanical damage	Low-Does not affect coating integrity (localized damage).
	Water intrusion from pool	NA, Pool still has not formed completely for this phase.
	Temperature gradient	Low-Does not have an affect on the surfacer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low-Can only occur through localized pathways during this phase.
	Increased radiation exposure	Low-Radiation levels still below test programs. Based on test data.
Interface Surfacer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-No difference in relative thermal expansion coefficients of the surfacer/topcoat.
	Blistering/Delamination.	High-
	Vapor buildup	High-Vapor collection under topcoat during Phase 3 continues.

Phenolic Epoxy Topcoat	Bulk movement	Low-See Surfacer Rationale.
	Temperature gradient	Low-Same as Surfacer.
	Increased radiation exposure	Low-Same as Surfacer.
	Diffusion air/water	Low-Small vapor transmissivity rate.
	Minor coating anomalies	High-Pathways for air/water buildup during Phase 3.
	Environmental exposure	Low-Short term exposure to thermal conditions during this phase.
	Chemical attack	Low-Formulated to withstand chemical attack.
	Cracking	Low-Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low-Does not affect overall coating integrity.
	Condensation./cold wall	Low-Formulation of coating is resistant to cold wall affect.
	Immersion in pool	NA, Pool has not formed completely during this phase.
	Washdown	Low-Not a major contributor.

Table C2-4 Ranking rationales; Concrete Substrate, Surfacer, Epoxy Topcoat; Phase 4, 30 min.-2hrs. After LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact.
	Pressure gradient	Low-Slow pressure transient during this phase.
	Temperature gradient	Low-Would not degrade concrete for this temperature phase.
	Increased radiation exposure	Low-No significant impact on concrete structure.
	Outgassing/Vapor Expansion	Medium-Still potential for outgassing due to slow depressurization.
Interface Surfacer/Substrate	Differential expansion/contraction	Low-Surfacer designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Low-No buildup expected during this phase.
	Blistering/Delamination.	High-Still coming down in pressure transient.
	Vapor Buildup	Medium-Vapor collecting under surfacer.
Surfacer	Bulk movement	Low-No bulk movement of surfacer. Thermal expansion of concrete is not significant.
	Environmental exposure	Low-Exposure period to thermal conditions is short term.
	Minor coating anomalies	Medium-Pathway for vapor transmission.
	Cracking	Low-Have not seen it, therefore, low priority.
	Chemical exposure	Low-Topcoat still serves to protect surfacer during this phase.
	Water diffusion (from concrete)	Low-No bulk diffusion in surfacer, but can occur through localized pathways.
	Mechanical damage	Low-Does not affect overall coating integrity, damage is localized.
	Water intrusion from pool	Low-Long term duration of immersion could have affect on surfacer.
	Temperature gradient	Low-Does not have impact on surfacer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low-Localized through pathways.
	Increased radiation exposure	Low-Not an impact based on test data.
Interface Surfacer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-No difference in relative thermal expansion coefficients of the surfacer/topcoat.
	Blistering/Delamination.	High-
	Vapor buildup	Medium-During Phase 4 continue to buildup vapor under topcoat at interstitial sites.

Phenolic Epoxy Topcoat	Bulk movement	Low-See Surfacer rationale.
	Temperature gradient	Low-Same as surfacer.
	Increased radiation exposure	Low-Same as surfacer.
	Diffusion air/water	Low-Small vapor transmissivity rate.
	Minor coating anomalies	Medium-Localized pathways for air/water buildup.
	Environmental exposure	Low-Still considered short term for thermal conditions exposure.
	Chemical attack	Low-Formulated to resist chemical attack.
	Cracking	Low-Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low-Does not affect overall coating integrity, localized only.
	Condensation./cold wall	Low-Formulation of coating is resistant to cold wall affect.
	Immersion in pool	Low-Not expected to be an issue for short term immersion.
	Washdown	Low-Not a major contributor.

Table C2-5 Ranking rationales; Concrete Substrate, Surfacer, Epoxy Topcoat; Phase 5, >2 Hours After initiation of LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact in concrete structures.
	Pressure gradient	Low-Slow pressure transient at this point in time.
	Temperature gradient	Low-Would not degrade concrete, temperature decreasing.
	Increased radiation exposure	Low-No significant impact on concrete structure, based on test data.
	Outgassing/Vapor Expansion	Medium-Still continuing to outgas due to pressure decrease, but slowly.
Interface Surfacer/Substrate	Differential expansion/contraction	Low-Surfacer designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Medium-Potential for buildup over long term.
	Blistering/Delamination.	High-Still coming down in pressure.
	Vapor Buildup	Medium-Vapor collecting under surfacer.
Surfacer	Bulk movement	Low-No movement of surfacer. Thermal expansion of concrete is insignificant.
	Environmental exposure	Medium-Will have long term exposure to thermal conditions.
	Minor coating anomalies	Medium-Pathway for vapor transmission.
	Cracking	Low-Have not seen this in surfacer.
	Chemical exposure	Low-Topcoat protects surfacer.
	Water diffusion (from concrete)	Low-No bulk diffusion in surfacer, but can occur through localized pathways.
	Mechanical damage	Low-Does not impact overall coating integrity. Localize damage.
	Water intrusion from pool	Medium-Long term duration of immersion could affect surfacer.
	Temperature gradient	Low-Does not have an affect on the surfacer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low-Can only occur through localized pathways.
	Increased radiation exposure	Low-Based on test data.
Interface Surfacer/Phenolic Epoxy Topcoat	Differential expansion/contraction	Low-No difference in relative thermal expansion coefficients of the surfacer/topcoat.
	Blistering/Delamination.	High-
	Vapor buildup	Medium-Vapor still collecting under topcoat long term conditions.

Phenolic Epoxy Topcoat	Bulk movement	Low-See surfacer rationale.
	Temperature gradient	Low-Same as surfacer.
	Increased radiation exposure	Low-Same as surfacer.
	Diffusion air/water	Low-Small vapor transmissivity rate.
	Minor coating anomalies	Medium-Pathways for air/water buildup.
	Environmental exposure	Medium-Exposure to thermal conditions long term.
	Chemical attack	Low-Formulated to withstand chemical attack.
	Cracking	Low-Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low-Does not affect overall coating integrity, localized only.
	Condensation./cold wall	Low-Formulation of coating is resistant to cold wall affect.
	Immersion in pool	Medium-Long term exposure could be an issue.
	Washdown	Low-Not a major contributor.

Table C3-1 Ranking Rationale; Steel Substrate, Epoxy Primer/ Epoxy Topcoat; Phase 1, Normal Operation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion/contraction	Low - No effect on steel, minimal expansion/contraction during normal operations and ILRT's.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Low - historically, no failures observed small difference in expansion/contraction rates between substrate and primer.
	Cold Wall	Low - Coating formulated against cold wall effects.
	Oxidation	Low - Small oxidation occurs after surface preparation before primer applied, low permeable membrane inhibits migration of moisture and air (oxygen).
Epoxy Primer	Expansion/contraction	Low - Historically, no failures observed minimal expansion/contraction during normal operations.
	Environmental exposure (heat, pressure, humidity, radiation)	High - Long exposure during normal operations imparts changes in mechanical properties.
	Minor coating anomalies	Low - Multi-coating systems less likely to have anomalies line up through entire thickness.
	Mechanical Damage	High - Precursor for pathways of water intrusion, localized impact, if localized damage occurs most likely to penetrate all the way to substrate, can then allow undercutting to occur.
	Increased Radiation Exposure	Low - Coatings are designed to withstand up to 1 x 10^9 Rads exposure based on test panels information.
Interface Primer / Epoxy Topcoat	Differential expansion/contraction	Low - Coefficients of expansion of primer and topcoat similar.
Epoxy Topcoat	Expansion/contraction	Low - Minimal expansion/contraction during normal operations/ILRTs.
	Environmental exposure	High - Polymer material properties change with time, heat and radiation
	Discoloration	Low - Industry experience (DBA testing and field observations), due to possible realignment of molecules in resin structure, doesn't impact mechanical properties.
	Mechanical damage	High - Same as Epoxy Primer rationale).
	Minor coating anomalies	Low - Not numerous and minor in nature, multi coat system prevents alignment of anomalies to substrate.

Table C3-2 Ranking Rationale; Steel Substrate, Epoxy Primer, Epoxy Topcoat; Phase 2, 0 Seconds to 40 Seconds After LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion	Low - Process just beginning, large heat sink, heat transfer low at this point in accident.
	Temperature gradient	Low - Temperature gradient in substrate not built up yet in this phase of accident.
	Increased radiation exposure	Low - Time limited due to short phase of the accident
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Low - Historically, no failures observed due to similar coefficients of expansion between substrate and primer.
	Cold Wall	Low - Epoxy primer formulated against cold wall effects.
	Oxidation	Low - Not enough time for rapid oxidation in substrate due to moisture intrusion.
	Blistering/Delamination	High - Based on industry data, DBA testing (don't know when it can occur during segment of DBA testing, but this phenomena has been seen during tests)
Epoxy Primer	Expansion/contraction	Low - Historically, no failures observed within primer.
	Temperature gradient	Low - Bulk stresses are low.
	Increased radiation exposure	Low - Not enough time to damage coating; DBA test results, qualified to 1 x 10^9 Rads.
	Diffusion rate of air/water	Low - Low permeability rate of topcoat; not enough time to damage coating
	Environmental exposure	Medium - High cyclic stresses with heat at this point in accident.
	Minor coating anomalies	Low - Anomalies would be covered by epoxy topcoat in multi coat system.
	Chemical, air, moisture intrusion	Low - Quantity of minor coating anomalies is small, only could get to primer from mechanical damage from Phase I. Coating system low permeability rate for water intrusion, formulated against chemical attack (not enough time in this phase to impact system).
	Mechanical Damage	Low - Type of LOCA generated debris will not significantly damage primer
Interface Between Epoxy Primer and Epoxy Topcoat	Differential expansion/contraction	Low - Maximum applied external stresses and maximum rate of change of coating stress and stress reversal, however, epoxy primer and epoxy topcoat have similar coefficients of expansion.
	Diffusion rate of air/water	Low - Time period is short for air/water diffusion through a system with low permeability.
	Blistering/Delamination	High - Based on DBA testing have seen this phenomena in tests, unsure when during test sequence it occurs.
Epoxy Topcoat	Expansion/contraction	Medium - Coating expands and contracts rapidly with liner.

	Temperature gradient	Low - Thermal gradient across coating film small
	Diffusion rate of air/water	Low - Short time; low permeability rate of topcoat
	Increased radiation exposure	Low - Short time; industry DBA test data
	Condensation (cold wall)	Low - Low permeability rate of topcoat; short time
	Chemical Attack	Low - Not enough time to have chemical attack; epoxy resistant to attack
	Minor Coating Anomalies	Low - Time span of this phase is short for impact on anomalies.
	Environmental Exposure	Medium - High cyclic stress at this point in time, with temperature/pressure/humidity.
	Mechanical damage	Low - Types of LOCA generated debris will not significantly damage topcoat

Table C3-3 Ranking Rationale; Steel Substrate, Epoxy Primer, Epoxy Topcoat; Phase 3, 40 Seconds to 30 Minutes LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - No effect on steel, containment pressure decreasing at this time
	Temperature gradient	Low - Gradient not built up yet completely, temperature has peaked.
	Increased radiation exposure	Low - Time limited, steel resistant to expected radiation release
Interface Epoxy Primer and Substrate	Differential expansion/contraction	Low - Industry experience, primer will expand/contract with liner, similar rates of expansion.
	Cold Wall	Low - Epoxy systems designed to resist cold wall effects.
	Oxidation	High - Attack of substrate through damaged sites (during normal operations, mechanical damage), water and boric acid spray getting to substrate. Causes expansion of oxidizing surface (in the interface) could lower adhesive strength of coating.
	Blistering/Delamination	High - Same as Phase 2 Rationale
Epoxy Primer	Contraction	Low - No failures observed; industry data
	Temperature gradient	Low - Bulk thermal stresses low within primer itself
	Increased radiation exposure	Low - Industry data; DBA test results
	Diffusion rate of air/water	Low - Low topcoat permeability rate.
	Chemical attack	Low - Fluid pH 5.5, primer resistant to attack at this pH (boric acid spray)
	Minor coating anomalies	Low - Anomalies are not aligned within multi coat system to substrate.
	Environmental Exposure	Medium - Continuation of transient, increased exposure to heat, pressure, and radiation.
Interface Epoxy Primer and Epoxy Topcoat	Differential expansion/contraction	Low - Similar mechanical properties of topcoat and primer.
	Diffusion rate of air/water	Low - Topcoat has a low permeability rate, not sufficient time for diffusion.
	Blistering/Delamination	High - Have seen it in DBA testing, don't know when in sequence occurs.
Epoxy Topcoat	Contraction	Low - Topcoat is moving with substrate
	Temperature gradient	Low - Temperature stable; temperature gradient small
	Diffusion rate of air/water	Low - Low permeability rate of topcoat
	Increased radiation exposure	Low - Industry data; DBA test data
	Condensation (cold wall)	Low - Low delta T (delta = 25 F) across coating. Phenomena caused by heating of wall with condensing steam.
	Chemical Attack	Low - Not enough time for chemical attack, topcoat resistant to chemical attack
	Minor Coating Anomalies	Medium - Have more time for topcoat anomalies exposure to environment.
	Washdown of surfaces	Low - Insufficient energy to damage topcoat from water films-containment spray

Table C3-4 Ranking Rationale; Steel Substrate, Epoxy Primer, Epoxy Topcoat; Phase 4, 30 Minutes to 2 Hours After LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - No effect on steel, based on experimental data.
	Temperature gradient	Low - Gradient within substrate has no effect on coatings
	Increased radiation exposure	Low - Time limited, also based on industry data.
Interface Epoxy Primer and Substrate	Differential expansion/contraction	Low - industry experience
	Cold Wall	Low - System is formulated against cold wall effects.
	Oxidation	High - Continuation of transient, more water/chemicals/air diffusion through previous mechanical damaged sites. Can cause expansion of substrate with oxidation layer (loss of cohesive strength in coating).
	Blistering/Delamination	High - Have seen it in DBA testing, not sure when in test sequence occurs.
Epoxy Primer	Contraction	Low - No failures observed; industry data
	Temperature gradient	Low - Bulk thermal stresses low
	Increased radiation exposure	Low - Industry data; DBA test results
	Diffusion rate of air/water above pool surface	Low - Industry data, low permeability of topcoat/primer
	Chemical attack	Low - Industry data, primer resistant to chemical attack
	Minor coating anomalies	Low - Anomalies not aligned with topcoat anomalies, no transport path to substrate.
	Moisture and air intrusion through damage sites	Medium - Isolated areas; industry data.
	Water intrusion below pool surface	Low - Low permeability rate; industry data
	Environmental Exposure	Medium - Continuation of transient (more time exposure to heat, radiation)
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - Transient differential pressure rate low at this time
	Diffusion rate of air/water	Low - Topcoat low permeability to water/air.
	Blistering/Delamination	High - Have seen in DBA testing, not sure when occurs in accident sequence

Epoxy Topcoat	Contraction	Low - Differential transient rate low
	Temperature gradient	Low - Low thermal loading
	Diffusion rate of air/water	Low - Low permeability rate
	Increased radiation exposure	Low - Industry data; DBA test data
	Condensation (cold wall)	Low - Low delta T (< 25 F) across coating, caused by condensing steam
	Washdown of surfaces	Low - Insufficient energy to damage topcoat from containment spray films
	Minor Coating Anomalies	Medium - Pathway for water intrusion localized
	Moisture and air intrusion through damage sites	Medium - Pathway for water, chemical intrusion, longer period of time for exposure
	Immersion to pool surface	Low - Very low bulk fluid velocity; localized zones of turbulence, low permeability through topcoat

Table C3-5 Ranking Rationale; Steel Substrate, Epoxy Primer, Epoxy Topcoat; Phase 5, > 2 Hours After LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - Thermal equilibrium reached in two weeks
	Temperature gradient	Low - Thermal equilibrium reached in two weeks
	Increased radiation exposure	Low - Steel unaffected
Interface Epoxy Primer/Substrate	Differential contraction	Low - Thermal equilibrium reached
	Cold Wall	Low - Coating systems designed to resist cold wall effects.
	Oxidation	High - Continuation long term of exposure to air/water, oxidized layer continues to build between substrate and epoxy primer.
	Blistering/Delamination	High - Have seen this in DBA testing, continued exposure increase chance of occurrence.
Epoxy Primer	Contraction	Low - Conditions have equilibrated
	Temperature gradient	Low - Conditions equilibrated
	Increased radiation exposure	Low - Industry data; DBA test results
	Diffusion rate of air/water	Medium - Limited industry data; long term exposure to chemicals, low permeability primer
	Chemical attack	Low - Industry data, boric acid at this point should be neutralized, but may have localized pockets of high or low pH.
	Minor coating anomalies	High - Long term exposure, some diffusion through topcoat to these locations.
	Moisture and air intrusion through damage sites	High - Long term exposure, electrochemical reactions
	Water intrusion below pool surface	Low - Low permeability rate; industry data
	Environmental exposure	High - Long term exposure to humidity/radiation.
Interface Epoxy Primer/ Epoxy Topcoat	Differential contraction	Low - Transient rate is low, system in equilibrium
	Diffusion rate of air/water	Low - Low permeability rate
	Blistering/Delamination	High - Have seen it but don't know when in accident sequence occurs.

Epoxy Topcoat	Contraction	Low - Transient rate low
	Temperature gradient	Low - Small delta T
	Diffusion rate of air/water	Medium - Low permeability; but long exposure at topcoat surface
	Increased radiation exposure	Low - Industry data; DBA testing
	Condensation (cold wall)	Low - Low delta T (< 25 F) across coating, from condensing steam.
	Chemical attack	Medium - Localized aggressive environment, bulk pool would be neutral
	Minor coating anomalies	Medium - Pathway for long term water intrusion
	Immersion to pool surface	High - Long term exposure; limited industry test data

Table C4-1 Ranking rationale; Concrete Epoxy Primer, Epoxy Topcoat; Phase 1, Normal Operation

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low - No evidence of significant impact during normal operations.
	Pressure gradient	Medium - Phase 1 ILRTs (Integrated Leak Rate Testing) could have situations when ILRT was depressurized too fast in the past and coatings have been seen to come off from such.
	Temperature gradient	Low - A temperature gradient during normal operation would not be expected to degrade concrete.
	Increased radiation exposure	Low - normal operation radiation exposure does not have significant impact on concrete structure based on known data.
	Outgassing/Vapor Expansion	High - Phase 1 Water vapor migration through concrete (damaged sites) from ILRT.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Medium - primer is designed to withstand some expansion/contraction. However, there is dissimilar expansion rate between concrete and primer.
	Calcium Carbonate Buildup	Medium - there is a potential for buildup of calcium carbonate with long term normal operation at the interface (if not removed before epoxy primer applied). Unknown what the impact is of calcium carbonate concentration buildup on epoxy primer.
	Blistering/Delamination.	High - Have seen blistering/delamination during normal operation. Need to examine reasons for this.
	Vapor Buildup	High - Vapor could collect in this interface area (under epoxy primer) during normal operations.
	Water intrusion	Medium - From the backside of concrete, from large pores, result of migration of water through concrete.
Epoxy Primer	Bulk movement	Low - During normal operations do not expect movement of epoxy primer. Thermal expansion of concrete during normal operations is not significant.
	Environmental exposure	Medium - During normal operations have long term exposure of epoxy primer to thermal conditions.
	Minor coating anomalies	High - During normal operations this could be a pathway for vapor transmission.
	Cracking	Medium - Have seen this from experience during normal operations.
	Chemical exposure	Low - During normal operations not an issue since topcoat protects epoxy primer.
	Water diffusion (from concrete)	Low - During normal operations do not have bulk diffusion through epoxy primer, but could have it through localized pathways.
	Mechanical damage	Low - During normal operations priority is low, because does not affect the coating integrity.
	Water intrusion from pool	NA - No water intrusion from a pool during normal operations.

	Temperature gradient	Low - During normal operations do not expect a gradient, and does not have an affect on the epoxy primer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low - During normal operation this can only occur through localized pathways.
	Increased radiation exposure	Low - During normal operation this is not an issue based on experimental data.
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - No difference in relative thermal expansion coefficients of the epoxy primer/topcoat.
	Blistering/Delamination.	Low - Have not seen this from experience in this system.
	Vapor buildup	High - Vapor could collect under topcoat during normal operations.
Epoxy Topcoat	Bulk movement	Low - See Epoxy Primer rationale.
	Temperature gradient	Low - Same as Epoxy Primer.
	Increased radiation exposure	Low - Same as Epoxy Primer.
	Diffusion air/water	Low - The topcoat has a low vapor transmissivity rate.
	Minor coating anomalies	High - During normal operations could serve as pathways for air/water buildup.
	Environmental exposure	High - During normal operations long term exposure to thermal conditions.
	Chemical attack	Low - Topcoat is formulated to withstand chemical attack.
	Cracking	Medium - During normal operations have seen topcoat cracking, based on containment/drywell walkdowns, historical data.
	Mechanical damage	Low - During normal operations does not affect coating integrity.
	Condensation./cold wall	Low - Do not have cold wall affect during normal operations.
	Immersion in pool	NA - Do not have pool immersion during normal operations.
	Washdown	Low - Do not have washdown impact during normal operations.

Table C4-2 Ranking rationale; Concrete Substrate, Epoxy Primer, Epoxy Topcoat; Phase 2, 0-40 Seconds After initiation of LOCA Initiation

Component	**Phenomena**	**Rank and Ranking Rationale**
Substrate (concrete)	Expansion/compression	Low - No evidence of significant impact in concrete that would impact coating.
	Pressure gradient	High - Have highest pressure gradient acting on concrete surfaces during Phase 2.
	Temperature gradient	Low - Not expected to degrade concrete.
	Increased radiation exposure	Low - No significant impact on concrete structure.
	Outgassing/Vapor Expansion	High - Could have vapor expansion during pressure decrease of LOCA.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Medium - Epoxy Primer has different coefficient of expansion than concrete.
	Calcium Carbonate Buildup	Low - Do not have additional buildup during this Phase.

	Blistering/Delamination.	High - Phase 2 has the maximum thermal loading
	Vapor Buildup	High - Phase 2 has maximum thermal/pressure loading and could cause vapor buildup at interstitial sites potential for more vapor buildup.
	Migration of Water	Low - From backside of concrete, not by bulk diffusion.
Epoxy Primer	Bulk movement	Medium - Some movement of epoxy primer, thermal expansion of concrete is not significant.
	Environmental exposure	Low - Exposure to thermal conditions is short term.
	Minor coating anomalies	High - Pathway for vapor transmission.
	Cracking	Medium - Have seen it in epoxy primer, rigid coating materials.
	Chemical exposure	Low - Topcoat protects epoxy primer during this Phase, epoxy primer is formulated also to be resistant to chemical attack.
	Water diffusion (from concrete)	Low - No bulk diffusion through epoxy primer, but can occur localized through pathways.
	Mechanical damage	Low - Will not impact coating integrity.
	Water intrusion from pool	NA - No pool formation in Phase 2.
	Temperature gradient	Medium - Primer thin film differential thermal expansion relative to bulk movement.
	Water/air diffusion (from outside the topcoat above submerged level)	Low - Can only occur through localized pathways. Epoxy Primer low diffusivity.
	Increased radiation exposure	Low - Epoxy Primer not subject to damage from radiation exposure, based on test data.
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - No difference in relative thermal expansion coefficients of the epoxy primer/topcoat.
	Blistering/Delamination.	Low - Based on coating manufacturer experience.
	Vapor buildup	Low - Vapor would not buildup under topcoat during Phase 2. Mechanical bonding between epoxy primer/epoxy topcoat prevents the buildup.
Epoxy Topcoat	Bulk movement	Medium - Same as Epoxy Primer rationale.
	Temperature gradient	Medium - Same as Epoxy Primer.
	Increased radiation exposure	Low - Same as Epoxy Primer.
	Diffusion air/water	Low - Small vapor transmissivity rate, even during Phase 2.
	Minor coating anomalies	High - Pathways for air/water buildup during Phase 2.
	Environmental exposure	Low - No long term exposure to thermal conditions during this phase.

	Chemical attack	Low - Formulated to withstand chemical attack.
	Cracking	Medium - Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low - Does not affect coating integrity.
	Condensation./cold wall	Low - Formulation of coating resistant to cold wall affect.
	Immersion in pool	NA - No pool formation in Phase 2.
	Washdown	Low - No washdown during Phase 2.

Table C4-3 Ranking rationale, Concrete Substrate, Epoxy Primer, Epoxy Topcoat; Phase 3, 40 seconds to 30 Minutes After LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low-No evidence of significant impact in concrete.
	Pressure gradient	High-Still at high pressure coming down slowly.
	Temperature gradient	Low - Would not degrade concrete.
	Increased radiation exposure	Low - No significant impact on concrete structure.
	Outgassing/Vapor Expansion	High - Could have outgassing during Phase 3 during depressurization.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Low - Epoxy primer will withstand contraction.
	Calcium Carbonate Buildup	Low - No buildup on short term process.
	Blistering/Delamination.	Medium - Phase 3 still coming down in pressure transient, have seen some at substrate.
	Vapor Buildup	High - Vapor still collecting under epoxy primer during this phase.
	Water Migration	Low - Water migration from normal operations would have already collected under primer.
Epoxy Primer	Bulk movement	Medium - Some movement of epoxy primer. Thermal expansion of concrete is small though.
	Environmental exposure	Low - No long term thermal exposure during this phase.
	Minor coating anomalies	High - Pathway for vapor transmission during this phase.
	Cracking	Medium - Have seen this, therefore, medium priority.
	Chemical exposure	Low - Topcoat still provides protection of epoxy primer.
	Mechanical damage	Low - Does not affect coating integrity (localized damage).
	Water intrusion from pool	NA - Pool still has not formed completely for this phase.
	Temperature gradient	Medium - Does have some affect on the epoxy primer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low - Can only occur through localized pathways during this phase.
	Radiation damage	Low - Radiation levels still below test programs. Based on test data.
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - No difference in relative thermal expansion coefficients of the epoxy primer/topcoat.
	Blistering/Delamination.	Low - No blistering between similar materials.
	Vapor buildup	Low - no vapor buildup between two similar materials with strong mechanical bonding, manufacturer experience.
	Water Diffusion	Low - Topcoat low permeability rate.
Epoxy Topcoat	Bulk movement	Medium - See Epoxy Primer Rationale.

	Temperature gradient	Medium - Same as Epoxy Primer.
	Increased radiation exposure	Low - Same as Epoxy Primer.
	Diffusion air/water	Low - Small vapor transmissivity rate.
	Minor coating anomalies	High - Pathways for air/water buildup during Phase 3.
	Environmental exposure	Low - Short term exposure to thermal conditions during this phase.
	Chemical attack	Low - Formulated to withstand chemical attack.
	Cracking	Medium - Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low - Does not affect overall coating integrity.
	Condensation./cold wall	Low - Formulation of coating is resistant to cold wall affect.
	Immersion in pool	NA - Pool has not formed completely during this phase.
	Washdown	Low - Not a major contributor.

Table C4-4 Ranking rationales, Concrete Substrate, Epoxy Primer, Epoxy Topcoat; Phase 4, 30 Minutes - 2 Hours After LOCA

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low - No evidence of significant impact.
	Pressure gradient	Low - Slow pressure transient during this phase.
	Temperature gradient	Low - Would not degrade concrete for this temperature phase.
	Increased radiation exposure	Low - No significant impact on concrete structure.
	Outgassing/Vapor Expansion	Medium - Still potential for outgassing due to slow depressurization.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Low - Epoxy Primer designed to withstand some expansion/contraction.
	Calcium Carbonate Buildup	Low - No buildup expected during this phase.
	Blistering/Delamination.	High - Still coming down in pressure transient, potential for more vapor expansion.
	Vapor Buildup	Medium - Vapor collecting under epoxy primer from concrete.
	Water Migration	Low - No more water migration from concrete.
Epoxy Primer	Bulk movement	Low - No bulk movement of epoxy primer. Thermal expansion of concrete is not significant. Moving towards equilibrium at this point.
	Environmental exposure	Low - Exposure period to thermal conditions is short term.
	Minor coating anomalies	Medium - Pathway for vapor transmission.
	Cracking	Medium - Have seen this phenomena in the field, therefore ranked as a medium priority.
	Chemical exposure	Low - Topcoat still serves to protect epoxy primer during this phase.
	Mechanical damage	Low - Does not affect overall coating integrity, damage is localized.
	Water intrusion from pool	Low - Short term duration of immersion could have affect on epoxy primer.
	Temperature gradient	Low - Does not have impact on epoxy primer.
	Water/air diffusion (from outside the topcoat above submerged level)	Low - Localized through pathways.
	Increased radiation exposure	Low - Not an impact based on test data.
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - No difference in relative thermal expansion coefficients of the epoxy primer/topcoat.
	Blistering/Delamination.	Low - Because of high mechanical bonding between primer/topcoat
	Vapor buildup	Low - Have not experienced this between primer/topcoat in this system.

Epoxy Topcoat	Bulk movement	Low - See Epoxy Primer rationale.
	Temperature gradient	Low - Same as epoxy primer.
	Increased radiation exposure	Low - Same as epoxy primer.
	Diffusion air/water	Low - Small vapor transmissivity rate.
	Minor coating anomalies	Medium - Localized pathways for air/water buildup.
	Environmental exposure	Low - Still considered short term for thermal conditions exposure.
	Chemical attack	Low - Formulated to resist chemical attack.
	Cracking	Medium - Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low - Does not affect overall coating integrity, localized only.
	Condensation./cold wall	Low - Formulation of coating is resistant to cold wall affect.
	Immersion in pool	Low - Not expected to be an issue for short term immersion.
	Washdown	Low - Not a major contributor.

Table C4-5 Ranking Rationale; Concrete Substrate, Epoxy Primer, Epoxy Topcoat; Phase 5, >2Hours After LOCA Initiation

Component	Phenomena	Rank and Ranking Rationale
Substrate (concrete)	Expansion/compression	Low - No evidence of significant impact in concrete structures.
	Pressure gradient	Low - Slow pressure transient at this point in time. Coming to equilibrium.
	Temperature gradient	Low - Would not degrade concrete, temperature decreasing slowly.
	Increased radiation exposure	Low - No significant impact on concrete structure, based on test data.
	Outgassing/Vapor Expansion	Medium - Still continuing to outgas due to pressure decrease, but slowly.
Interface Epoxy Primer/Substrate	Differential expansion/contraction	Low - Epoxy Primer designed to withstand expansion/contraction.
	Calcium Carbonate Buildup	Medium - Potential for buildup over long term, indeterminate time for buildup.
	Blistering/Delamination.	High - Still coming down in pressure, lack of industry data.
	Vapor Buildup	Medium - Vapor collecting under epoxy primer.
	Water Migration	Low - Water no longer continues to migrate from concrete, no bulk diffusion.
Epoxy Primer	Bulk movement	Low - No movement of epoxy primer. Thermal expansion of concrete is insignificant.
	Environmental exposure	Medium - Will have long term exposure to thermal conditions.
	Minor coating anomalies	Medium - Pathway for vapor transmission.
	Cracking	Medium - Have seen this in epoxy primer.
	Chemical exposure	Low - Topcoat protects epoxy primer.
	Mechanical damage	Low - Does not impact overall coating integrity. Localize damage.
	Water intrusion from pool	Medium - Long term duration of immersion could affect epoxy primer.
	Temperature gradient	Low - Does not have an affect on the epoxy primer, system in equilibrium.
	Water/air diffusion (from outside the topcoat above submerged level)	Low - Can only occur through localized pathways.
	Increased radiation exposure	Low - Based on test data.
Interface Epoxy Primer/ Epoxy Topcoat	Differential expansion/contraction	Low - No difference in relative thermal expansion coefficients of the epoxy primer/topcoat.
	Blistering/Delamination.	Low - Mechanical bonds strong between primer and topcoat.
	Vapor buildup	Low - vapor has not been seen to buildup between epoxy primer/topcoat.

Epoxy Topcoat	Bulk movement	Low - See epoxy primer rationale.
	Temperature gradient	Low - Same as epoxy primer.
	Increased radiation exposure	Low - Same as epoxy primer.
	Diffusion air/water	Low - Small vapor transmissivity rate.
	Minor coating anomalies	Medium - Pathways for air/water buildup.
	Environmental exposure	Medium - Exposure to thermal conditions long term.
	Chemical attack	Low - Formulated to withstand chemical attack, bulk pH would be neutral.
	Cracking	Medium - Based on walkdowns of containments/drywells, historical data.
	Mechanical damage	Low - Does not affect overall coating integrity, localized only.
	Condensation/cold wall effects	Low - Formulation of coating is resistant to cold wall affect.
	Immersion in pool	Medium - Long term exposure could be an issue. Could have localized conditions of high/low pH in pool.
	Washdown	Low - Not a major contributor, epoxy topcoat resistant to water films from spray

Table C5-1 Ranking Rationale; Steel Substrate, Untopcoated Inorganic Zinc; Phase 1, Normal Operation

Component	Processes & Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion/contraction	Low - Does not affect substrate because can move freely, and substrate was designed for expansion/contraction under normal operating conditions, including ILRTs (performed adequately).
	Chemical attack	Low - Paint system designed to protect liner and regular inspections occur to catch problem areas and fix (localized areas).
	Environmental attack	Medium - Potential for SCC attack from chlorides in salt or groundwater, lack of industry data for long term cyclic conditions (i.e. open to atmosphere during outages, and then go back to normal operations). Several plants are located where these phenomena could exist (coastal air). Outages early years were typically 90 days or greater (so could have had 3 months of environmental exposure at a time). No real data that this is a problem or not.
	Radiation damage	Low - Substrate designed for long term exposure (DBA conditions). Substrate, (i.e. shell) is removed from neutron streaming. Steel even embrittled can still handle it's function without significantly cracking.
Substrate/primer interface	Differential expansion and contraction	Low - Differential expansion/contraction-Dominant material in IOZ is Zinc (90% approximately), and has a similar thermal coefficient of expansion as steel. The ethyl silicate (10%) does not play a significant factor for movement inhibition of this primer.
	Oxidation	Low - Under properly applied conditions this is low, because of design of zinc primer, which is sacrificial to the substrate. Zinc oxide formed as a result, and maintains integrity of coating under normal operating conditions.
	Cold-wall effect	Low - Cold Wall-Primer is designed to pull water through, and will still protect the substrate under normal operating conditions.

Primer (inorganic zinc)	Expansion/contraction	Low - Expansion/contraction-Coefficient of expansion of primer is similar to steel (bulk movement), and the amount of movement (substrate/primer coupled system) is low during normal operations and even under ILRT.
	Differential expansion and contraction stresses	Medium - There is a difference between zinc and ethyl silicate thermal coefficients of expansion. Also, could have a different zinc-to-binder ratio through the primer film, setting up a potential for cracking (micro cracking between zinc particles and binder). There is a lack of industry data on these phenomena.
	Oxidation	Medium - Do not have data for 40/60 year aging of Zn primer for nuclear applications. Not known if the significant changes in Zn (i.e. volume changes from Zn to ZnO) would set up propensity for failure during normal operations. Surface oxidizes faster than through the film.
	Environmental attack	Low - Zinc formulated to withstand atmospheric contaminants. Historical data shows that this primer withstands environmental aging over normal operations (i.e. bridges, structural members).
	Minor coating anomalies	Low - Industry experience has shown that this is not a major failure mechanism. Have not seen wholesale failure from minor anomalies during normal operations.
	Pigment/binder ratio	High - Preliminary data from SRTC shows this to be a possible mechanism for failure due to reduced binder at the film free surface.
	Erosion	NA - Bulk Dry/Over Spray-Particles are loosely adhered to the surface but would not come off during normal operation.
	Radiation damage	Low - Zn is formulated to be resistant to irradiation damage during normal operations.
	Chemical attack	Low - During normal operation only minor leakage (boric acid spills) would impact isolated areas, not exposed to chemicals that would attack the Zn during normal operating conditions.
	Mechanical damage	Low - Zinc primer is designed to be resistant to mechanical damage. Film integrity is still intact, as a result of mechanical damage, do not have film delamination.

Table C5-2 Ranking Rationale; Steel Substrate, Untopcoated Inorganic Zinc; Phase 2, 0-40 Seconds After LOCA Initiation

Component	Processes & Phenomena	Rank and Ranking Rationale
Substrate (steel)	Expansion/contraction	Low - Expect small movement in steel with the pressure/temperature seen during this phase.
	Temperature gradient	Low - Liner is designed to withstand temperature gradient during this phase.
	Chemical attack	Low - Short time of exposure to weak acidic conditions will not impact substrate.
	Environmental attack	NA - Not Applicable, containment is closed system from environment during accident.
	Radiation damage	Low - Total absorbed neutron dose during this phase will not impact steel, based on historical data.
Substrate/primer interface	Differential expansion and contraction	Low - Dominant material in IOZ is Zinc (90% approximately), and has a similar thermal coefficient of expansion as steel. The ethyl silicate (10%) does not play a significant factor for movement inhibition of this primer.
	Oxidation	Low - Short time duration of exposure to accident conditions not significant enough to warrant damage to substrate.
	Cold-wall effect	Low - Industry data from DBA tests does not suggest coating failures due to cold wall affects.

Primer (inorganic zinc)	Expansion	Low - Primer designed to move with the substrate
	Differential expansion and contraction stresses	Low - Preliminary SRTC test data shows this is not a significant failure mechanism.
	Temperature gradient	Low - Haven't seen from preliminary SRTC data (DBA tests) that this is a significant failure.
	Diffusion of air and water	Low - Due to short time duration not enough driving force through primer for significant diffusion to occur.
	Oxidation	Low - Time duration during this phase too short for damage caused by weak acidic conditions.
	Environmental attack	NA - Closed system not open to environment.
	Minor coating anomalies	Low - Industry experience has shown that this is not a major failure mechanism. Have not seen wholesale failure from minor anomalies during normal operations.
	Pigment/binder ratio	Low - Based on preliminary SRTC data (PWR plant chips, Dimecote) shows that during first part of DBA not a probable mechanism for failure.
	Erosion	Low - Areas around the break Zone of Influence, Zn would be affected, areas removed from break would not be impacted.
	Radiation damage	Low - Primer is formulated to be resistant to radiation damage (in addition time duration of exposure to radiation too short during this phase).
	Chemical attack	Low - Time duration too short for significant chemical damage due to exposure to weak acidic conditions.
	Mechanical damage	Low - Zinc primer is designed to be resistant to mechanical damage. Film integrity is still intact, as a result of mechanical damage, do not have film delamination.

Table C5-3 Ranking Rationale; Steel Substrate, Untopcoated Inorganic Zinc; Phase 3, 40 Seconds to 30 Minutes After LOCA Initiation

Component	Processes & Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - Expect small movement in steel with the pressure/temperature seen during this phase.
	Temperature gradient	Low - Liner is designed to withstand temperature gradient during this phase.
	Chemical attack	Low - Substrate is protected by primer during this phase of the event.
	Environmental attack	NA - Not Applicable, containment is closed system from environment during accident.
	Radiation damage	Low - Total absorbed neutron dose during this phase will not impact steel, based on historical data.
Substrate/primer interface	Differential contraction	Low - Dominant material in IOZ is Zinc (90% approximately), and has a similar thermal coefficient of expansion as steel. The ethyl silicate (10%) does not play a significant factor for movement inhibition of this primer.
	Oxidation	Low - Short time duration of exposure to accident conditions not significant enough to warrant damage to substrate.
	Cold-wall effect	Low - Industry data from DBA tests does not suggest coating failures due to cold wall affects.

Primer (inorganic zinc)	Contraction	Low - Primer designed to move with the substrate. However, only small, thin (2" x 4" x 1/4") coupons have been tested; large, thick sections have note been studied.
	Differential contraction stresses	Low - Temperature gradient through zinc film is small during this phase of the transient.
	Temperature gradient	Low - Temperature gradient through zinc film is small during this phase of the transient.
	Diffusion of air and water	Low - Conditions have equilibrated across the film during this phase of the event; no observed failures due to this phenomena reported by the industry.
	Oxidation	Low - Time duration during this phase too short for significant damage caused by exposure to weak acidic conditions.
	Environmental attack	NA - Closed system not open to environment.
	Minor coating anomalies	Low - Industry experience has shown that this is not a major failure mechanism. Have not seen wholesale failure from minor anomalies during normal operations.
	Pigment/binder ratio	Low - Based on preliminary SRTC data (PWR plant chips, Dimecote) shows that during first part of DBA not a probable mechanism for failure.
	Erosion	Medium - Removal of loosely adhered surface zinc due to action of containment sprays.
	Radiation damage	Low - Primer is formulated to be resistant to radiation damage (in addition time duration of exposure to radiation too short during this phase).
	Chemical attack	Low - Time duration too short for significant chemical damage due to exposure to weak acidic conditions.
	Mechanical damage	Low - Zinc primer is designed to be resistant to mechanical damage. Film integrity is still intact, as a result of mechanical damage, do not have film delamination.

Table C5-4 Ranking Rationale; Steel Substrate, Untopcoated Inorganic Zinc; Phase 4, 30 Minutes to 2 Hours After LOCA Initiation

Component	Processes & Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - Expect small movement in steel with the pressure/temperature seen during this phase.
	Temperature gradient	Low - Temperature gradient is small; liner is designed to withstand temperature gradient during this phase.
	Chemical attack	Low - Substrate is protected by primer during this phase of the event.
	Environmental attack	NA - Not Applicable, containment is closed system from environment during accident.
	Radiation damage	Low - Total absorbed neutron dose during this phase will not impact steel, based on historical data.
Substrate/primer interface	Differential contraction	Low - Transient is slow moving during this phase. Dominant material in IOZ is Zinc (90% approximately), and has a similar thermal coefficient of expansion as steel. The ethyl silicate (10%) does not play a significant factor for movement inhibition of this primer.
	Oxidation above pool surface	Low - Industry data indicates anodic protection still provided by zinc during this time frame of the transient.
	Oxidation below pool surface	Low - Time duration during this period is small; industry data indicates anodic protection still provided by zinc during this time frame of the transient.
	Cold-wall effect	Low - Conditions have equilibrated, small temperature gradients exist, Industry data from DBA tests does not suggest coating failures due to cold wall affects.

	Contraction	Low - Transient is slow moving at this time; contraction is slow.
	Differential contraction stresses	Low - Temperature gradient through zinc film is small during this phase of the transient.
	Temperature gradient	Low - Temperature gradient through zinc film is small during this phase of the transient.
	Diffusion of air and water above pool surface	Low - Conditions have equilibrated across the film during this phase of the event; no observed failures due to this phenomena reported by the industry.
	Oxidation above pool level	Medium - Both the time available for and the rate of reaction of zinc with accident conditions allows for increased challenge to zinc film from oxidation.
	Oxidation below pool level	Medium - Both the time available for and the rate of reaction of zinc with accident conditions allows for increased challenge to zinc film from oxidation.
	Environmental attack	NA - Closed system not open to environment.
Primer (inorganic zinc)	Minor coating anomalies	Low - Industry experience has shown that this is not a major failure mechanism. Have not seen wholesale failure from minor anomalies during normal operations.
	Pigment/binder ratio	Low - Based on preliminary SRTC data (PWR plant chips, Dimecote) shows that during first part of DBA not a probable mechanism for failure.
	Erosion	High - Lack of knowledge about zinc removal due to impingement of containment spray under accident conditions. Data needed to assess if this is a mechanism for of loss of film integrity.
	Radiation damage	Low - Primer is formulated to be resistant to radiation damage (in addition time duration of exposure to radiation too short during this phase).
	Chemical attack above pool surface	Medium - Reaction time has been long enough, and pH effect (4.0) will cause acceleration in zinc corrosion.
	Chemical attack below pool surface	Medium - Reaction time has been long enough, and pH effect (4.0) will cause acceleration in zinc corrosion.
	Mechanical damage	Low - Zinc primer is designed to be resistant to mechanical damage. Film integrity is still intact,

Table C5-5 Ranking Rationale; Steel Substrate, Untopcoated Inorganic Zinc; Phase 5, >2 Hours After LOCA Initiation

Component	Processes & Phenomena	Rank and Ranking Rationale
Substrate (steel)	Contraction	Low - Expect small movement in steel with the pressure/temperature seen during this phase.
	Temperature gradient	Low - Temperatures changes are slow and small during this phase, liner tends to be in thermal equilibrium with containment atmosphere.
	Chemical attack	Low - Substrate is protected by primer during this phase of the event.
	Environmental attack	NA - Not Applicable, containment is closed system from environment during accident.
	Radiation damage	Low - Total absorbed neutron dose during this phase will not impact steel, based on historical data.
Substrate/primer interface	Differential contraction	Low - Transient is slow moving during this phase. Dominant material in IOZ is Zinc (90% approximately), and has a similar thermal coefficient of expansion as steel. The ethyl silicate (10%) does not play a significant factor for movement inhibition of this primer.
	Oxidation above pool surface	Low - Containment sprays have been isolated. Humidity remains high. Above pool pH can be vary from 7.0. Industry data indicates anodic protection still provided by zinc during this time frame of the transient.
	Oxidation below pool surface	Medium - Do have zinc polarity reversal for a period of time during which steel is sacrificial to zinc (temperature range of 150°F to 180°F). Below 150°F, zinc is again sacrificial to steel. Impact of this polarity reversal is unknown.
	Cold-wall effect	Low - Conditions have equilibrated, small temperature gradients exist, Industry data from DBA tests does not suggest coating failures due to cold wall affects.

Primer (inorganic zinc)	Contraction	Low - Transient is slow moving at this time; contraction is slow.
	Differential contraction stresses	Low - Temperature gradient through zinc film is small during this phase of the transient.
	Temperature gradient	Low - Conditions are tending to equilibrium, temperature gradient through zinc film is small during this phase of the transient.
	Diffusion of air and water above pool surface	Low - Conditions have equilibrated across the film during this phase of the event; no observed failures due to this phenomena reported by the industry.
	Water intrusion below pool surface	Low - Zinc formulated to not fail due to submergence in water.
	Oxidation above pool level	Low - Containment sprays have been isolated but humidity remains high. Industry data indicates anodic protection still provided by zinc during this time frame of the transient.
	Oxidation below pool level	Medium - Prolonged exposure to fluid with variable pH and somewhat elevated temperature provide for increased rate of reaction of zinc with accident conditions, increasing challenge to zinc film from oxidation.
	Environmental attack	NA - Closed system not open to environment.
	Minor coating anomalies	Low - Industry experience has shown that this is not a major failure mechanism. Have not seen wholesale failure from minor anomalies during normal operations.
	Pigment/binder ratio	Low - Based on preliminary SRTC data (PWR plant chips, Dimecote) shows that during first part of DBA not a probable mechanism for failure.
	Erosion	NA - Containment sprays terminated. Only mechanism for erosion is bulk pool movement and condensation on structures.
	Radiation damage	Low - Primer is formulated to be resistant to radiation damage (in addition time duration of exposure to radiation too short during this phase).
	Chemical attack above pool surface	Low - Containment sprays isolated; wash down complete.
	Chemical attack below pool surface	High - Zinc is in contact with numerous chemical species and fluid at an elevated temperature and

APPENDIX D

Application Guide for Inorganic Zinc Coatings

APPENDIX D

APPLICATION GUIDE FOR INORGANIC ZINC COATINGS

1.0 General Information

1.1 This guide provides general information for application of multi-component inorganic zinc coatings. This type of coating has been extensively used for coating of steel substrates in light water nuclear power plants, either as a single coat system or as a primer for epoxy or epoxy phenolic topcoats.

1.2 If the inorganic zinc coatings are used for Nuclear Coating Service Level One, the application must be conducted in compliance with the requirements of the plant licensee's Nuclear Quality Assurance Program.

2.0 Material Storage

2.1 Inorganic zinc coatings should be stored indoors in a controlled environment in accordance with the manufacturer's recommended temperature range.

2.2 Storage Duration

2.2.1 Shelf life in accordance with the manufacturer's specification (normally one year).

2.2.2 Use prior to expiration date stated on the container.

3.0 Application Conditions

3.1 Temperature

3.1.1 The temperature of the ambient air, the substrate and the coating material should be controlled in accordance with the manufacturer's specified range.

3.2 Humidity

3.2.1 The manufacturer should specify a maximum relative humidity or the temperature of the substrate should be at least 5 deg F above the dew point in the specified temperature range.

4.0 Application Preparation

4.1 Packaging

4.1.1 Epoxy coating materials are general packaged in two-component kits (Part A – liquid vehicle and Part B – zinc filler).

4.1.2 The Part proportions are accurately pre-determined by the manufacturer.

4.1.2.1 The kits should not be sub-divided.

4.2 Mixing

4.2.1 The coating mixing area should be maintained in a clean condition to prevent

contamination of the coating material.

4.2.2 Thoroughly mix Part A (liquid vehicle) with a high shear, low speed power mixer.

4.2.3 Pour the mixed Part A into a clean container and ensure that complete mixing has been achieved (no residue in the bottom or on the sides of the Part A container).

4.2.4 Slowly add Part B (zinc filler) to Part A, mixing continuously. Care should be taken to prevent air being entrained in the mixed coating by ensuring that the mixer blades are completely submerged in the coating at all times.

4.3 Thinning

4.3.1 Inorganic zinc coatings should only be thinned with the manufacturer's specified thinner.

4.3.2 The amount and type of thinner required varies with temperature, humidity, elapsed time since mixing and the application method.

4.4 Pot Life

4.4.1 Inorganic zinc coating materials have a pot life or a time after mixing during which the product may be properly used.

4.4.2 Inorganic zinc coating materials should not be used once the material has exceeded the pot life specified by the manufacturer.

5.0 Curing Time

5.1 Inorganic zinc coatings cure by reaction with atmospheric moisture. During cure, it is <u>imperative</u> that relative humidity should be maintained above the minimum level specified by the coating manufacturer (typically 50 percent).

5.2 If humidity during inorganic zinc is anticipated to fall below the manufacturer's minimum limit during cure, force curing using water misting can be utilized. Instructions for forced curing should be obtained from the coating manufacturer.

5.3 Prior to over coating of inorganic zinc coatings with epoxy or epoxy phenolic coatings, the inorganic zinc coating must have achieved sufficient cure. Measurement of the degree of cure of inorganic zinc coatings can be performed in several ways including methyl ethyl ketone rub testing and pencil hardness testing. Instructions concerning measurement of the degree of curing of inorganic zinc coatings is available from the coating manufacturer.

6.0 Application Methods

6.1 Inorganic zinc coatings are generally applied by conventional (air) spray as the preferred method.

6.1.1 When applied by spray the manufacturer will suggest spray equipment including nozzle size, pressure, viscosity and fluid hose size.

6.1.2 Continuous pot agitation must be used when applying inorganic zinc coatings to ensure that the zinc powder remains in suspension.

6.2 Inorganic zinc coatings cannot be roller-applied, are not normally brush- or dauber-applied. Brush or dauber application may be used in limited situations when applying inorganic coatings to small areas (less than one square foot).

7.0 Cleanliness

7.1 Application equipment should be thoroughly cleaned after each working shift to insure quality work.

7.2 If the weather is extremely warm, clean the equipment even sooner (example: every 4 hours).

7.3 Always clean equipment with thinners/solvents approved by the manufacturer.

APPENDIX E

Application Guide for Epoxy Coatings

APPENDIX E

APPLICATION GUIDE FOR EPOXY COATINGS

1.0 General Information

1.1 This guide provides general information for application of multi-component epoxy primers, sealers, surfacers, topcoats and floor coatings. These types of coatings have been extensively used for coating of both steel and concrete substrates in light water nuclear power plants.

1.2 If the epoxy coatings are used for Nuclear Coating Service Level One, the application must be conducted in compliance with the requirements of the plant licensee's Nuclear Quality Assurance Program.

2.0 Material Storage

2.1 Epoxy coatings should be stored indoors in a controlled environment in accordance with the manufacturer's recommended temperature range.

2.2 Storage Duration

2.2.1 Shelf life in accordance with the manufacturer's specification (normally one year).

2.2.2 Use prior to expiration date stated on the container.

3.0 Application Conditions

3.1 Temperature

3.1.1 The temperature of the ambient air, the substrate and the coating material should be controlled in accordance with the manufacturer's specified range.

3.2 Humidity

3.2.1 The manufacturer should specify a maximum relative humidity or the temperature of the substrate should be at least 5 deg F above the dew point in the specified temperature range.

4.0 Application Preparation

4.1 Packaging

4.1.1 Epoxy coating materials are general packaged in multi-component kits (Part A – liquid vehicle, Part B – converters; sometimes Part C – filler).

4.1.2 The proportions are accurately pre-determined by the manufacturer.

4.1.2.1 The kits should not be sub-divided.

Mixing

4.2.1 The coating mixing area should be maintained in a clean condition to

prevent contamination of the coating material.

4.2.2 Thoroughly individually mix each liquid Part by "boxing" (pouring back and forth) between the original container and another clean container at least 10 times to insure uniform mixing of each individual part, ending with each part in the new clean container (rather than in the original container supplied by the manufacturer). This avoids the used of "uncatalyzed" material.

4.2.3 If thinning is necessary or required for application, follow the same procedures as outlined in 4.2.1 and 4.2.2.

4.2.4 Power mixing is acceptable but it should be noted that such equipment induces heat which, in turn could significantly shorten the pot life.

4.3 Thinning

4.3.1 Epoxy coatings should only be thinned with the manufacturer's suggested thinner.

4.3.2 The amount of thinner required varies with temperature, humidity, elapsed time since mixing and the application method.

4.4 Pot Life

4.4.1 Epoxy coating materials have a pot life or a time after mixing during which the product may be properly used.

4.4.2 Epoxy coating materials should not be used once the material has exceeded the pot life specified by the manufacturer.

4.4.2 Some epoxy coating materials have an "induction period" or a period of time when the material is allowed to react after mixing and prior to application.

5.0 Curing Time to Recoat

5.1 Epoxy coatings should be cured prior to recoating in accordance with the manufacturer's recommendations.

5.2 Most epoxy coatings can be force cured using a minimal amount of heat (up to 200° F) for a reduced period of time (example: 15-30 minutes) for atmospheric service.

5.3 Most epoxy coatings must be cured for an extended periods (example: 10 days at 70° F) before being exposed to <u>continuous immersion service.</u>

6.0 Application Methods

6.1 Epoxy coatings are generally applied by spray (either conventional (air) or airless) as the preferred method.

6.1.1 When applied by spray the manufacturer will suggest spray equipment including nozzle size, pressure, viscosity and fluid hose size.

6.2 Brush, roller, squeegee and broad knife can be used for specific applications when approved by the coating manufacturer.

7.0 Cleanliness

7.1 Application equipment should be thoroughly cleaned after each working shift to insure quality work.

7.2 If the weather is extremely warm, clean the equipment even sooner (example: every 4 hours).

7.3 Some epoxy coatings have a very short pot life which means precaution should be taken to assure the protection of equipment.

7.4 Always clean equipment with thinners/solvents approved by the manufacturer.

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