



# REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

## REGULATORY GUIDE 1.54

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### SERVICE LEVEL I, II, AND III PROTECTIVE COATINGS APPLIED TO NUCLEAR POWER PLANTS

#### A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for the selection, application, qualification, inspection, and maintenance of protective coatings applied to Nuclear Power Plants.

Title 10, of the *Code of Federal Regulations*, Part 50, “Domestic Licensing of Production and Utilization Facilities” (10 CFR Part 50) (Ref. 1), Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion (GDC) 1, “Quality Standards and Records,” requires, in part, that structures, systems, and components (SSCs) important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. GDC 1 also requires licensees to establish and implement a quality assurance (QA) program to provide adequate assurance that these SSCs will satisfactorily perform their safety functions.

GDC 4, “Environmental and Dynamic Effects Design Bases,” requires, in part, that SSCs important to safety be designed for compatibility with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.

Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50 establishes overall QA program requirements for the design, fabrication,

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The NRC issues regulatory guides to describe and make available to the public methods that the NRC staff considers acceptable for use in implementing specific parts of the agency’s regulations, techniques that the staff uses in evaluating specific problems or postulated accidents, and data that the staff needs in reviewing applications for permits and licenses. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

This guide was issued after consideration of comments received from the public.

Regulatory guides are issued in 10 broad divisions—1, Power Reactors; 2, Research and Test Reactors; 3, Fuels and Materials Facilities; 4, Environmental and Siting; 5, Materials and Plant Protection; 6, Products; 7, Transportation; 8, Occupational Health; 9, Antitrust and Financial Review; and 10, General.

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construction, and 10 CFR Part 50 establishes overall QA program requirements for the design, fabrication, construction, and testing of safety-related SSCs in nuclear power plants (NPPs). The U.S. Nuclear Regulatory Commission (NRC) maintenance rule, 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," includes in its scope safety-related SSCs that are relied on to remain functional during and following design-basis events with respect to specified functions and nonsafety-related SSCs (1) that are relied on to mitigate accidents or transients or are used in plant emergency operating procedures, (2) whose failure could prevent safety-related SSCs from fulfilling their safety-related functions, and (3) whose failure could cause a reactor scram or an actuation of a safety-related system. To the extent that protective coatings meet these criteria, these coatings are within the scope of the maintenance rule. The maintenance rule requires the licensee to monitor the effectiveness of maintenance for protective coatings within its scope (as discrete systems or components or as part of any SSC) or to demonstrate that their performance or condition of these coatings is being effectively controlled through the performance of appropriate preventive maintenance, in accordance with 10 CFR 50.65(a)(1) or 10 CFR 50.65(a)(2), as appropriate. Regulatory Guide (RG) 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 2, issued March 1997 (Ref. 2), provides further guidance.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

## **B. DISCUSSION**

NPPs have used protective coatings extensively to protect the surfaces of facilities and equipment against corrosion and contamination from radionuclides and for wear protection during plant operation and maintenance activities. For plants that have a design basis that includes a commitment to RG 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants," Revision 0, issued June 1973 (Ref. 3), the regulations cited above require that protective coatings be qualified and capable of surviving a design-basis accident (DBA) without adversely affecting the safety-related SSCs needed to mitigate the accident.

The NRC issued RG 1.54 to describe an acceptable method for complying with NRC QA requirements for protective coatings applied to ferritic steels, stainless steel, zinc-coated (galvanized) steel, concrete, or masonry surfaces of water-cooled NPPs. Protective coatings that met these guidelines would presumably not degrade over the design life of the plant. However, operating history has shown that undesirable degradation, detachment, and other types of failures of coatings have occurred, as described in 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," dated July 14, 1998 (Ref. 4). Detached coatings from a substrate that are subsequently transported to the intake structures of emergency core cooling systems (ECCSs) may make those systems unable to satisfy the requirement in 10 CFR 50.46(b)(5) to provide long-term cooling.

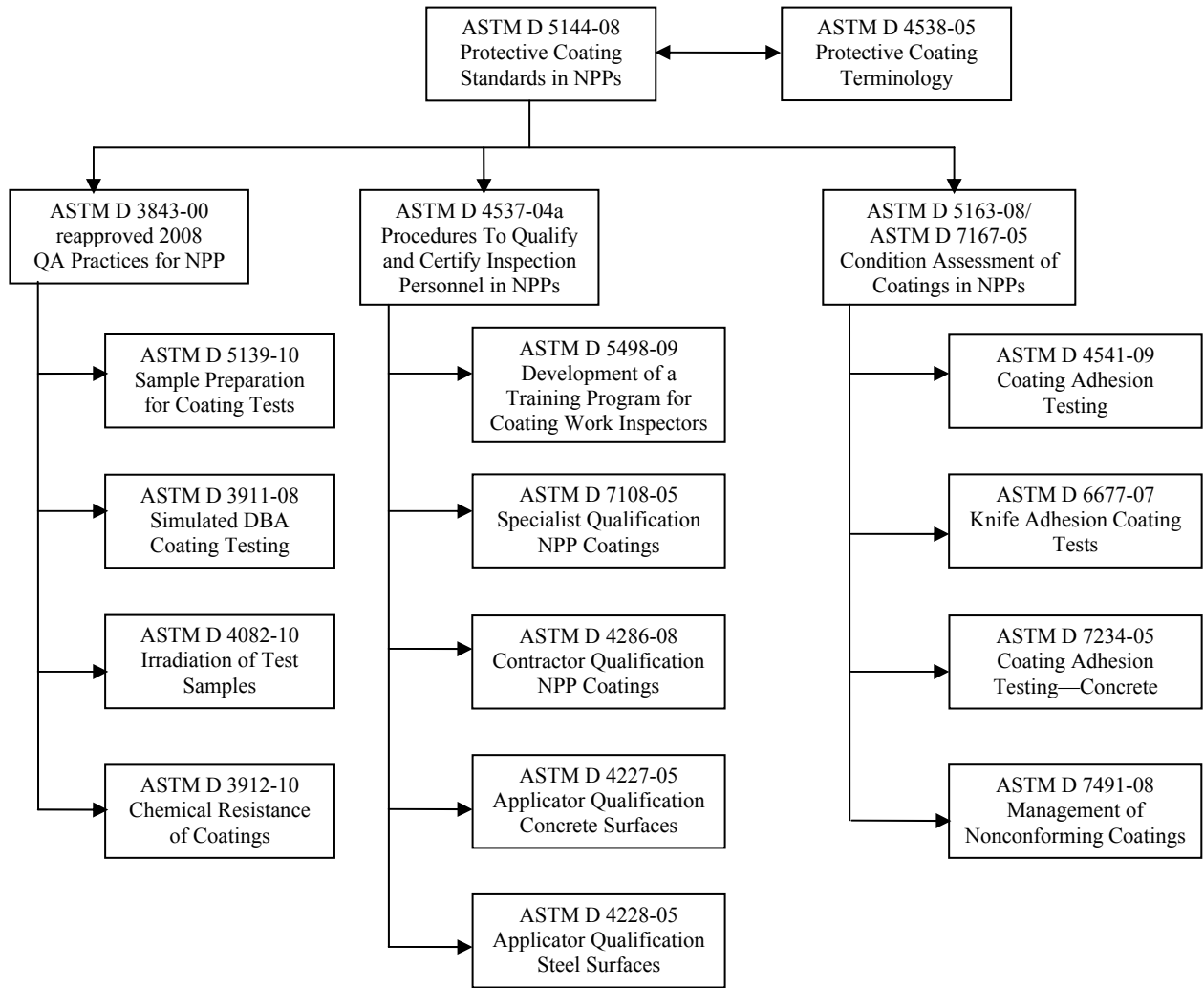
Revision 0 to RG 1.54 conditionally endorses American National Standards Institute (ANSI) N101.4-1972, "Quality Assurance for Protective Coatings Applied to Nuclear Facilities" (Ref. 5), and indirectly endorses guidance provided in ANSI N101.2-1972, "Protective Coatings (Paints) for Light-Water Nuclear Reactor Containment Facilities" (Ref. 6). ANSI formally withdrew ANSI N101.4-1972 and ANSI N101.2-1972 in 1988 and transferred the responsibility for updating, rewriting, and issuing appropriate replacement standards to the American Society for Testing and Materials (ASTM),

specifically ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities.

ASTM has developed appropriate standards to replace ANSI N101.4-1972 and ANSI N101.2-1972. The NRC issued RG 1.54, “Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants,” Revision 1, in July 2000 (Ref. 7), to provide the agency’s endorsement and regulatory positions on ASTM standards relevant to NPP protective coatings. Since the issuance of Revision 1 to RG 1.54, ASTM has updated many of the standards that RG 1.54 endorses to reflect the current industry practice. The NRC is revising RG 1.54 to provide the agency’s regulatory positions on the updated ASTM standards relevant to NPP protective coatings. The NRC has reviewed the ASTM standards cited in Section C of this guide for the selection, qualification, application, and maintenance of protective coatings applied to NPPs and considers them acceptable with the exceptions noted below.

ASTM approved and issued ASTM D 3843-00, “Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities,” (Ref. 8) as a partial replacement for ANSI N101.4-1972. ASTM D 3843-00 was reapproved in 2008 with no changes as ASTM D 3843-00 (reapproved 2008) (Ref. 9). ASTM has approved and issued ASTM D 3911-95, “Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design-Basis Accident (DBA) Conditions,” (Ref. 10) to replace the DBA test standard referenced in ANSI N101.4-1972 and RG 1.54. ASTM then revised ASTM D 3911-95 as ASTM D 3911-08 (Ref. 11). Nonmandatory Appendix X2 to this standard discusses witness coupons in primary containment. These test coupons, if properly placed, provide a realistic mechanism to test and evaluate the aging of coatings. Selected coupons could be periodically removed and tested to identify changes in various physical properties and could be DBA-tested to provide much better and more realistic predictions of coating life. New NPPs should consider the installation of coated test coupons at various locations in the primary containment. The coated test coupons would be representative of the aged condition of similar coatings within the primary containment. The licensee could use the test coupons for coating condition analysis and aging studies during the commercial life of the NPP.

ASTM developed and issued ASTM D 5144-08, “Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants” (Ref. 12), to provide a common basis on which protective coatings for the surfaces of nuclear power generating facilities may be qualified and selected through reproducible evaluation tests. This ASTM standard provides guidance for the application and maintenance of protective coatings under the expected environmental, operating, and postulated accident conditions for pressurized-water reactors and boiling-water reactors. ASTM D 5144-08 addresses, by reference, the preparation of test specimens, radiation tolerance testing, the decontaminability of coatings, physical properties, chemical resistance tests, fire evaluation tests, DBA testing, surface preparation, coating application and inspection, and thermal conductivity testing. Therefore, ASTM D 5144-08 can be viewed as a top-level ASTM standard that provides detailed requirements through reference to other key ASTM standards. Figure 1 shows the additional ASTM standards that provide application-specific guidance; these standards are discussed below.



**Figure 1 ASTM standards relevant to NPP Service Level I, II, and III protective coatings**

The NRC developed this RG using definitions and insights from operating reactors. New reactor designs may use design features that are different from the operating reactors that formed the basis for this RG, and, therefore, adjustments may be necessary. For example, a plant with passive containment cooling features may have different requirements for protective coatings on containment surfaces, or a plant might rely on the density of failed protective coating particles inside containment that limits their transport to the ECCS. Therefore, this RG provides guidance for new reactor designs with the recognition that the licensee or applicant may need to adjust some features based on the particular plant design.

## C. REGULATORY POSITION

### 1. Guidance in American Society for Testing and Materials Standards

ASTM D 5144-08 and the other ASTM standards discussed below provide guidance on practices and programs that the NRC staff finds acceptable for the selection, application, qualification, inspection, and maintenance of protective coatings applied to NPPs. ASTM Committee D-33 has defined Service Level I, II, and III coating locations to include both safety-related and nonsafety-related regions as set forth below.

Service Level I, II, and III coatings are defined as follows:

- a. Service Level I coatings are used in areas inside the reactor containment where coating failure could adversely affect the operation of postaccident fluid systems and thereby impair safe shutdown.
- b. Service Level II coatings are used in areas where coating failure could impair, but not prevent, normal operating performance. The functions of Service Level II coatings are to provide corrosion protection and decontaminability<sup>1</sup> in those areas outside the reactor containment that are subject to radiation exposure and radionuclide contamination. Service Level II coatings are not safety related.
- c. Service Level III coatings are used in areas outside the reactor containment where failure could adversely affect the safety function of a safety-related SSC. (Note that a coating on the external surface of a reactor containment may be designated Service Level III, although no plants licensed under 10 CFR Part 50 have applied this designation.)

The QA provisions and guidance contained in the standards in this regulatory position are generally acceptable and provide methods that the NRC staff finds acceptable for complying with the pertinent QA requirements in Appendix B to 10 CFR Part 50, subject to the following two exceptions:

- a. When using this RG, NRC licensees should meet the QA provisions and guidance contained in the standards in this RG and must also meet the commitments and provisions contained in their QA program descriptions.
- b. Applicants for design certifications and combined licenses under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," (Ref. 14) may propose to use coatings in ways that do not conform to the service level definitions above. For example, an applicant could propose to designate coatings in certain areas of containment as Service Level II based on an evaluation that demonstrates that these coatings cannot be transported to the ECCS. Such exceptions may be acceptable to the NRC staff if the applicant provides a technical justification and corresponding technical and quality requirements in a licensing-basis document such as the final safety analysis report.

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<sup>1</sup> ASTM withdrew ASTM D 4256-94, "Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants," issued in 1994 (Ref. 13). U.S. plants found that this test method is faulty in that almost any coating system will pass the test. In addition, this test method generates mixed hazardous waste and does not comply with occupational dose as low as reasonably achievable practices.

## 2. Quality Assurance

ASTM D 3843-00 (reapproved 2008) provides QA practices that are acceptable to the NRC staff and are applicable to safety-related protective coating work in coating Service Level I areas of nuclear facilities. Licensees may use applicable portions of the QA practices described in ASTM D 3843-00 (reapproved 2008) as the basis for limited QA for protective coating work in coating Service Level II areas of nuclear facilities.

ASTM D 5139-10, “Standard Specification for Sample Preparation for Qualification Testing of Coatings To Be Used in Nuclear Power Plants” (Ref. 15), provides guidance that the NRC staff finds acceptable on the size, composition, and surface preparation for test samples of protective coatings for use in the qualification testing of coatings that will be applied to NPPs, as described in ASTM D 3911-08 and in ASTM D 4082-10, “Standard Test Method for Effects of Gamma Radiation on Coatings for Use in Nuclear Power Plants” (Ref. 16).

ASTM D 3911-08 provides guidance that the NRC staff finds acceptable on procedures for evaluating test specimens for protective coating systems under simulated DBA conditions. ASTM D 3911-08 also provides guidance on conditions and test apparatus for temperature-pressure testing; on conditions for radiation testing; and on procedures for preparing, examining, and evaluating samples. ASTM D 3911-08 does not specify minimum acceptance criteria. For Service Level I coatings, licensees or applicants shall meet the following minimum acceptance criteria:

- a. Peeling and delamination shall not be permitted.
- b. Cracking is not considered a failure unless it is accompanied by delamination or loss of adhesion.
- c. Blisters shall be limited to intact blisters that are completely surrounded by sound coating bonded to the surface.

The licensee may establish more stringent acceptance criteria; the above criteria are meant to establish minimum standards only.

ASTM D 4082-10 provides a standard test method that the NRC staff finds acceptable for evaluating the effects of gamma radiation on the lifetime radiation tolerance of Service Level I and II coatings.

ASTM D 3912-10, “Standard Test Method for Chemical Resistance of Coatings and Linings for Use in Nuclear Power Plants” (Ref. 17), provides guidance that the NRC staff finds acceptable for evaluating the chemical resistance of coatings applied to light-water NPPs.

## 3. Training and Qualification of Nuclear Coating Specialists, Protective Coating Inspectors, and Coating Applicators

ASTM D 4537-04a, “Standard Guide for Establishing Procedures To Qualify and Certify Personnel Performing Coating Work Inspection in Nuclear Facilities” (Ref. 18), provides guidance that the NRC staff finds acceptable on the qualification and certification of personnel who inspect protective coatings in nuclear facilities. This standard provides guidance on the inspection of the education, training, experience, qualifications, and certification of Service Level I, II, and III coatings inspectors.

ASTM D 5498-09, “Standard Guide for Developing a Training Program for Personnel Performing Coating Work Inspection for Nuclear Facilities” (Ref. 19), provides guidance that the NRC staff finds acceptable for developing a training program for personnel who perform coating work inspection at nuclear facilities.

ASTM D 7108-05, “Standard Guide for Establishing Qualifications for a Nuclear Coatings Specialist” (Ref. 20), provides guidance that the NRC staff finds acceptable for establishing qualifications for a nuclear coatings specialist. A nuclear coatings specialist must meet one of the combinations of qualification attributes provided in Table 2 of ASTM D 7108-05.

ASTM D 4227-05, “Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces” (Ref. 21), provides guidance that the NRC staff finds acceptable for the qualification of coating applicators to verify that they are proficient and can attain the quality required for the application of specified coatings to concrete surfaces, including those in a nuclear facility.

ASTM D 4228-05, “Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces” (Ref. 22), provides guidance that the NRC staff finds acceptable for the qualification of coating applicators to verify that they are proficient and can attain the quality required for applying specified coatings to steel surfaces, including those in a nuclear facility.

ASTM D 4286-08, “Standard Practice for Determining Coating Contractor Qualifications for Nuclear Powered Electric Generation Facilities” (Ref. 23), provides criteria and methods that the NRC staff finds acceptable to assist utility owners, architects, engineers, and contractors in determining the overall qualifications of a coating contractor to perform coating work for the primary containment and other safety-related facilities of NPPs. The criteria and requirements for coating contractors address their capabilities to perform nuclear coating work.

#### 4. Maintenance of Coatings

ASTM D 5163-08, “Standard Guide for Establishing a Program for Condition Assessment of Coating Service Level I Coating Systems in Nuclear Power Plants” (Ref. 24), provides guidelines that the NRC staff finds acceptable for establishing an in-service coating monitoring program for Service Level I coating systems in operating NPPs and for Service Level II and other areas outside containment (as applicable) with the following conditions:

- a. Licensees should establish an acceptable condition assessment program using qualified personnel and should perform condition assessments at a periodicity that would allow them to detect potential coating degradation and to implement repairs before such degradation would adversely impact postaccident safety systems.
- b. Licensees should perform condition assessments under the direction of a nuclear coating specialist, as defined in ASTM D 7108-05.
- c. Licensees should evaluate degraded coatings identified during condition assessments for their impact on the ECCS postaccident function consistent with the guidance in RG 1.82 “Water Sources for Long-Term Recirculation Cooling Following a Loss-Of-Coolant Accident,” (Ref. 25) and in accordance with applicable licensing-basis documents.
- d. Although the ASTM D 5163-08 standard provides reasonable assurance that qualified coatings left in service after a visual inspection will remain adhered to their substrates under accident conditions, it does not guarantee that visual inspection will detect all degraded coatings. Therefore, the NRC recommends that licensees account for the potential that visual inspections may not identify some degraded coatings by using margin in debris-generation calculations for ECCS strainer performance or by using a debris transport analysis to show that the debris will not reach the strainer.

ASTM D 7167-05, “Standard Guide for Establishing Procedures To Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant” (Ref. 26), provides guidelines that the NRC staff finds acceptable for establishing procedures to monitor the performance of Service Level III lining systems in an operating NPP.

ASTM D 4541-09, “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers” (Ref. 27), provides guidance that the NRC staff finds acceptable for a test method used to evaluate the pull-off strength of coatings on metal substrates using fixed-alignment adhesion testers.<sup>2</sup>

ASTM D 6677-07, “Standard Test Method for Evaluating Adhesion by Knife” (Ref. 28), provides guidance that the NRC staff finds acceptable for a test method used to evaluate adhesion using a knife.

ASTM D 7234-05, “Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers” (Ref. 29), provides guidance that the NRC staff finds acceptable for a test method used to evaluate the pull-off strength of coatings on concrete using portable pull-off adhesion testers.<sup>3</sup>

ASTM D 7491-08, “Standard Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants” (Ref. 30), provides guidance that the NRC staff finds acceptable for managing nonconforming coatings within the Service Level I areas of a NPP.

5. American Society for Testing and Materials Standard Terminology

ASTM D 4538-05, “Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities” (Ref. 31), defines standard terms related to protective coating and lining work for power generation facilities that the NRC staff finds acceptable and that are also relevant to protective coatings applied to NPPs.

6. Additional Information

Electric Power Research Institute (EPRI) Topical Report No. 1019157, “Guideline on Nuclear Safety-Related Coatings,” Revision 2, issued December 2009 (formerly EPRI Topical Report Nos. 109937 and 1003102) (Ref. 32), provides additional information on the selection, application, inspection, and maintenance of safety-related protective coatings applied to NPPs. EPRI Topical Report No. 1019157 discusses, in detail, the important considerations related to protective coatings and can be used to supplement the ASTM standards as deemed necessary, with the exception of Section 3.4.2 of the report, which discusses the application of specialized coatings for restoring the structural integrity of a component. The NRC does not endorse the use of specialized coatings for restoring structural integrity.

## **D. IMPLEMENTATION**

The purpose of this section is to provide information on how applicants and licensees<sup>4</sup> may use this guide and information regarding the NRC’s plans for using this Regulatory Guide. In addition, it describes how the NRC staff has complied with the Backfit Rule, 10 CFR 50.109 and any applicable finality provisions in 10 CFR Part 52.

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<sup>2</sup> A fixed-alignment adhesion Tester Type II (Test Method B) is the test method that NPPs have historically used.

<sup>3</sup> This test standard is new. Historically, adhesion testing of coatings on concrete was performed in accordance with ASTM D 4541-09.

<sup>4</sup> In this section, “licensees” include applicants for standard design certifications under 10 CFR Part 52.



## **Applicant and Licensees' Use**

Applicants and licensees may (i.e., voluntarily) use the information in this regulatory guide to develop applications for initial licenses, amendments to licenses, or other requests for NRC regulatory approval (e.g., exemptions). Licensees may use the information in this regulatory guide for actions which do not require prior NRC review and approval (e.g., changes to a facility design under 10 CFR 50.59 which do not require prior NRC review and approval). Licensees may use the information in this Regulatory Guide or applicable parts to resolve regulatory or inspection issues (e.g., by committing to comply with provisions in the regulatory guide).

Current licensees may continue to use the guidance that was found acceptable for complying with specific portions of the regulations as part of their license approval process, which may be a previous version of this Regulatory Guide.

A licensee who believes that the NRC staff is inappropriately imposing this Regulatory Guide as part of a request for a license amendment or request for a change to a previously issued NRC regulatory approval may file a backfitting appeal with the NRC in accordance with applicable procedures.

## **NRC Staff Use**

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this Regulatory Guide. The staff does not expect any existing licensee to use or commit to using the guidance in this Regulatory Guide in the absence of a licensee-initiated change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this Regulatory Guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide (e.g. issuance of an order requiring the use of the Regulatory Guide, requests for information under 10 CFR 50.4(f) as to whether a licensee intends to commit to use of this regulatory guide, generic communication, or promulgation of a rule requiring the use of this Regulatory Guide) without further back-fit consideration.

During inspections of specific facilities, the staff may suggest or recommend that licensees consider various actions consistent with staff positions in this regulatory guide. Such suggestions and recommendations would not ordinarily be considered backfitting even if prior versions of this Regulatory Guide are part of the licensing basis of the facility with respect to the subject matter of the inspection. However, the staff may not represent to the licensee that: (i) the licensee's failure to comply with the positions in this Regulatory Guide constitutes a violation; (ii) the licensee may avoid the violation by agreeing to comply with this Regulatory Guide; or (iii) the only acceptable way for the licensee to address the NRC-identified non-compliance or violation is to commit to this Regulatory Guide (i.e., including this Regulatory Guide in the facility's licensing basis).

If an existing licensee seeks a license amendment or change to an existing regulatory approval, and the staff's consideration of the request involves a regulatory issue which is directly relevant to this Regulatory Guide and the specific subject matter of the new or revised guidance is an essential consideration in the NRC staff's determination of the acceptability of the licensee's request, the staff may require the licensee to use this Regulatory Guide as a prerequisite for NRC approval. This is not considered back-fitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

## **Conclusion**

This regulatory guide is not being imposed upon current licensees and may be voluntarily used by existing licensees. In addition, this Regulatory Guide is issued in conformance with all applicable internal NRC policies and procedures governing backfitting. Accordingly, the NRC's staff issuance of this regulatory guide is not considered backfitting, as defined in 10 CFR 50.109(a)(1), nor is it deemed to be in conflict with any of the issue finality provisions in 10 CFR Part 52.

## REFERENCES<sup>1</sup>

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.
2. Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 2, U.S. Nuclear Regulatory Commission, Washington, DC, March 1997.
3. Regulatory Guide 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water Cooled Nuclear Power Plants," Revision 0, U.S. Nuclear Regulatory Commission, Washington, DC, June 1973.
4. 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," U.S. Nuclear Regulatory Commission, Washington, DC, July 14, 1998.
5. ANSI N101.4-1972, "Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American National Standards Institute, Washington, DC.<sup>2</sup>
6. ANSI N101.2-1972, "Protective Coatings (Paints) for Light-Water Nuclear Reactor Containment Facilities," American National Standards Institute, Washington, DC.
7. Regulatory Guide 1.54, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants," Revision 1, U.S. Nuclear Regulatory Commission, Washington, DC, July 2000.
8. ASTM D 3843-00, "Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American Society for Testing and Materials, West Conshohocken, PA.<sup>3</sup>
9. ASTM D 3843-00 (reapproved 2008), "Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities," American Society for Testing and Materials, West Conshohocken, PA.
10. ASTM D 3911-95, "Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design-Basis Accident (DBA) Conditions," American Society for Testing and Materials, West Conshohocken, PA.

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Copies of American National Standards Institute (ANSI) standards may be purchased from ANSI, 1819 L Street, NW., 6<sup>th</sup> floor, Washington, DC 20036; telephone (202) 293-8020. Purchase information is available through the ANSI Web site at <http://webstore.ansi.org/ansidocstore/>.

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Copies of American Society for Testing and Materials (ASTM) standards may be purchased from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959; telephone (610) 832-9585. Purchase information is available through the ASTM Web site at <http://www.astm.org>.

11. ASTM D 3911-08, "Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design-Basis Accident (DBA) Conditions," American Society for Testing and Materials, West Conshohocken, PA.
12. ASTM D 5144-08, "Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
13. ASTM D 4256-94 "Test Method for Determination of the Decontaminability of Coatings Used in Light-Water Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
14. 10 CFR Part 52, "Licenses, Certifications and Approvals for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.
15. ASTM D 5139-10, "Standard Specification for Sample Preparation for Qualification Testing of Coatings To Be Used in Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
16. ASTM D 4082-10, "Standard Test Method for Effects of Gamma Radiation on Coatings for Use in Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
17. ASTM D 3912-10, "Standard Test Method for Chemical Resistance of Coatings and Linings for Use in Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
18. ASTM D 4537-04a, "Standard Guide for Establishing Procedures To Qualify and Certify Personnel Performing Coating Work Inspection in Nuclear Facilities," American Society for Testing and Materials, West Conshohocken, PA.
19. ASTM D 5498-09, "Standard Guide for Developing a Training Program for Personnel Performing Coating Work Inspection for Nuclear Facilities," American Society for Testing and Materials, West Conshohocken, PA.
20. ASTM D 7108-05, "Standard Guide for Establishing Qualifications for a Nuclear Coatings Specialist," American Society for Testing and Materials, West Conshohocken, PA.
21. ASTM D 4227-05, "Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces," American Society for Testing and Materials, West Conshohocken, PA.
22. ASTM D 4228-05, "Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces," American Society for Testing and Materials, West Conshohocken, PA.
23. ASTM D 4286-08, "Standard Practice for Determining Coating Contractor Qualifications for Nuclear Powered Electric Generation Facilities," American Society for Testing and Materials, West Conshohocken, PA.
24. ASTM D 5163-08, "Standard Guide for Establishing a Program for Condition Assessment of Coating Service Level I Coating Systems in Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.

25. Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-Of-Coolant Accident," Revision 3, U.S. Nuclear Regulatory Commission, Washington, DC, November 2003.
26. ASTM D 7167-05, "Standard Guide for Establishing Procedures To Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant," American Society for Testing and Materials, West Conshohocken, PA.
27. ASTM D 4541-09, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers," American Society for Testing and Materials, West Conshohocken, PA.
28. ASTM D 6677-07, "Standard Test Method for Evaluating Adhesion by Knife," American Society for Testing and Materials, West Conshohocken, PA.
29. ASTM D 7234-05, "Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers," American Society for Testing and Materials, West Conshohocken, PA.
30. ASTM D 7491-08, "Standard Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants," American Society for Testing and Materials, West Conshohocken, PA.
31. ASTM D 4538-05, "Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities," American Society for Testing and Materials, West Conshohocken, PA.
32. EPRI Topical Report No. 1019157 "Guideline on Nuclear Safety-Related Coatings," Revision 2, Electric Power Research Institute, Palo Alto, CA, December 2009.<sup>4</sup>

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Copies of the listed Electric Power Research Institute (EPRI) standards and reports may be purchased from EPRI, 3420 Hillview Ave., Palo Alto, CA 94304; telephone (800) 313-3774; fax (925) 609-1310.