ELECTRIC POWER
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Plant Support Engineering: Guideline on Nuclear Safety-Related Coatings, Revision 2 (Formerly TR-109937 and 1003102)

Guideline on Nuclear Safety-Related Coatings, Revision 2 (Formerly TR-109937 and 1003102)

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REPORT SUMMARY

This report provides a programmatic overview of the elements that should be considered in establishing a utility-unique coatings program consistent with plant-specific licensing and regulatory requirements.

Background

The goal of a nuclear power plant coatings program is to ensure that coating systems are properly applied and maintained so that the coatings can perform their intended function. In nuclear power plants, coatings are often used to prevent corrosion and erosion, facilitate decontamination, and help achieve visual objectives such as enhancing the efficiency of area lighting or basic aesthetics. Coatings typically do not have a safety function *per se*; it is the detachment of the coating from its surface that is the safety concern. Detached coatings have the potential to prevent the performance of the safety function of other equipment, typically by fouling the flow path, which can result in flow rates lower than those required for the performance of a particular safety function.

Objective

- To provide guidance that will assist nuclear plant personnel in developing, maintaining, and periodically assessing the effectiveness of safety-related coatings programs

Approach

In 1996, the Electric Power Research Institute's (EPRI's) Plant Support Engineering (PSE) was approached by utility representatives on the Nuclear Utility Coatings Council for assistance in developing a comprehensive guideline to assist utilities in maintaining their safety-related coatings. In response, a PSE Task Group was formed and met five times between July 1997 and January 1998 to develop this report. During development of the original EPRI report, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 98-04, "Potential for Degradation of the Emergency Core Cooling and Containment Spray Systems Following a Loss-of-Coolant Accident Due to Construction and Protective Coatings Deficiencies and Foreign Material in the Containment." This report was originally published in April 1998 and has been revised twice since, primarily to reflect changes in regulations and standards applicable to safety-related coatings, industry experience, and ongoing research conducted by the industry and the NRC. Additionally, this revision of the EPRI report reflects the technical information generated during closeout of GL 98-04 and GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors."

Note that at the time of publication of this report, new nuclear power plant designs are being finalized. Detailed information concerning the coating system designs for these plants is not currently available.

Results
This report provides detailed guidance on the following aspects of a plant nuclear safety-related coatings program:

- Key concepts and definitions
- Qualification and selection of coating systems
- Procurement and materials management
- Surface preparation and coating application
- Inspection of surface preparation and application
- Condition assessment
- Management of non-conforming coatings
- Personnel training and qualification

EPRI Perspective
This report is a revision to the original guideline to ensure that the information pertaining to safety-related coatings and the standards that are used for the design basis are communicated. Plant personnel use this guideline as a tool to assist them in ensuring that the coatings used in the plant do not create any issues relating to the safety and reliable operation of the plant.

Keywords
Coating specialist
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Advanced Corrosion Engineering, Inc. (George Spires, Principal Investigator)

Sequoia Consulting Group, Inc. (William Houston and Michael Tulay, Principal Investigators)

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An ongoing task group developed the original edition of this report. As such, the members of the group have made significant contributions to the development of this report by guiding the report's scope and content, providing technical expertise, attending task group meetings, and reviewing and commenting on draft versions of the report. The following individuals were members of the task group:

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INTRODUCTION AND BACKGROUND

1.1 Background

The goal of a nuclear power plant coatings program is to ensure that coating systems are properly applied and maintained for the coatings to perform their intended function. In nuclear power plants, coatings are often used to prevent corrosion and erosion, facilitate decontamination, and help achieve visual objectives, such as enhancing the efficiency of area lighting or basic aesthetics. Coatings typically do not have a safety function *per se*, but it is the detachment of the coating from its surface that is the safety concern. Detached coatings have the potential to prevent the performance of the safety function of other equipment, typically by fouling the flow path, which may result in flow rates less than required for the performance of a particular safety function.

Several factors, including settling, transport, and the characteristics of detached coatings, determine whether detached coatings affect the safety functions of other equipment. Plant applications that use coatings that could potentially detach and affect the operation of plant safety equipment include the following:

- Inside primary containment
- Safety-related service water system internal coatings and linings
- Emergency diesel fuel tank coatings and linings
- Coatings for tanks containing water used during emergency core cooling system (ECCS) operation

In 1997, the U.S. Nuclear Regulatory Commission (NRC) expressed concerns that safety-related coatings may be failing in service. The NRC initially issued Information Notice 97-13, Deficient Conditions Associated with Protective Coatings at Nuclear Power Plants, to express its concerns. Subsequently, on July 14, 1998, the NRC issued Generic Letter (GL) 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System After a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment." This GL further expressed the NRC concerns and required licensees to provide detailed information concerning Service Level 1 coatings programs in licensed nuclear power plants.

Each U.S. nuclear power plant licensee, in its response to GL 98-04, committed to conducting scheduled, periodic condition assessments and implementing the Maintenance Rule for the reactor containment safety-related coatings. After review of the licensee responses, the NRC closed out GL 98-04.

The NRC has, since preparation of the previous revision to this EPRI report (1003102), identified a Generic Safety Issue (GSI) 191, "Assessment of Debris Accumulation on PWR Sump Performance" (January 2002). It identifies the potential effects of failure of reactor containment coatings. An associated GL—GL 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors—has been issued by the NRC. All coating issues related to GL 2004-02 have been resolved between the licensees and the NRC at this time.

1.2 Report Objective

The objective of this report is to provide guidance that will assist nuclear plant personnel in developing, maintaining, and periodically assessing the effectiveness of safety-related coatings programs. This report provides a programmatic overview of the elements that should be considered in establishing a utility-unique coatings program consistent with plant-specific licensing and regulatory requirements.

Key Point

As a result of commitments made in responses to GL 98-04, all nuclear utilities now have formal nuclear safety-related coatings programs. These programs provide reasonable assurance that safety-related coatings in each plant's reactor containment are procured, applied, and maintained in compliance with applicable regulatory requirements and the plant-specific licensing basis for the facility.

At the time of preparation of this revision to the report, new nuclear power plant designs are being finalized. Detailed information concerning the coating system designs for these plants is not currently available. As such, certain portions of this report may not be applicable to certain portions of new plant designs.

1.3 Regulatory Background

Regulatory Guide (RG) 1.54, Revision 0 (1973), Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants, addresses safety-related coatings. It endorses American National Standards Institute (ANSI) Standard N101.4 (1972), Quality Assurance for Protective Coatings Applied to Nuclear Facilities, as an acceptable method for complying with quality assurance (QA) requirements for nuclear power plant coating work.

However, there are plants that are not committed to the RG because their licensing process was well advanced or completed prior to its issuance in 1974. These licensees have evaluated the issue of potentially detached containment coatings and have concluded that their plants are safe to operate. By authorizing these older plants to operate, the NRC also concluded that the effect of detached coatings on the requirements in 10 CFR 50.46 regarding the assurance of long-term operability of ECCSs was adequately addressed. Most plants licensed since 1975 are committed to RG 1.54, Revision 0, and many plants licensed prior to 1975 have subsequently committed to compliance with RG 1.54, Revision 0.

In July 2000, the NRC issued Revision 1 to RG 1.54, Service Level I, II and III Protective Coatings Applied to Nuclear Power Plants. This broad revision to RG 1.54 provides NRC regulatory positions on ASTM International (ASTM) standards as applicable to nuclear power plant coatings. At the time of preparation of this revision to the EPRI report, only one U.S. nuclear power plant has revised its licensing basis documents to adopt Revision 1 to RG 1.54.

NRC is in the process of preparing Revision 2 to RG 1.54, which is scheduled to be issued in 2010.

Key Point

Although many standards are referenced throughout this report, the particular standards selected for implementation should be consistent with each plant's licensing basis.

1.4 Implementing the 10 CFR 50, Appendix B QA Program for Coatings

The 18 criteria for the 10 CFR 50, Appendix B QA program all contribute to ensuring that a system, structure, component, or part will perform as it is designed to perform. Program implementation varies, depending on the type of item and its particular end-use application in the plant. Section 1.4.1 describes how a licensee typically implements its 10 CFR 50, Appendix B QA program for coatings that are classified as safety-related. Section 1.4.2 contrasts licensee implementation with how a manufacturer of coatings would typically implement its 10 CFR 50, Appendix B QA program.

Safety-related coatings work is a "special process" as described in Criterion IX of 10 CFR 50, Appendix B. Criterion IX states:

> Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

Safety-related coatings work is considered a special process because the quality of the finished work or product cannot be verified without qualification processes, in-process controls, and inspections to ensure the performance of the coating under the design service conditions.

Application and quality controls are needed to ensure the quality of safety-related applications that are performed by certified painters and inspectors, as qualified in accordance with approved procedures.

1.4.1 Program Implementation by Licensees

Table 1-1 provides a listing of the 18 criteria and a brief description of how each applicable criterion is typically implemented by a licensee when ensuring the quality of safety-related coatings. Program implementation guidance is cross-referenced to the appropriate section of this report to further assist the reader in understanding the implementation of the 10 CFR 50, Appendix B QA program and how the guidance contained in this report addresses many of the 18 quality criteria.

Table 1-1
Implementation of 10 CFR 50, Appendix B by licensees

Quality Assurance Criteria	Program Implementation for Coatings
I. Organization	Many utilities have centralized responsibility of the coatings program under the Nuclear Coating Specialist. This individual's responsibilities are described in Section 10.
II. Quality Assurance Program	1019157 describes the program elements of a typical nuclear coatings program that would be implemented under the 10 CFR 50, Appendix B QA program.
III. Design Control	Each licensee must select a coating that is suitable for a given application in the plant. Section 4 describes design basis considerations to remember when selecting a suitable coating and essential variables to consider when qualifying that coating.
IV. Procurement Document Control	Sections 4 and 5 describe factors that should be considered when classifying the safety function of a coating and when developing a specification for coatings.
V. Instructions, Procedures, and Drawings	Each licensee typically develops plant-specific procedures describing the selection, specification, receipt, control, surface preparation, physical application, and assessment of coatings.
VI. Document Control	Each licensee typically documents the implementation of coatings related procedures to meet the specific needs of each plant.
VII. Control of Purchased Material, Equipment, and Services	Coatings are accepted for nuclear safety-related use either by purchasing the coating from a supplier with a 10 CFR 50, Appendix B QA program or by performing a commercial grade dedication under the licensee's 10 CFR 50, Appendix B QA program. Section 5 describes the procurement of coatings in detail.
VIII. Identification and Control of Materials, Parts, and Components	Coatings are traceable to a purchase order and procurement requisition and are typically assigned a utility/plant unique identifier (for example, stock code). Controls are employed to ensure that the coating is traceable while it is in storage, issued for use, and applied on a plant structure, system, or component.

Table 1-1 (continued)
Implementation of 10 CFR 50, Appendix B by licensees

Quality Assurance Criteria	Program Implementation for Coatings
IX. Control of Special Processes	Coatings work is a special process that is controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements. Mixing, surface preparation, physical application, and drying/curing are typical elements of the special process (coatings work) implemented by the licensee and are described in Section 6. These special process elements are implemented for both the initial application of coatings and for repairs.
X. Inspection	Section 5 describes receipt inspections that a licensee may perform. Section 7 describes the inspections associated with surface preparation and physical application of coatings. Section 8 describes ways to assess the condition of coatings once applied to a system, structure, or component.
XI. Test Control	Section 4 describes design basis accident (DBA) qualification test controls that a licensee may have performed on its behalf. Section 5 describes some receipt tests that a licensee may perform during the acceptance of coatings.
XII. Control of Measuring and Test Equipment	Each licensee is typically responsible for ensuring that any test equipment used for measuring attributes/characteristics of coatings is calibrated and in proper working condition.
XIII. Handling, Storage, and Shipping	Section 5 describes general requirements for handling, storing, and shipping of coatings.
XIV. Inspection, Test, and Operating Status	This criterion is typically not applicable to coatings work.
XV. Non-Conforming Materials, Parts, or Components	Section 9 describes methods by which a licensee can identify and manage non-conforming coatings.
XVI. Corrective Action	Section 9 describes corrective actions a licensee can take after identifying a non-conforming coating.
XVII. Quality Assurance Records	Each licensee typically documents the implementation of coatings-related procedures to meet the specific needs of each plant. These documents are retained/stored to meet plant-specific requirements.
XVIII. Audits	Engineering/QA personnel may conduct internal audits of the nuclear coatings program and external audits of coatings manufacturers and service contractors to meet plant-specific requirements. The nuclear coatings program may also be subject to external audits conducted by the Institute of Nuclear Power Operations or regulatory personnel.

1.4.2 Program Implementation by Nuclear Suppliers

Table 1-2 provides a listing of the 18 criteria and a brief description of how each applicable criterion is typically implemented by a nuclear supplier when ensuring the quality of safety-related coatings.

Table 1-2
Implementation of 10 CFR 50, Appendix B by nuclear suppliers

Quality Assurance Criteria	Program Implementation for Coatings
I. Organization	A nuclear supplier would typically describe its organization and independent QA function in its nuclear QA products manual.
II. Quality Assurance Program	A nuclear supplier describes the implementation of its 10 CFR 50, Appendix B QA program in its nuclear QA products manual.
III. Design Control	The supplier/manufacturer is responsible for formulating coatings and controlling formulation changes. Qualification of coatings used in safety-related applications may include DBA testing, engineering analysis, or historical demonstration.
IV. Procurement Document Control	A supplier documents the specification and procurement of raw materials procured from subsuppliers.
V. Instructions, Procedures, and Drawings	Each supplier typically has procedures to document the formulation, formulation changes, qualification, testing, manufacture, and control of coatings.
VI. Document Control	Each supplier/manufacturer typically documents the implementation of procedures to meet the specific needs of the purchaser.
VII. Control of Purchased Material, Equipment, and Services	Raw materials used in the manufacture of nuclear coatings may be accepted by the supplier through receipt testing, audits of the sub-suppliers, inspection at the subsupplier facility, and/or historical demonstration of the subsupplier and the raw materials furnished over time.
VIII. Identification and Control of Materials, Parts, and Components	Raw materials are traceable to a purchase order and procurement requisition. Controls are employed to ensure that the raw materials are traceable while they are in storage and issued for production. Nuclear coatings are typically controlled by batch number.
IX. Control of Special Processes	Mixing of raw materials and determination of curing parameters are the special processes implemented by the supplier/manufacturer to ensure that the coating conforms to design requirements.
X. Inspection	Acceptance of raw materials may be achieved with receipt inspections. A supplier/manufacturer may employ in-process or final product inspections to ensure that the manufactured coating conforms to design requirements.
XI. Test Control	Tests performed by the manufacturer either for the qualification of a coating design or for the acceptance of a batch of product are typically described in procedures.

Table 1-2 (continued)
Implementation of 10 CFR 50, Appendix B by nuclear suppliers

Quality Assurance Criteria	Program Implementation for Coatings
XII. Control of Measuring and Test Equipment	Each supplier/manufacturer is responsible for ensuring that any test equipment used for measuring attributes/characteristics of coatings is calibrated and in proper working condition.
XIII. Handling, Storage, and Shipping	Each supplier/manufacturer is responsible for handling, storing, and shipping both raw materials and nuclear coatings to preclude damage prior to manufacture/delivery.
XIV. Inspection, Test, and Operating Status	Each manufacturer must establish measures to identify inspection and test status. These measures include provisions for ensuring that required tests and inspections are performed, inspection and test status is known throughout the manufacturing process as specified on batch tickets or other documents, non-conforming materials are identified, only materials that have passed required inspections and tests are used, and individual inspections and tests are signed off by authorized personnel.
XV. Non-Conforming Materials, Parts, or Components	Each manufacturer's QA manual should describe methods for identifying non-conforming materials or conditions.
XVI. Corrective Action	Each manufacturer's QA manual should describe corrective actions that can be taken after identifying a non-conforming raw material, condition, or finished product.
XVII. Quality Assurance Records	Each supplier/manufacturer should document the implementation of coatings-related processes. These documents are retained/stored to meet customer requirements.
XVIII. Audits	Supplier QA personnel conduct internal audits and external audits of raw material sub-suppliers to meet QA program requirements. The nuclear coatings program may also be subject to audits by nuclear utility representatives/groups, the Nuclear Utility Procurement Issues Committee (NUPIC), or regulatory personnel.

1.4.3 Program Implementation by Others

The following is a list of other organizations in the supply chain or associated with nuclear coatings work that may maintain a 10 CFR 50, Appendix B QA program:

- Third-party service contractors
- Coatings applicators
- Coatings inspectors
- Test facilities or laboratories
- Original equipment manufacturers furnishing coated or lined equipment

QA program implementation will vary among these organizations based on the specific scope of work or supply being procured by the licensee. Information and guidance on how each of these organizations implements its nuclear QA program may be found in the most recent utility audit report, which is typically accessible at each plant site.

1.5 Definitions and Acronyms

1.5.1 Definitions

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

certification. The written documentation of the qualification of personnel or material (from ASTM D3843).

chemical spray. A solution of chemicals that could be used during a LOCA to suppress the incident, to scavenge the fission products, and to return the facility to near-ambient conditions.

condition assessment. A systematic approach established to assess and document the condition of existing coating systems with respect to prescribed performance attributes.

DBA-qualified coating system. A coating system used inside primary containment that can be attested to having passed the required laboratory testing, including irradiation and simulated DBA, and has adequate quality documentation to support its use as DBA-qualified.

DBA-unqualified coating system. A coating system used inside reactor containment that cannot be attested to having passed the required laboratory testing, including irradiation and simulated DBA, or has inadequate quality documentation, or both, to support its use as DBA-qualified.

design basis accidents (DBAs) and events. Postulated accidents and transients specified in the safety analysis of the plant used in the design to establish acceptable performance requirements for structures, systems, and components (SSC). DBAs and transients are generally defined in Chapter 15 of the FSAR (from EPRI NP-6895).

deviation. A departure of a characteristic from established procedures or from specified requirements (from ASTM D3843).

identical coatings. Coating materials having the same constituent solids in the same proportions to produce a dry film having the same physical and chemical characteristics.

inaccessible areas. Areas (such as inside tube steel or the backsides of items) that are inaccessible to surface preparation tools and/or coating application. Nonrepresentative areas (such as corners, bolt heads, bolt holes, pockets, confined spaces, or other small areas inaccessible for normal surface preparation or coating application) are not representative and therefore should *not* be selected for verification of DFT. Such areas should be considered acceptable if coating work is accomplished as nearly in conformance with the specification as is reasonably achievable.

inspection. A phase of quality control that by way of examination, observation, or measurement determines the conformance of materials, supplies, components, parts, appurtenances, systems, processes, or structures to predetermined quality requirements (from ASTM D3843).

nonconformance. A deficiency in characteristic, documentation, or procedure that renders the quality of an item unacceptable or non-conforming. Examples of nonconformance include physical defects, test failures, incorrect or inadequate documentation, or deviation from prescribed processing, inspection, or test procedures (from ASTM D3843).

non-conforming coating. a coating or coating system in a Coating Service Level I application that lacks or has insufficient documentation to support or verify DBA qualification.

non-conforming condition. A condition of an SSC in which there is failure to meet requirements or licensee commitments. The following are some examples of non-conforming conditions:

- There is failure to conform to one or more applicable codes or standards specified in the FSAR.
- As-built equipment, or as-modified equipment, does not meet FSAR descriptions.
- Operating experience or engineering reviews demonstrate a design inadequacy.
- Documentation mandated by NRC requirements, such as 10 CFR 50.49, is not available or deficient.

safety-related coatings program. The systematic and planned activities conducted at a nuclear power plant to ensure that the safety-related coatings perform all of their design functions.

safety-related coating system. A coating system used inside or outside of primary containment, the detachment of which could adversely affect the safety function of a safety-related SSC.

service life. The period of time an item (coating) is expected to meet the operational readiness requirements without maintenance.

1.5.1.1 Common Terms Related to Coating Work

anchor pattern. The roughened surface that results from abrasive blast cleaning or power tool cleaning to the substrate.

batch. A uniquely identifiable mix or lot of paint manufactured under controlled conditions.

bughole. A void or cul-de-sac-like air pocket at or near the surface of formed concrete.

coating applicator. An organization or individual responsible for applying a protective or decorative coating system (from ASTM D3843).

coating manufacturer. An organization responsible for manufacturing coating materials (from ASTM D3843).

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

For pressurized water reactors (PWRs), coating work for the following structures and equipment is under Coating Service Level I:

- Reactor containment building liner plate
- Structural and miscellaneous steel, steam generator support steel, and gallery steel
- Concrete surfaces inside the reactor containment building
- Exposed uninsulated carbon steel surfaces of mechanical equipment, of piping and auxiliaries, and of electrical and auxiliaries

For boiling water reactors (BWRs), coating work for the following structures and equipment is under Coating Service Level I:

- Drywell
- Suppression chamber
- Structural and miscellaneous steel
- Concrete surfaces inside the drywell and the wetwell (that is, Mark II pedestals)
- Exposed uninsulated carbon steel surfaces of mechanical equipment, of piping and auxiliaries, and of electrical equipment and auxiliaries

Coating Service Level II. Term used to describe areas outside the reactor containment where coating failure could impair, but not prevent, normal operating performance. The function of Coating Service Level II coatings is to provide corrosion protection and decontaminability in those areas outside the reactor containment subject to radiation exposure and radionuclide contamination (from ASTM D5144-00).

The previous definition would logically include some coatings that may not be classified as safety-related coatings but that protect systems essential to plant operability, such as tank linings (for example, fire and potable water) and linings for circulating water pipe and main condenser tubesheets and waterboxes.

Coating Service Level III. Term used to describe areas outside the reactor containment where failure could adversely affect the safety function of a safety-related SSC (from ASTM D5144-00).

Selection of coating materials and performance of coating work for this service level should reflect immersion and such other service conditions as might be anticipated throughout the coatings service life expectancy. Specifically, coating work for the following structures and equipment is under Coating Service Level III: fuel pools and canals, if coated (generally applicable only for older plants), and refueling water storage tanks or such other tanks constituting ECCS water sources.

coating (paint) system. A protective film consisting of one or more coats, applied in a predetermined order by prescribed methods to a defined substrate (from ASTM D4538-95).

coating work. An all-inclusive term to define all operations required to accomplish a complete coating job. The term shall be construed to include materials, equipment, labor, preparation of surfaces, control of ambient conditions, application, repair of coating systems, and inspection (from ASTM D3843).

cracking. A break or a split in the coating (paint) system extending through the film or to the substrate (from ASTM D3911).

cure time. The two phases of cure are as follows: (1) *cure to recoat:* minimum dry time to recoat. This is the minimum time required for applying a full overcoat (second and third coat of a multiple coat system). It does not apply to in-process repair of mechanical damage. (2) *Cure to handle*: minimum time before which the coating film can resist the extent of impression expected in conjunction with the handling and transport of a coated item.

curing. The transformation of a coating or other material into a solid phase or film (from ASTM D3911).

defects. Flaws such as cracks, sags, runs, flaking, orange peel, overspray, checks, blisters, bubbles, and craters or any condition that adversely affects the ability of a coating film to function as intended.

delamination. Separation of one coat or layer from another coat or layer or from the substrate (from ASTM D3911).

dry film thickness (DFT). The thickness of a coating when dry, as measured in a prescribed manner (for example, per SSPC PA2 or with a scratch-type gauge), read in mils (thousandths of an inch).

exposed surface. A surface that, in its final condition of installation, is exposed to the view of people performing routine duties or using the area for its normal function.

flatwork. The up-facing “traffic” surface of a cast-in-place concrete grade slab or deck (that is, a concrete floor).

formed surfaces. The sides or undersides of cast-in-place or precast concrete that are against the forms during placement. Formed surfaces include ceilings, walls, and the sides of freestanding concrete girders and columns.

hiding/shadow through. Visual judgment regarding the property of a coating that enables it to obliterate beyond recognition any background over which it may be applied.

holiday. A skip, discontinuity, or void in a coating film usually detected visually or, in the case of lining systems, with an electrical continuity-type device.

jet impingement. Associated with a high-energy line break (HELB) event, resulting in high-pressure fluid striking and damaging adjacent equipment and materials.

kerf. A slit or notch made by cutting with a saw.

lower explosive level. Lower limit of explosivity of a gas or vapor at ordinary ambient temperatures expressed in percent of the gas or vapor in air by volume.

microbiologically influenced corrosion. A form of corrosion wherein microbes extant on a metal surface tend, by their metabolic activity, to promote corrosive attack. Microbes typically are found within corrosion product mass (for example, in rust tubercules) and are not necessarily totally eradicated by the blast process alone.

paints/coatings/linings. Essentially synonymous terms for liquid-applied materials consisting of pigments and fillers bound in a resin matrix that dry or cure to form a thin, continuous protective or decorative film. “Linings” indicates an immersion environment.

peeling. Separation of one or more coats or layers of a coating from the substrate.

potentially contaminated areas (PCAs). Areas within the plant that during normal operation routinely experience splash or spillage of fluids containing radionuclides or solutions having dilute chemical concentration.

prime coat (primer). The initial coat applied uniformly and overall to an otherwise unprimed or previously painted substrate.

profile. The distance, in mils (thousandths of an inch), measured perpendicular to the surface between adjacent high and low points on a substrate resulting from the surface preparation process (for example, from the cutting action of a blast cleaning abrasive). Conceptually, a cross-sectional view of a prepared surface.

runs. Heavy, V-shaped or pencil-shaped vertical buildups on the surface of a coating that are visually and tactually perceptible.

sags. Heavy U-shaped buildups or horizontal lips on the surface of a coating that are visibly and tactually perceptible. Broad sags are referred to as *curtains*.

seal coat. A special low-viscosity coat designed to wet into the substrate or previous coat, binding it together and helping to release entrapped air. Certain seal coats serve as barrier or tie coats, bridging between preexisting paints and new finishes.

spot priming. Application of a primer at discrete spots rather than overall, usually necessitated by damage to a previously applied coating or at an exposed substrate.

stripe painting. Supplemental priming of a limited proportion of steel shapes to counter the tendency for coating materials, while liquid, to pull back from sharp edges, which results in diminished thickness. Striping, when required, may be performed before or after any general overall priming that may be specified (see Subsection 6.6 of SSPC-PA1).

substrate. The surface to which a particular coating system will be applied (that is, steel, concrete, masonry, and so on).

surfacer. A special thixotropic, high-viscosity material specifically intended for use on concrete formed surfaces. Surfacers are used to fill bugholes and render a smooth base for the finish coats.

topcoats/finish coats. These terms are used interchangeably to reference the coat visible when the intended, overall system (that is, the final coat) is complete. It is this coat that is exposed to the environment. In some coating systems, multiple coats of the same topcoat are used to enhance the resistance of the overall system to the environment. In such instances, the terms *first finish coat* and *final finish coat* are used. When the term *intermediate coat* is used, such differentiation implies that the intermediate coat is different from the topcoat/finish coat.

ultra-high-pressure water jetting (UHPWJ). Water jet cleaning performed at pressures in excess of 25,000 psi (172.369 MPa). UHPWJ will not produce a significant profile. If the surface was previously blasted and coated and the coating is in good condition, UHPWJ exposes the preexisting blast profile.

volatile organic compound (VOC). As defined by the Enviornmental Protection Agency (EPA; Reference Method 24), any organic compound that participates in atmospheric chemical reactions is a VOC; that is, any organic compound except those designated as *exempt solvents* by virtue of their having negligible photochemical reactivity.

wet film thickness (WFT). The thickness of a wet coating immediately after its deposition, and prior to the evaporation of any volatile constituents or the onset of curing, read in mils with a WFT gauge in accordance with ASTM D4414.

zone of influence (ZOI). The volume about a HELB in which the fluid escaping from the break has sufficient energy to generate debris from insulation, coatings, and other materials within the zone.

1.5.1.2 Other Sources of Definitions Related to Nuclear Coating Work

ASTM Manual of Coating Work, Appendix A: Glossary of Terms

ASTM D4538, "Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities"

ANSI N45.2.10, "Quality Assurance Terms and Definitions"

SSPC *Steel Structures Painting Manual, Volume 1*, *Good Painting Practice*—Appendix B: Definitions

1.5.2 Acronyms

ACI American Concrete Institute

ALARA as low as reasonably achievable

ANS American Nuclear Society

ANSI American National Standards Institute

API American Petroleum Institute

ASME American Society of Mechanical Engineers

ASQE American Society of Quality Engineers

ASTM ASTM International

AWS American Welding Society

BWR boiling water reactor

CFR Code of Federal Regulations

CIP Coating Inspector Program

DBA design basis accident

DFT dry film thickness

DH dehumidification

DOE Department of Energy

ECCS	emergency core cooling system
EEQ	environmental equipment qualification
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FSAR	final safety analysis report
FTIR	Fourier transform infrared
GALL	Generic Aging Lessons Learned
GL	Generic Letter
GSI	Generic Safety Issue
HELB	high-energy line break
HEPA	high-efficiency particulate air
HPWJ	high-pressure water jetting
HVAC	heating, ventilation, and air conditioning
ID	inside diameter
ILRT	integrated leak rate test
ISI	in-service inspection
LOCA	loss-of-coolant accident
MR	megarads
MSLB	main steam line break
NACE	National Association of Corrosion Engineers (NACE International)
NBR	National Board of Registration for Nuclear Safety-Related Coating Engineers and Specialists
NPP	nuclear power plant
NPSH	net positive suction head

NRC	U.S. Nuclear Regulatory Commission
NUCC	Nuclear Utility Coatings Council
NUREG	Nuclear Regulation
OSHA	Occupational Safety and Health Administration
psig	pounds per square inch gauge
PWR	pressurized water reactor
QA	quality assurance
QC	quality control
RG	Regulatory Guide
SAR	safety analysis report
SSC	structures, systems, and components
SSPC	The Society for Protective Coatings
SSPC-SP [#]	Steel Structures Painting Council Surface Preparation [Specification No.___]
TOC	total organic varbon
UHPWJ	ultrahigh-pressure eater jetting
VOC	volatile organic compound
WCAP	Westinghouse Commercial Atomic Power
WFT	wet film thickness
ZOI	zone of influence

1.6 Key Points

Throughout this report, key information is summarized in Key Points. Key Points are bold-lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to act for the benefit of their plant. Key Points are shown in the following way:

Key Point
By reviewing this information, users of the report can determine if they have taken advantage of important information that the writers of this report believe would benefit their plants.

The Key Points Summary section (see Appendix C) of this report is a list of all key points. The summary restates each key point and provides a reference to its location in the body of the report. By reviewing this list, users of this report can determine if they have taken advantage of key information that the writers of this report believe would benefit their plants.

2
KEY CONCEPTS AND DEFINITIONS

2.1 Suitability of Application

Documentation of design verification and suitability of application is required for safety-related coatings by Criterion III of 10 CFR 50, Appendix B. Criterion III states, in part:

> III. Design Control
>
> Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in §50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions. These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled. *Measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of the structures, systems, and component.* (Emphasis added.)

Because coatings could fail in a manner that would adversely affect the operation of a safety-related structure, system, or component (SSC), a review for the suitability of application of all safety-related coatings must be conducted. This review is an important factor in establishing reasonable assurance that the coating will not adversely affect the safety-related function(s) of an SSC.

Key Point

The term application, when used in the context of 10 CFR 50, Appendix B, refers to the end use or service for the particular coating. The term is not used to refer to the physical act of applying coatings to a particular surface.

The scope and depth of the review for suitability of application of a safety-related coating may vary and are often affected by commitments made when the plant was licensed. For coatings used inside primary containment, plants of more recent vintage may have made licensing commitments to perform DBA qualification testing, consistent with the requirements of ANSI N101.2, in order to satisfy the suitability of application requirement. Other plants, typically those of older vintage, may not have made commitments to perform DBA-qualification testing of coatings and instead used other means to establish the suitability of application of a coating inside primary containment.

Early in 1975, ANSI assigned overall responsibility for coordination among technical societies, development, and maintenance of nuclear power quality assurance standards to the American Society of Mechanical Engineers (ASME). The ASME Committee on Nuclear Quality Assurance was constituted on October 3, 1975, and began operating under the ASME Procedure for Nuclear Projects Committee. The ASME Committee on Nuclear Quality Assurance currently operates under the ASME Operating Procedures and Practices for Nuclear Codes and Standards Development Committees. This committee prepared ANSI/ASME NQA-1, Quality Assurance Program Requirements for Nuclear Power Plants, which was first issued in 1979.

NQA-1-1979 was based, in part, on the contents of ANSI/ASME N45.2-1977, Quality Assurance Program Requirements for Nuclear Facilities and ANSI N45.2.6, Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants.

In the process of renewal of plant operating licenses, some licensees have elected to change some, if not all, of the plant's QA commitments from ANSI to applicable ASTM and ASME codes and standards. For instance, qualification requirements for safety-related coating inspectors have been changed from ANSI N45.2.6 to ASME NQA-1. In developing a safety-related coatings program for a particular nuclear power plant, these changes in commitments must be taken into account and reflected in the program documents. Qualification testing standards typically have not been developed explicitly for safety-related coatings used outside of primary containment. However, the licensee is responsible for meeting the Appendix B requirements for reviewing the suitability of application of outside containment safety-related coatings. In order to adequately demonstrate suitability of application, safety-related coatings used outside of containment in demanding service environments (for example, service water linings) may require a level of evaluation, analysis, test, or performance history, coupled with appropriate surface preparation and other application controls.

Key Point

The terminology for the levels of safety-related coatings may differ from site to site. For instance, Coating Service Level III coatings at some plants are NOT considered to be safety-related due to the site-specific licensing-basis definition. In preparing or revising a plant's safety-related coatings program, the licensing basis definitions of the various levels must be clearly identified and either used or properly changed.

There are many factors that can affect whether a coating is suitable for a given application. Although not intended as a comprehensive list, some of the factors typically considered include the following, as applicable:

- Service conditions the coating will experience (temperature, humidity, immersion, fluid type, and so on)
- Radiation levels, if applicable
- Flow conditions (for coatings used as linings)

- Coating adhesion properties
- Flammability and smoke generation
- Thermal conductivity
- Interaction when exposed to chemicals (ex., hydrogen generation)
- Resistance to wear (ex. erosion)
- Ease of application (new and repair)
- Surface preparation requirements (new and repair)
- Required environmental conditions during surface preparation and application

Consideration should be given to normal, transient, and accident conditions when the utility is reviewing the suitability of application of a coating.

ASTM Committee D-33 has developed two of several planned standards to provide guidance in selection, testing, and application of safety-related coatings outside of containment. These standards are:

- ASTM D7167-05, "Standard Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant"
- ASTM D7230-06, "Standard Guide for Evaluating Polymeric Lining Systems for Water Immersion in Coating Service Level III Safety-related Applications on Metal Substrates"

2.2 Definitions Associated with Safety-Related Coating Work

The concept of safety-related coatings outside of containment was not addressed in early ANSI standard development. Because coatings outside of containment may be of safety significance, it is appropriate for a definition of safety-related coatings that embraces all potential locations to be available.

Section 1.5 of this report contains key definitions and acronyms commonly used in the nuclear coatings industry and used throughout this report. Included in this section are the definitions of coating service levels provided in the various ANSI and ASTM standards and NRC RGs that illustrate the differences among these definitions.

Appendix A of this report contains listings of the numerous regulatory standards and guidelines referenced throughout this report.

2.2.1 Safety-Related Coating System

The following is the definition of a *safety-related coating system* as used in this report:

> A coating system used inside or outside the reactor containment, the detachment of which could adversely affect the safety function of a safety-related structure, system, or component (SSC).[1]

This definition of safety-related coating system has been formally adopted by the ASTM in Standard Guide D5144-00, Use of Protective Coating Standards in Nuclear Power Plants. The NRC has recognized this definition by virtue of its acceptance of ASTM D5144-00 in RG 1.54, Revision 1. ASTM D5144-08 contains the same definition and it is anticipated that Revision 2 to RG 1.54 will accept ASTM D5144-08. The shaded portion of Figure 2-1 represents coatings that are classified as safety-related. The figure clearly illustrates that coatings located inside or outside of containment may be classified as safety related, but the vast majority of safety-related coatings are located inside of containment. Though not drawn to exact proportion, Figure 2-1 also illustrates that most of the coatings in the plant are outside of containment and are normally classified as non-safety-related.

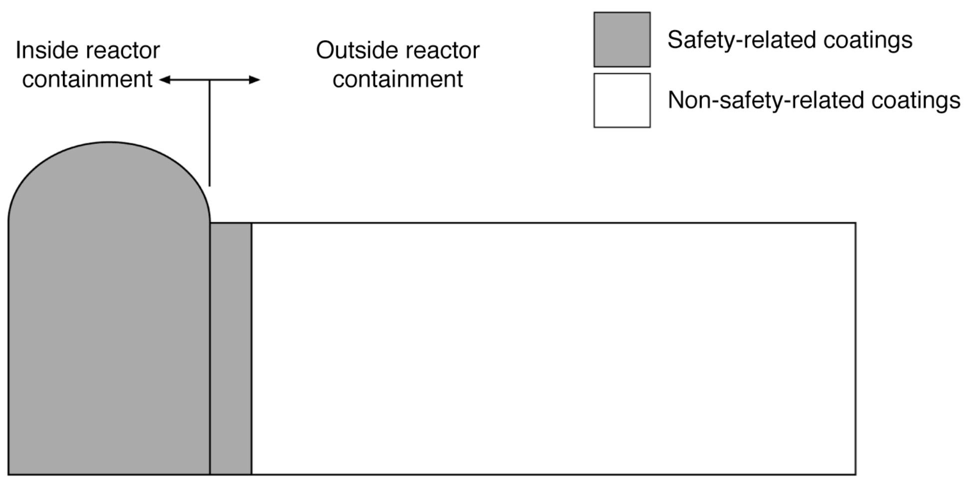

Figure 2-1
Safety-related and non-safety-related coatings

Although they are not shown in Figure 2-1, there may be some areas inside of containment that do not communicate with the ECCS pump suctions where the use of safety-related coatings is not required. Once a coating has been classified as safety-related, the requirements of 10 CFR 50, Appendix B are applicable. This is the case whether the safety-related coating is inside or outside of containment.

The determination of whether a coating should be classified as safety-related or non-safety-related is based primarily on the effects that detachment (failure) of the coating would have on the ability of plant systems/components to perform their safety functions. Although the coating does not have a safety function per se, consideration of the effects of postulated failures is consistent with how plant SSC and parts are classified in a nuclear power plant. Thus as shown

[1] For the purposes of this report, the term *primary containment* is synonymous with the term *reactor containment*.

in Figure 2-1, coatings should not be classified safety-related or non-safety-related based only on their physical locations in the plant.

The classification determination becomes very subjective because each engineer will have a different level of conservatism concerning the credibility of postulated failures (detachment of the coating) and the effects that those postulated failures will have on plant safety systems and components. Thus, the classification of coatings should be performed on a case-by-case basis, taking into careful account the potential for failure (detachment) and the effects of those failures. This report recognizes that classifications of coatings will vary from plant to plant.

2.2.2 DBA-Qualified Coating System

The following is the definition of a DBA-qualified coating system as used in this report:

> A coating system used inside reactor containment that can be attested to having passed the required laboratory testing, including irradiation and simulated design basis accident (DBA), and has adequate quality documentation to support its use as DBA qualified.

This definition of DBA-qualified coating system has been formally adopted by ASTM in Standard Guide D 5144-00, Use of Protective Coating Standards in Nuclear Power Plants. The NRC has recognized this definition by virtue of its acceptance of ASTM D 5144-00 in RG 1.54, Revision 1. ASTM D 5144-08 contains the same definition, and it is anticipated that Revision 2 to RG 1.54 will accept ASTM D 5144-08. The patterned area of Figure 2-2 depicts DBA-qualified, safety-related coating systems, as applicable for those utilities where required by their plant licensing basis. The DBA most applicable to coatings qualification is the loss-of-coolant accident (LOCA). As such, a DBA-qualified coatings system has been tested under accident conditions simulating a LOCA for the plant in which it will be used.

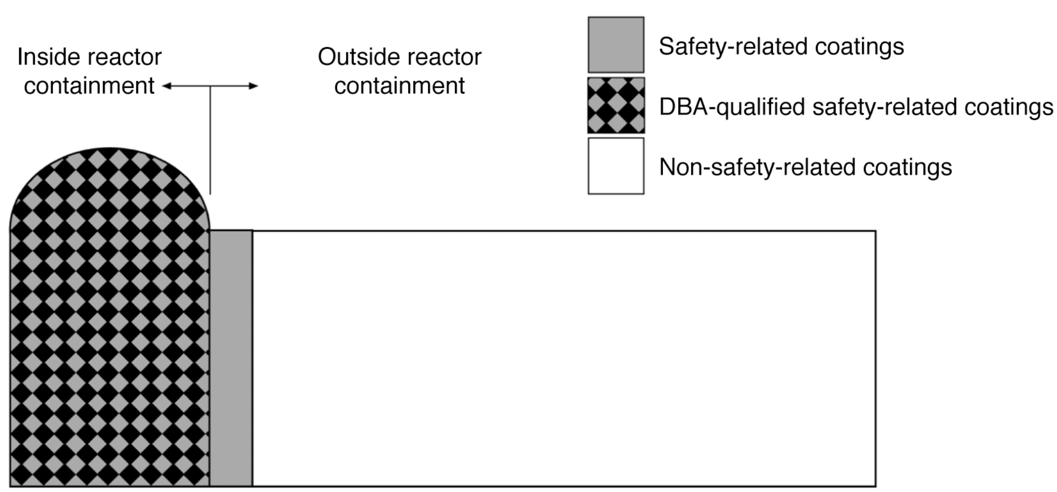

Figure 2-2
DBA-qualified coating systems

2.2.3 Acceptable Coating or Lining System

The following is the definition of an acceptable coating or lining system as used in this report:

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

This definition of acceptable coating or lining system has been formally adopted by ASTM in Standard Guide D 5144-00, Use of Protective Coating Standards in Nuclear Power Plants. The NRC has recognized this definition by virtue of its acceptance of ASTM D 5144-00 in RG 1.54, Revision 1. ASTM D 5144-08 contains the same definition and it is anticipated that Revision 2 to RG 1.54 will accept ASTM D 5144-08.

Key Point

The difference between an "acceptable" coating or lining system and a "DBA-qualified" coating system must be understood. All safety-related coating or lining systems must be "acceptable," but only where required by the plant licensing basis must a "DBA-qualified" coating system be used inside of primary containment. Where use of a "DBA-qualified" coating system is required by the plant licensing basis, it is considered "acceptable."

Although these guidelines do not refer to safety-related coatings or linings used in applications outside of containment as "DBA-qualified" coating or lining systems, certain requirements of 10 CFR 50, Appendix B still apply. For instance, Criterion III of 10 CFR 50, Appendix B—regarding the "suitability of application"—is applicable. Appropriate records should be available to support the determination that safety-related coatings outside of containment are suitable for the intended application. If these provisions are addressed, outside of containment coatings or linings should be considered acceptable, as defined below.

Even though a safety-related, outside of containment coating or lining system need not be "DBA-qualified" as defined herein, this should not be interpreted as meaning that outside-of-containment coatings or linings have less stringent technical and quality requirements than inside-of-containment safety-related coatings. In order to adequately demonstrate suitability of application, safety-related coatings or linings used outside of containment in demanding service environments (for example, service water linings) may require a level of evaluation, analysis, test, or performance history, coupled with appropriate surface preparation and other application controls. Again, the key concept is suitability for the application where used. Also, the consequences on the safety functions of other SSS, as a result of the detachment of a coating or lining will be an important consideration when the utility establishes an adequate level of evidence to demonstrate suitability for a given application.

The cross-hatched area of Figure 2-3 represents acceptable safety-related coatings or linings for any plant.

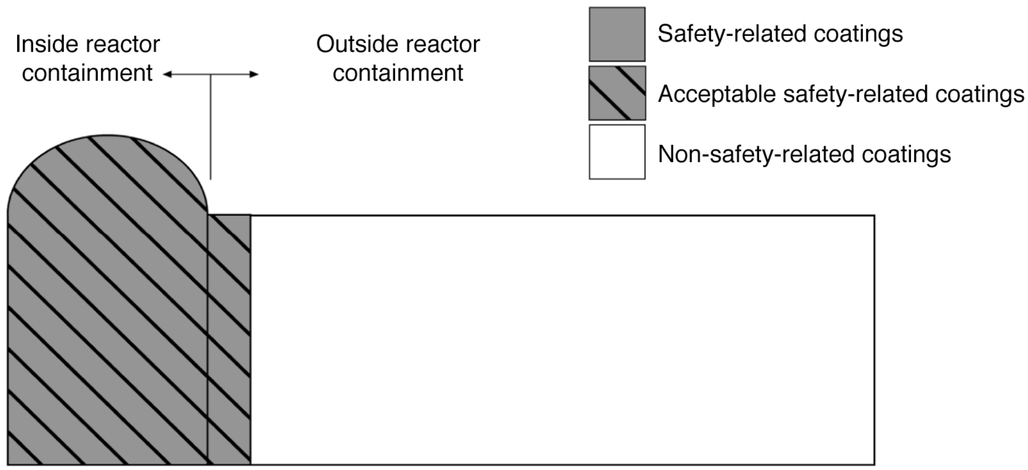

Figure 2-3
Acceptable coating systems

It should be recognized that because of the differences in vintage among plants and the standards to which they are committed, variations can be expected in the scope and level of detail of documentation that supports a conclusion of reasonable assurance that a coating will not detach (fail) during a DBA. Plants of a more recent vintage may have requirements for extensive documentation that address the DBA testing of a coating, the preparation of the surface to which it was applied, the qualification of personnel applying the coating, and inspection of the coating at the completion of application. Older plants may have considerably less documentation because the requirements and practices at the time they were constructed typically did not require preparation or retention of extensive documentation for coatings. The documentation of the acceptability of coatings should be consistent with the requirements of the plant licensing basis and the coating-related standards to which the plant is committed. Licensees should undertake periodic assessments of the condition of coatings and perform any necessary corrective actions to maintain the coatings to ensure that they have not degraded to the point that their acceptability is suspect. Section 8 provides additional details on the elements of condition assessment as part of an overall coatings program.

2.2.4 Non-Conforming Coating System

Another term used in this report that requires definition is non-conforming coating system. There may be instances in which a licensee determines that some documentation needed to support a conclusion that a safety-related coating is acceptable is either missing or incomplete. As covered in Section 9, the licensee may take steps necessary to compensate for the documentation discrepancies and restore or upgrade the reasonable assurance that the coating is acceptable.

The following is the definition of a non-conforming coating system as used in this report:

> A safety-related coating or lining system for which there is insufficient evidence to demonstrate that it is suitable for its intended use and that it is acceptable.

This definition of non-conforming coating system has been formally adopted by ASTM in ASTM D7491-08, Standard Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants. It is anticipated that Revision 2 to RG 1.54 will accept ASTM D7491-08. Ultimately, a decision must be made as to whether a non-conforming coating system can be made acceptable. References to regulatory documents and standards regarding the suitability of coatings to various applications are provided in Appendix A of this report.

3
SAFETY-RELATED COATINGS PROGRAM

3.1 Program Ownership

Ownership of the coatings program should be clearly defined and typically will reside in a single organization, such as engineering. However, other organizations (for example, maintenance, procurement, operations, and purchasing) must also take responsibility for implementing appropriate elements of a coatings control program.

An individual or individuals satisfying specific qualifications should be designated as having responsibility for developing and maintaining the safety-related coatings program. This individual is referred to as the Nuclear Coating Specialist in this report and would typically be responsible for numerous issues regarding coatings in the plant. The qualifications of the Nuclear Coating Specialist are covered in more detail in Section 10 of this report. The Nuclear Coating Specialist will require the committed support of management and the specific organizations charged with implementation of or otherwise affected by safety-related coatings work.

Those responsible for the program should define strategic objectives for the program and outline the design and process controls that will be used to secure those objectives. The design bases, specifications, training, and procedures necessary to effectively enact the program should be addressed. Potential licensing bases modifications required to achieve the goals of the program need to be identified. Finally, a set of milestones for enacting each element of the program should be defined.

The interrelationship between the coatings program and the Maintenance Rule (10 CFR 50.65) program should be addressed during the development of the coatings program.

3.2 Scope of Coatings Program

The following is the definition of a safety-related coatings program as used in this report:

> The systematic and planned activities conducted at a nuclear power plant to ensure that safety-related coatings perform all of their design functions.

The safety-related coatings program should encompass all coatings that meet the definition of safety-related coating system, which is provided in Section 2 of this report.

3.3 Design Basis Considerations and Licensing Commitments

When defining the scope of the safety-related coatings program, the design basis and licensing commitments related to coatings should be reviewed. Sources of information that may be considered are as follows:

- Final safety analysis report (FSAR)
- Results of DBA simulation testing
- Results of performance testing
- RGs (that is, RG 1.54, RG 1.82, and RG 1.137)
- Technical specifications or licensee-controlled specifications
- Materials qualification program documentation
- License renewal commitments

The following considerations should be assessed and reflected in the structure of the safety-related coatings program:

- Inside primary containment—non-immersion coatings
- Inside primary containment—immersion coatings
- Outside containment—non-immersion coatings
- Outside containment—immersion coatings

3.3.1 Inside Primary Containment—Non-Immersion Coatings

The terms DBA qualified and DBA qualification are often used in the discussion that follows because most plants are required to have DBA-qualified coatings inside of containment. For those plants with a licensing basis that does not require DBA-qualified coatings as defined herein, the use of acceptable and suitability for application are intended in the context of the discussion.

Non-immersion coatings are those that are applied to surfaces not generally subject to immersion during normal operation. BWR plants contain suppression pools that are essentially water-containing vessels intended to suppress the energy released during a DBA. The balance of the BWR containment (the vapor phase of the suppression pool and the air phase comprising the totality of the drywell) is non-immersed. Likewise, the entirety of a PWR primary containment is non-immersed except during certain DBAs, such as a LOCA. A PWR LOCA results in a pool of water several feet deep accumulated over the containment floor.

Non-immersed primary containment coatings, other than those in the vapor phase of a BWR suppression pool, generally experience a warm, dry environment throughout the normal operating life of the plant. The normal operating radiation dose for the life of the plant, other than to surfaces immediately adjacent to the reactor, is moderate.

When developing and maintaining the safety-related coatings program, the following issues should be considered:

- The use of alternative maintenance coating materials and the less rigorous surface preparation alternatives necessitated for an operating facility (compared with the construction phase processes upon which the original qualification testing was likely predicated) should be documented to ensure that the original design basis is maintained. Many materials DBA-qualified during construction are no longer available.
- The supplier has DBA-qualified an alternative replacement coating to verify that the alternative coating meets or exceeds the design requirements of the original. The supplier's design change documentation then should be requested and examined upon receipt. This documentation may be used to support the utility's design change documentation required by plant-specific procedures for compliance to 10 CFR 50.59.
- The range of coating thicknesses and the coating system configuration should be DBA-qualified. Primer A, intermediate B, and topcoat C, used for current and projected maintenance work, should also be DBA-qualified.

The effect that coatings can have on thermal conductivity, chemical/metallurgical interaction, and hydrogen generation may be considered. If applicable, the necessary controls should exist to ensure that the bounds of those analyses using the thermal conductivity of coatings are not exceeded.

- In the case of thermal conductivity, the licensee must ensure that the types and thicknesses of the coating systems applied to surfaces within the containment are bounded by what is specified in the accident section of the updated FSAR (UFSAR). The peak fuel cladding temperature and the containment pressure/temperature response in main steam line break (MSLB) and LOCA analyses are both potentially affected by changes in coating configuration.
- In the case of chemical/metallurgical interaction, recent testing related to closeout of GL 2004-02 indicates that aluminum-pigmented coatings may react with certain containment spray chemistries to produce a gelatinous precipitate that may adversely affect the ECCS system operation.
- In the case of hydrogen generation, it has been recognized for many years that zinc-pigmented coating, when exposed to strong acids and caustics (such as PWR containment spray), will produce hydrogen gas as a byproduct of corrosion.

3.3.2 Inside Primary Containment—Immersion Coatings

Suppression pools are the only areas typically requiring immersion coatings. Coatings used to line BWR suppression pools experience a demanding service environment under normal operating conditions. The immersion-phase coating is subjected to continuous immersion in high-purity, demineralized water, which is very aggressive compared with normal, mineral-bearing water with respect to its propensity to permeate coatings.

The cold wall effect, the tendency of water to permeate through a coating from the water toward a relatively cooler substrate, is a significant design consideration with respect to suppression pool coatings. The greater the temperature differential across the coating film, the greater the tendency for water vapor transmission through the coating film. This phenomenon is a factor particularly in a Mark I torus, which is a freestanding metal vessel located in a chamber that is typically cooler than the water within the torus. Mark II and III suppression pools typically use steel liners backed with concrete that reduce the temperature gradient.

The lifting of safety relief valves, which discharge into the suppression pool, agitates the water. This action further stresses the immersion phase and may release plumes into the vapor phase that result in condensation accumulating on vapor-phase surfaces. For this reason, vapor-phase coatings should be capable of protecting steel under protracted conditions of high humidity.

BWR suppression pool DBA temperature transients are considerably moderated from those that affect the drywell and PWR containments. Nonetheless, suppression pool lining designs of most plants require coatings to be qualified to drywell LOCA conditions. The requirements that implement application of suppression pool coatings should be complete and rigorous with respect to the criteria for achieving surface preparation and application commensurate with this critical immersion service. Systems for achieving and maintaining proper ambient conditions throughout installation and the curing phase are important considerations and are discussed in more detail in Section 6 of this report.

The suppression pool immersion-phase design review should consider the thermal conductivity issue along with system modifications/reconfigurations that may have affected the original pool or vapor-phase coating design bases and justification for use of modern repair coatings compatible with simplified surface preparation and underwater application.

3.3.3 Outside Containment—Non-Immersion Coatings

The extent of these safety-related coatings is extremely limited because most plants have very few applications requiring a nonimmersed, safety-related coating outside of containment.

Those few applications where these coatings are used may include coatings on steel or concrete that in case of detachment might become airborne and subsequently be ingested into safety systems. Such ingestion may cause blockage and prevent certain components from performing safety functions. An example of this type of application is the coating on the emergency diesel generator air intakes.

3.3.4 Outside Containment—Immersion Coatings

This category of safety-related coatings is typically applied to the internal areas of systems containing fluids required for safe shutdown of the reactor and may include the following:

- Cooling water systems servicing safety-related components
- Storage tanks for reactor-grade water
- Emergency fuel oil systems

3.3.4.1 Cooling Water Systems Servicing Safety-Related Components

Linings in these systems are installed to maintain the integrity of the system components by preventing corrosion and erosion of the metals from which they are fabricated. The lining isolates the metal from the process fluid. Selection criteria are required to ensure that the linings, when properly applied, will prevent corrosion.

The linings used in safety-related cooling water systems are often high solids, solvent-free epoxy systems composed of a primer, intermediate coat, and a topcoat. In some cases, a pastelike build coat is used in place of the intermediate coat to rework corroded or eroded areas or add thickness to a tubesheet cladding. Other linings include the following:

- Shop-applied elastomeric linings such as polyvinyl chloride (PVC) or vulcanized rubber
- Cementitious linings
- Shop-applied thermoset coatings such as polyethylene
- Extruded-type linings (very few instances)
- Other epoxies
- Reinforced linings

A second selection consideration is to ensure that failure of the coating will not result in the blockage of any piece of equipment (piping or heat transfer surfaces), thereby preventing the system from performing its intended function. This could occur if the coating, degraded by some method, became detached and blocked the small-diameter piping, the small orifice plates, or the flow into the heat transfer surfaces or an upstream screen failed which is installed to keep debris from lodging in heat exchanger tubes.

Standard design guidance that encompasses the various coating design aspects that come together within a service water system is not available. Appropriate suitability requirements must be researched and developed on a plant-specific basis. Tests (for example, Atlas Cell conditioning) may be required on candidate service-water system coating materials to determine the long-term effects of the immersion environment on the coating. These tests are completed by evaluating test specimens exposed to immersion at defined temperatures over a protracted duration.

3.3.4.2 Storage Tanks for Reactor-Grade Water

Components that store process water, which may be introduced into safety systems, should be included in this category. An example is linings for tanks that store refueling water and water potentially used for ECCSs.

3.3.4.3 Emergency Fuel Oil Systems

Internal coatings for diesel generator storage tanks should be applied in accordance with appropriate safety-related procedures to ensure that the coatings do not detach or dissolve and consequently impair an adequate and uninterrupted supply of fuel oil to the diesel generators. Assurance that the coating will prevent corrosion is essential because the corrosion products could contribute to fuel oil system suction strainer blockage that starves the diesel generator of the necessary fuel. Failure of the coating could also contribute to fuel oil system suction strainer blockage.

It must also be ensured that the coating system applied to the interior of fuel oil storage tanks has been demonstrated to resist chemical degradation caused by exposure to the particular fuel oil contained in the tank. See NRC IE Circular 77-15 and IN 85-08 for regulatory information on this subject.

3.4 Surface Restoration Coatings in Immersion Service

3.4.1 Nonstructural Applications

Certain coatings are used to restore substrates in immersion service that have been damaged by erosion or corrosion or in mechanical ways. These specialized coatings are typically high-solids, high-viscosity materials. The guidance contained in this report typically applies to these types of coatings when used in nonstructural applications.

3.4.2 Structural Applications

There are applications in which these specialized coatings are used to restore the structural integrity of a component. The guidance currently provided in this report may be applicable to these coatings but does not encompass all the requirements associated with these applications. The evaluation and restoration of structural integrity must be performed in accordance with plant-specific design control processes. At this time no polymeric repair compounds have been approved for making ASME code repairs to SSC. As such, the Nuclear Coating Specialist **MUST** ensure that no such repairs are performed.

3.5 Safety-Related Coatings Program Information

After the program ownership has been assigned and the scope of the program has been defined, including investigation and documentation of the applicable design and licensing bases, the Nuclear Coating Specialist should consider compiling an index of this important information. In addition to those topics discussed in this section, other topics that may be included in a safety-related coatings program are provided below with cross-reference to the appropriate section of this report where additional guidance may be found:

- Section 4: Qualification and Selection of Coating Systems
- Section 5: Procurement and Materials Management

- Section 6: Surface Preparation and Coating Application
- Section 7: Inspection of Surface Preparation and Application
- Section 8: Condition Assessment
- Section 9: Management of Non-Conforming Coatings
- Section 10: Personnel Training and Qualification

3.6 Risk Management Based Coating Work Planning

Recently, some utilities have recognized that scheduling of plant coating maintenance work may have a direct impact on risks associated with operation of plant systems. As such, coating work load analysis programs have been developed to analyze risk associated with corrective and elective work order backlog. This process is not designed to replace probabilistic risk assessment, but rather to complement it.

This programmatic approach is used to identify and develop a risk score associated with having work activities, including coating work, in the backlog or pending. This is the risk associated with operating the plant with an affected coating that is waiting to be repaired. This risk level score is then used to prioritize the work activities in the backlog that are waiting for completion.

4
QUALIFICATION AND SELECTION OF COATING SYSTEMS

Sections 4.1–4.5 describe the design considerations for coatings in various plant applications. Table 4-1 summarizes these design considerations.

4.1 Inside Primary Containment—Non-Immersion Coatings

Safety-related containment coating systems (not directly affected by a LOCA jet) are designed not to detach when exposed to the radiation, pressure, and temperature transients accompanying a DBA. Current standards for DBA qualification of containment coatings require subjecting coating specimens to simulated DBA conditions, such as a LOCA, in accordance with specific test parameters. At the completion of the test, the coatings are evaluated to assess the extent of degradation, with detachment being of particular significance.

4.1.1 Existing Standards for DBA Testing

Traditionally, candidate coatings for containment were selected from systems screened per ANSI N5.12. The standards defining DBA qualification criteria for containment coatings are ANSI N101.2 for most existing plants and ASTM D3911 for some operating units. The particular standard endorsed should be consistent with each utility's licensing basis. As previously discussed, ANSI N101.2 is not generically endorsed by the NRC, although ANSI N101.2 is indirectly referenced via ANSI N101.4 (which is endorsed by NRC in RG 1.54 Revision 0). These standards offer recommended temperature/pressure transients, which are useful for a given plant only to the extent that under most circumstances they conservatively envelope that plant's DBA transients. The D3911 curves denote specific temperature/pressure "rise and drop-leg" rates. The depressurization "drop leg" is probably the more disruptive test parameter with regard to inducing blistering or delamination in a test coupon. The ANSI standard has explicit criteria for blister size and frequency (see Section 4.5.3 of ANSI N101.2), whereas the latest edition of D3911 requires that the plant licensee establish coating system acceptance criteria consistent with the plant licensing basis.

4.1.2 Defining DBA-Qualification Criteria

Sufficient technical direction, provided in utility specifications and/or procedures, is needed in order for containment qualification testing to properly address the applicable plant-specific DBA criteria. Acceptance criteria for DBA-qualification testing must be consistent with each plant's licensing basis. In the course of preparing the containment qualification criteria, the following factors should be considered:

- Test facilities
- Test coupon preparation and conditioning
- Test parameters
- Test report interpretation

4.1.2.1 Test Facilities

The availability of test facilities will affect the schedule for obtaining results. The safety-related coating manufacturers may be contacted for advice regarding organizations that perform radiation and DBA testing. Some manufacturers of safety-related coatings provide DBA testing. If the DBA testing does not meet the applicable elements of 10 CFR 50, Appendix B, the utility should supplement the program with other quality controls provided by their own 10 CFR 50, Appendix B QA program. Organizations that perform DBA testing may not necessarily provide irradiation except through a subvendor. This is an important factor in planning and scheduling the testing.

4.1.2.2 Test Coupon Preparation and Conditioning

Test coupons may be prepared and conditioned by implementing ANSI or ASTM standards. Several ASTM standards require test coupons to be prepared per ASTM D5139. Film thickness is a key parameter in the test coupon preparation process because it impacts the containment design basis by affecting conductive heat transfer. For example, if containment pressure recalculation shows margin reduction, with respect to peak pressure, a "not-to-exceed" limit on dry film thickness (DFT) could become a necessary design parameter with respect to maintenance overcoating. 10 CFR 50, Appendix K should be considered when determining the range of film thicknesses used for testing.

The following wording, found in ASTM D5139, is of particular importance when maintenance painting is required over coatings applied during a plant's construction phase:

> 8.3 Test samples for maintenance painting test programs may include simulated aging of the existing coating, intermediate surface preparation and wide ranges of coating film thicknesses. Field conditions should be duplicated as close as is possible including coating application methods that may differ from the manufacturer's published data.

The means to accomplish the simulated aging is not described in the ASTM standards, though irradiating and thermal baking are appropriate methods for simulating aging of organic materials such as epoxy coatings. Subsection 5.3.2 of ANSI N101.2 describes aging for maintenance systems as a two-week, 150°F (66°C) bake.

Chapter 6 of the report *ASTM Manual on Maintenance Coatings for Nuclear Power Plants* (PCN: 28-008090-14) offers valuable guidance regarding test coupon preparation.

4.1.2.3 Test Parameters

Duration of the DBA Simulation Test

The *duration* of the DBA simulation test is a primary factor that should be determined. Another way of analyzing this issue is to ask the question, "How long into the hypothetical accident must a containment coating remain intact?" The time from accident initiation to when coatings are expected to detach can be a very significant factor because the parameters that affect the transport and settling of coating debris prior to reaching the sump/strainers can change substantially as the accident progresses. Also, there is some point into the accident beyond which containment spray, core spray, and the ECCS will have achieved sufficient decay heat removal duty that clogging screens/strainers or core flow channels with coating-related debris are no longer a factor. The licensing and design basis of the plant should be reviewed in making this determination, so that an unreviewed safety question is not introduced if the duration of testing is different from that previously approved by the NRC.

Temperature/Pressure Transients

Plant-specific DBA transient parameters, as found in the SAR or conditions that conservatively envelope plant-specific criteria, should be used when determining what temperature/pressure transients to use in testing. Caution should be exercised because, in some cases, design bases have been changed over time and DBA qualification testing criteria used during the construction phase may need to be updated.

Radiation

ASTM D3911 requires half the test coupons to be irradiated per ASTM D4082, which, in turn, requires an integrated dose of 1000 megarads (MR) ($1x10^9$ rads) to be delivered at a rate of at least 1 MR/hr. A dose of 1000 MR should be considered a conservative value for PWRs, BWR drywells, and the immersed part of suppression pools, but may not be adequate for some BWR Mark II suppression pool vapor phases. An appropriate source of plant-specific radiation criteria may be the design criterion for environmental equipment qualification (EEQ).

To further investigate aging of containment coatings, EPRI is currently conducting a joint research project with Électricité de France (EDF). Results of this project are scheduled to be published in 2011.

Spray Chemistry

For PWRs, spray chemistry is often plant-specific. ASTM D3911, Section 7.2.1 indicates, "Unless otherwise specified, use deionized water . . ." This differs from ANSI N101.2, which near the conclusion of Subsection 1.4.2.2 indicates (parentheses and italics added):

> (DBA) Tests of the coatings for a specific application (presumably for a particular plant) *shall be conducted with the* (spray) *solution to be used* in that application (plant) . . . The chemical composition of spray solutions used in the coating test *shall be determined before each test*.

EEQ criteria are a source for PWR spray chemistry. Typical spray solutions are presented in Table 3 of ANSI N101.2; however, use of specific plant spray chemistry may be considered.

4.1.2.4 Interpretation of Test Reports

The majority of DBA irradiation and decontamination testing, fire evaluation testing, and thermal conductivity evaluations that have been performed for the commercial nuclear power industry in the past have been by third-party organizations or by the coating manufacturers themselves. Coating manufacturers submit samples of their candidate coating materials and systems for testing and subsequently compile the test results into a master report.

Key Point

This master report is used by the individual nuclear power plant licensee as justification for the use of the coating material/ system in its facility in safety-related applications.

Typical Format of Coating Manufacturer's DBA-Qualification Reports

A standard format for the coating manufacturer's master report has not been used and is usually not contained in any reference documents. The following outline has been provided by a safety-related coatings manufacturer and is representative of a typical master report format used to date:

- Table of Contents
- Section 1
  - **Introduction**. Specifies the standards that were followed (ANSI, ASTM, and architect/engineer specified), as well as the location of the test facilities.
  - **Preparation of test specimens**. For each test included in the report, this section states the type of substrate (steel, concrete, and so on), surface preparation, surface profile, and method of specimen identification.
  - **Test procedure**. This section states where the test specimens were prepared, as well as where in the report they are located.
  - **Test results**. Gives a brief synopsis of the testing performed.

- Section 2—Test report for radiation, decontamination, and DBA tests; specimen preparation data sheets
- Section 3—Physical properties testing per ANSI N5.12 and various ASTM standards; specimen preparation data sheets for physical properties testing
- Section 4—Chemical resistance testing per ANSI N5.12 and ASTM D 3912; specimen preparation data sheets for chemical resistance testing

Information about DBA Qualification Reports

The reader should recognize that there may be minor variations of the format from one report to another. Section 1 provides the reader with an overview of the whole report, whereas Sections 2–4 provide specifics. The reader needs to verify the acceptability of the test parameters with relation to plant-specific criteria. The initial step would be to obtain a copy of the plant licensing document, if available (older plants may not have commitments to perform tests such as DBA/LOCA and instead use other ways to establish the suitability of a coating). This licensing document will define what standards are applicable, such as ANSI N101.2. Within this standard are two separate DBA curves showing temperature and pressure versus time. One is for PWR containment and the other for BWR containment facilities. These two generic curves were intended to envelop plant-specific DBA curves. It is required to validate either one of these curves against plant design bases or to use plant-specific design basis parameters to determine the most appropriate curve to employ. The DBA temperature-pressure-time curves are simulated by the testing facility in one of two ways: as a continuous function or as a step function (use as many steps as necessary to represent the DBA curve conservatively).

The reader must review the section of the report in which DBA testing was performed. A table in this section, typically titled "DBA Test Conditions," provides the reader with the test parameters that were followed in conducting the testing. If the test parameters envelop the conditions of the reader's plant design basis, it is an acceptable report and the contents can then be considered for use.

Historical coatings test reports may contain some of the following additional information:

- Radiation dose rate, both initial and cumulative
- Cumulative radiation dose
- Thermal conductivity (this might be in a separate report)
- Fire evaluation tests (this might be in a separate report)
- Decontamination tests
- Chemical resistance tests
- Physical properties tests

The next step in interpreting the qualification report is to compare the parameters of the plant design basis with those of the report. If the parameters are consistent between the plant design basis and the test report, the reader must next define the scope of the project in question. A major factor is whether the item to be coated is new or existing. If it is new, it is simply a matter of accepting and incorporating the coating system into the plant specifications. If the item in question has an existing coating in place and requires subsequent coating, the report should address the existing coating and the repair system should be qualified on bare surface, transition zone, and with the new system applied over the old.

If the report does not have the proposed coating system tested as previously specified, it is difficult to properly perform a coating operation. For instance, if the existing qualified coating had been tested with the proposed new coating system only, application to bare substrate and transition zone would not have been qualified, presenting a lack of qualification for these areas.

Considerations that need to be taken into account when performing an engineering evaluation and/or writing a technical justification are as follows:

- **Level of cleanliness and profile depth**. The test report should indicate the level of cleanliness (for example, SSPC-SP 10/NACE No. 2, Near White Blast Cleaning) and profile depth (for instance, 1.5–2.5 mils [0.0375–0.625 mm]). Additionally, the method(s) used to achieve the requisite surface profile and cleanliness should be reported. The Nuclear Coating Specialist should determine whether the surface profile and cleanliness level reported in the qualification test report are commensurate with the actual production work to be performed. Historically, qualification of coatings over a lower level of surface cleanliness (for instance, SSPC-SP 6/NACE 3 Commercial Blast Cleanliness) qualifies the coating system involved applied to a substrate with a higher level of surface cleanliness (for example, SSPC-SP-10/NACE 2, Near White Blast Cleanliness).
- **Method of application of coating materials**. Standard methods of application are brush, roller, conventional spray, airless spray, squeegee, trowel, and so on. The report may state that the method of application was by conventional spray. This does not mean that the applicator is limited solely to applying the material by conventional spray. The literature for the coating material that is supplied by the coating manufacturer should state acceptable methods of application. In some instances, it may be necessary to supply a letter of verification from the coating manufacturer stating the acceptability and suitability for use of a specific application tool.
- **Coating thickness per coat**. The specimen preparation data sheets provide the information for coating thickness applied per coat and the accumulated thickness. In most instances, the coating material is applied at a minimum as well as a maximum DFT. This would be the coating thickness range that governs the recommendation in the manufacturer's technical literature.
- **Number of coats of material that have been applied**. The specimen preparation data sheets provide the information on how many coats have been applied for a given material. The number of coats that have actually been tested for a particular product does not necessarily restrict the user to that exact number.
- **Relationship between DFT/coat and the number of coats of material**. The way a product has been tested may in some cases provide relief in the number of coats required or the actual DFT that has been obtained when applying a product in the field. To further clarify this point, take the example of a product originally qualified as a two-coat system applied at

8.0–18.0 mils (0.2–0.4 mm) DFT total. As a result of the way this system was qualified, it is acceptable to apply the product as a three- or four-coat system as long as the DFT range is 8.0–18.0 mils (0.2–0.4 mm). This is possible because a relationship has been established between the DBA testing and intercoat adhesive values of the product. This data is available in the appropriate sections of the report. Normally, four coats would not be applied when two coats are adequate, except when actual field application results in a low aggregate DFT. An example would be when an inspector takes DFT readings and the results are all low. It is acceptable to apply as many coats as are required to fall into the tested range of the coating system.

- **Application conditions such as temperature and humidity**. The application conditions are listed on the specimen preparation data sheets and report the ambient temperature and humidity. In more recent testing, the surface temperature is also recorded. These conditions do not limit the application of material out of the range in the report. Most of the sample preparation for qualification testing is applied in laboratory conditions. For instance, the temperature during sample preparation may have been 70–75°F (21–24°C) with humidity of 50–55%. It would be impossible to limit the application of coatings at a nuclear facility to the actual ranges during sample preparation. The coating manufacturers should list the suitable application condition range in the technical literature for the specified material.
- **Substrate type**. If a product or coating system is Service Level 1 qualified on a specific substrate it cannot be assumed that the same product or coating system will pass the Service Level 1 criteria on a different type substrate. An example would be that when a product or coating system has passed the criteria on steel surfaces it cannot be assumed that it will pass on copper, stainless steel, brass, and so on. A separate test would have to be performed on the particular substrate.
- **New application versus maintenance**. Consideration must be given to the differences between the initial application of coating systems to bare substrates versus maintenance/overcoating of existing coatings, including overlap of maintenance coating over existing coating.

Recommended Content for Coating Material Testing Reports

The information required to be contained in any coating material testing report will be dictated by the requirements of the plant licensing basis. The following list of test parameters is provided as a recommendation concerning what test parameters should appear in a comprehensive test report.

All test reports should contain the following information:

- Codes and standards (including revision dates) followed in testing, including the following:
  - Pre-ANSI: manufacturers or architect/engineer procedures, for example, Westinghouse Commercial Atomic Power (WCAP)
  - Post-ANSI: ANSI N5.12, ANSI N101.2, ANSI N101.4
  - Post-RG 1.54, Rev. 1: ASTM D5144, ASTM D3911, ASTM D4082

- Names and locations of test facilities
- Identification numbers and dates of test reports
- Type of coating system tested, as in the following:
  - Epoxy, inorganic zinc, and so on
  - New application vs. maintenance
- Detailed coating system description, including the following:
  - Coating material manufacturers
  - Coating material identifiers
  - Accelerators (if used)
- Identification numbers of test specimens
- Substrate, such as carbon steel or concrete
- Prepared substrate cleanliness according to Society for Protective Coatings (SSPC) or National Association of Corrosion Engineers (NACE) standard levels
- Prepared substrate profile (surface roughness)
- DFTs: DFT per coat and total system DFT
- Curing and/or aging descriptions: time duration and temperature

Coating Material Testing Reports

The following tests may be required to meet plant-specific licensing requirements and should be performed prior to DBA-qualification testing to facilitate the selection of a coating for a given application. The following items may be contained in the test report as applicable:

- Irradiation of coated samples (ANSI N101.2, ASTM D4082), including the following:
  - Radiation source
  - Total absorbed radiation dose
  - Radiation dose rate
- Physical property testing (ANSI N5.12 or ASTM D5144), including the following:
  - Abrasion resistance
  - Adhesion
  - Direct-impact testing
  - Weathering
- Chemical resistance testing (ANSI N5.12 or ASTM D5144)

- Decontamination testing (ANSI N5.12 or ASTM D4256); discontinued by ASTM in 1995, but still in use in countries other than the United States
- Thermal conductivity testing (ANSI N101.2, ASTM D5144)
- Fire evaluation testing (ANSI N101.2, ASTM D5144)

DBA-Qualification Testing Reports

After completion of materials testing and irradiation, candidate coating materials and systems must be tested for DBA qualification in accordance with plant licensing basis requirements. Results of the following tests should be documented within the test report as appropriate:

- Pressure and temperature curves specified (for example, ANSI N101.2, ASTM D3911, plant-specific)
- Pressure and temperature test profiles recorded
- Composition of spray solution specified (for example, ANSI N101.2, ASTM D3911, plant-specific)
- Positioning of samples in autoclave (vapor phase only, at waterline, or full immersion)
- Special test conditions
- Analysis of post-test coatings debris and autoclave condensate chemistry (optional Appendix in D3911-08)

4.1.3 Evaluation and Acceptance of Test Data

4.1.3.1 Testing Performed to ANSI N101.2

Refer to Section 4.5 of ANSI N101.2, "Methods of Examining and Evaluating the Exposed Test Specimens." Note that its Subsection 4.5.3 indicates:

> "Blistering shall be limited to a few intact blisters, size No. 4, ASTM D714…"

4.1.3.2 Testing Performed to ASTM D3911-89 through ASTM D3911-03

Refer to Section 8 of ASTM D3911, "Examination and Report," and Section 9 of ASTM D3911, "Acceptance Criteria." The following criteria of Section 9 of ASTM D3911should be considered:

> 9.4 Blisters shall be limited to intact blisters which are completely surrounded by sound coating bonded to the substrate.
>
> 9.5 An owner may establish acceptance criteria more stringent than above. The above criteria are meant as minimum standards only.

4.1.3.3 Testing Performed to ASTM D3911-05 and ASTM D3911-08

Refer to Section 8 of ASTM D3911, "Examination and Report," and Section 9 of ASTM D3911, "Acceptance Criteria." The following criterion of Section 9 of ASTM D3911 should be considered:

> 9.1 The plant design basis shall be reviewed against the report generated in 8.2 for coating acceptability. The licensee is responsible for establishing acceptance criteria for Coating Service Level I coatings.

4.1.3.4 Jet Impingement Testing

During investigations related to GSI-191, U.S. PWR licensees were required to determine the ability of various DBA-qualified coatings to resist jet impingement by the two-phase (steam-water) jet produced by a primary coolant line break. A spherical volume, called the zone of influence (ZOI), was defined as the volume adjacent to the break within which **all** coatings will fail, including DBA-qualified coatings. Two tests were developed to define the ZOI for various DBA-qualified coatings, one by Westinghouse Electric Company and one by Florida Power and Light and AREVA. The NRC eventually accepted the results of both test methods as discussed in "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluation" (March 2008):

ZOI: The NRC generic safety evaluation (SE) (ADAMS Accession No. ML043280007) stated that licensees should use a coatings ZOI spherical-equivalent determined by plant-specific analysis, based on experimental data that correlate to plant materials over the range of temperatures and pressures of concern, or 10D (10 pipe diameters.) In response to this conservative position, several industry groups conducted destructive jet impingement testing of qualified coatings in order to reduce the 10D value. The staff positions on the two sets of testing are provided below for licensees who use the reduced ZOI value rather than the default 10D:

- WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI)for DBA-Qualified/Acceptable Coatings": Licensees may use this report as the basis for using a ZOI of 4D or greater for qualified epoxy coatings and a ZOI of 5D or greater for qualified untopcoated inorganic zinc coatings.
- FPL Tests with supporting calculations performed by AREVA: Licensees may use this report as the basis for using a ZOI of 4D or greater for qualified epoxy coatings. The reports submitted to the NRC by FPL and AREVA at the time of this guidance do not establish a value for untopcoated inorganic zinc. The untopcoated inorganic zinc that was included in the test data eroded at the distances tested (4D).

The testers had not established a ZOI for inorganic zinc other than the data that showed it was some value greater than 4D. Unless other data is provided by the licensee, the ZOI for inorganic zinc should remain the default 10D. Licensees may submit other data such as supplemental FPL/AREVA data or WCAP-16568 data, to justify a reduced ZOI for untopcoated inorganic zinc. Similarly, the data submitted to the NRC indicates that Amercoat-90 epoxy failed the tests at the distances tested. Licensees reducing the ZOI to less than 10D for Amercoat 90 should also provide supplemental data. The AREVA calculation (Report No. 32-5066085-000) recommends a ZOI greater than 3.39D. Independent calculations performed for the NRC, using the AREVA inputs, found the maximum bounding break to be 3.67D. The staff therefore determined that a ZOI of 4D for epoxy coatings would be conservative and acceptable.

Remember that the above information is only applicable to PWR plants.

4.2 Inside Primary Containment—Immersion Coatings

ANSI N5.12 contains requirements in Section 5.3.2 for testing coatings to establish their suitability for use as linings for deionized (DI) water immersion (that is, BWR suppression pool immersion zones).

The Nuclear Coating Specialist should determine whether both DBA and continuous water immersion should be reflected in the design basis for coatings used under water.

Some coating manufacturers use ANSI N5.12 as a general screening test prior to or in conjunction with DBA test programs. Section 5.3.2 of ANSI N5.12 stipulates:

> 5.3.2.3 . . . the . . . systems shall be tested by immersion . . . in deionized water for a minimum period of six months. The . . . water shall (be) 77°F . . .ASTM D3912-95 (Reapproved 2001) also contains guidance concerning immersion testing of linings:
>
> 6.2 *Lining Test*:
>
> 6.2.1 Test in accordance with NACE TM-01-74, Procedure B, Immersion Testing, except when a significant temperature differential (cold wall effect) is anticipated across the coating film, as seen with tank linings, then use NACE TM-01-74 Procedure A, One-Side Testing.
>
> 6.2.2 Immerse lining test specimens in the appropriate test solutions specified for a minimum of 180 days.
>
> 6.2.3 Use reagent grade chemicals and distilled water for all solutions.

The test methods in Section 4.5 of this report may also be applicable to inside primary containment—immersion coatings, as determined by the Nuclear Coating Specialist.

4.3 Inside Primary Containment—Maintenance of Non-Immersion Coating Systems

The initial phase of developing a qualification program for maintenance of containment coatings should be to review the existing coatings. This information is a key parameter for planning future maintenance coating because any new work will need to cover or merge with preexisting products. The term cross-qualification is used to describe the process in which one particular coating is used over another. This might be necessary when the initially applied product is no longer available and/or is unacceptable for environmental or worker health reasons. Cross-qualification of coatings is also done to avoid dependency on a single supplier. Today, only a few U.S. coating manufacturers continue to manufacture and service nuclear containment coatings under a nuclear QA program meeting the intent of 10 CFR 50, Appendix B. For example, epoxies A, B, and C could be qualified over and under each other to allow a switch from one coating manufacturer to another at some future time. Records for all application parameters, including DFTs, should be reviewed to support cross-qualification because the testing should establish application limits for the combination of products.

Some plants may have combinations of qualified and unqualified coatings applied in safety-related applications. Interfaces and overlaps, where both qualified and unqualified coatings may exist, should be addressed as part of each utility's coatings program. Care should be exercised to ensure that the concept described in the ASTM standard regarding continued use of unqualified coatings is consistent with the plant's licensing commitments. Section 9 of this report provides additional discussion about the cautions associated with applying more unqualified coatings.

Normally, one objective of the coatings program is to maintain qualified coatings. The program should outline a test plan that demonstrates how future containment maintenance coating is suitable and compatible with existing systems. Generally, this may be accomplished by one of the following methods:

- Obtaining fresh coating material objectively certified as equivalent to discontinued products: when preparing the cross-qualification test specimens, the material representing the existing coating would be applied as the undercoat and the coating proposed for future maintenance overcoating as the topcoat.
- Obtaining testing specimens representing preexisting, discontinued coating products or systems from existing surfaces; this may entail coping from steel or coring from concrete. These surfaces should then be prepped and coated with the products proposed for future maintenance coating work.
- Minimizing overlaps onto existing coatings and evaluating incidental overlaps as insignificant.
- Stripping unknown or discontinued coating systems to expose the substrate prior to maintenance coating.
- Encapsulating problematic coatings; in such cases, consideration should be given to seismic design and material selection (expanded stainless sheet metal, mail-type insulation).

ASTM D3911-08 contains the following guidance, which might be considered when qualifying maintenance coatings:

> Section 11. Repairability:
>
> 11.1 Test repair coatings applied to significant areas within Service Level I in accordance with the requirements for radiation and DBA conditions.
>
> 11.2 The test shall include evaluation of the repair coating applied in accordance with the repair procedure over the intended surface preparation or the original qualified coating system, or both.

4.4 Outside Primary Containment—Non-Immersion Coatings

From a practical standpoint, the design basis for such coatings should be limited to the same criteria as those used to screen industrial coatings for moderate outdoor exposures. Additional conditions may be imposed based on plant-specific design basis needs or requirements (for example, Service Level III).

4.5 Outside Primary Containment—Immersion Coatings

4.5.1 Coatings Evaluation and Selection (Cooling Water Systems)

The ASTM report *Manual on Coating and Lining Methods for Cooling Water Systems in Power Plants* contains useful guidance that is applicable when selecting and applying coatings for circulating and service water systems. The manual is effectively a checklist to help establish a rational basis for design and installation, but it is not prescriptive. In fact, there are no test standards that provide definitive criteria for screening candidate lining systems for cooling water systems. For this reason, selection of these coatings has been based primarily on performance history. Prior experience is an excellent basis for drafting a list of candidate linings, particularly if that service was essentially identical to the particular raw water lining work or maintenance being considered.

Consideration may be given to the following test methods when formulating the suitability basis for cooling water system coatings:

- Tests replicating immersion coatings
- Testing for related service conditions
- Physical testing
- Chemical testing

ASTM standard D7230-06, “Standard Guide for Evaluating Polymeric Lining Systems for Water Immersion in Coating Service Level III Safety-Related Applications on Metal Substrates,” has been issued recently to provide guidance concerning selection of internal coatings for Coating Service Level III coatings for cooling water systems.

ASTM D7230 provides guidance concerning the use of ASTM and NACE standards, which are described in detail in the next section.

4.5.1.1 Tests Replicating Immersion Coatings

NACE TM 0174 (Procedure A—“Cold Wall”) “Laboratory Methods for the Evaluation of Protective Coating and Lining Material in Immersion Service,” which is similar to ASTM C868 (see the following description of these tests).

ASTM C868 “Standard Test Method for Chemical Resistance of Protective Linings”

Collectively, these tests are referred to as "Atlas Cell testing." The primary objective of such testing is to determine the effect of cold wall on the coating system. Cold wall occurs when there is a temperature difference between the outside surface of the coating and the substrate. This normally occurs in heat exchanger endbells and channels but can occur in return legs of cooling water systems carrying elevated temperature water.

The temperature difference drives moisture through the coating and causes cold wall blistering. Warm water flowing through a pipe surrounded by a cold environment creates the environment most likely to promote cold wall permeation. Atlas Cell tests are used to ascertain the resistance of candidate coatings to the cold wall phenomenon.

When preparing the carbon steel test plates, the application should closely replicate the application requirements that will be included in the specification governing the application of the coating ultimately selected for use within the cooling water system.

The Atlas Cell test may be supplemented by the following methodologies:

- Assessment of total organic carbon (TOC) extraction by Environmental Protection Agency (EPA) Method 415.1.
- AC impedance/electrochemical impedance spectroscopy (EIS). No standards govern the use of these theoretically complex techniques. Interpretation of results is subjective.
- Corrosion potential.

The latter two methods indicate the relative propensity for subfilm corrosion that is not visually detectable.

Typically, the Atlas Cell test medium is DI water. Some suggest that this is unrealistically harsh, because power plant service is raw water. Others who use this test believe that using high-purity DI water is appropriate because it effectively accelerates the permeation that will eventually occur with raw water. Atlas Cell exposure could also be used to "condition" specimens for subsequent physical testing (see Section 4.5.2.1).

ASTM D1653, "Standard Test Method for Water Vapor Transmission of Organic Coating Films."

The test method covers the determination of the rate at which water vapor passes through films of paint, varnish, lacquer, and other organic coatings. The films may be free films, or they may be applied to porous substrates.

There are two test methods: Test Method A - Dry Cup Method and Test Method B - Wet Cup Method. Agreement should not be expected between results obtained by different test methods or test conditions. The method that most closely approaches the conditions of use should be selected.

4.5.1.2 Testing for Related Service Conditions

Radiation per ASTM D4082

This test evaluates the radiation resistance of a coating. Section 8.2 of ASTM D4082 does not apply.

Cathodic Disbondment per ASTM G8 or G42

This test evaluates a lining's ability to remain bonded, despite the electrochemically aggressive regions surrounding flaws in linings on metal subject to cathodic protection. The test standard ASTM G42 requires 140°F (60°C) water to exacerbate coating degradation. The test standard ASTM G8 uses room-temperature water to exacerbate coating degradation.

Dielectric Strength (Copper Substrate)

This test establishes the suitability of applied coatings to be subjected to high-voltage testing per ASTM D115. Coating thicknesses need not be in accordance with the ASTM standard referenced in D115. Any suitable method of applying a film of fairly uniform thickness to a single side of the copper substrate is acceptable.

4.5.1.3 Physical Testing

Reverse Impact per ASTM D2794

This test assesses the effect of rapid deformation of the substrate on a coating. It indicates both the relative adhesion and ductility of the cured film. A 0.635 in. (16.129 mm) punch should be used. If the ASTM G42 cathodic disbondment exposure was chosen to precondition the test plates, both sides of the plate will have been coated. Consequently, it will be necessary to remove the coating at the impact point over a sufficiently large area to accommodate the punch guide flush with the test plate.

Abrasion Resistance per ASTM D4060

In this test, a rubber wheel impregnated with abrasive is rotated against the coated test specimen. Measurements of coating weight loss and wear-through rate indicate the relative resistance of coatings to abrasion, as would result from particulate entrained in a cooling water stream. An appropriate test parameter is 1000 cycles using the CS-17 wheel.

An alternative method would be in ASTM D658, which impinges dry abrasive on the coated test panel and reports the film thickness degradation rate.

Adhesion Testing per ASTM D3359 and ASTM D4541

Adhesion testing determines the adherence of the entire coating system to the substrate and the adherence of each coat that comprise the coating system. The acceptance criteria for this test should be developed by the Nuclear Coating Specialist, engineering, and the coating manufacturer on a case-by-case basis. Adhesion testing per ASTM D4541 has been successfully used to determine whether coating systems have remained robust over time (see *Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level I Coatings.* EPRI, Palo Alto, CA: 2007. 1014883).

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

The pull-off adhesion strength and mode of failure of a coating from a concrete substrate are important performance properties that are used in specifications. This test method serves as a means for uniformly preparing and testing coated surfaces and evaluating and reporting the results.

Variations in strength results obtained using different instruments, different substrates, or different loading fixtures with the same coating are possible. Therefore, it is recommended that the specific test instrument and loading fixture be mutually agreed on between the interested parties.

Standard Test Method for Evaluating Adhesion by Knife (ASTM D6677)

This test method covers the procedure for assessing the adhesion of coating films to substrate by using a knife.

This test method is used to establish whether the adhesion of a coating to a substrate or to another coating (in multicoat systems) is at a generally adequate level.

Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings (ASTM D522)

Testing should be performed in order to determine the percent elongation of a coating. Thinner coating thicknesses will yield better results in this test. The thickness of the coating applied to the test specimens should be representative of the intended thickness of the coating for actual service. Test specimens should be coated in accordance with ASTM D832, Method B.

4.5.1.4 Chemical Testing

Standard Test Method for Chemical Resistance of Coatings Used in Light-Water Nuclear Power Plants (ASTM D3912)

Chemical testing is performed to assess the performance of various coating materials and systems when exposed to chemicals in normal and accident plant conditions. Specific chemicals used for testing should be selected to characterize the anticipated exposure of the coating materials and system.

4.5.2 Evaluation and Acceptance of Test Data (Cooling Water Systems)

The information contained in this section of the report is not represented to be all inclusive. The user of this report may choose to use additional standards and test methods not listed herein to the determine the suitability of coating or lining systems for use in cooling water systems.

4.5.2.1 Atlas Cell Testing

The results of this type of testing should be assessed in light of known service performance. Favorable Atlas Cell performance alone is of little merit. When comparing candidate products that in general are known to be reliable, the product having the better Atlas Cell performance might then be viewed favorably. There are no standard values for Atlas Cell testing for these applications, so the following are suggested guidelines:

- There should be no evidence of blistering or *leopard spot* corrosion. Lightly tapping the exposed coating may indicate disbondment that may not be evident with visual inspection.
- There should be no sign of substrate corrosion or disbondment in micrographs of the cross-sectioned panel.

Values for resistance (megohms), mass gain (ounces or grams), adhesion value in the cell exposed zone (psi or kPa), and the reverse impact resistance of Atlas cell conditioned samples (inch-pounds or newton meters) may be established for each plant-specific application should those additional criteria be selected for verification by Atlas Cell testing.

4.5.2.2 Water Vapor Transmission per ASTM D1653

There are no standard values, so the following is only a suggested criterion. A value of between 0.1 perms and 0.3 perms could be considered as an acceptable basis, depending on the nature of the raw water to which a coating is exposed. For example, lower perm ratings would be appropriate for warm seawater.

4.5.2.3 Radiation

Under the applicable integrated gamma dose, the test specimens should satisfy Section 8, "Acceptance Criteria," of ASTM D4082-02:

> 8.1 Unless otherwise specified, checking, cracking, flaking, delamination, peeling, and blistering are not permitted.

4.5.2.4 Abrasion per ASTM D4060

Section 6.3 of ASTM D4060 and ANSI N5.12 establishes the following criterion:

> 6.3 Weight loss shall not exceed 175 mg/1000 cycles when a CS-17 wheel is used with a 1000 gram load.

4.5.3 Coating Evaluation and Selection (Storage Tanks for Reactor Grade Water)

Many factors influence the selection of linings for storage tanks for reactor grade water. The following are the five most critical of these factors:

- Resistance to the water chemistry of the reactor grade water
- Resistance to undercutting, underfilm attack, and/or pitting at breaks (holidays, film defects such as blisters, or mechanical damage) in the lining
- Physical properties of the lining (such as flexibility, adhesion, and elongation) as compared with the service conditions imposed by the tank environment and operation
- Leachable compounds (for example, halogens, sulfates, or TOC) consistent with those tested for immersion coatings inside of containment
- Heavy metals (such as lead, chromium, or cadmium) content

Other factors to be considered in lining selection are the following:

- Resistance to oxygen and water permeation
- Abrasion resistance
- Application and curing characteristics
- Cost

Coatings qualified for wetwell immersion are generally suitable for comparable services outside primary containment. The qualification guidance presented in Section 4.2 for "Inside Primary Containment—Immersion Coatings," pertaining to BWRs, would be appropriate. Note that cold wall thermal gradients across lined tanks that are outdoors can be substantial unless the tank is insulated.

4.5.4 Evaluation and Acceptance of Test Data (Storage Tank Coatings)

Evaluation and acceptance of testing performed for coating systems for this type of immersion service should be similar to those discussed in Section 4.2, "Inside Primary Containment—Immersion Coatings," except that the DBA performance criteria are not applicable. To the extent that radiation had been identified as an appropriate design variable, the criteria found in Section 8.1 of ASTM D4541 should be considered.

4.5.5 Coating Evaluation and Selection (Emergency Fuel Oil Systems)

Assessment of diesel fuel coatings is performed to verify their suitability under the applicable service conditions. The objective of such assessments is to ensure that the coating provides adequate corrosion protection and that it will not detach from the substrate. Either of these coating failures may result in fuel contamination.

A determination of the suitability of application can be accomplished by (1) using a coating that has been manufactured to an industry standard for linings in fuel oil service and (2) imposing appropriate testing requirements upon completion of application to ensure that the coating is compatible with the fuel oil environment and remains fully adhered to the metal substrate.

Military Specification MIL-C-4556D or American Petroleum Institute (API) RP 1631 may be used as the technical basis for establishing a coating's suitability for use in fuel oil. Performing Sections 5.3.2 and 6.2, respectively, of ANSI N5.12 and ASTM D3912, using the designated fuel as the test reagent, may be considered as a way of obtaining corroborating test results. Consideration must be given to potential chemical reaction between the fuel stored in the tank and the tank lining itself. If the type or grade of stored fuel is changed during the life of the tank, the compatibility of the fuel and tank lining should be reevaluated. The NRC has issued two reports on this issue: IE Circular 77-15: "Degradation of Fuel Oil Flow to the Emergency Diesel Generator" (November 28, 1977) and IN No. 85-08: "Industry Experience on Certain Materials Used in Safety-Related Equipment" (January 30, 1985).

4.5.6 Evaluation and Acceptance of Test Data (Emergency Fuel Oil Systems)

Confirmation that the coating is compatible with the fuel oil service can be accomplished by conducting a solvent rub assessment using diesel fuel oil and/or methyl-ethyl ketone in accordance with ASTM D5402. Confirmation that the coating adequately adheres to the surface of the tank can be accomplished using a Type III device per ASTM D4541, which describes pull-off type adhesion testing.

4.5.6.1 Rub Testing per ASTM D5402

The following acceptance criterion should be considered:

> Using a rub cloth of contrasting color from the coating tested, there should be no evidence of transfer of coating onto the cloth after 25 double rubs using a solvent recommended by the coating manufacturer.

4.5.6.2 Pull-Off Adhesion per ASTM D4541

Appropriate acceptance criteria may be found in applicable API RP 1631.

4.6 Summary of Design Considerations (Sections 4.1–4.5)

Table 4-1
Summary of design considerations

Standards	Section 4.1 Inside Primary Containment—Non-immersion Coatings	Section 4.2 Inside Primary Containment—Immersion Coatings	Section 4.3 Inside Primary Containment—Maintenance of Non-Immersion Coatings	Section 4.4 Outside Primary Containment—Non-Immersion Coatings	Section 4.5 Outside Primary Containment—Immersion Coatings
ANSI	N5.12 and N101.2	N5.12 and N101.2	N5.12 and N101.2		
ASTM	D5144 D3911 (DBA) D4082 (Irradiation) D5139 (Sample Preparation)	D5144 D3911 (DBA) D4082 (Irradiation) D5139 (Sample Preparation) NACE TM-10-74 (Note 1)	D5144 D3911 (DBA) D4082 (Irradiation) D5139 (Sample Preparation)	EPRI 1003102	C868 (Chemical Resistance) D1653 (Vapor Transmission) D4082 (Irradiation) G8, G42 (Cathodic Disbondment) D4060 (Abrasion) D7230 (CSL III Coating Selection) D4541 (Adhesion) D3359 (Adhesion) D6677 (Adhesion) D7234 (Adhesion) D3912 (Chemical Resistance) D522 (Mandrel Bend) D5402 (Rub Test)
NACE					TM-0174, Procedure A (Cold Wall)

Note:
The test methods in Section 4.5 may be applicable to inside primary containment—immersion coatings, as determined by the Nuclear Coating Specialist.

5
PROCUREMENT AND MATERIALS MANAGEMENT

5.1 Development of the Procurement Specification

The specification of safety-related coatings should meet the applicable criteria of 10 CFR 50, Appendix B and may follow the process described in two EPRI reports, *Guidelines for the Technical Evaluation of Replacement Items in Nuclear Power Plants* (1008256) and *Supplemental Guidance for the Application of EPRI Report NP-5652 on the Utilization of Commercial Grade Items* (TR-1020260). The specification of technical procurement requirements should reflect the current design criteria for the coating deemed suitable for a given application.

Typical technical procurement requirements for a coating intended for safety-related applications may be as follows:

- Trade name of coating
- Generic name/type of coating (polyamide epoxy, epoxy phenolic, and so on)
- Manufacturer's name
- Manufacturer's currently available product number
- Reference to coatings qualification report, if applicable
- Traceability to a particular production lot or batch
- Packaging, shipping, storage, and handling requirements
- Design conditions for intended application(s)
- Applicable codes and standards
- Shelf life requirements

Much of this design information is typically found on product data sheets or material safety data sheets.

When specifying a replacement coating, the technical procurement requirements should meet or exceed the design criteria of the original coating. When an identical replacement coating is no longer available and an alternative must be specified, a plant design change should be documented in accordance with plant-specific procedures. The design change evaluation must demonstrate that the alternative coating design meets or exceeds the design of the coating being replaced.

5.2 Procurement of Coatings from 10 CFR 50, Appendix B Approved Suppliers

Coatings procured from a supplier maintaining a 10 CFR 50, Appendix B QA program are considered *basic components* as defined in 10 CFR 21and EPRI Report NP-5652, *Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07).* The acceptance basis for these coatings is described in ANSI N45.2.13 and should be evidenced by a performance-based audit of the supplier, which indicates that the supplier is adequately implementing the appropriate elements of a 10 CFR 50, Appendix B QA program. Acceptable nuclear suppliers are generally noted on a utility’s approved vendors list.

Care should be taken to invoke the applicable nuclear QA program in the procurement document as well as 10 CFR 21, Reporting of Defects and Noncompliances. References to the safety-related coatings system qualification report would also be appropriate when procuring from vendors maintaining a nuclear QA program.

5.3 Procurement of Coatings from Commercial Suppliers

5.3.1 Commercial Grade Dedication of Coatings

Coatings procured from a supplier not maintaining a 10 CFR 50, Appendix B QA program, can be considered to be commercial-grade items as defined in 10 CFR21. Therefore the acceptance of these coatings should be based on the guidance contained in 10 CFR 21and the generic process described in EPRI report NP-5652, as conditionally endorsed by NRC GL 89-02 and 91-05. Correct implementation of the dedication process depends on the identification and verification of critical characteristics (which are based on the safety-related functions of the coating for the applications in which it will be used). EPRI report NP-5652 provides four methods for verifying that the selected critical characteristics meet specified requirements and conform to design. Critical characteristics that may be considered for verification when dedicating commercial grade coatings are as follows:

- Manufacturer’s product number
- Product identification
- Color or color designation
- Chemical composition of pigment
- Chemical composition of solvent
- Chemical composition of resin
- Mix ratio by weight and volume
- Total solids by volume
- DFT (build)
- Volatile organic compounds (VOCs)

- Pigment volume concentration
- Weight per gallon by component before mixing
- Mixed weight per gallon
- Total solids by weight
- Viscosity
- Fineness of grind
- Drying time
- Pot life
- Hardness after cure
- Adhesion
- Chemical resistance
- Fourier transform infrared (FTIR) scan for cured coating (dry film)

The Nuclear Coating Specialist should provide input to the utility procurement engineering group when identifying and selecting critical characteristics.

5.3.2 Commercial Grade Dedication of Qualification Services

If the qualification of the coating system is performed by a supplier or third party without an approved 10 CFR 50, Appendix B QA program, the qualification service must be accepted and dedicated under the utility's nuclear QA program. The acceptance of these services should meet the requirements contained in 10 CFR 21and may employ the guidance contained in EPRI Report TR-102260.

5.4 Packaging, Shipping, Handling, Storage, and Shelf Life

Guidance for specifying the appropriate packaging, shipping, storage, and handling requirements for coatings may be found in ANSI N45.2.2 and EPRI Report TR-107101, *Packaging, Shipping, Storage, and Handling Guidelines for Nuclear Power Plants*. Although packaging requirements for shipping may vary somewhat among manufacturers, coatings are typically packaged with multiple cans/containers, boxed or crated, to prevent physical damage during transit. Shipping should be provided via an enclosed carrier. Provisions may be necessary to ensure that the coating manufacturer's recommended temperature limits are maintained while the coating is being shipped.

In general, coatings are stored on an open shelf, with multiple cans boxed to prevent physical damage. ANSI Storage Level B is typically used for storing coatings, taking into consideration any special manufacturer instructions. Manufacturers may often specify shipping and storage temperature limits that are more stringent than those described in ANSI N45.2.2.

Remaining shelf life should be specified in the purchase document. It is recommended that the purchase order require that the date of manufacture, with a shelf life or end of shelf life date, be clearly marked by the manufacturer on the label of each container of coating material.

5.5 Receipt Inspection for Coatings

A standard receipt inspection should be performed in accordance with ANSI N45.2.2 to inspect the general condition of the items, the quantity or amount received, the part number, and the supplier documentation requested in the purchase order.

In the case of DBA-qualified coatings procured from a 10 CFR 50, Appendix B vendor, the receipt inspection will also include matching batch numbers or the received coating materials to the Certificate of Analysis for the DBA-qualified coatings, whereas other safety-related coating receipt inspections (non-DBA-qualified) may only inspect for product codes.

Dedication of coatings may require special tests and inspections as described in EPRI reports NP-5652 and TR-102260. These special tests/inspections may be conducted to verify some or all of the selected critical characteristics (which are based on the safety-related functions of the coating). These special tests and inspections verify that the coatings received meet specified requirements, conform to the manufacturer's design, and will perform intended safety-related functions. Consideration may be given to conducting these special tests/inspections on site or at an approved test facility. Any special tests or inspections deemed appropriate for specific brands or classes of safety-related coatings should be identified in material procurement documents.

5.6 Documentation

5.6.1 Certificates of Conformance

When procuring from an approved supplier (that is, a 10 CFR 50, Appendix B audit or commercial grade survey was conducted), a certificate of conformance should be requested certifying the supplier has met the technical and quality requirements specified in the procurement document.

5.6.2 Qualification Reports

If the approved supplier has qualified the coating to verify that the design of the coating is suitable for the plant-specific, safety-related applications, then the coating system qualification report should also be requested and examined upon receipt. In some cases, traceability is required between the coatings furnished and those that underwent DBA qualification testing. In these cases, a certificate of conformance that references the batch number of the coatings that were tested and those that were shipped should be requested.

5.6.3 Design Change Documentation

If the supplier has qualified an alternative replacement coating, the supplier's coating material design change documentation should be requested and examined by the purchaser to verify that the alternative coating meets or exceeds the design requirements of the original. This documentation may be used to support the utility's design change process, including compliance with 10 CFR 50.59.

5.7 Procurement of Vendor-Supplied Items

Procurement of vendor-supplied items that will be coated with Coating Service Level I coating systems prior to installation may be accomplished in the following four ways:

- Procure the items uncoated and subsequently coat the items in the licensee's shop under the licensee's 10 CFR 50, Appendix B coatings program.
- Procure the items shop-coated by a vendor with an approved 10 CFR 50, Appendix B coating program. When procuring items that are shop-coated with safety-related coating systems, the Nuclear Coating Specialist must ensure that all applicable provisions of the plant safety-related coating system are accurately reflected in the procurement documents. The purchase order documents provided to the vendor by the plant should include the applicable special process requirements for coating work (see Table 1-2 of this report).
- From a vendor, procure the items coated with a commercial coating system. Subsequently remove the commercial coating system and apply an approved coating system at the licensee's shop under the licensee's 10 CFR 50, Appendix B coatings program. The coating work procedures used by the licensee should include the applicable special process requirements for coating work (see Table 1-1 of this report).
- Send licensee's personnel to the vendor's shop and have the items coated in the vendor's shop under the licensee's 10 CFR 50, Appendix B coatings program. The coating work documents used by the licensee's personnel should include the applicable special process requirements for coating work in vendor shops (see Table 1-2 of this report).

The Nuclear Coating Specialist should ensure that all parties are completely aware of the procurement specifications and safety-related coatings requirements.

Note that some items can be coated only in the vendor shop to prevent damage to the equipment. A decision must be made by the Nuclear Coating Specialist as to whether or not an item coated with an unqualified coating system should be installed in the containment. This decision should be based on the following:

- The available margin for unqualified coatings related to the ECCS system design (strainers)
- The potential for damage to the item related to disassembly, surface preparation, recoating, and reassembly
- Whether the item needs to be coated at all (little potential for corrosion or chemical exposure)

6
SURFACE PREPARATION AND COATING APPLICATION

6.1 Surface Preparation

6.1.1 General Guidance

The following surface preparation criteria should be addressed:

- Limitations on abrasive blasting, protective measures to avoid grit intrusion, and dust control (negatively ventilated enclosures, dust minimizing blast media, and vacuum blasting)
- Preliminary cleaning/degreasing, limitations on solvent and cleanser use with respect to plant heating, ventilation, and air conditioning (HVAC), charcoal filters, expendables that are plant-approved (controlled chemical list)[2]
- Determination of lead (29 CFR 1926.62), cadmium (29 CFR 1926.1127), chromium (29 CFR 1926.1126), and other hazardous constituents
- Systems to ensure clean, dry compressed air (for example, coalescing/deliquescent filters downstream of air or water-cooled moisture separators)
- Source of compressed air, compressor location, weatherproofing and spill containment, fuel delivery, and provisions for a standby compressor
- Suitability of tools and media
- Cleanliness and profile requirements and how they are measured
- Radiological concerns, such as the following:
  - Mixed waste (handling/prevention)
  - Personnel protection
  - Minimization of airborne contamination
  - Decontamination of substrates
  - Potential loss of contractor-supplied equipment
  - Containing, collecting, and disposing of waste

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[2] Refer to the report *ASTM Manual on Maintenance Coatings for Nuclear Power Plants* (PCN:28-008090-14), Chapter 4, Item 3 for further guidance.

Chapter 4 of the ASTM "Manual on Maintenance Coating" provides further insights. Partial removal of a coating should be evaluated to ensure that a hazardous condition (for example, asbestos and lead) does not result.

Generally, such criteria would be set forth in specifications and implemented by procedures, although the methods for defining these objectives should be based on each plant's licensing commitments for its safety-related coatings program.

To the extent applicable, and in order to ensure that the specifications achieve the intent of RG 1.54, the specifications should address the following:

- Implementation should be in accordance with process procedures approved by the licensee (typically the Nuclear Coating Specialist), the coating manufacturer, and the applicator. Section 5.2.2 of ANSI N101.4 requires:

  > The application procedures shall be approved by the coating applicator, the coating manufacturer, and the owner or his representative.

- Safety-related coating work is a "special process" as described in Criterion IX of 10 CFR 50, Appendix B. Criterion IX states:

  > Measures shall be established to assure that special processes . . . are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

- Application and quality control to ensure the quality of safety-related applications need to be performed by certified painters and inspectors, as qualified in accordance with approved procedures.

Key Point

If a coating work project involves removal of radiologically contaminated hazardous material (such as lead and asbestos) materials, all work must be performed by personnel trained as required by local, state, and federal regulations using detailed special process procedures and specialized equipment.

6.1.2 Surface Preparation for Primary Containment—Non-Immersion Coatings

6.1.2.1 Maintenance and Repair

The surface cleanliness and profile must be consistent with that used during the coating qualification to ensure that the coating qualification is maintained. Although abrasive blasting was normally used to qualify construction-era coatings, it is often unfeasible for maintenance coating work and impractical for small repairs. The qualification basis for maintenance coating work should therefore include alternative power tool methods, such as SSPC-SP3, "Power Tool Cleaning," SSPC-SP11, "Power Tool Cleaning to Bare Metal." Such methods are usually suitable to be outfitted with vacuum recovery, which is a valuable tool for dust and contamination control. Vacuum blasting, wherein the spent abrasive is contained and recovered by a shroud around the blast nozzle, is a method that offers dust control superior to “open” abrasive blasting. Foam particles that have been impregnated with a variety of abrasive media are effective blast media that minimize airborne dust. Self-propelled centrifugal shot-projecting machines are effective for stripping existing coatings and preparing concrete floors. These machines also use vacuum recovery and filtration to minimize dust.

Manual surface preparation methods may be satisfactory, particularly for repairing small areas (SSPC-SP2). Hand-scarifying, using abrasive media impregnated into a suitable fabric, has the advantage over mechanical methods by minimizing airborne dust. However, manual methods are usually slower and may increase radiological exposure. As with certain power tool media, some hand cleaning methods (for example, a wire brush) may tend to burnish a metal surface. Such methods should be avoided because coating adhesion can be compromised. Section 8.2, “General,” of ANSI N5.12 defines criteria for pre-preparation activities. Chapter 8 of the ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants* offers valuable guidance with respect to the various methods of surface preparation used in surface preparation for containment maintenance coating work.

The full array of surface preparation methods that might be used should be reflected in the maintenance coating DBA qualification basis.

6.1.2.2 New Fabrications or General Refurbishment/Replacement

In the event that gross removal/recoating might be necessary, the following standards and guidance should be consulted:

ANSI N101.2, Section 6, “Surface Preparation for Shop and Field Applications.”

- Section 6.3.1.2, “Occasional . . . Exposure to Strong Decontamination Materials,” is the least demanding category under Section 6, and it invokes SSPC-SP6, “Commercial Blast Cleaning.”
- Sections 6.3.2, 6.3.3, and 6.3.4.2 address surface preparation of stainless steel, galvanizing, and aluminum, respectively.

Maintenance of coatings on concrete substrates would also most often entail manual or power tools such as those discussed in the previous section for preparing metal. However, on occasion, extensive areas might need to be totally stripped of the existing coating and recoated. This is more likely to be required on concrete floors. Further, some PWR containments may have freshly placed concrete, for example, concrete placed during steam generator replacement modifications. In addition to the general surface preparation provisions listed in Section 6.1.1 of this report, requirements that are expressly applicable to coating containment concrete are considered in the sections that follow.

Considerations for Previously Coated Formed Concrete

The following three considerations apply:

- Extent to which the surface must be treated to decrease or eliminate chemical and radiological contamination and the methodology for accomplishing treatment.
- Extent to which scarification/abrading/chemical conditioning is needed to promote a bond to aged coating (as required to replicate qualification test design basis).
- Extent to which the existing coating must be removed or abraded. Conceivably, maintenance overcoating might result in film thicknesses that exceed the maximum DBA-qualification limits for DFT. The existing coating may need to be abraded to reduce the thickness, as required to accommodate the fresh coating without exceeding prescribed DFT limits.

ASTM standards D4258, "Practice for Surface Cleaning Concrete for Coating," and D4259, "Practice for Abrading Concrete," and SSPC-SP13/NACE No. 6, "Surface Preparation of Concrete," provide useful guidance that is applicable when preparing coated concrete.

Considerations for Previously Coated Flatwork (Such as Walking Surfaces)

- All the considerations from the preceding list apply, in addition to the viability of self-propelled centrifugal shot machines. Such devices result in a deep profile that may not be suitable for thinner floor coatings. These machines are generally used for self-leveling and trowel-applied floor systems. Deep profiles also tend to promote air entrapment when overcoating.
- Protecting expansion joint sealant from blast damage.

Considerations for Freshly Placed Formed Concrete

When it is necessary to coat newly cast concrete, the following factors should be considered:

- Extent of cure prior to preparation
- Compatibility of coating with curing compounds and form release agents
- Cement finishing (sacked/grout clean down/board formed/tie holes filled-unfilled)
- Treatment of bugholes, expansion, and control joints
- Determine whether embeds were prepared at the same time as the surrounding concrete

Considerations for Freshly Placed Flatwork (Such as Walking Surfaces)

The following two considerations apply:

- Compatibility of the system to be applied with the surface hardener (for example, silicate/waterglass)
- Acid etching of concrete flatwork in containment should be avoided

Direction with respect to preparing fresh-formed concrete for coating is found in the following:

- ANSI N5.12, Sections 8.4, “Surface Preparation for Concrete”, and 8.5, “Surface Preparation for Masonry”
- ANSI N101.2, Section 6.4, “Concrete and Masonry”
- ASTM D4258, D4259, and SSPC-SP13/NACE No. 6, “Surface Preparation of Concrete”

6.1.3 Surface Preparation for Primary Containment—Immersion Coatings

In addition to the general surface preparation provisions listed in Section 6.1.1 of this report, the following additional issues (expressly applicable to wetwell linings) should be considered:

- Drying the torus/suppression pool.
- Requirements/limitations regarding the use of high-pressure water jetting to remove existing linings (SSPC-SP12/NACE No. 5).
- Detection and elimination of biologic and soluble salts (H2O2/bromination/steam cleaning).
- Dust containment, ventilation, and confined space considerations.
- Blast sequence (rough blast/clean blast/profile blast) and blast media (slag/sponge/garnet/alumina).
- Assessment to determine whether corrosion has resulted in encroachment upon the minimum wall thickness limits. If such concerns exist, care should be taken to ensure that surface preparation does not result in excessive scour at such areas.
- Metalwork (grinding, routing, weld and edge contouring): NACE SP0178, American Society of Mechanical Engineers (ASME) Section XI considerations.
- Air flow patterns to ensure visibility and, upon rough blast completion, to ensure that the surface is maintained above dew point. Provisions to ensure that critical components, such as dehumidifiers, are protected with filters to prevent blast dust damage.

6.1.3.1 Maintenance and Repair

Minor touchup typically should be performed underwater by divers to avoid the cost and schedule impact necessitated by dewatering the wetwell. Coating materials suitable for underwater use should, as a minimum, be DBA-qualified on panels prepared by a method achievable underwater. Pneumatically driven power tools are typically used to clean discrete spots needing such repairs to a SSPC-SP11 “Power Tool Clean to Bare Metal” condition.

6.1.3.2 General Refurbishment/Replacement

Should major repairs or total replacement of a wetwell lining be necessary, the following should be considered for guidance:

- ANSI N101.2, Section 6.3.1.1, "Continuous Immersion in DI Water"
- ANSI N101.2, Sections 6.3.2, "Stainless Steel" and 6.3.2.1, "Continuous Immersion Service"

6.1.4 Surface Preparation Outside Containment—Non-Immersion Coatings

6.1.4.1 Maintenance and Repair

It is unlikely that safety-related coatings would be required for concrete or masonry in these areas. Therefore, only steel surface preparation is addressed in this report.

The extent of surface preparation will depend on the nature of the substrate, the extent of deterioration of the existing coating, and the service environment. Where there is significant likelihood that detached coating could be ingested into a safety-related component, such as a diesel generator, SSPC-SP11 provides a satisfactory level of surface cleanliness. The guidance set forth in Chapter 8 of the ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants* would also be applicable to this category of work.

6.1.4.2 New Fabrications or General Refurbishment/Replacement

The user should ensure that critical equipment, such as diesel generator internals, is sealed against intrusion of blast dust and grit when abrasive blasting or power tool cleaning is near critical equipment.

6.1.5 Surface Preparation Outside Containment—Immersion Coatings

Similar to repairs in the wetwell, underwater repairs are often the more practical approach for tanks. Similar surface preparation techniques should be used. However, certain tanks are more readily dewatered than a wetwell and repair "in the dry" will usually result in more reliable performance.

Typically, raw water piping systems should be dewatered, cleaned of fouling, and dried prior to the surface preparation required to support repair or replacement of lining materials. However, there are epoxies that can be applied on wet surfaces.

Fuel oil tanks should be defueled and thoroughly cleaned before performing coating repairs or recoating. API RP 1631 may be referenced for detailed guidance. In the above cases, low-pressure water cleaning, as defined under Section 2.1.3 of SSPC-SP12/NACE No.5, steam cleaning with detergent by methods in accordance with SSPC-SP1, or comparable methods capable of removing fuel residues without damaging the coating should be considered. Similar cleaning would also be appropriate for cleaning biologics and mud from service water systems prior to general surface preparation.

Surface preparation cleanliness and profile should be consistent with the coating design basis and/or the coating application instructions.

6.1.5.1 General Guidance

Prior to commencement of surface preparation activities, air flow should be established in the work area to provide worker safety and adequate visibility. Preliminary blasting, sometimes called *rough blasting,* performed for initial substrate cleaning, does not mandate establishment of environmental controls. To achieve a high degree of post-blast cleanliness, atmospheric controls may be necessary to maintain the substrate temperature at least 5°F (-15°C) above the dew point and control humidity within specified limits. The cost and complexity of the required atmospheric controls should be carefully considered when making a decision whether to repair the coating on a component or replace it entirely with a new component.

6.1.5.2 Environmental Control Systems

The configuration of service water systems often makes it difficult to control ambient conditions in the coating work location. If individual piping spool pieces cannot be removed to the shop for recoating, the conditioned air delivery and exhaust configuration required in the work area must be carefully designed. Use of a containment enclosure will prevent unconditioned ambient air from entering the work zone. Conditioned air should be conducted via ducts or flex hoses from the air conditioning equipment (dehumidifiers, heaters, and so on) into the containment through sealed openings. Containment entrances should be configured as air locks with Velcro-sealed opening seams. In the case of large tanks, conditioned air should be introduced into the vessel via plenums or headers so that uniform air flow is maintained throughout the work area.

6.1.5.3 In-Line Heaters and Coolers

If ambient (outdoor) air is used as the source of process air, the air handling equipment should be sized to account for anticipated extremes of temperature and humidity. When the weather is damp, a rotary honeycomb dehumidification (DH) unit's reactivation may be impaired. Running return ducting from the workspace plenum to the reactivation air inlet should be considered. Alternatively, air conditioners may be used to deliver somewhat drier air to the DH unit. Rotary honeycomb DH units warm the air, which can be helpful in cold weather. Supplemental heaters may be needed, particularly if the schedule requires accelerated curing of the completed lining. In hot weather, the temperature bump associated with DH use can encroach on the maximum temperature specified for the lining material application and cure. Use of a chiller or air conditioner either upstream or downstream of the DH unit will mitigate this effect.

6.1.5.4 Maintenance and Repair—Underwater

Surface preparation methods are selected based on the condition of the substrate and the presence of exiting coatings. Historically, steel substrate surface preparation is often specified as SSPC-SP11 and SSPC-SP12. Concrete substrate surface preparation is often specified as SSPC-SP12.

6.1.5.5 Maintenance and Repair—Dewatered Condition

If feasible, abrasive blasting should be performed in accordance with SSPC-SP10 requirements unless other criteria are identified by the Nuclear Coating Specialist in conjunction with the coatings manufacturer. Vacuum blasting or use of sponge abrasive media may be considered in lieu of open blasting if airborne dust is an issue. Using power tool methods to achieve the requirements of SSPC-SP11 could be a practical alternative, particularly for small, discrete spot-type repairs.

Guidance concerning surface preparation of concrete substrates is provided in Section 6.1.2.2 of this report.

6.1.5.6 General Refurbishment/Replacement/Repair

Service water system lining work is often complex and demanding. Whenever feasible, an on-site painting shop, outfitted with the necessary surface preparation and process air generating and control systems, should be established. Lining and relining of pipe spools, valves, and components should be controlled if performed in such a facility. This approach may necessitate modifications to cut long runs of piping into pieces that are accessible and easily handled.

Standards serving as the basis for surface preparation of outside of containment immersion surfaces to support general rework are limited. Abrasive blasting should be performed in accordance with SSPC-SP10 requirements unless other criteria are identified by the Nuclear Coating Specialist in conjunction with the coatings manufacturer. An alternative, which might be used if the existing coating to be removed is contaminated with radionuclides or hazardous ingredients such as asbestos or heavy metals, is to strip the lining and clean the substrate by high-pressure water jetting/ultrahigh-pressure water jetting (HPWJ/UHPWJ) per SSPC-SP12 followed by abrasive blasting to SSPC-SP10. If HPWJ/UHPWJ methods are used, contaminated wastewater must be contained, collected, and disposed of properly.

When abrasive blasting heat exchanger tubesheets, the inside diameter (ID) of heat exchanger tubes should be outfitted with temporary plugs to prevent abrasive scour and tube wall damage. Water-jetting tubesheets can cause the formation of “warts” within tube ends unless measures are taken to preclude the jet impinging on the tube ID. The warts represent a buckling of the tube wall in the rolled zone (that is, at the tubesheet) that can hamper future use of projectile-type tube cleaners and may interfere with the plastic plugging used as part of the polymer tubesheet cladding process. Historically, it has been noted that warts are often encountered in water jetting of tubes when pressures of approximately 10,000 psig (68.95 MPa [gauge]) are used.

It has been observed that improper waterjetting can, if improperly performed, leak paths between the primary and secondary sides of heat exchangers.

Useful technical information concerning HPWJ/UHPWJ is contained in "Recommended Practices for the Use of Manually Operated High Pressure Water Jetting Equipment" (Water Jet Technology Association).

6.2 Application

6.2.1 General Guidance

The methods used for application are influenced by the extent of the coating work to be performed and the work environment. The following factors should be considered when using spray application within primary containment or the power block:

- Mists are noxious to those working in the area and can trip airborne radiation monitors.
- Spraying results in a more rapid release of solvents that affect atmosphere cleanup filters, and spray droplets can settle on critical equipment, fogging the surface.
- Spraying is not usually warranted because most projects are limited in scope.
- Recirculation, tumbling, or agitation of the air may be necessary for proper curing of certain coatings and for controlling the concentration of VOCs.

For large-scale floor resurfacing, trowels, squeegees, and a screed box-type applicator may be used instead of spraying when applying highly filled floor toppings. Roller application of thinner, multicoat high-solids epoxy floor coatings has also been successful.

Spraying is usually impractical within the confines of *in situ* service water spools. The primary uses of spray application should be confined to large-scale projects where the increase in applicator efficiency and corresponding as-low-as-reasonably-achievable (ALARA) benefits warrant spraying.

Brush and/or roller application is generally used for maintenance coating work. The coating manufacturer's product data sheets and application procedures should constitute the first, and most applicable, references for proper application criteria. Those criteria should be incorporated within, or attached to, the applicable job procedures. Useful guidance regarding application is provided in the ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants*, Section 9, "Practical Methods of Coating Application." Likewise, SSPC-PA1 provides guidance regarding maintenance coating work that, though not expressly tailored to nuclear power plants, should be of generic benefit.

The following application criteria should be addressed in the plant procedures defining the safety-related coating work process:

- Establish and maintain the following ambient/environmental conditions (that is, commencing with final blast):
  - Surface temperatures warmer than the dew point (quantify)
  - Air temperature (indicate range)
  - Relative humidity (indicate range)
- Maintain ambient conditions until a defined extent of cure is reached. Measure conditions continuously (for example, with a hygrothermograph) or at regular intervals.
- Protect/mask surfaces that are not to be coated.
- Define the intended application method. If spraying in primary containment, an enclosure may be needed with suction taken on the enclosure via an induction fan outfitted with a high-efficiency particulate air (HEPA) charcoal filter. Monitoring of the enclosure's atmosphere using an alarming explosion meter should be considered.
- Establish criteria regarding the following:
  - The thickness of each coat
  - How film thickness will be monitored
  - The number of coats for a given system
  - Film defect limitations (that is, no visible pinholes, runs, sags, orange peel, or craters)
- Identify provisions to be taken to minimize the impact of coating work on plant personnel, equipment, and fume-sensitive materials, such as activated charcoal and nonmetallic compounds, during both the application and cure intervals. Ventilation should be designed to maintain workspaces well below the lower explosive limit.
- Determine limits on the rate of application or isolate HVAC charcoal filters from coating operations to preclude impairing the absorption capabilities of the charcoal. Protection of charcoal filters may be required by plant technical specifications.

6.2.2 Application for Primary Containment—Non-Immersion Coatings

Brushes and/or rollers are generally used. Protection against drips and coating droplets on surfaces not to be coated should be considered. The repair coating should be confined to properly prepared interfaces, and indiscriminate overlaps should be avoided. The applicator should provide and maintain the requisite ambient conditions from the time the first coat is mixed until the complete system has sufficiently cured, to the extent that demobilization is appropriate. The applicator should ensure that any masking or protective covering is completely removed, collected, and withdrawn from containment upon completion of the work.

If extensive recoating is necessary, spraying may be warranted. Construction of a dust-tight enclosure is usually considered necessary to confine dust associated with surface preparation and to control ambient conditions. Such enclosures should be thoroughly cleaned and vacuumed prior to advancing to the application phase of the work. The applicator should apply protective coverings or shrouds to any equipment within the work area that is not intended to be coated.

For coating concrete surfaces, the following issues should be addressed:

- The concrete should be free of noncompatible curing compounds or other contaminates.
- The extent to which epoxy surfacer must be used to fill or close bugholes and the method of application (that is, airless spray followed by squeegee, and so on) should be determined.
- The concrete should be surface dry (plastic sheet method—ASTM D4263 or moisture meter) and adequately cured.
- Concrete that is deeply profiled (for example, more than coarse sandpaper) can cause air release that leaves bubbles in the coating. Use a thin penetrating presealer that is compatible with the coating system to help mitigate this tendency.
- Expansion and control joint details should be examined. Excess epoxy may need to be raked from joints to maintain the joint groove. Thin-film floor systems should wrap the corner of both faces of a joint so that the elastomer caulk to be laid in the joint will contact coating rather than bare concrete. Thick-film floor systems such as self-leveling epoxies and resin/glass laminates should traverse expansion joints atop suitable bond breakers. For details, see NACE RP0892, Linings over Concrete for Immersion Service, SSPC/NACE Joint Task Group H, "Design, Installation and Repair of Coating Systems for Concrete Used in Secondary Containment," and American Concrete Institute (ACI) 515.1R.
- Termination details for self-leveling, trowel-applied, and similar toppings greatly influence their serviceability. Such coatings generally should be squared and not feathered. Terminating at a sawed-in kerf is usually the preferred approach. When applying such systems, duct tape L-shaped dams may be used at cold joints. When a clear finish will be used, it is appropriate to require repairs in the body coat to be completed first. The clear coat application will erase abrasion scratches. For colored concrete floor toppings, batch control is critical if subtle but obvious shade mismatches are to be avoided. Where feasible, the entire room or vicinity should be coated with the same batch.

6.2.3 Application for Primary Containment—Immersion Coatings

Coatings applied underwater are either mixed above water or plural component application syringes are used by a diver to deposit the required amount of the mixed material. A spatula, broad knife, squeegee, or gloved finger should then be used to spread the coating over the prepared area. Underwater brushing and rolling may be feasible for larger areas.

6.2.3.1 General Refurbishment/Replacement

Major relining of a wetwell involving draining and drying should use spray application. Environmental control systems may be required throughout the surface preparation and application processes.

Plural Component Spray Equipment

Experience with plural component spray in lining work has been inconsistent. If plural spray equipment is considered, a trial application to validate its operability is recommended.

Most problems encountered with the use of plural component coating application technology involve improper or "off ratio" mixing of the individual components making up the mixed coating. Other problems have been encountered related to inadequate or inconsistent heating of the material supply lines from the pump to the spray gun or static mixer.

Note that "clear" hardeners do not lend themselves to detection of nonuniformity of the mix. Whenever possible, use pigmented components.

Accelerated Curing

Liquid-applied thermoset polymers like epoxies, by definition, can be heat cured. This is done to accelerate cure time and to improve performance. The curing process criteria should be specified in the procedure. The procedure should consider the following guidance.

First, increase the temperature gradually to the cure temperature. The manufacturer typically defines the ultimate cure temperature. Higher temperatures will result in faster cures, but there is a limit above which the coating could be impaired. The coating manufacturer should provide the following information:

- The rate at which the surface temperature should be raised.
- The extent of cure as a function of temperature (in this way, an incremental cure "credit" can be assigned during the "ramp up" to the final cure temperature "plateau").
- Recommendations, if appropriate, for imposing cure heat from the exterior of the vessel.
- Limitations with respect to the "ramp down" from the cure temperature. Too fast a temperature drop might impair the coating (for example, by causing pretension stresses).
- A way for verifying adequacy/completeness of cure (Barcol impressor per ASTM D2583, solvent rub per ASTM D5402 [organic coatings], and pencil hardness per D3363).

Second, measure the surface temperature as the preferred parameter for tracking curing. Measuring the temperature of the air within the lined vessel is not a reliable basis for assessing cure. An array of temperature measurement points should be used, particularly in larger vessels, to account for stratification and regional differences in temperature caused by an imperfect air mix. Usually, lower regions have cooler temperatures. The degree of cure should be based on the lowest recorded temperature. On projects involving large surface areas, the use of thermocouples or radio telemetry-type temperature sensors is recommended. These may be attached to the exterior of the lined surface on the skin of the vessel beneath any insulation used to enhance the efficiency of the cure.

The guidance described in Section 6.2.5, “Application Outside Containment—Immersion Coatings,” is provided to counter conditions that might occur if the shell of the surface to be lined is outdoors. However, the same considerations should be evaluated whenever a lining material with solvent will be subjected to force curing.

6.2.4 Application Outside Containment—Non-Immersion Coatings

Refer to Section 6.2.2 of this report for guidance regarding the application of non-immersion coatings inside primary containment. Similar requirements should be observed for the category of coating work described in this section.

Applicable guidance is contained in ANSI N5.12 Section 9, “Coating Application for Shop and Field Work.”

6.2.4.1 Thermal Spray/Metalizing

Thermal spray and metalizing represent both a coating material and a method of application. Thermal spray and metalizing occur when a molten metal, most commonly aluminum, zinc, aluminum/zinc alloy, or stainless steel, is directly applied to a steel surface. Thermal spray and metalizing are used both as an economical means of revitalizing a worn substrate (stainless steel), and as a protective coating (aluminum, zinc, aluminum/zinc alloy). Thermal spray and metalizing are also used for correction of erosion and flow-induced corrosion (FAC) damage to fluid systems. Structural credit cannot be taken for thermal spray/metalizing rebuild of worn substrates, however.

These are considered “cold” processes (relative to the substrate material being coated), as the substrate temperature can be kept low during processing to avoid damage, metallurgical changes, and distortion to the substrate material. The coated surface can be placed into service very quickly.

The application process consists of feeding a metallic wire or a powder through a plasma arc or hot flame that melts the metal and turns it into a stream of molten particles. The liquefied metal is sprayed onto the substrate using air or, in some cases, an inert gas. Usually, the type of application process and metal applied determine the porosity level. Sometimes, an organic or inorganic coating is applied over the metalizing to fill the voids and thus improve the performance.

The required surface cleanliness is either SSPC-SP10 or SSPC-SP5, with a minimum 3 mil (0.8 mm) surface profile.

In service, a zinc and aluminum coating will function as an anode and protect the steel surface by the principle of cathodic protection. Overcoating reduces the depletion rate of the zinc and aluminum thermal sprayed/metalized layer from general atmospheric corrosion and extends the life of the relatively porous thermal sprayed/metalized layer. Topcoated zinc and aluminum thermal spray/metalizing can provide long-term protection in atmospheric service.

Useful information concerning thermal spray/metalizing is contained in NACE No. 12/American Welding Society (AWS) AWS C2.23M/SSPC-CS 23.00, "Specification for the Application of Thermal Spray Coatings (Metalizing) of Aluminum, Zinc and their Alloys and Composites for the Corrosion Protection of Steel."

6.2.5 Application Outside Containment—Immersion Coatings

This section addresses safety-related fluid systems, although outside of containment 10 CFR 50, Appendix B requirements apply because the coatings have been classified as safety-related.

The following guidance is applicable to liquid-applied, polymeric resinous type coatings. If determined to be appropriate, comparable direction may be developed for elastomeric and other types of coatings.

Consistent with the requirements of 10 CFR 50, Appendix B, Criterion IX, individuals performing such applications should be certified as qualified to apply the particular lining system that will be installed. Guidance concerning the personnel qualification process specified is provided in Section 10 of this report.

Refer to Section 6.2.3 of this report for application guidance for other immersion coatings. Similar criteria and guidance would apply for lining applications in this category of immersion coating work.

6.2.5.1 Maintenance and Repair

Coatings within water tanks can be touched up by divers using similar techniques and materials to those that are used for wetwell repairs. It may be possible for some elements of a safety-related fluid system such as valves, heat exchanger channels, endbells, and covers to be removed to a facility having equipment, including a blast booth and an environmentally controlled spray booth. Doing this simplifies the repair process and improves the probability of a successful application because attaining proper conditions in the field is usually difficult. When localized repairs are made, the new coating should be feathered (that is, have a smooth transition) into the existing coating adjacent to the repair.

6.2.5.2 General Refurbishment/Replacement

Establishing and maintaining proper environmental conditions are essential to successful relining of service water systems and safety-related tanks. Section 6.2.3 of this report describes the environmental control process that should be established during the final phase of the abrasive blast cleaning process. The same ambient control system should remain fully functional throughout application, and the equipment should have sufficient flexibility in capacity and distribution to then function in the cure stage, particularly if accelerated curing is required. The ability to provide supplemental cooling and heating is important to avoid having the work schedule interrupted as a result of weather changes. The curing guidance discussed in Section 6.2.3 of this report applies to outside containment safety-related immersion applications.

Enclosures typically are used to contain process air within the work environment. During the blast phase, grit and dust invade crevices within the enclosure fabric, scaffolding, and the items to be coated. It is critical that the enclosure be thoroughly cleaned of debris that may be released into fresh coating. Totally disassembling and rebuilding such enclosures and turning over scaffold boards and loosening scaffold joints so that grit can be knocked out are reliable ways of avoiding contamination of the fresh coating.

When coating surfaces are exposed to the atmosphere (such as aboveground portions of pipe and water tanks) in cold weather, introducing warm air into the interior to accelerate the lining's cure can cause blistering. This is of particular concern if the coating contains solvent. If the substrate is cool with respect to the surface of the lining, solvent in the lining is driven by the "cold wall" phenomenon to the substrate where it accumulates and hinders the cure. Accelerated curing on a relatively cool substrate will result in the formation of a cured "skin" on the surface of the lining that traps the solvent within the film. When ultimately immersed, the trapped solvent causes blistering.

If an outdoor vessel must be coated in cold weather, a tent should be draped over the vessel and warm air pumped into the annular space between the shroud and the exterior of the vessel. Alternatively, the exterior of the vessel may be temporarily insulated. At the same time, the interior should be ventilated so that solvent-laden air is removed from the confined space. If possible, multiple venting nozzles should be used, and provisions for tumbling of the air to prevent air stratification should be considered. A portion of the volume of heated air serving the tented space needs to be directed into the interior of the vessel. The supply air volume should exceed the exhaust air volume so that the space inside the shroud is positively pressurized with respect to the surrounding environment. Otherwise, cold and/or wet air can be drawn within the enclosure and into the vessel.

7

INSPECTION OF SURFACE PREPARATION AND APPLICATION

Requirements for inspection of surface preparation and application should be consistent with each utility's licensing basis as discussed in Section 3 of this report. Criteria governing inspection within primary containment are contained in Section 6, "Coating Inspection," of ANSI N101.4. Subsection 6.2.4 of N101.4 requires that:

> Inspections shall conform to all the applicable requirements of Section 7, Inspection, of ANSI N5.9.

However, ANSI N5.12 superseded N5.9. The corresponding inspection requirements of N5.12 are found in Section 10 of ANSI N5.12.

To a large extent, the inspection requirements found in Section 6 of ANSI N101.4 are redundant but less comprehensive than those in N5.12 (although the inspection documentation set forth in N101.4 establishes details not addressed in N5.12). The following additional standards should be considered to supplement the guidance contained in ANSI N101.4 and to assist with program implementation.

ASTM D3276, "Standard Guide for Painting Inspectors (Metal Substrates)," should be considered an excellent primer for coating inspectors and surveillance personnel. It presents a global view of all aspects of coating work in textbook fashion. Its appendix, "Inspection Checklist," represents a summation of the key information essential to effective coating inspection that is cross-referenced to the text of that standard.

ASTM D5161, "Standard Guide for Specifying Inspection Requirements for Coating and Lining Work," outlines typical coating work inspection attributes. It uses a matrix categorizing four different levels of service environments to indicate the level of inspection appropriate for each environment. The two most aggressive environments are identified as "severe" and "immersion" and require essentially the same level of inspection. For all categories of safety-related coating work, the inspection attributes suggested in ASTM D5161 (for severe/immersion environments) apply. ASTM D5161 references applicable ASTM standards for implementing the inspection attributes listed.

7.1 Types of Inspection

Generally, three forms of inspection are recognized: surveillance inspection, hold point inspection, and final inspection. The inspector normally should perform surveillance inspection randomly throughout the job. As the name infers, hold point inspection requires that at specific junctures within the process, the work not proceed until such time as a particular attribute considered critical to the overall suitability of the process (and one that, inherent to that process, cannot be subsequently verified) is confirmed as conforming to the established requirements. Final inspection is conducted upon work completion to verify that essential design objectives were reached.

Some of these inspections may be considered either surveillance or hold-point based on the type of coating work being performed and the degree of inspection deemed necessary.

In all cases, inspection must be performed by trained and qualified personnel.

7.2 Typical Surveillance Inspections

The following guidance is applicable to safety-related coating work, both inside and outside primary containment.

Surveillance inspections determine the following:

- Surface preparation and application equipment systems (including environmental control systems) are functional and ambient conditions are monitored.
- Protective coverings (for overblast and foreign material exclusion protection) and masking (for overspray protection) are in place, and conditions are monitored.
- Confirm blast media is the proper type and size and are suitably free of foreign material, soluble contaminants, and oil residue (see ASTM D4940 and SSPC-AB 1, Section 4.1; SSPC-AB 2, Section 4; and SSPC-AB 3, Section 4).
- The required coating work documentation is accurate. This could include coatings inventory logs, equipment preventative maintenance schedules, and so on.
- The mixing and thinning process is monitored to ensure the following:
  – The components are properly combined and no excessive residues remain in containers.
  – Induction time, if applicable, is as required for the temperature in the mix area.
  – Proper type and quantity of thinner is used, and thinning is not being used as a way of extending pot life.
- Material is used within the pot life established for the prevailing temperature.
- Visual inspection confirms that the appearance and condition of the applied coating is representative of good work practices (that is, the applied film is essentially free of bubbles, pinholes, pigment agglomerates, craters, runs, sags, embedded particles, and so on).
- Correct material is used and its shelf life has not expired.
- Verify that any ventilation required for surface preparation, coating application, and cure is operating properly and continuously as required by the coating work specification.
- Proper curing methods are being used if heating is required.

7.3 Typical Hold Point Inspections

7.3.1 Primary Containment—Non-Immersion Coatings

Hold point inspections may determine the following, when applicable:

- Qualification certifications for applicators are current.
- Ambient conditions, just prior to commencing final surface preparation, are satisfactory.
- Blotter test of compressed air for surface preparation and spray painting (ASTM D4285) shows air stream to be clean and dry.
- Concrete tests are within pH limits (ASTM D4262).
- Required surface cleanliness has been achieved.
- Profile on metal (ASTM D4417) meets specified requirements.
- Ambient conditions and surface temperatures are suitable for mixing and applying coating (ASTM E337).
- Film thickness is controlled as required to achieve the specified film thickness (ASTM D4414).
- Verification of final cure (see Section 7.3.2).

7.3.2 Primary Containment—Immersion Coatings

In addition to those listed in Sections 7.2 and 7.3.1, hold point inspections for immersion coating work may determine the following, when applicable:

- Testing process for microbial disinfecting was effective (achieving proper results for this test may require an extended period of time).
- Metal edges and surfaces have been rounded as required (NACE SP0178).
- Minimum recoat time was confirmed to have been achieved. In most cases, the minimum recoat times are provided by the coatings manufacturer. In some instances, specific testing may be needed to ascertain that these times have been met. These times are most often dependent on the temperature.
- Overcoating performed before maximum recoat time has elapsed. This is usually temperature-dependent, so consultation with the coating manufacturer for details confirming maximum recoat times should be considered.
- Passing of continuity (Holiday) testing was confirmed (for steel, ASTM D5162; for concrete, ASTM D4787).

Inspection standards applicable for containment immersion coatings (that are not normally hold points) include the following:

- ASTM D4752, "Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub"
- ASTM D4940, "Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives"
- ASTM D5162, "Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates"
- ASTM D5402, "Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs"
- NACE 6F166, "Recommended Practices for Inspection of Linings on Steel and Concrete"

7.3.3 Outside Containment—Non-Immersion Coatings

The same inspections and criteria covered in Sections 7.2 and 7.3.1 apply to this category of coating work.

7.3.4 Outside Containment—Immersion Coatings

Appendix D of this report provides detailed guidance regarding surface preparation for immersion coatings outside containment. The same inspections and criteria discussed in Sections 7.2 and 7.3.2 apply for this category of coating work. In addition, the hold point inspection surface chlorides test (refer to SSPC-SP12, Appendix B, Procedures for Extracting and Analyzing Soluble Salts) typically applies for systems that have been exposed to seawater or other types of salt contaminants.

7.4 Typical Final Inspections

7.4.1 Non-Immersion Coatings

Non-immersion coatings, whether inside or outside primary containment, should be assessed for cure, appearance and dry film thickness.

Degree of curing of liquid-applied coatings is usually determined in the shop or field by one of three methods:

- ASTM D3363, "Standard Test Method for Film Hardness by Pencil Test"
- ASTM D4752, "Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub"
- ASTM D5402, "Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs"

A standard that is often used to define requirements for appearance of coating work is SSPC-PA1, Shop, Field, and Maintenance Painting of Steel.

Dry film thickness is generally determined by the standard methods for magnetic substrates and nonmagnetic substrates.

7.4.1.1 Magnetic Substrates

SSPC-PA2, "Measurement of Dry Paint Thickness with Magnetic Gages"

ASTM D7091-05, "Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals"

7.4.1.2 Nonmagnetic Substrates

- (Metals) ASTM D7091-05, "Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals."
- (Concrete) ASTM D4138, "Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means."
- Nondestructive ultrasonic techniques can be used for measurement of coating thickness on metal and concrete substrates.

7.4.2 Immersion Coatings

Immersion coatings, whether inside or outside primary containment, should typically be subject to the following final tests:

- Dry film thickness (SSPC-PA2, ASTM D7091, and ASTM D7234)
- Continuity (Holiday) testing (for steel, ASTM D5162 and NACE SP0188; for concrete, ASTM D4787 and NACE SP1088)
- Sufficiency of cure (solvent rub testing per ASTM D4752, inorganic zinc and ASTM D5402, organic coatings)
- Barcol Hardness test (some buried fuel oil storage tanks): ASTM D2583, "Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor"

A standard that is often used to define requirements for appearance of coating work is SSPC-PA1, Shop, Field, and Maintenance Painting of Steel.

7.5 Inspection Records

Records of safety-related coating inspections shall be controlled and retained in accordance with each utility's QA program.

7.5.1 Non-Immersion Coatings

Pro forma inspection forms are provided in:

- ANSI N101.4, see subsection 7.3.3 and pp. 12–21
- ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants,* Figures 34–36

7.5.2 Immersion Coatings

Inspection forms comparable to the forms mentioned in Section 7.5.2 should also be applicable to immersion coating work. Some rewording or modification of the forms may be necessary to track the following:

- Testing for soluble salts and for the presence of microbial activity
- Recoat windows
- Degree of cure
- Holiday test results

A curing log showing the cumulative percentage of cure of an immersion coating over time may also be helpful for lining work.

8
CONDITION ASSESSMENT

8.1 Coatings to Be Assessed

Typically, coating condition assessment includes:

- Coatings applied to walls, floors, piping, other equipment, and structural steel inside primary containment.

Equipment that is removed from the primary containment during outages should be included in the inspection program. These may include items such as the containment head and the "spider" used to attach reactor head insulation.

In a BWR wetwell, coatings applied to vapor-phase surfaces as well as submerged portions of the containment, piping, and components should be evaluated.

- Safety-related service water coatings (that is, lined surfaces of safety-related service water system components). Coatings are typically found on heat exchanger components (that is, channels, endbells, coverplates, tubesheets, and so on) or on piping ID surfaces. Pipe linings may be full length or applied in specific problem areas.
- Diesel-generator storage tank coatings. Generally, fuel storage tanks are lined with either a coal tar or other type of epoxy proven in fuel service or inorganic zinc coating. ANSI/API RP 12R1 contains useful guidance for inspecting fuel tank coatings.
- Coatings applied to water storage tanks used during refueling or ECCS operations.
- Coatings on diesel generator combustion air intakes.
- Polymeric repair compounds.
- Condition assessment of non-safety-related coatings can also be performed using the applicable guidance provided in this section of the report.

8.2 Prioritization and Frequency of Coating Assessments

Because ANSI and ASTM standards have not previously required explicit assessment of safety-related coatings, some plants may not have formally performed and documented assessments of the condition of safety-related coatings in the past. In the past, most plants have included coating inspections/assessments to some degree, but there remained wide variation in the scope and formality of these activities, the documentation of the results, and the corrective actions taken.

As a result of commitments made in response to GL 98-04 and license renewal commitments made to comply with NRC report NUREG 1801 (Generic Aging Lessons Learned [GALL]

Report), Volume 2, Appendix XI.S8, all nuclear power plants now conduct periodic and detailed condition assessments of safety-related coatings throughout the plant.

It is recognized that it is not practicable to do a baseline assessment of all safety-related coatings at one time. Instead, it is suggested that the coating program include development of a prioritized approach to the coating assessment. This may include assessing a representative sample of all the types of coatings within the program scope. The goal of prioritization should be to gain an early indication of the conditions and to use this information for refining the coating assessment prioritization process. For example, it probably is not practical for every diesel fuel storage tank or every service water pipe spool to be inspected during the initial inspection.

When a comprehensive inspection program is deemed necessary, deciding which applications to inspect first should include consideration of the impact of coating failures on plant safety. In conjunction with the safety impact, any potential problem areas that can be identified via a review of prior inspections, specifications, procedures, and quality control records should have high priority. Non-conforming coatings may also be given high priority when developing the condition assessment program. Factors such as availability of and accessibility to the coated equipment or surfaces, ALARA considerations, and outage schedules also should be factored into the prioritization process.

Table 8-1 provides a list of safety-related applications for coatings with recommended condition assessment frequency and the bases for those recommendations. The assessment frequencies primarily consider the safety functions of the coating and assume that no significant degradation is observed during the initial condition assessment. The indicated frequencies could be influenced by trended results, as discussed in Section 8.12 of this report. The table does not attempt to prioritize the list of applications but is intended to illustrate considerations for each. The actual prioritization of applications will vary among utilities. Plant-specific commitments (for example, to GL 89-13 for service water, plant technical specifications, and so on) may affect the frequency of assessment suggested in Table 8-1.

Table 8-1
Condition assessment applications and frequency

Safety-Related Application	Assessment Frequency	Technical Basis
Containment—Non-immersion coatings	General walkdown every refueling outage	The coatings are believed to have a significant potential for impact on ECCS operation. Access for inspection is easy.
Safety-Related fluid systems coatings	A representative sample every other fuel cycle or three to five years	These are installed in an aggressive environment.
Containment—Immersion coatings	Each pool every three to five years	These are installed in aggressive environments. Difficulty of inspection is appreciable.

Safety-Related Application	Assessment Frequency	Technical Basis
Diesel fuel storage tank coatings	Each tank every ten years	These are installed in aggressive environments. Difficulty of inspection is appreciable.

Table 8-1 (continued)
Condition assessment applications and frequency

Safety-Related Application	Assessment Frequency	Technical Basis
ECCS water storage sources	General inspection once every five years	These are in a moderately aggressive environment but are normally used only as a secondary source for water supply or during refueling.
Outside containment—Non-Immersion coatings	General inspection once every ten years	These are low priority because the environment is generally nonaggressive. Introduction of particulate into filtration systems is usually considered in the plant design. Access is easy.
Polymeric repair compounds	Specific to each application	Specific to each application

Development of an assessment frequency baseline should include a review of documentation regarding existing coatings and may include the following:

- Specifications and procedures that may indicate inappropriate surface preparation techniques or application
- Quality control records indicating problems such as incomplete or missing coating material batch traceability (certification), improper environmental criteria, poor surface preparation, missed intercoat windows, or inadequately qualified applicators or inspectors
- Evidence of past problems that may be documented via a plant concerns program (for example, coatings exemption list)
- Condition assessment reports and available service data/records

After initial inspections have been conducted on the safety-related coatings, the inspection scopes can be adjusted based on an analysis of the findings. Should inspections indicate satisfactory conditions, the frequency of future inspections may need to be adjusted accordingly.

Coatings within safety-related fluid systems may be prioritized by the nature of the environment. Problem areas, as identified by plant experience, may be the first sites of inspection. Coatings in areas where erosion, cavitation, impingement, or mechanical damage may exist can be inspected first. Heat exchangers with higher service temperatures may be assessed prior to those with lower service temperatures. Manholes and joints (subject to intrusion during maintenance), fit-up zones (for example, flanges subject to mechanical damage during disassembly and reassembly), and interfaces between dissimilar metals are historical problem areas.

Piping in the warmest parts of the system downstream of the heat exchanger could receive priority over the piping leading to the heat exchangers, provided that this part of the system is considered safety-related. Consideration should be given to the possibility of the failed coating causing flow blockages in spray nozzles in ponds or in cooling towers.

Consideration may also be given to prioritization of coatings based on the results of probabilistic risk assessments conducted at the utility.

8.3 Coordination with Other Inspections

The nuclear safety-related coating inspection and assessment program should be coordinated with existing inspection programs or maintenance activities when possible. One area of particular confluence is the inspection of the containment liner required by changes to Sections IWE and IWL of ASME Section XI. The containment liner inspection includes a requirement for inspection of the coating when assessing the minimum wall thickness.

If plant commitments require examination of containment liner coatings in accordance with ASME Section XI inspection of the liner plate, and if inspectors are appropriately trained and qualified to perform both the liner inspection and the general coating inspection, it may be feasible to complete a portion of the containment coating assessment at the same time that inspections of the containment liner are performed. Such personnel would be expected to be qualified to the ASME inspection requirements and the coatings program qualification requirements, as defined in the plant's coating program. The coordination of the liner inspection and the general containment coating assessment should be addressed in the overall coating program.

Various types of other inspections, with which a coating condition assessment might be coordinated, are as follows:

- Assessments of non-immersion coatings inside containment can be conducted during snubber surveillance activities (inspections and tests) or one of the many containment walkdowns conducted each outage.
- Maintenance rule walkdowns (10 CFR 50.65).
- Outside containment, safety-related service water system inspections can be conducted in conjunction with heat exchanger inspections required by NRC GL 89-13. These inspections are required to ensure adequate heat removal by safety-related service water heat exchangers.
- Diesel fuel storage tank inspections can be conducted in conjunction with the required diesel maintenance outages.

If the assessments will be performed during an outage, inspections should be a function of outage management's priorities and system availability and will need to be closely coordinated with work planning. It is advisable to schedule regular meetings so that changes that might affect the assessment plan's scope can be recognized in advance and will promote effective prioritization.

8.4 Recognizing Degradation Mechanisms of Coatings

Coatings degrade in ways that are easily detected visually and prior to detachment.

ASTM D5163 and Chapter 3 of the ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants* provide guidelines for conducting condition assessments of safety-related coatings. Visual inspections will determine the general condition of the various safety-related nuclear coatings, identifying areas with coating deterioration (for example, blistering and corrosion) or other coating deficiencies noted in Table 8-2.

Table 8-2
Examples of typical coating degradation mechanisms

Coating System	Typical Degradation Mechanism
Inorganic zinc primer topcoated with epoxy	Intercoat and intra-zinc delamination
Epoxies on concrete surfaces, immersion coatings	Blistering related to either integrated leak rate test (ILRT) or due to moisture vapor transmission
Coatings in elevated temperature areas	Discoloration, embrittlement, or flaking
Inorganic zinc lining immersed in a suppression pool or other corrosion areas	Corrosion nodules, general depletion of zinc
Interface areas between a liner plate and a concrete slab and other inaccessible areas	Rust
Generally all coating systems	Checking, cracking, susceptibility to mechanical damage

After the general observations have been identified, more comprehensive investigations can be conducted at the problem areas.

8.5 General Methodology for Performing Condition Assessments

The most effective way to conduct a thorough coating condition assessment and detect coating degradation is through visual inspection. Figure 8-1 illustrates a number of reasons that visual inspections are the most suitable way for assessing the condition of safety-related coatings. The overall advantages of performing visual inspections are derived by considering the nature of coating failures, basic premises regarding the application of safety-related coatings, and the relative merits of visual inspections compared with other ways of testing.

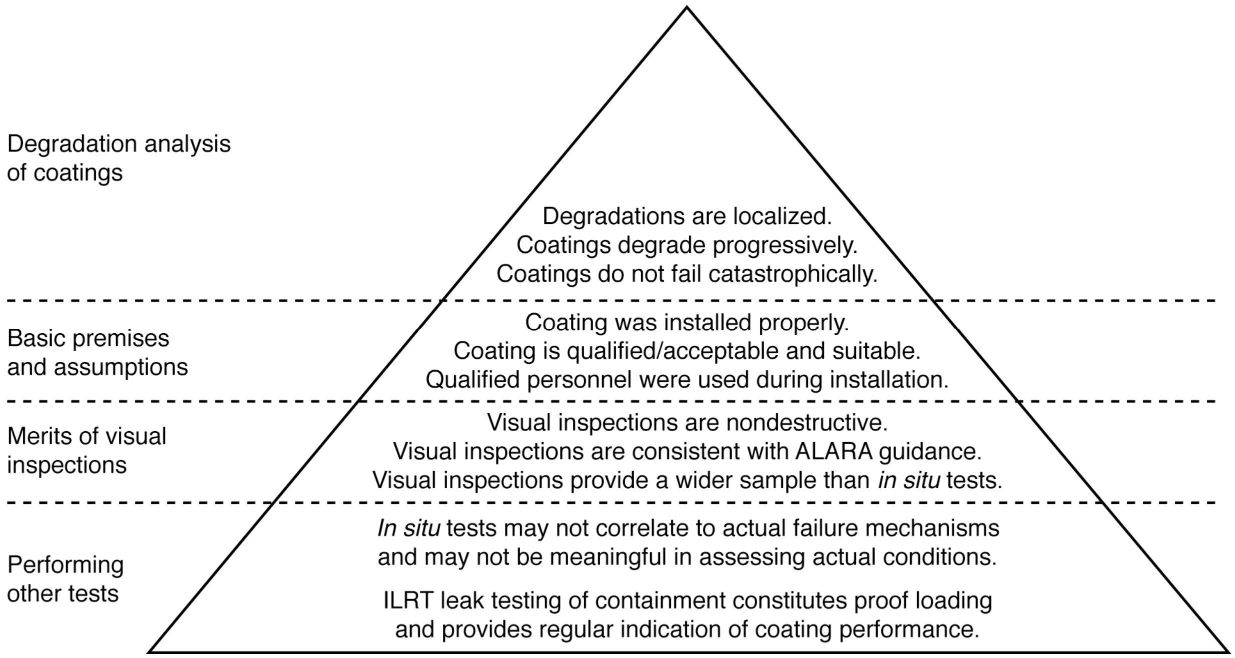

Figure 8-1
Advantages and benefits of visual inspections for coating condition assessment

Figure 8-2 illustrates a generic process for addressing the results after performing the visual inspection. Steps in the generic process are cross-referenced to the appropriate sections of the report in which additional guidance may be found.

During work related to GSI-191, the NRC questioned the validity of visual inspection as a tool to accurately detect incipient failure of safety-related coatings in a timely manner. In response to the NRC questions, EPRI commissioned a task in 2006 titled "Evaluation of Coating Failures and the Potential Influence of Aging/Adhesion Data Collection Procedure." In this task, industry experts traveled to four U.S. nuclear power plants and performed visual inspection of containment safety-related coatings and performed pull-off adhesion testing at coated areas that exhibited acceptable visual conditions. In all cases, the areas that exhibited acceptable visual conditions also had measured pull-off adhesion strengths of 200 psig (13.79 MPa gauge) or greater (the original design requirement required by ANSI N5.12). These data are referenced by the NRC in NRC Staff Review Guidance Regarding Generic Letter 2004-02, Closure in the Area of Coatings Evaluation (March 2008).

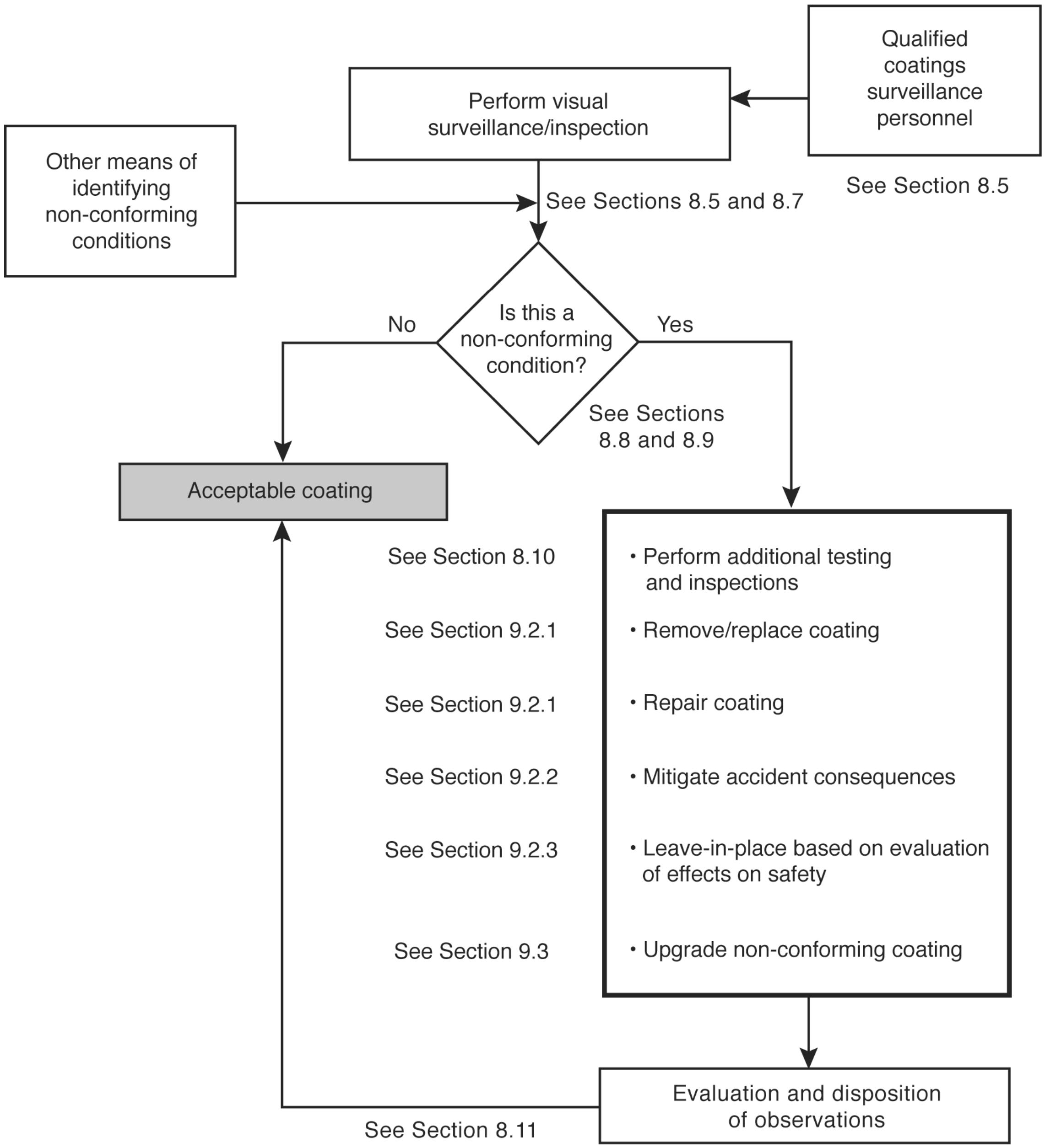

Figure 8-2
Generic process for performing condition assessments

8.6 Personnel Qualification

Individuals performing the condition assessment visual inspections are referred to in this report as Coatings Surveillance Personnel. These individuals should meet the applicable plant licensing commitments (typically, a certified ANSI N45.2.6 Level II or III and/or ASME NQA-1 coatings inspector) and be approved by the utility Nuclear Coating Specialist. Coatings surveillance personnel should have demonstrated knowledge of coatings, obtained through training or plant experience, and should be knowledgeable about applicable plant procedures. Appendix B of this report provides a syllabus for developing a training program that may be considered for this type of inspection personnel. The qualifications of Coatings Surveillance Personnel should be verified to be current and properly documented in accordance with plant-specific requirements regarding personnel qualification.

The Nuclear Coating Specialist is the most appropriate individual to evaluate inspection results and complete the condition assessment. A more detailed discussion of qualifications of various personnel associated with the coatings program is provided in Section 10 of this report.

8.7 Documentation of Condition Assessment Visual Inspection Results

An important aspect of the condition assessment process is the documentation of the coating condition. Photography and video are common methods for providing consistent and comparable documentation of the coating condition. The results of coatings inspections, which may indicate both satisfactory and degraded coating performance, should be documented.

In addition to the photographic documentation, written descriptions of the condition, as well as records of testing and evaluations that were performed, should be compiled into an inspection report. ASTM D5163 offers guidance with respect to the constituents of an effective inspection report (refer to Section 10 of D5163, Reporting and Documentation).

The following standards should be considered when characterizing the degree of coating degradation:

- ASTM D714, “Method for Evaluating Degree of Blister of Paints”
- ASTM D772, “Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints”
- ASTM D610, “Method for Evaluating Degree of Rusting on Painted Steel Surfaces”
- SSPC VIS2, “Standard Method of Evaluating Degree of Rusting on Painted Surfaces”

8.8 Developing Acceptance Criteria

The acceptance criteria for coating assessment should be addressed in the specifications and procedures that implement the coating program. There are many factors that affect the amount of degraded coating that is acceptable; consequently, the acceptance criteria should be established on a plant-specific basis. In general, the effect of degraded coating on the required safety functions of other equipment will be a key issue in acceptance. Consequently, the Nuclear Coating Specialist should consider consulting with personnel knowledgeable about the component and system operational requirements when establishing acceptance criteria for coating assessments. The acceptance criteria should include consideration of further coating deterioration that may occur prior to the next time the area of degraded coating is inspected.

A second consideration in establishing acceptance criteria is the size of the physical area of degraded coating. If the size is relatively large with respect to the surface areas used in

calculations for thermal conductivity and/or hydrogen generation, the degraded condition may affect the containment accident analysis. It may be possible to establish bounding values for these factors such that no action is required unless these limits are approached.

For some plants, a third consideration may be the expected rate of corrosion with the coating in a degraded condition and whether the corrosion rate is such that the minimum acceptable wall thickness might be exceeded prior to the next required inspection of wall thickness. Note that although coatings are used to inhibit corrosion, it is the wall thickness inspections, typically invoked through ASME Section XI requirements, that are relied on to ensure that the minimum wall thickness requirements are met.

8.8.1 Inside Primary Containment—Non-Immersion Coatings

The determination of whether a degraded or unqualified coating is acceptable to leave as is should be based on the quantity and characteristics (for example, size, thickness, and specific gravity) of degraded coating that may detach after exposure to a DBA environment. Engineering analyses suggest that in many plants a significant portion of the coating debris will settle and will not reach the sump/strainers. Although this settling behavior is generally expected, it should be quantified on a plant-specific basis if settling will be credited in the strainer/sump blockage analysis, as several plant-specific parameters can affect the overall settling of coating debris.

NRC GL 98-04 and 2004-02 and RG 1.82, Revision 3 address the issue of LOCA-generated debris blockage of ECCS pump suction strainers in BWRs and PWRs. As a result, essentially all domestic BWRs and PWRs have installed suction strainers that have significantly improved debris-handling capacity.

8.8.2 Inside Primary Containment—Immersion Coatings

Acceptance criteria for inside primary containment immersion coatings are typically the same as for non-immersion coatings and apply to BWR suppression pools.

Failure of containment coatings in immersion service generally occurs in the form of blisters or nodules in epoxy coatings, or, in the case of untopcoated inorganic zinc, nodules that ultimately merge to create vertical tracks referred to as *tiger stripes*. Over time, if the blistered area or nodules/stripes are not repaired, corrosion of the substrate may ensue. Acceptance criteria for permitting the blister or nodules to remain without repair are based on both the effect of the degradation on the pool liner plate or vessel wall (ASME Section XI requirements) and on the potential effect of the coating on ECCS sump/strainers blockage. ASME Section XI requirements and the plant licensing and design bases will govern the minimum acceptable wall thickness.

8.8.3 Outside Primary Containment—Non-Immersion Coatings

The criteria for acceptance of these coatings need to be based on the degraded coating's effect on the required safety functions of equipment it could affect. Factors such as the type of failure and the consequences of potential coating detachment or corrosion, including fouling of filters, on the operation of adjacent or associated equipment need to be considered in the acceptability determination.

8.8.4 Outside Primary Containment—Immersion Coatings

Coating failures in safety-related service water systems, ECCS water supply storage tanks, and fuel oil systems should also be evaluated with respect to the impact of the coating failure on the operation of the safety-related system. Specifically for service water systems, the primary concerns are the effect of the degraded coating debris on heat exchanger tube blockage given design margins and the effect of the lodging of coating chips within a tube that might result in erosion that, if unchecked, could cause the tube wall to perforate.

Suction strainer and supply line blockage is the concern for ECCS water supply storage tanks and fuel oil systems.

In addition to the effects on system operation, the effect on system integrity also needs to be addressed. For instance, the coating failure cannot be allowed to result in piping, tank, or heat exchanger breaches that would limit or prevent delivery of an adequate quantity of cooling water or fuel oil to equipment essential to safe shutdown.

8.9 Initial Review and Analysis of Inspection Results

Data derived from the inspections should be reviewed by the Nuclear Coating Specialist so that the condition can be assessed and strategic planning for required maintenance can be accomplished. The data should identify any areas with significant coating deterioration. An important aspect of the evaluation is to determine and analyze the severity of the physical deterioration or degradation when it is the reason for the non-conforming condition. In general, non-conforming condition is defined as follows:

> A condition of an SSC in which there is failure to meet requirements or licensee commitments. Some examples of non-conforming conditions include the following:
>
> - Failure to conform to one or more applicable codes or standards specified in the FSAR is demonstrated. As-built equipment, or as-modified equipment, does not meet FSAR descriptions.
> - Operating experience or engineering reviews demonstrate a design inadequacy.
> - Documentation required by NRC requirements such as 10 CFR 50.49 is not available or deficient.

The first step in assessing the cause of nonconformance is to review the available documentation of the surface preparation and application process. Reviews of coating procurement documents, application specifications, procedures, and quality control documents can provide information.

Second, a review of the service life history of the coating needs to be performed. Temperature and chemical exposures need to be determined. Other environmental effects, such as abrasion and physical abuse, need to be considered. After the documentation review and service life history have been completed, a more thorough inspection of the degraded area should be performed.

After the severity of the failure has been determined and documented, an evaluation of the cause is the next step. The following standards and tests may be used to assist in determining the causes of coating degradation:

- ASTM D7091-05, "Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals"
- ASTM D3359, "Test Methods for Measuring Adhesion by Tape Test"
- ASTM D3363, "Standard Test Method for Film Hardness by Pencil Test"
- ASTM D4541, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers"
- ASTM D4787, "Practice for Continuity Verification of Liquid or Sheer Linings Applied to Concrete Substrates"
- ASTM D5162, "Standard Practice for Discontinuity (Holiday) Testing of Nondestructive Protective Coatings on Metallic Substrates"
- ASTM D6677, "Standard Test Method for Adhesion Testing by Knife"
- ASTM D7234, "Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers"

Additional testing may be required to determine the root cause of the degradation. Nonvisual inspections may provide additional information in specialized circumstances or for localized areas. Laboratory tests such as the following can be performed:

- Atomic absorption spectroscopy and FTIR spectroscopy fingerprinting of the coatings to verify formulation and stoichiometry
- Microscopic examination of coating cross-sections
- Electron spectroscopy for chemical analysis of coating–substrate or coating–coating interfaces to determine the presence of chemical contaminants

During this evaluation, the Nuclear Coating Specialist should determine whether a non-conforming condition exists. Section 9 of this report provides guidance on actions that may be taken when a non-conforming condition has been identified.

8.10 Considerations for Performing Other Inspections

The scope of nuclear safety-related coating inspections encompasses many different types of applications (for example, underwater inspections, piping interior inspections, and rubber coatings/linings); therefore, certain special inspection methods may need to be considered based on plant-specific circumstances.

Robotics inspections may be considered to minimize the risk of injury or exposure to radiation to Coatings Surveillance Personnel.

Inspections performed on coatings used in the water phase of nuclear suppression pools and water storage tanks may have to be performed underwater. Nuclear safety requirements may prevent drainage of the pools and tanks to permit normal inspections. Note, however, that diver inspections do yield many advantages, such as the time and cost saved by preserving the water or fuel, the mobility offered the diver–inspector to reach all surfaces, and the shielding value of the water. Divers examining the coatings will usually be required to be trained to perform the inspections and tests. It may also be acceptable for a qualified diver to be directed by Coatings Surveillance Personnel remote from the diver via audio/video linkage. The assessment of the Coatings Surveillance Personnel would determine where the diver goes, what is visually inspected, and what test procedures, if any, are implemented. Video coverage of the underwater operation is an effective way to ensure thorough documentation of the inspection.

In some plants service water piping has been coated either prior to or during installation, or subsequent to commercial operation, to prevent corrosion or erosion. Access to these areas is not easily achieved in an operating power plant, especially if small pipe diameters were required or if welded joints were used instead of flanged connections. Inspection points may need to be retrofitted into the current configuration to permit inspection. One method that has been successful is installing “drop-out” flanged spools at locations representative of the entire system. Extreme care should be taken to prevent damage to coated flanges during removal and reinstallation of these “drop-out” flanged spools.

8.11 Evaluation and Disposition of Observations

The coating program should address the review of assessment data to determine the acceptability of the safety-related coating. For any coatings that have experienced significant failure or degradation, steps should be taken to prevent recurrence. The information learned about the degraded coatings may also be an aid in the early identification of other areas where coatings may be susceptible to failure.

Failures of coatings, as determined by the Nuclear Coating Specialist, should be evaluated using plant procedures for corrective actions and disposition of nonconformances and controlled under Criteria XV and XVI of the utility’s 10 CFR 50, Appendix B QA program

In determining the corrective actions required and the schedule for completion, consideration should be given to the following:

- Impact of the degraded coating on safety-related system integrity and operability
- Extent of subsequent degradation that may occur until the time the safety-related coating can be repaired
- Consequences of additional degradation
- Rescheduling the future condition assessment for areas determined to be more susceptible to degradation

Section 9 of this report provides additional guidance for the assessment and disposition of degraded coatings identified during condition assessments that result in a non-conforming condition.

8.12 Service Life Monitoring and Coating Performance

As suggested in the ASTM report *Manual on Maintenance Coatings for Nuclear Power Plants* (Section 3) and ASTM D5163 (Section 11), records should be kept and reviewed prior to the next inspection. Records of coating assessments should include a listing of areas evidencing deterioration, an explanation of any changes that have occurred since the prior inspection, a prioritization of all repair areas, and recommendations for future inspections.

Consideration should be given to trending key coating data. Trending of information can provide early identification of potential trouble areas, input for the scheduling of future assessment activities, and input for evaluating corrective actions.

8.13 Plant Life Extension

Historically, light-water nuclear power plants in the United States have been licensed to operate for a 40-year period. Advances in plant operation and maintenance technology have facilitated the renewal of certain plant licenses for additional 20-year increments. As part of the plant life extension process, the NRC has issued guidance to the industry as *GALL Report* (NUREG-1801, Volume 2, April 2001).

Section XI.S8 of the GALL Report, titled "Protective Coating Monitoring and Maintenance Program," addresses Service Level I coating monitoring and maintenance. To be credited as having an acceptable aging management program for license renewal, a Service Level I coating monitoring and maintenance program must include the attributes in Section XI.S8 of the GALL Report. EPRI report 1019157, Revision 2 provides guidance to facilitate compliance with this section of the GALL Report.

9
MANAGEMENT OF NON-CONFORMING COATINGS

The reader of this report should recognize that essentially every plant may have some amount of non-conforming coatings inside of primary containment and that this is an acceptable condition. Thus, in most plants, the actual conditions of coatings would be represented as shown in Figure 9-1.

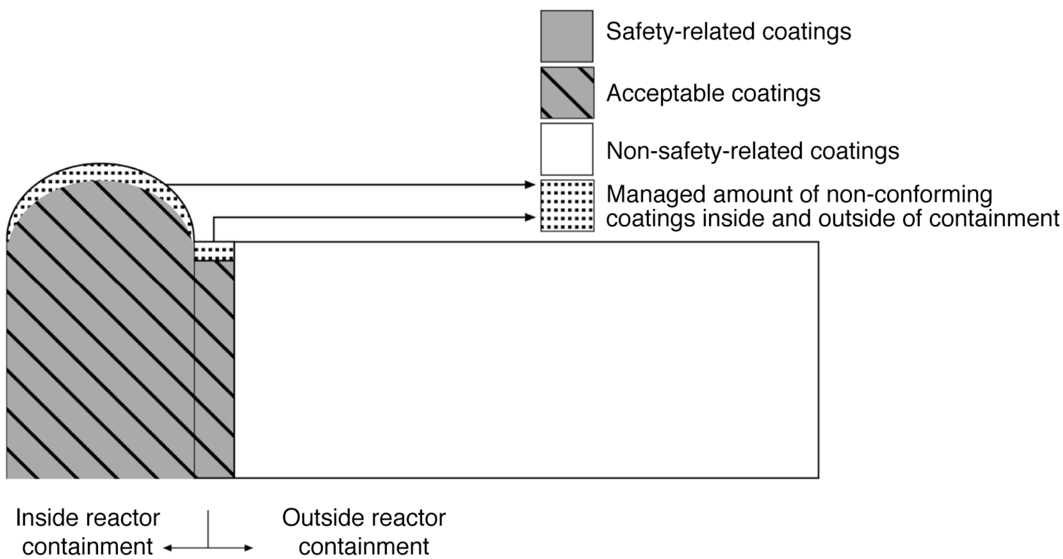

Figure 9-1
Managing certain amounts of non-conforming coatings

As shown in Figure 9-1, a plant may also have some amount of non-conforming or unacceptable safety-related coatings outside containment, and this could also be an acceptable condition. The key to ensuring plant safety is to manage the amount of non-conforming coatings so that it does not exceed the amount assumed in calculations that support plant operation, such as sump/strainer head loss or service water heat exchanger duty calculations.

9.1 General Guidance for Determining the Amount of Non-Conforming Coatings

Much of the following discussion focuses on coatings used inside containment because that is the location with the largest amount of safety-related coatings. The same concepts are intended for use with safety-related coatings used outside primary containment.

There are two considerations when identifying non-conforming coatings, both of which stem from the definition provided in Section 8 of this report.

- Does the coating meet the licensing basis commitments? For plants that have commitments to meet RG 1.54 and/or related ANSI/ASTM standards typically requiring DBA testing of coatings and extensive documentation associated with the application of the coatings (that is, qualified coatings), this may be a more significant requirement to satisfy than for an older plant that has not made commitments to these requirements.
- Is there reasonable assurance that the coating will not detach during normal operation or a DBA? In addition to meeting the licensing basis commitments for coatings, which is a significant input to reaching a conclusion that the coating will not detach during normal or accident conditions, consideration should also be given to the results from periodic coating assessments discussed in Section 8.

When undertaking an effort to identify and manage non-conforming coatings, consideration should be given to the capacity of the ECCS sump/strainer to accommodate debris expected to reach the ECCS sump/strainer (including coating debris) without reducing the overall ECCS pump net positive suction head (NPSH) margin below an acceptable value. Plants with significant operational NPSH margin for accommodating additional debris may require less precision when determining the amount of non-conforming coatings; simplified bounding techniques may be sufficient. In cases in which the NPSH margin is nearer the limit and the potential impact of non-conforming coatings may result in exceeding the limit, those plants may require more precise determinations of the amount of non-conforming coatings to ensure that a sufficient margin indeed remains after accounting for the amount of non-conforming coatings.

The amount of coating that was installed inconsistent with licensing commitments and design requirements needs to be identified. For example, if a qualified coating was applied and inspected by individuals not certified as qualified to recognized or definable qualification standards, or if documentation of the application phase is missing or incomplete, and these requirements are consistent with the licensing basis, the application should not be considered to constitute a qualified coating. However, actions may be taken to upgrade non-conforming coatings to an acceptable status. Section 9.3 provides additional detail on the upgrade of non-conforming coatings.

It may also be appropriate to review procurement documents for equipment installed in containment to determine whether coating applications performed off site resulted in acceptable coatings. For instance, nuclear steam supplier system-supplied components or steel used in steam generator modifications could have been purchased with the expectation that it would be coated in accordance with RG 1.54.

The actual types and brands of coating need to be categorized. It would be helpful to account for coatings that have been DBA tested separately from those coatings that have not been DBA tested. EPRI report TR-106160, *Coatings Handbook for Nuclear Power Plants,* may be helpful when performing the categorization.

If records cannot be found that identify the types and quantities of coatings installed in containment, some area estimations need to be performed. Containment drawings, piping isometrics, piping area drawings, structural steel details, and equipment outline drawings are all useful in determining the amount of coated area in containment.

Another method for determining the quantity of coatings in containment would be to perform a walkdown survey of the containment using painting contractor's estimating practices.

After the sizes of the various surface areas have been determined, these areas should be broken down into the types of coatings that are applied to each surface. If that information is not readily determinable from existing documentation, FTIR fingerprinting may be performed to generically classify the coating.

The results of the investigation should be tabulated according to the various containment surfaces, indicating the type, quantity, location, and qualification classification of the coating applied. If there is some question as to whether the coating is completely acceptable, the qualification classification section should identify the degree of acceptability. This information will be useful should subsequent efforts be taken to upgrade the coating to an acceptable status.

The tabulation should also consider identification of the complete system as applied. For instance, if epoxy was applied over inorganic zinc it should be noted.

Frequently, this tabulation of non-conforming coatings is referred to as a non-conforming or unqualified coatings log. The tabulation should be updated every time unqualified coating is added to or removed from the containment. Tracking in this manner will support periodic updates of calculations for sump/strainer head loss.

9.2 Guidance on Managing Non-Conforming Coatings

Development and maintenance of a "coatings log" *per se* is not required. The basic requirement is to have appropriate controls in place such that quantities of coatings assumed in various calculations, such as ECCS sump/strainer blockage, are not exceeded. Use of a coating log has been shown to be an effective way of meeting that basic requirement. However, other suitable ways for controlling the amount of non-conforming coatings may also be employed.

Once an accounting of the amount of unacceptable and non-conforming coatings is prepared, a decision will need to be made as to how to manage the results. It is important to know the reason a particular area of coating is non-conforming.

If a condition assessment reveals that the coating has physically degraded in service, the coating should be removed or replaced in order to restore that area to an acceptable status. Another alternative may be to mitigate the consequences of further coating degradation by repairing the coating or constructing enclosures that would capture any detached coatings. Yet another alternative may be to leave the non-conforming coating in place. Figure 8-2 illustrates options available for resolving non-conforming coatings identified during the condition assessments, which are discussed in the next section.

If the basis of the nonconformance stems from missing or incomplete documentation needed to support the acceptability and proper application of the coating, it may be possible to upgrade the coating to an acceptable status. Section 9.3 provides additional detail on upgrading the status of non-conforming coatings.

9.2.1 Remove, Repair, or Replace Non-Conforming Coatings

In some cases, it may be appropriate to just remove the coating. If corrosion of the uncoated surface is anticipated, impact of the additional amount of corrosion products available should be considered in ECCS sump/strainer head loss calculations.

Repair of the localized areas of degradation of an otherwise acceptable coating is also an option. Sections 4–7 of this report provide details on the selection of coatings, procurement, surface preparation, application, and inspection of new coatings.

Another option is the replacement of a non-conforming coating with an acceptable coating. Again, Sections 4–7 provide useful information in this regard.

9.2.2 Mitigate the Consequences of Further Coating Degradation

To preclude the removal, repair, or replacement of non-conforming coatings, techniques may be used to mitigate the consequences of further degradation and detachment of coatings. These measures may include construction of containment devices around the equipment coated with the non-conforming coating. The following example illustrates how one utility lessened the consequences of further coating degradation. The example does not imply that other resolutions are not also acceptable based on plant-specific conditions.

Problem: The discovery of a potent non-conforming coating system applied to equipment with significant surface area inside of containment was discovered through visual inspection.

Resolution: After concluding that the coating system was non-conforming, the following options were evaluated:

- Complete removal of the coating and reapplication with an acceptable coating system
- Complete removal of the existing equipment and replacement of it with new equipment having an acceptable coating
- “Containment” of the existing equipment with appropriate materials and design

The decision was made to “contain” the affected surfaces with an engineered stainless steel screen wire that enclosed the equipment like a cage. The enclosure was designed to capture and prevent the migration of any detached coating debris that might result from a DBA.

9.2.3 Evaluate the Safety Impact of Non-Conforming Coatings

An evaluation that determines the impact of the non-conforming coating on the operation of the ECCS suction strainers following a LOCA may need to be performed. Typically, this will be required only when the total amount of non-conforming coating exceeds the amount considered in the ECCS sump/strainer head loss calculation. Consideration of the failure characteristics of the coating, the time of failure, and the transport and strainer head loss characteristics of the detached coatings can all be used in the evaluation. This evaluation can quickly become complex and care should be taken to ensure consistency with the parameters considered in the overall analysis of the head loss across the ECCS sump/strainer.

Use of the plant corrective action program will typically be required when the amount of non-conforming coatings exceeds that considered in the current ECCS sump/strainer head loss calculations. Further evaluation and corrective actions should be pursued in a timely fashion because there is a high probability that ECCS operability issues and related reportability requirements will need to be addressed.

9.2.4 Managing the Addition of New Coatings

The coatings program should also address the use of appropriate controls, such as procedural requirements and specifications, to ensure that the amount of non-conforming coatings does not increase in an uncontrolled manner. The introduction of new equipment or structural components as a result of plant modifications or maintenance on existing equipment and structures could lead to an unwanted increase in the amount of unacceptable coatings.

The Nuclear Coating Specialist should ensure that technical requirements specified for replacement or repaired items adequately address coatings requirements.

Acceptance of their respective responsibilities by organizations that do not own the overall coating program is an important issue. The responsibilities of other disciplines should be clearly resolved early in the development of a safety-related coating control program.

ASTM D7491, “Standard Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants,” provides guidance for managing non-conforming coatings in containment.

9.3 Upgrading Non-Conforming Coatings

The upgrade of non-conforming coatings to an acceptable status can be accomplished by conducting evaluations and/or tests that will compensate for the missing or incomplete documentation that supports the acceptability of the coating. The activities performed should result in reasonable assurance that the coatings were acceptable when applied.

It is important to recognize that the objective in moving particular coating work from a non-conforming to an acceptable status is the achievement of reasonable assurance that is consistent with the licensing basis of the plant. Especially for older plants that predate commitments to ANSI and ASTM standards for DBA testing of coating systems, it is not required that the upgrade criteria meet the more recent requirements, but instead the appropriate objective is evidence showing consistency with the requirements for original coatings and the current licensing basis.

The requirements for evaluation/test are not predefined because they should be tailored to address the specific weaknesses identified. For example, if some documentation of the application of a coating is missing or incomplete for application in one area, but there are records to support the proper application of the coating in other areas, it may be acceptable to evaluate the available information and reach a conclusion as to whether there is reasonable assurance that the coating with missing documentation was applied correctly. In some cases, it may be appropriate to supplement the documentation evaluation with limited testing to bolster the conclusions or address areas in which the results of the documentation evaluation are inconclusive.

In lieu of performing extensive documentation reviews to upgrade the status of a coating, it may be more practicable and cost-effective to perform tests that would provide at least an equivalent level of assurance with regard to coating acceptability as would be achieved via a documentation review. For example, laboratory analysis of the coating material, coupled with sample-based testing appropriate to provide confidence that it was properly applied, could be an effective way of upgrading the status of the coating.

Because the specification of which evaluations/tests are appropriate will vary based on the specific circumstances, it is recommended that a plan be prepared for upgrading the coatings. The upgrade plan should address which coatings are being evaluated, the reasons they are not currently considered acceptable, the evaluations/tests that will be performed to upgrade the coatings, and the schedule for completion. This upgrade plan should be critically reviewed by personnel knowledgeable on coating issues, possibly including a knowledgeable third party, and appropriate levels of plant management. It may also be helpful to have the licensing and regulatory-related aspects of the plan reviewed by the licensing organization. When developing the schedule for completion of the upgrade plan, consideration should be given to the potential impact of the coatings that are currently considered non-conforming on the sump/strainer head loss and ECCS pump NPSH.

Once the upgrade plan has been prepared, it is recommended that the plan be reviewed and coordinated with plant licensing personnel. The purpose of this review is to ensure that the planned upgrade activities are consistent with plant licensing requirements.

The following are examples of conditions that may cause a coating to be non-conforming for reasons other than physical degradation/deterioration:

- Incomplete documentation for the application process
- Incomplete documentation regarding applicator qualification
- Incomplete documentation regarding inspector qualification

- Inadequate design change documentation for the use of alternative coatings
- Improper or inadequate specification of technical and quality procurement requirements
- Improper dedication of commercial grade coatings
- Incomplete documentation for the testing used to establish the design basis
- Incomplete/inadequate specifications and procedures
- Undefined or vague personnel qualification criteria
- Application documentation lost or not issued
- Applicator qualification documentation lost or not issued
- Inspector documentation lost or not issued
- Design basis (qualification) test data lost or not issued

The extent to which these conditions result in coating work being non-conforming or even unacceptable will depend on plant-specific licensing commitments.

The following examples illustrate how some utilities have upgraded coatings to an acceptable status. These examples are not all-inclusive of conditions constituting non-conforming coatings. The examples do not imply that other resolutions are not also acceptable based on plant-specific conditions.

Problem: A qualified coating was applied to 42,500 sq ft (3948 m^2) of pipe hangers distributed throughout the containment. This coating work was applied by the same painting crew that had applied all other safety-related containment coating. However, the hanger work was not specifically controlled with procedures in accordance with 10 CFR 50, Appendix B.

Resolution: Drawings were used to determine the distribution of such surfaces within the containment. A “hanger reduction program” to withdraw unneeded hangers from the containment provided a source of hanger steel from which test specimens representative of the suspect qualification could be fabricated. The number of specimens comprising the total population of specimens representative of a given zone was proportionate to the surface area of hangers within that zone. Subsequent irradiation and DBA testing of those specimens allowed some 35,000 sq ft (3252 m^2) to be upgraded to *qualified* status.

Problem: The original plant design established a bounding limit of 55 sq ft (5 m^2) of unqualified coating within a certain debris source “cone of influence” with respect to the containment recirculation spray sump screens. The plant in question later committed to a broad scale programmatic review of various containment systems in response to regulatory review concerns. As a result, one of the design issues revisited was the unqualified coating tracking program. The subsequent walkdown discovered that a major component comprising some 110 sq ft (10 m^2) had been replaced. The coating was applied by the equipment vendor. Although there was reason to expect that the product applied was a “qualified” coating, no documentation existed for the coating or for the coating application process.

Resolution: There was too much uncertainty with respect to the vendor-applied coating to suggest that the coating could, practically, be upgraded. The coating had to be regarded as "unqualified," thereby exceeding the design basis. It was decided that a method for capturing any coating debris would be constructed beneath the component to ensure that debris could not reach the sump screens.

10
PERSONNEL TRAINING AND QUALIFICATION

10.1 Nuclear Coating Specialist

The nuclear safety-related coatings program should be under the technical direction of an engineer or technical specialist knowledgeable in the areas of coating/lining selection, application, and inspection. In addition, the individual should have sufficient experience in the nuclear industry to assist in the performance of various evaluations and assessments on the impact of coating work on any plant systems that may be affected by that work. Assessing the impact on other systems should typically involve systems engineering or other personnel knowledgeable in the design and operation of the affected systems and components. The qualification recommendations and duties of a Nuclear Coating Specialist are defined in ASTM D7108, "Standard Guide for Establishing Qualifications for a Nuclear Coating Specialist".

The duties of a Nuclear Coating Specialist should be detailed in the facility safety-related coatings program and typically may include, but are not limited to, the following:

- Developing and managing the safety-related coating program
- Developing and maintaining coating inspection criteria
- Resolving and dispositioning issues that arise during the performance of coating work
- Performing and/or evaluating condition assessment data, generating written assessment reports, and initiating the appropriate corrective actions
- Approving personnel performing coating inspections (ensuring that coating inspection is performed in accordance with the facility's or organization's approved QA program)
- Supplying input for maintaining the design bases for safety-related coatings and linings, including preparation of coating system specifications and reviewing/approving test procedures, results, and reports
- Preparing and assisting in the update of specifications for safety-related coating and lining systems
- Reviewing and/or approving application procedures and, as necessary, preparing or assisting in their preparation and review
- Preparing or assisting in the preparation of design and other evaluations (such as 10 CFR 21, 10 CFR 50.59 associated with specific coating systems and resolution of coating-related issues)
- Assisting the licensing organization with coating-related safety analysis report updates

- Assisting with the evaluation of unqualified and/or non-conforming coatings, considering plant-specific, safety-related systems design bases
- Preparing or assisting in the preparation of training manuals and examinations required in conjunction with the facility's or organization's applicator certification program, presenting training sessions, and grading any exams
- Preparing and presenting training (to the extent required) in conjunction with the certification process for personnel performing safety-related coatings inspection. This may entail assisting the facility or organization QA/quality control (QC) and/or the training organizations
- Evaluating candidate applicators' proficiency
- Evaluating coating failures and non-conforming conditions in accordance with the facility's or organization's approved QA program

Table 10-1 provides a list of Nuclear Coating Specialist attributes that may be used to develop qualification criteria specific to each plant or utility. The qualification criteria ultimately adopted must be flexible in order to ensure that capable candidates are not unnecessarily excluded. However, the combination of attributes should be consistent with each utility's licensing commitments and meet the intent of ANSI N45.2.6 or ASME NQA-1 as applicable based on the plant's licensing commitments.

Table 10-1
Examples of typical coating engineer/specialist qualifications

Qualification Category	Qualification Criteria
Education	Four-year engineering/science degree Two-year associate degree High school graduate
Professional achievements	National Board of Registration (NBR) for Nuclear Safety-Related Coatings Engineers and Specialists Board of International Registration for Nuclear Coating Specialists (BIRNCS) SSPC Certified Protective Nuclear Coating Specialist NACE Certified Coatings Inspector NACE Certified Nuclear Coating Inspector Certified as having successfully completed a recognized program in coatings technology (for example, EPRI Comprehensive Coatings Course) Registered Professional Engineer American Society of Quality Control Qualified Engineer ANSI N45.2.6 Level III or ASME NQA-1Inspector
Nuclear coatings experience	As necessary to supplement education and professional achievements

Table 10-1 (continued)
Examples of typical coating engineer/specialist qualifications

Qualification Category	Qualification Criteria
Technology participation	Publication of technical papers regarding nuclear power industry coatings Participation in technical committees responsible for nuclear coating standards Preparing and presenting training aimed at qualifying personnel to apply or inspect safety-related coatings

The matrix shown in Table 10-2 provides a number of examples of combinations of qualification attributes for a Nuclear Coating Specialist. The table illustrates that in general, higher education level and/or more professional achievements can compensate for having less nuclear coatings experience. Conversely, more nuclear experience is necessary for individuals with less formal education and professional achievements. Other evidence of participation in Nuclear Coatings Technology may supplement any of the qualification criteria described in Table 10-2 for the Nuclear Coating Specialist. The examples illustrated in Table 10-2 should not be interpreted as representing all the possible combinations that may be considered. Each utility should ensure that the qualifications selected meet plant licensing commitments and are accurately described in appropriate plant procedures.

Table 10-2
Examples of combined Nuclear Coating Specialist qualifications

Education	Professional Achievements	Nuclear Coatings Experience
Accredited four-year engineering/science cegree	Coatings training (Note 1)	Three years of related equivalent (Note 4)
Accredited two-year associate degree	Coatings training (Note 1)	Five years of related equivalent (Note 4)
High school graduate	Coatings training (Note 1)	Seven years of related equivalent (Note 4)
SSPC/NACE or other industry recognized Coating Specialist certification (Note 2)		Three years of related equivalent (Note 4)
Board of International Registration for Nuclear Coating Specialists (BIRNCS) (Note 3)		

Notes:

1. SSPC, NACE, or other documented coating specialist training. The EPRI Comprehensive Coatings Training Course and the NACE Nuclear Power Plant Training for Coating Inspectors Course address the specific education requirements for nuclear coatings personnel.
2. Appropriate levels of formal education and training are integral to obtaining this type of certification and, as such, are not shown on this table.
3. Appropriate levels of formal education, training, and nuclear experience are integral to obtaining this type of certification and, as such, are not shown on this table.
4. Credit for "related equivalent" experience in coating work other than nuclear coatings shall be limited to one year total.

10.2 Coating Applicator's Qualifications

10.2.1 Proficiency Demonstration

The following are ASTM standards that provide guidance on nuclear safety-related coatings applicator qualifications:

- ASTM D4227, "Standard Practice for Qualification of Journeyman Painters for Application of Coatings to Concrete Surfaces of Safety-Related Areas in Nuclear Facilities"
- ASTM D4228, "Standard Practice for Qualification of Journeyman Painters for Application of Coatings to Steel Surfaces of Safety-Related Areas in Nuclear Facilities"

The standards require that the candidate applicator be experienced in coating application, that the applicator demonstrates proficiency in the application of coatings to a surface similar to one that will be coated in the plant, and that the test application is evaluated in accordance with the requirements of the governing documents (procedures, specifications, and manufacturer's product data sheets).

In addition, ANSI Standard N45.2, "Quality Assurance Requirements for Nuclear Power Plants," requires that the necessary qualifications of personnel involved in "special processes" be defined.

The standards referenced earlier in this section provide specific direction for coating applicator qualification. The following sections summarize those requirements and provide additional industry-accepted practice in areas that are not addressed by the standards. Specifically, direction is included for portions of the personnel qualification process that would need revision or addition to cover safety-related coating applications other than within containment.

The ASTM standards provide specific requirements for conducting a proficiency demonstration. The demonstration should be preceded by a joint review of the established objectives by the qualifying agent and the candidate applicator. For containment coatings, test surfaces comparable to those of ASTM D4227 (concrete) and D4228 (steel) should be used. Some utilities include formal training and performance-based assessment as an adjunct to the applicator qualification process, although this is not required by these standards.

For lining work, a representative test surface should be used. Evidence of proficiency might include a demonstration within a mockup configured to be truly representative of constricted workspaces, such as those existing within service water systems. Special techniques associated with epoxy-type tubesheet cladding applications (coating plug insertion and setting) may need to be demonstrated or proficiency in special curing techniques may be necessary.

The proficiency demonstration does not need to include surface preparation since the suitability of that process parameter (that is, cleanliness and profile) can be judged by QC at a hold point. However, personnel performing abrasive blasting need to be briefed on any precautions that need to be taken to avoid damaging equipment, scouring the pressure boundary plate, and so on.

Mixing of coating to ensure that a homogenous material is applied is an important part of the coatings process, and as such, a proficiency demonstration regarding mixing should be included in the candidate applicator's qualifications.

10.2.2 Evaluation and Documentation of Assessment

The ASTM applicator qualification standards provide specific guidance for evaluating safety-related coating applications. The ability of the applicator to apply films within prescribed DFT limits is a primary assessment parameter. Generally, criteria relating to the uniformity and appearance (for example, free of runs, holidays, and brush bristles) may also be defined.

The standards provide prescriptive requirements for documentation of the assessment and the certifications. Record retention should be in accordance with the applicable plant policies and QA procedures.

10.2.3 Certification/Recertification

The ASTM standards suggest appropriate documentation for recording certification and raise the possibility that qualifications might need to be updated after some period of time. Each utility should determine whether recertification is necessary and, if so, the required frequency for recertification. Some utilities consider the extent to which an individual has performed safety-related applications when making such determinations.

10.3 Qualifying Agent's Qualifications

The ASTM applicator qualification standards require that two qualifying agents be involved in the qualification. Some utilities have elected to use a single individual to qualify applicators. According to the ASTM standards, one of the qualifying agents may be production related. The ASTM standards do not provide any required credentials for the qualifying agents. However, if a single individual serves as the qualifying agent, he or she should be independent of any coatings production. The following are examples of some credentials used in the industry and should be considered when determining utility-specific qualification criteria:

- Nuclear coating specialist or designee
- Certified Level II or III Nuclear Coatings Inspector consistent with ANSI N45.2.6
- Individual experienced in preparation and demonstration of painter training programs
- Individual certified by the BIRNCS

Not all of the above qualifications are required. A qualifying agent should possess one or more of the credentials noted and should meet the utility's licensing basis and ANSI N45.2.6 and/or ASME NQA-1 as applicable.

10.4 Coating Inspector's Qualifications

10.4.1 General Qualification Guidance

The qualifications for coatings inspectors are typically found in the plant operational QA manual. In cases in which the qualifications are not already provided, the following standards provide requirements and/or guidance for establishing the qualifications of safety-related coatings inspectors:

- ANSI N45.2, "Quality Assurance Requirements for Nuclear Power Plants," endorsed by RG 1.28 and referenced in the Foreword of ANSI N101.4
- ANSI N45.2.6, "Qualification of Inspection, Examination and Testing Personnel for Nuclear Power Plants," referenced in the Foreword of ANSI N5.2
- ANSI N101.4, "Quality Assurance for Protective Coatings Applied to Nuclear Facilities"
- ASTM D4537, "Standard Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities"
- ASTM D5498, "Standard Guide for Developing a Training Program for Coating Work Inspectors in Nuclear Facilities"
- ASME NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications"

The ANSI standards provide general guidance for QA at nuclear facilities and the training and qualification of all inspection personnel at nuclear facilities.

Section 2.3.5 of ANSI N101.4 defines organizational criteria for inspection agencies. Section 6.2.4 invokes ANSI N5.9, which was superseded by N5.12. Section 10.3.2 of N5.12 includes the following requirement:

> As an additional qualification, before starting work each assigned inspector may be required to undergo a training course with the materials to be used for the coatings work.

Section 6.3 of ANSI N101.4, "Qualification of Coating Inspection Personnel," states:

> …These qualifications shall include his (the inspector's) prior training and inspection experience for work of comparable scope with generic coating systems similar to those used for the work in question.

This latter requirement is interpreted by some as suggesting that safety-related coating inspectors should have verifiable experience performing inspection of coating work.

ASME NQA-1 has been prepared to replace ANSI N45.2 and its daughter documents. Applicability of NQA-1 versus ANSI N45.2 will be dictated and detailed by each licensee's regulatory commitments.

Requirement 2, "Quality Assurance Program," of NQA-1 outlines the requirements and responsibilities for indoctrination and training and for determination of initial capabilities of inspection and test personnel.

10.4.2 Other ASTM Standards

The more recent ASTM standards that are shown in this section and referenced in the preceding list of applicable standards may also be considered for establishing appropriate qualifications for inspector personnel.

10.4.2.1 ASTM D4537, "Standard Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities"

This standard is a prescriptive standard with respect to requirements for coatings inspector qualifications. Unlike the standard for coating applicator qualification, this ASTM standard addresses all aspects of the inspector's qualification. The standard may be used as a basis for establishing qualification requirements for safety-related coatings inspectors.

The standard provides requirements for the inspector's physical capabilities (vision), education, training, and experience. With regard to prior experience, the standard is not definitive. Section 5.3 states that "A candidate's qualifications . . . shall be initially determined by a suitable evaluation of the candidate's . . . experience . . ." The following is an example of the types of documentary evidence of prior experience that might be considered appropriate:

- Prior certification as a safety-related coatings inspector
- Successful completion of NACE International's Coating Inspector Certification Program
- Testimony from a prior or present supervisor attesting to the fact that the candidate for certification has had experience inspecting or applying industrial coatings

Consistent with ANSI N45.2.6, ASTM D4537 identifies and defines the qualifications and capabilities for the three levels of coating inspectors. The standard also requires that a candidate inspector successfully complete an examination that covers the general, specific, and practical aspects of coating inspection. Finally, the standard specifies the certification periods and recertification requirements for the qualification.

10.4.2.2 ASTM D5498, "Standard Guide for Developing a Training Program for Coating Work Inspectors in Nuclear Facilities"

This standard presents a blueprint for developing an inspector training program. Section 2 of this standard is a definitive list of all the various ASTM standards that address coating inspection. Some 32 such standards are listed. The standard outlines the topics that need to be covered for Levels I, II, and III, respectively. Each successive level builds on the topics for the lower level. Appendix B of this report provides a suggested training syllabus for coatings inspectors.

10.5 Coatings Surveillance Personnel Qualifications

Individuals performing the condition assessment visual inspections are referred to in this report as Coatings Surveillance Personnel. These individuals should meet the applicable plant licensing commitments and be approved by the utility Nuclear Coating Specialist. Coatings Surveillance Personnel should have demonstrated knowledge of coatings, obtained through training or plant experience, and should be knowledgeable in applicable plant procedures. Appendix B of this report provides a syllabus for developing a training program that may be considered for this type of inspection personnel. The qualifications of Coatings Surveillance Personnel should be verified to be current and properly documented in accordance with plant-specific requirements regarding personnel qualification.

A
APPLICABLE REGULATORY DOCUMENTS, STANDARDS, AND GUIDELINES

A.1 Code of Federal Regulations

Documents referenced in this section are available from Code of Federal Regulations, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Title 10, Chapter 1, Energy, Part 50, Domestic Licensing of Production and Utilization Facilities.

50.34a: Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents - Nuclear Power Reactors (relates to filtration systems for normal area airborne radionuclide control [RG 1.140] and post-accident atmosphere cleanup [RG 1.52] in response to GDC 41-43; see also ANSI N195)

50.44: Standards for Combustible Gas Control Systems in Light-Water-Cooled Power Reactors (relates to hydrogen generation; galvanizing and zinc-rich paint are contributors)

50.46: Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors (relates to the need for conservatism in calculations associated with maximum containment pressure that can be credited for core reflood calculations. For some plants, these calculations could include the assigned values for coating thermal conductivity. This issue is addressed in 10 CFR 50, Appendix K via SRP 6.2.1.5.)

50.54a: Conditions of License (would govern changes in QA requirements related to coatings. Note that changes to the QA program requirements for coatings [for example, change from ANSI N101.4 to ASTM standards] may require NRC approval to comply with 50.54a requirements and should not be done via a 50.59 safety evaluation alone.)

50.59: Changes, Tests, and Experiments (could apply to changes to accommodate the maintenance and qualification bases of coatings where different from the current bases. Dictates the requirements for safety evaluations.)

50.65: Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants (the “maintenance rule.” The NRC has indicated that this regulation is interpreted to require monitoring of those coatings whose failure could prevent the performance of a safety function.)

Appendix A, General Design Criteria (GDCs)

- Note that not all plants are committed to the GDCs.
- Criterion 3, "Fire Protection" (paint films are limited with respect to flame spread, fuel and smoke contribution)
- Criterion 38, "Containment Heat Removal" (thermal conductivity of containment coatings impact heat sink calculations*)*
- Criterion 41, "Containment Atmosphere Clean-up" (relates to hydrogen generation; galvanizing and zinc-rich paint are contributors)
- Criterion 50, "Containment Design Basis" (thermal conductivity of coatings impact to heat sink calculations. Requires conservatism of calculation models in assessing containment design margins.)

Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," resulted in ANSI N45.2 and ANSI N101.4.

Appendix K, "ECCS Evaluation Modules"

Thermal conductivity of coatings impact heat sink calculations. Refer to Appendix K, (D) (2) "Containment Pressure . . . pressure used for evaluating cooling effectiveness during reflood and spray . . . shall (be) . . . calculated conservatively." Appendix K relates to SRP 6.2.1.5 and 10 CFR 50.46.

- 10 CFR 21, "Reporting of Defects and Noncompliances"
- 10 CFR 20.1, "Standards for Protection Against Radiation"
- 10 CFR Part 20.1—Labor

The following are Occupational Safety and Health Administration (OSHA) rules that could affect coating operations, including surface preparation intrusive to coating films containing asbestos, lead, and other hazardous constituents often found in containment coatings. Whether the OSHA rules are requirements for nuclear power plants or are superseded by NRC regulations should be addressed on a plant-specific basis.

29 CFR 1910.146, "Permit Required Space"

29 CFR 1910.1000, "Air Contaminants"

29 CFR 1910.1000, "Subpart Z, Identification and Limits of Hazardous Substances, Solvents, and Vapors"

29 CFR 1926, "Safety and Health Regulations for Construction" (Construction Industry Standards)

29 CFR 1926.21, "Safety Training and Education"

29 CFR 1926.24, "Fire Protection and Prevention"

29 CFR 1926.55, "Gases, Vapors, Fumes, Dusts and Mists"

29 CFR 1926.56, "Illumination"

29 CFR 1926.57, "Ventilation"

29 CFR 1926.59, "Hazard Communication"

29 CFR 1926.62, "Lead"

29 CFR 1926.63, "Cadmium"

29 CFR 1926.100, "Head Protection"

29 CFR 1926.101, "Hearing Protection"

29 CFR 1926.102, "Eye and Face Protection"

29 CFR 1926.103, "Respiratory Protection"

29 CFR 1926.200, "Accident Prevention Signs and Tags"

29 CFR 1926.252, "Disposal of Waste Materials"

29 CFR 1926.301, "Hand Tools"

29 CFR 1926.302, "Power-Operated Hand Tools"

29 CFR 1926.303, "Abrasive Wheels and Tools"

29 CFR 1926.306, "Air Receivers"

29 CFR 1926.451, "Scaffolding"

A.1.1 Title 40 CFR—Protection of Environment Documents

40 CFR 265.177, "Special Requirements for Incompatible Wastes" (See section B.9.1. for EPA Test Method 24 from 40CFR, Chapter I, Part 50, Appendix A.)

A.2 Nuclear Regulatory Commission Regulatory Guides

Documents referenced in this section are available from NRC/GPO Sales Program. Note that the existence of a RG does not mean that a licensee has made a commitment to comply with it. Only those RGs to which a licensee has committed to are required.

A.2.1 Regulatory Guides

RG 1.120, “Fire Protection Guidelines for Nuclear Power Plants” (Section C4 (a)(4)(a) limits surface flame spread to 50 per ASTM E84. Other, more restrictive criteria, may govern. These could include NEL-PIA or MAERP specifications or NRC Branch Technical Position ASB 9.5-1 (see SRP) or NUREG-0050.)

RG 1.137, “Fuel-Oil Systems for Standby Diesel Generators” (invokes ANSI N195, Section 7.5 of which requires that “Protection against internal and external corrosion shall be provided.” Provision for cathodic protection is also addressed. Section 7.3 of ANSI N195 addresses ISI per ASME Section XI. RG 1.137 C(2)(f) mentions a 10-year tank inspection interval and C(2)(h) indicates annual and bimonthly cathodic protection system testing to assess overall system and rectifier operability, respectively.)

RG 1.140, “Design, Testing and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants.” (The solvent in paint can degrade filter performance.)

RG 1.140 references ANSI N509 and N510. Section C (5)(d) of RG 1.140 calls for leak testing (per ANSI N510) of absorbers “ . . . (4) following painting . . .”

RG 1.33, “Quality Assurance Program Requirements (Operational)”

RG 1.38, “Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage and Handling of Items for Water-Cooled Nuclear Power Plants” (necessitates 10 CFR 50, Appendix B programmatic control for safety-related coatings)

RG 1.54 Revision 0, June 1973, “Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants” (recognizes ANSI N101.4)

RG 1.54 Revision 1, July 2000, “Service Level I, II and III Protective Coatings Applied to Nuclear Power Plants” (recognizes ASTM D5144 et. al. with comments)

RG 1.58, “Qualification of Nuclear Power Plant Inspection, Examination and Testing Personnel” (governs qualification of inspectors for safety-related coatings. ANSI N45.2.6, Section 6.3, as well as ASTM D3276, D3843, D4537 and D5498, offer criteria that address RG 1.58.)

RG 1.7, “Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident” (relates to hydrogen generation; galvanizing and zinc-rich paint are contributors. References GDC 41 and 10 CFR 50.44. Part B of RG 1.7 lists “Item 3. Corrosion of Metals by Solutions for Emergency Cooling or Containment Spray.”)

RG 1.8, “Personnel Selection and Training”

RG 1.82, “Sumps for Emergency Core Cooling and Containment Spray Systems” (paint debris post-accident transport/settling analyses and strainer/sump paint debris loads and debris characteristics affect the NSPH available to the ECCS pumps)

RG 8.8, “Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable” (encourages use of coatings to seal substrates against radionuclide sorption and to facilitate decontamination

A.2.2 NRC NUREGs

NUREGs cover a wide range of issues and are often technical reports summarizing the results of NRC research. NUREGs typically are not regulatory requirements unless invoked through other ways, such as regulations or RGs, or by licensees voluntarily making commitments to them, such as in response to a Generic Letter.

NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants”

> 6.1.2, “Protective Coatings Systems (Paints)—Organic Materials” (Part IV, “Evaluating Findings,” indicates that positive findings will result if the plant QA program meets 10 CFR 50 App. B via RG 1.54 and have established DBA resistance via ANSI N101.2-the findings basis seems garbled in the way N101.2 is referenced as a QA standard)
>
> 6.2.1, “Containment Functional Design” (thermal conductivity of coating impact heat sink calculations. This standard review plan section relates to such calculations and to the temperature/pressure profiles for the spectra of LOCA and MSLB used to qualify equipment and [presumably] containment coatings.)
>
> 6.2.1.1.A, “PWR Dry Containments, Including Subatmospheric Containments” (Section I, Items (2) through (4) expressly relate to passive heat sink calculations that are influenced by coating thickness and thermal conductivity)
>
> 6.2.1.1.C, “BWR Pressure-Suppression Type Containments (Mark I, II, and III)” (similar association as for 6.2.1.1.A above)
>
> 6.2.1.5, “Minimum Containment Pressure Analysis for ECCS Performance Capability Study” (Part I) indicates, “The core flooding rate is governed by the capability of the ECCS water to displace the steam generated in the reactor vessel during the core reflooding period. For PWR plants, there is a direct dependence of core flooding rate on containment pressure.” Part III notes, “The CSB [Containment Systems Branch]

evaluates the conservativeness of the assumptions used by the applicant regarding the . . . effectiveness of structural heat sinks." The computer modeling that drives these calculations generally consider the influence of paint thickness and thermal conductivity. See, in particular, Section B (3), "Passive Heat Sinks," of the BTP CSB6-1 "Minimum Containment Pressure Model for PWR ECCS Performance Evaluation." 10 CFR 50.46 and App. K relate to this SRP section.

6.2.5, "Combustible Gas Control in Containment" (relates to hydrogen generation. 10 CFR 50.44, GDC 41 and RG 1.7, among others, are referenced. Appendix A to SRP 6.2.5 expressly notes that, post-LOCA, there occurs "4. Zinc corrosion by water solutions, producing hydrogen.")

NUREG-1801, "Generic Aging Lessons Learned (GALL)", April 2001.

A.2.3 NRC Inspection Manual

NRC Inspection Manual: Part 9900-Technical Guidance, "Maintenance-Filled Organic Coatings Used in Maintenance of Safety-Related Equipment"

A.2.4 NRC Bulletins

Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers"

Bulletin 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in the Suppression Pool Cooling Mode"

Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors"

Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks"

A.2.5 NRC Generic Letters

GL 85-22, "Potential for Loss of Post Loss of Coolant Accident Recirculation Capability Due to Insulation Debris Blockage"

GL 89-02, "Actions to Improve the Detection of Counterfeit and Fraudulently Marketed Products"

GL 89-13, "Service Water System Problems Affecting Safety-Related Equipment"

GL 91-05, "Licensee Commercial Grade Procurement and Dedication Programs"

GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident because of Construction and Protective Coating Deficiencies and Foreign Material in Containment"

GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

A.2.6 NRC Information Notices and Circulars

IE Circular 77-15, "Degradation of Fuel Oil Flow to the Emergency Diesel Generator"

IN 85-08, "Industry Experience on Certain Materials Used in Safety-Related Equipment"

IN 88-28, "Potential for Loss of Post Loss of Coolant Accident Recirculation Capability Due to Insulation Debris Blockage"

IN 89-77, "Debris in Containment Emergency Sumps and Incorrect Screen Configurations"

IN 92-71, "Partial Blockage of Suppression Pool Strainers at a Foreign BWR"

IN 92-85, "Potential Failures of Emergency Core Cooling Systems by Foreign Material Blockage"

IN 93-34, "Potential for Loss of Emergency Core Cooling Function Due to a Combination of Operational and Post Loss of Coolant Accident Debris in Containment"

IN 93-34, "Supplement 1, Potential for Loss of Emergency Cooling Function Due to a Combination of Operation and Post Loss of Coolant Accident Debris in Containment"

IN 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers"

IN 94-57, "Debris in Containment and the Residual Heat Removal System"

IN 95-06, "Potential Blockage of Safety Related Strainers by Material Brought Inside Containment"

IN 95-47, "Unexpected Opening of a Safety/Relief Valve and Complications Involving Suppression Pool Cooling Strainer Blockage"

IN 96-10, "Potential Blockage by Debris of Safety System Piping Which is Not Used During Normal Operation or Tested During Surveillance"

IN 96-27, "Potential Clogging of High Pressure Safety Injection Throttle Valves During Recirculation"

IN 96-55, "Inadequate Net Positive Suction Head of Emergency Core Cooling and Containment Heat Removal Pumps Under Design Basis Accident Conditions"

IN 96-59, "Potential Degradation of Post Loss of Coolant Accident Recirculation Capability as a Result of Debris"

IN 97-13, "Deficient Conditions Associated with Protective Coatings at Nuclear Power Plants"

A.3 American National Standards Institute (ANSI)

American National Standards may be obtained from ANSI.

Note: Where so indicated, certain American National Standards (ANSs) may be obtained from the American Society of Quality Engineers (ASQE), ASME, the National Electrical Manufacturers Association (NEMA), the API, or American Nuclear Society (ANS).

ANSI N18.1-1971, "Selection and Training of Nuclear Power Plant Personnel"

ANSI N18.7/ANS 3.2-1976, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants"

ANSI N5.9-1967, "Protective Coatings (Paints) for the Nuclear Industry"

ANSI N5.12-1974, "Protective Coatings (Paints) for the Nuclear Industry"

ANSI N45.2-1977, "Quality Assurance Program Requirements for Nuclear Power Plants"

ANSI N45.2.2-1972, "Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants"

ANSI N45.2.6, "Qualifications of Inspection, Examination and Testing Personnel for Nuclear Power Plants"

ANSI N45.2.10-1973, "Quality Assurance Terms and Definitions"

ANSI N45.2.13-1976, "Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants"

ANSI N101.2-1972, "Protective Coatings (Paint) for Light Water Nuclear Reactor Containment Facilities"

ANSI N101.4-1972, "Quality Assurance for Protective Coatings Applied to Nuclear Facilities"

ANSI N195-1976 (ANS-59.51), "Fuel Oil Systems for Standby Diesel Generators"

ANSI N510-1975, "Testing of Nuclear Air Cleaning Systems"

ANSI/ANS-3.1, "Selection, Qualification and Training of Personnel for Nuclear Power Plants"

ANSI/ASME N509-1976, "Nuclear Power Plant Air Cleaning Units and Components"

ANSI/ASQE Standard Q92, "Quality Systems—Model for Quality Assurances in Production and Installation"

ANSI Z535.1-1991, "Safety Color Code"

ANSI Z535.5-1991, "Scheme for the Identification of Piping Systems"

ANSI/API RP 12R1, "Setting, Maintenance, Inspection, Operation and Repair of Tanks in Production Service"

A.4 American Petroleum Institute

API RP 1631, "Interior Lining of Underground Storage Tanks"

A.5 American Society of Mechanical Engineers

NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications"

A.6 American Society for Testing and Materials

Documents referenced in this subsection are available from ASTM.

ASTM A380-88, "Recommended Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems"

ASTM C868, "Standard Test Method for Chemical Resistance of Protective Linings" (see also NACE TM-0174)

ASTM D115, "Standard Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation"

ASTM D-16-93a, "Terminology Relating to Paint, Varnish, Lacquer and Related Products"

ASTM D610, "Method for Evaluating Degree of Rusting on Painted Steel Surfaces"

ASTM D648, "Test Method for Deflection Temperature of Plastics Under Flexural Load"

ASTM D658, "Test Method for Abrasion Resistance of Organic Coatings By Air Blast Abrasive"

ASTM D714, “Method for Evaluating Degree of Blistering of Paints”

ASTM D823, “Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels”

ASTM D1005-84, “Test Method for Measurement of Dry Film Thickness of Organic Coating Using Micrometers 1990”

ASTM D1186, “Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base”

ASTM D1640-83, “Test Method for Drying, Curing or Film Formation of Organic Coatings at Room Temperature”

ASTM D2092-86, “Practice for Preparation of Zinc Coated (Galvanized) Steel Surfaces for Painting”

ASTM D2197-86, “Adhesion of Organic Coatings by Scrape Adhesion”

ASTM D2200, “Pictorial Surface Preparation Standards for Painting Steel Surfaces”

ASTM D2794, “Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)”

ASTM D3276, “Guide for Painting Inspectors (Metal Substrates)”

ASTM D3335, “Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy”

ASTM D3359-9, “Method for Measuring Adhesion by Tape”

ASTM D3363-92a, “Test Method for Film Hardness by Pencil Test”

ASTM D3486, “Standard Practice for Installation of Vulcanizable Rubber Tank Linings and Pipe Linings” (discontinued 1994)

ASTM D3806, “Test Method for Small-Scale Evaluation of Fire Retardant Paints (2-ft Tunnel Method)”

ASTM D3842, “Guide of Selection of Test Methods for Coatings for Use in Light-Water Nuclear Power Plants” (discontinued 1995; replaced by D5144)

ASTM D3843, “Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities”

ASTM D3911, “Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions”

ASTM D3912, “Test Method for Chemical Resistance of Coatings Used in Light-Water Nuclear Power Plants”

ASTM D4060, “Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser”

ASTM D4082, “Test Method for Effects of Radiation on Coatings Used in Light-Water Nuclear Power Plants”

ASTM D4121, “Practice for Photographic Documentation of Coating and Lining Failures and Defects” (discontinued 1992)

ASTM D4138, “Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means”

ASTM D4227, “Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces”

ASTM D4228, “Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces”

ASTM D4258, “Practice for Surface Cleaning Concrete for Coating”

ASTM D4259, “Practice for Abrading Concrete”

ASTM D4260, “Practice for Acid Etching Concrete”

ASTM D4261, “Practice for Surface Cleaning Concrete Unit Masonry for Coating”

ASTM D4262, “Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces”

ASTM D4263, “Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method”

ASTM D4276-84, “Standard Practice for Confined Area Entry”

ASTM D4285, “Test Method for Indicating Oil or Water in Compressed Air”

ASTM D4286, “Practice for Determining Coating Contractor Qualifications for Nuclear Powered Electric Generation Facilities”

ASTM D4414, “Practice for Measurement of Wet Film Thickness of Organic Coatings by Notched Gages”

ASTM D4417, “Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel”

ASTM D4537, “Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities”

ASTM D4538, “Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities”

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

ASTM D4597-92, “Practices for Sampling Workplace Atmospheres to Collect Organic Gases or Vapors with Activated Charcoal Diffusional Samplers”

ASTM D4598-87, “Practice for Sampling Workplace Atmosphere to Collect Organic Gases with Liquid Sorbent Diffusional Samplers”

ASTM D4590-90, “Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length of Stain Dosimeter”

ASTM D4610-94, “Guide for Determining the Presence of and Removing Microbial (Fungal and Algel) Growth on Paint and Related Coatings”

ASTM D4752, “Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub”

ASTM D4787, “Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates”

ASTM D4938, “Test Method for Erosion Testing of Antifouling Paints Using High Velocity Water”

ASTM D4939, “Test Method for Subjecting Marine Antifouling Coating to Biofouling and Fluid Shear Forces in Natural Seawater”

ASTM D4940, “Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives”

ASTM D5064, “Practice for Conducting a Patch Test to Assess Coating Compatibility”

ASTM D5139, “Standard Specification for Sample Preparation for Qualification Testing of Coatings to be Used in Nuclear Power Plants”

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

ASTM D5161, "Standard Guide for Specifying Inspection Requirements for Coating and Lining Work (Metal Substrates)"

ASTM D5162, "Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates"

ASTM D5163, "Standard Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coatings in an Operating Nuclear Power Plant"

ASTM D5402, "Standard Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs"

ASTM D5498, "Standard Guide for Developing a Training Program for Coating Work Inspectors in Nuclear Facilities"

ASTM D5702, "Standard Practice for Field Sampling of Coating Films for Analysis for Heavy Metals"

ASTM D5962, "Standard Guide for Maintaining Unqualified Coatings (Paints) Within Level I Areas of a Nuclear Power Facility" (withdrawn 2008)

ASTM D6677, "Standard Test Method for Evaluating Adhesion by Knife"

ASTM D7091, "Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals"

ASTM D7108, "Standard Guide for Establishing Qualifications for a Nuclear Coating Specialist"

ASTM D7167, "Standard Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coatings Service Level III Lining Systems in an Operation Nuclear Power Plant"

ASTM D7230-06, "Standard Guide for Evaluating Polymeric Lining Systems for Water Immersion in Coating Service Level III Safety Related Applications on Metal Substrates"

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

ASTM D7491, "Standard Guide for Management of Non-Conforming Coatings in Costing Service Level I Areas of Nuclear Power Plants"

ASTM E84, "Test Method for Surface Burning Characteristics of Building Materials"

ASTM D1653, "Standard Test Method for Water Vapor Transmission of Organic Coating Films"

ASTM E337, "Test Method for Measuring Humidity with a Psychrometer (The Measurement of Wet-Bulb and Dry-Bulb Temperatures)"

ASTM G14, "Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)"

ASTM G42, "Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures"

ASTM G62, "Test Methods for Holiday Detection in Pipeline Coatings"

A.6.1 Other ASTM Publications

PCN:03-433091-14, "Protective Coating Standards for Use in Nuclear Power Plants," 1994

PCN:03-433094-14, "ASTM Protective Coating Inspection Standards for Field and Shop Application," 1994

PCN:20-008090-14, "Manual on Maintenance Coatings for Nuclear Power Plants" (ASTM Manual Series MNL 8)

PCN:28-008090-14, "ASTM Manual on Maintenance Coatings for Nuclear Power Plants"

A.7 NACE International

Documents referenced in this section are available from NACE International.

RP0274-2004, "High Voltage Electrical Inspection of Pipeline Coatings Prior to Installation"

SP0178-2007, "Standard Recommended Practice—Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service" (Note: The "visual comparator" referenced in the foreword and Appendix C of NACE RP-0178-91 is no longer available from NACE. It may be obtained from other sources; supply may be limited since there are no plans for further manufacture of this comparator.)

SP0188-2006, "Standard Recommended Practice for Discontinuity (Holiday) Testing of Protective Coatings"

RP0288-2004, "Inspection of Linings on Steel and Concrete"

NACE SP0892, "Linings over Concrete for Immersion Service"

TM0174-2002, "Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials in Immersion Service"

TM0186-2002, “Holiday Detection of Internal Tubular Coatings of 10–130 Mils Dry Film Thickness”

TM0382-2002, “Holiday Detection of Internal Tubular Coatings of Less Than 10 Mils Dry Film Thickness”

A.8 The Society for Protective Coatings

Documents referred to in this section are available from SSPC.

Unless otherwise noted by a preceding asterisk (*), the following standards may be found in the *Steel Structures Painting Manual, Volume 2*, “Systems and Specifications,” Seventh Edition.

SSPC-AB 1, “Mineral and Slag Abrasives”

*SSPC Guide 6, “Guide for Containing Debris Generated During Paint Removal Operations”

*SSPC Guide 7, “Guide for the Disposal of Lead-Contaminated Surface Preparation Debris”

SSPC-PA1, “Shop, Field & Maintenance Painting”

SSPC-PA2, “Measurement of Dry Paint Thickness with Magnetic Gages”

SSPC-PA Guide 3, “A Guide to Safety in Paint Application”

SSPC-PA Guide 5, “Guide for Maintenance Painting Programs”

SSPC-PA Guide 10, “Guide to Safety and Health Requirements for Industrial Painting Projects”

SSPC-QP1, “Standard Procedure for Evaluating the Qualifications of Painting Contractors”

SSPC-QP2, “Standard Procedure for Evaluating the Qualifications of Painting Contractors to Remove Hazardous Paint”

SSPC-QP3, “Standard Procedure for Evaluating Qualifications of Shop Painting Contractors”

SSPC-SP1, “Solvent Cleaning”

SSPC-SP5, “White Metal Blast Cleaning”

SSPC-SP6, “Commercial Blast Cleaning”

SSPC-SP10, “Near-White Blast Cleaning”

SSPC-SP11, “Power Tool Cleaning to Bare Metal”

SSPC-SP12, "Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultra-High-Pressure Water Jetting Prior to Recoating"

SSPC SP-COM, "Surface Preparation Commentary"

SSPC-SP-TR1, "Informational Report and Technology Update: Thermal Precleaning"

SSPC-Guide to VIS1, "Visual Standard for Abrasive Blast Cleaned Steel"

SSPC-Guide to VIS3, "Visual Standard for Power and Hand-Tool Cleaned Steel" (The actual visual standards used in conjunction with SSPC-Guide to VIS1 and SSPC-Guide to VIS3 must be procured separately.)

SSPC-Guide 12, "Guide for Illumination of Industrial Painting Projects"

SSPC-VIS4I, "Interim Visual Reference Photographs for High- and Ultra-High-Pressure Water Jet Cleaning"

A.9 Other U.S. Government Documents

A.9.1 Environmental Protection Agency (EPA)

SW-846, "Test Methods for Evaluating Solid Wastes, Volume 1A; Laboratory Manual-Physical/Chemical Methods"

Method 0415.1, Organic Carbon Total-Combustion as found in "Methods for Chemical Analysis of Water and Waste" (600/4-79-020).

Method 6010, Inductively Coupled Plasma Atomic Emission

Method 7000, Atomic Absorption

Test Method 24, Determination of Volatile Matter Content, Water Content, Density, Volume Solids and Weight Solids of Surface Coatings (40CFR, Chapter I, Part 50, Appendix A)

A.9.2 Department of Defense/Military Specifications

MIL-C-4556D, Coating Kit, Epoxy for Interior of Steel Fuel Tanks

A.9.3 National Oceanic and Atmosphere Administration (NOAA)

Psychometric Tables for Obtaining the Vapor Pressure, Relative Humidity, and Temperature of the Dew Point

A.10 EPRI Reports

PWR Primary Water Chemistry Guidelines: Vol. 1: Revision 4; Vol. 2: Revision 4; Volume 2. EPRI, Palo Alto, CA: 1999. AP-105714-R4.

Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07). EPRI, Palo Alto, CA: 1988. NP-5652.

Guidelines for the Technical Evaluation of Replacement Items in Nuclear Power Plants (Revision 1). EPRI, Palo Alto, CA: 2006. 1008256.

Modifications of Alloy Surfaces Using Pulsed Energy—Phase 2. EPRI, Palo Alto, CA: 1993. TR-102232.

Supplemental Guidance for the Application of EPRI Report NP-5652 on the Utilization of Commercial Grade Items. EPRI, Palo Alto, CA: 1994. TR-102260.

Chemistry Monitoring and Control for Fuel Reliability. EPRI, Palo Alto, CA: 2004. 1009731.

Coatings Handbook for Nuclear Power Plants. EPRI, Palo Alto, CA: 1996. TR-106160.

Packaging, Shipping, Storage, and Handling Guidelines for Nuclear Power Plants. EPRI, Palo Alto, CA: 1997. TR-107101.

B
TRAINING SYLLABUS FOR COATINGS INSPECTORS

B.1 Outline for Training Syllabus (Level I Coatings Inspectors)

The following outline for a training syllabus, patterned after the guidance offered by ASTM D4537 and D5498, is offered for consideration when developing training for nuclear coatings inspectors (Level I):

1. Inspections Plans/Procedures
2. Basic Corrosion Theory
3. Coating Technology
4. Health Physics
5. Quality Assurance
6. Engineering Specifications
7. Coating Work Procedures
8. Nuclear Documents
9. Pre-Job and Job Conferences
10. Materials Receiving, Storage, and Handling
11. Safety
12. Pre-Surface Preparation Inspection
13. Surface Preparation Methods/Equipment
14. Surface Preparation Inspection
15. Calibration and Proper Use of Inspection Instruments
16. Mixing Methods/Equipment
17. Application Methods/Equipment
18. Application Inspection
19. Coating Defects
20. Remedial Action
21. Documentation

B.2 Outline for Training Syllabus (Levels II and III Coatings Inspectors)

The following topics may be considered when developing training for coatings inspectors (Levels II and III):

1. Abbreviations/Acronyms
2. Safety-Related Coatings
3. Design Control for Containment Coatings
4. Process for Qualifying Safety-Related Coatings
5. Technology of Coating Materials
6. Coatings for Nuclear Power Facilities
7. Surface Preparation for Carbon Steel, Alloy, and Concrete
8. Monitoring and Maintaining Environmental Control Systems and Equipment
9. Application
10. Curing Systems and Evaluation of Completeness of Cure
11. Ambient Condition Determinations
12. Determining DFT on Metal and Concrete Substrates
13. Methods for Determining Continuity of Non-Conductive Coatings on Metal and Concrete Substrates
14. Methods for Detecting Soluble Surface Contaminants and Corrective Actions

B.3 Additional Inspector Training Courses

NACE Nuclear Power Plant Training for Coating Inspectors

This course prepares qualified coating inspectors to conduct inspections in nuclear power plants (NPPs). The training focuses on the unique challenges presented by the restrictive and safety-critical environment, plus the verbatim compliance demanded in NPPs, as well as plant and industry regulations, technical specifications, and procedures.

There are no prerequisites to attend the training course; however, NACE Coating Inspector Program (CIP) Level 1 certification is recommended. Those who successfully complete the course examination but do not qualify for certification receive a certificate of attendance and a grade letter.

To achieve certification, NACE CIP Level 1 Certification is required, along with documented work experience with coatings focused projects for a nuclear power plant.

C
KEY POINTS SUMMARY

The following list provides the location of Key Point information in this report.

Section	Page	Key Point
1.2	1-2	As a result of commitments made in responses to GL 98-04, all nuclear utilities now have formal nuclear safety-related coatings programs. These programs provide reasonable assurance that safety-related coatings in each plant's reactor containment are procured, applied, and maintained in compliance with applicable regulatory requirements and the plant-specific licensing basis for the facility.
1.3	1-3	Although many standards are referenced throughout this report, those particular standards selected for implementation should be consistent with each plant's licensing basis.
2.1	2-1	The term *application*, when used in the context of 10 CFR 50, Appendix B, refers to the end use or service for the particular coating. The term is not used to refer to the physical act of applying coatings to a particular surface.
2.1	2-2	The terminology for the levels of safety-related coatings may differ from site to site. For instance, Coating Service Level III coatings at some plants are not considered to be safety-related due to the site-specific licensing-basis definition. In preparing or revising a plant's safety-related coatings program, the licensing basis definitions of the various levels must be clearly identified and either used or properly changed.
2.2.3	2-6	The difference between an *acceptable* coating or lining system and a *DBA-qualified* coating system must be understood. All safety-related coating or lining systems must be acceptable, but only where required by the plant licensing basis must a DBA-qualified coating system be used inside of primary containment. Where use of a DBA-qualified coating system is required by the plant licensing basis, it is *acceptable*.
4.1.2.4	4-6	This master report is used by the individual nuclear power plant licensee as justification for the use of the coating material/system in its facility in safety-related applications.
6.1.1	6-2	If a coating work project involves removal of radiologically contaminated hazardous material (such as lead and asbestos) materials, all work must be performed by personnel trained as required by local, state, and federal regulations using detailed special process procedures and specialized equipment.

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