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Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants[1]

This standard is issued under the fixed designation D5144; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Protective coatings (paints) have been used extensively in the nuclear industry to protect the surfaces of facilities and equipment from corrosion and contamination by radioactive nuclides in accordance with ALARA. In the absence of a standard method of selecting, testing, and evaluating coatings, many sites evaluated paints by empirical tests to determine which were useful in their particular operation. Understandably, the methods of testing were not uniform throughout the industry. It has been very difficult, consequently, to compare the results obtained at one site with those obtained at another. Standard tests whereby industrial (nuclear) users of paints systematically prepare specimens and subject them to selected evaluations, thus permitting uniform comparisons, are advantageous, internationally as well as domestically.

The designer of light water-moderated nuclear reactor systems must consider the possibility of a Design Basis Accident (DBA) and the subsequent events which might lead to the release or expulsion of a fraction of the fission-product inventory of the core to the reactor containment facility. Engineered safety features, principally a reactor containment facility, are provided to prevent the release of fission products to the biological environment during and after this improbable event. The design, fabrication, quality assurance, and testing of these engineered safety features ensure reliable operation and safety under all anticipated conditions.

Large areas of the reactor-containment facility are painted with safety-related coatings. If severe delamination, peeling, or flaking causes significant portions of the coating to be discharged into the common water reservoir, the performance of the safety systems could be seriously compromised by the plugging of strainers, flow lines, pumps, spray nozzles, and core coolant channels. Safety-related coatings may also exist outside of the reactor-containment.

This guide is the result of a comprehensive examination of the experience and data that have been developed on protective coatings in the nuclear industry over approximately 50 years. Standards pertaining to nuclear coatings have historically been covered by ANSI N5.12, ANSI N101.2, and ANSI N101.4. Responsibility for updating, rewriting, and issuing appropriate ANSI replacement standards has been transferred to ASTM, specifically ASTM Committee D33, on Protective Coating and Lining Work for Power Generation Facilities.

The objective of this guide is to provide a common basis on which protective coatings for the surfaces of nuclear power generating facilities may be qualified and selected by reproducible evaluation tests. This guide also provides guidance for application and maintenance of protective coatings. Quality assurance in the nuclear industry is a mandatory requirement for all aspects of safety-related nuclear coatings work. Licensees of nuclear power plants are required to determine if coated surfaces are within the scope of 10CFR50.65, “The Maintenance Rule.” Any coated surfaces found to be within the scope of 10CFR50.65 must satisfy the requirements of 10CFR50.65. ASME Section XI, Subsection IWE contains the requirements for periodic evaluation of the reactor-containment steel pressure boundary.

1. Scope*

1.1 This guide provides a common basis on which protective coatings for the surfaces of nuclear power generating facilities may be qualified and selected by reproducible evaluation tests. This guide also provides guidance for application and maintenance of protective coatings. Under the environmental operating and accident conditions of nuclear power generation facilities, encompassing pressurized water reactors (PWRs) and boiling water reactors (BWRs), coating performance may be affected by exposure to any one, all, or a combination of the following conditions: ionizing radiation; contamination by radioactive nuclides and subsequent decontamination processes; chemical and water sprays; high-temperature high-pressure steam; and abrasion or wear.

1.2 The content of this guide includes:

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1.2.1 In addition, this guide addresses technical topics within ANSI N5.12 and ANSI N101.2 that are covered by separate ASTM standards, for example, surface preparation, (shop and field) and coating application, (shop and field).

1.2.2 Applicable sections of this guide and specific acceptance criteria may be incorporated into specifications and other documents where appropriate.[2]

1.3 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

D3843 Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities

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

D3912 Test Method for Chemical Resistance of Coatings and Linings for Use in Nuclear Power Plants

D4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

D4082 Test Method for Effects of Gamma Radiation on Coatings for Use in Nuclear Power Plants

D4227 Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces

D4228 Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces

D4537 Guide for Establishing Procedures to Qualify and Certify Personnel Performing Coating and Lining Work Inspection in Nuclear Facilities

D4538 Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities

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

D5139 Specification for Sample Preparation for Qualification Testing of Coatings to be Used in Nuclear Power Plants

D5163 Guide for Establishing a Program for Condition Assessment of Coating Service Level I Coating Systems in Nuclear Power Plants

D7167 Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant

D7230 Guide for Evaluating Polymeric Lining Systems for Water Immersion in Coating Service Level III Safety-Related Applications on Metal Substrates

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

D7491 Guide for Management of Non-Conforming Coatings in Coating Service Level I Areas of Nuclear Power Plants

E84 Test Method for Surface Burning Characteristics of Building Materials

E648 Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source

E1461 Test Method for Thermal Diffusivity by the Flash Method

E1530 Test Method for Evaluating the Resistance to Thermal Transmission of Materials by the Guarded Heat Flow Meter Technique

2.2 *Other Standards:*

ANSI N5.12 Protective Coatings (Paints) for the Nuclear Industry[4]

ANSI N101.2 Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities[4]

ANSI N101.4 Quality Assurance for Protective Coatings Applied to Nuclear Facilities[4]

[1] This guide is under the jurisdiction of ASTM Committee D33 on Protective Coating and Lining Work for Power Generation Facilities and is the direct responsibility of Subcommittee D33.02 on Service and Material Parameters.

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[2] Certain ASTM standards are available in compilation form (which includes this guide), as *Compilation of ASTM Standards for Use of Protective Coating Standards in Nuclear Power Plants* for expedient reference and usage by personnel involved in nuclear coating work.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from IHS, 321 Inverness Drive South, Englewood, CO 80112, http://www.ihs.com.

ASME Boiler and Pressure Vessel Code (BPVC) Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsection IWE Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Power Plants[5]

EPRI 1019157 Plant Support Engineering: Guideline on Nuclear Safety-Related Coatings Revision 2 (formerly TR-109937 and 1003102)[6]

10CFR50 Appendix B: Title 10, Chapter 1, Energy, Part 50, Domestic Licensing of Production and Utilization Facilities, Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants[7]

10CFR50.65 Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants[7]

USNRC Standard Review Plan 6.1.2 Protective Coating Systems (Paints) Organic Materials[7]

USNRC Regulatory Guide 1.54 Regulatory/(1973) Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants, Revisions 0, 1, and 2[7]

USNRC Regulatory Guide 8.8 Information Relevant to Ensuring that Occupational Radiation Exposures At Nuclear Power Stations Will Be As Low As Is Reasonably Achievable[7]

3. Terminology

3.1 *Definitions*—Definitions for use with this guide are shown in Terminology D4538 or other applicable standards.

4. Significance and Use

4.1 This guide addresses the concerns of Regulation Guide 1.54 and USNRC Standard Review Plan 6.1.2, and the replacement of ANSI Standards N5.12, N101.2, and N101.4. This guide covers coating work on previously coated surfaces as well as bare substrates. This guide applies to all coating work in Coating Service Level I and III areas (that is, safety-related coating work). Applicable sections of this guide may also be used to evaluate and select protective coatings for Coating Service Level II areas where deemed appropriate by the licensee.

4.2 The testing referenced in this guide is particularly appropriate for safety-related coatings inside the reactor-containment. Other test methods may be used for assessing the suitability for service of safety-related coatings outside the reactor-containment. Criteria for qualification and performance monitoring of Coating Service Level III coatings shall be addressed in job specifications. Guidance for selecting and performance monitoring of Coating Service Level III coatings is provided Guides D7230 and D7167 respectively, and Sections 4.4 and 4.5 of EPRI 1019157 (formerly TR-109937 and 1003102.).

4.3 Users of this guide must ensure that coatings work complies not only with this guide, but also with the licensee's plant-specific quality assurance program and licensing commitments.

4.4 *Safety-Related Coatings:*

4.4.1 The qualification of coatings for Coating Service Levels I and III are different even though they are both safety-related. This guide provides the minimum requirements for qualifying Coating Service Level I coatings and also provides guidance for additional qualification tests that may be used to evaluate Coating Service Level I coatings. This guide also provides guidance concerning selection of Coating Service Level III coatings.

4.4.2 *Coating Service Level I Coatings:*

4.4.2.1 All Coating Service Level I coatings must be resistant to the effects of radiation and must be DBA qualified. The test specimens shall be prepared, irradiated and DBA tested and evaluated in accordance with the requirements of:

(a) Test Method D3911 or plant specific requirements as applicable,

(b) Test Method D4082, and

(c) Specification D5139.

4.4.2.2 In addition to the requirements of 4.4.2.1, Coating Service Level I coatings may be evaluated for additional qualities or may require application controls when deemed applicable by the job specifications or licensing commitments. The following documents provide guidance for application, possible additional testing or for the further evaluation of Coating Service Level I coatings when applicable:

(a) Test Method C177,

(b) Practice D3843,

(c) Test Method D3912,

(d) Test Method D4060,

(e) Practice D4227,

(f) Practice D4228,

(g) Guide D4537,

(h) Test Method D4541,

(i) Test Method E84,

(j) Test Method E648,

(k) Test Method E1461, and

(l) Test Method E1530.

4.4.2.3 Condition assessment and management of Coating Service Level I coatings is also required by the licensee to maintain the coatings following the initial application and subsequent repairs. The following documents provide guidance for the monitoring and management of the Coating Service Level I coatings:

(a) Guide D5163 and

(b) Guide D7491.

4.4.3 *Coating Service Level III Coatings:*

4.4.3.1 Coating Service Level III coatings must be evaluated for use in accordance with the requirements of plant licensing commitments and the job specifications. Coating Service Level III coatings may include linings used in areas such as service water systems, essential cooling water heat exchanger heads and emergency diesel generator air intakes. There are *no* specific testing or qualification *requirements* included in this guide for Coating Service Level III coatings or

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hills, CA 94523, http://www.epri.com.

[7] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

linings. Testing and evaluation of Coating Service Level III coatings should be conducted as necessary to ensure that the coatings are suitable for the specific service environment. The following documents provide guidance for testing and inspection, which the licensee may consider when preparing job specifications for Coating Service Level III coatings or linings:

(a) Test Method D4541,
(b) Guide D7167,
(c) Guide D7230,
(d) EPRI 1019157 (formerly TR-109937 and 1003102), Sections 4.4 and 4.5,
(e) 10CFR50.65, and
(f) 10CFR50. Appendix B.

4.5 *Coatings Service Level II Coatings:*

4.5.1 Coating Service Level II coatings are not safety-related and are restricted to the radiation controlled area (RCA) outside of the reactor-containment in nuclear power plants. There are *no* specific testing or qualification *requirements* included in this guide for Coating Service Level II coatings. The following documents provide guidance for testing and inspection, which the licensee may consider when evaluating or specifying Coating Service Level II coatings:

(a) Test Method D3912,
(b) Test Method D4060,
(c) Test Method D4082,
(d) Test Method D4541,
(e) Specification D5139,
(f) Test Method E84,
(g) Test Method E648, and
(h) USNRC Regulatory Guide 8.8.

4.5.2 Some nuclear power plant licenses may include requirements for Coating Service Level II coatings; these requirements must be satisfied when selecting Coating Service Level II coating materials and systems.

5. Coating Material Testing

5.1 The coating material test specimen preparation and testing standards in 5.2 – 5.8 may be used to evaluate coatings applied in nuclear power plants as discussed in Section 4 of this guide.

5.2 *Preparation of Qualification Test Specimens:*

5.2.1 All test specimens used for qualification testing of coatings shall be prepared in accordance with Specification D5139 or as specified by the licensee.

5.3 *Radiation Tolerance Tests:*

5.3.1 Coating film resistance to radiation exposure shall be evaluated in accordance with Test Method D4082.

5.4 *Decontamination:*

5.4.1 Certain coatings may contaminate more readily than others, and the responses to decontamination treatments also vary. For this reason, there is no reliable test to compare the decontaminability of different coatings. In some cases, the desired level of decontamination may be achieved merely by cleaning the coating surface; in other cases, decontamination may be achieved only by partial or complete removal of the coating.

5.5 *Physical Properties:*

5.5.1 *Adhesion:*

5.5.1.1 *Steel Substrate*—Panels shall be tested for adhesion in accordance with Test Method D4541. A minimum of five panels shall be tested for each coating system. For Coating Service Level I coating systems, the minimum adhesion shall be 200 psi for 4 of the 5 panels.

5.5.1.2 *Concrete Substrate*—Panels shall be tested for adhesion in accordance with Test Method D7234. A minimum of five panels shall be tested for each coating system. For Coating Service Level I coating systems, the minimum adhesion shall be 200 psi for 4 of the 5 panels.

5.5.2 *Abrasion Resistance*—Abrasion resistance characteristics of coating systems for floors and other surfaces where abrasion is a factor shall be determined in accordance with Test Method D4060.

5.5.2.1 Weight loss shall not exceed 175 mg/1000 cycles when a CS-17 wheel is used with a 1000-g load per arm.

5.6 *Chemical Resistance Tests:*

5.6.1 Test specimens shall be tested in accordance with Test Method D3912.

5.6.2 The specific chemicals to be used should be selected to characterize the anticipated exposure; the chemicals indicated in Test Method D3912 are shown only as examples and are not mandatory.

5.7 *Fire Evaluation Tests:*

5.7.1 *Flame Spread Tests*—Flame-spread tests, when required, shall be conducted and evaluated in accordance with Test Method E84. The permissible flame-spread and smoke generation, when tested on a noncombustible substrate, shall not exceed the limits set by the nuclear power generating facility. Test Method E648 has been used as an alternate method to evaluate floor coatings in other industries.

5.7.2 The coating systems should be tested to cover the specified film thickness range (or greater) since the flame-spread and smoke density can vary with film thickness. Smoke density is significant where a coating is utilized in enclosed spaces and smoke generation can reduce visibility and prevent effective fire fighting operations. Historic test data indicates that most coatings applied at less than 25-mils dry film thickness over noncombustible substrates and tested in accordance with Test Method E84 demonstrate flame-spread values below 25.

5.8 *Thermal Conductivity*—If required, thermal conductivity for coating systems may be determined by Test Methods C177, E1461 or E1530. See Appendix X1 for typical thermal conductivity values.

5.9 *DBA Testing:*

5.9.1 The test specimen shall be tested and evaluated in accordance with plant specific requirements or Test Method D3911 as applicable.

6. Surface Preparation, Coating Application, and Inspection for Shop and Field Work

6.1 Surface preparation for steel, concrete, and previously coated surfaces shall be equal to or better than that used in the qualification testing of the coating system intended for use.

6.2 Coating application shall be in accordance with the job specifications and procedures and the coating manufacturer's latest published instructions to the extent referenced in the job specification and procedures. Coating Applicator qualification shall meet the requirements of the applicable quality assurance (QA) program. Practices D4227 and D4228 provide guidance for qualifying coating applicators. Coating dry film thickness shall be in the acceptable range determined in the qualification testing of the coating system.

6.3 Coatings work shall be inspected by coatings inspectors qualified and certified in accordance with QA program requirements specified by the licensee. Guide D4537 provides guidance for qualifying coating work inspectors. Inspections shall be documented to provide a record of the coatings work.

6.4 Maintenance painting work shall follow the requirements of 6.1, 6.2, and 6.3. The maintenance painting specifications shall take into consideration the plant environment in which the coating work must be accomplished. Maintenance painting work qualification testing should be based on proposed surface preparation, coating application methods, and film thickness ranges, all of which may be different than the original design qualification work. Guidance concerning maintenance painting of nuclear power plants is provided in ASTM MNL8.[8]

[8] MNL8, *Manual 8, Maintenance Coatings for Nuclear Power Plants*, Ninth Edition, compiled by ASTM Subcommittee D33.10 on Protective Coatings Maintenance Work for Power Generation Facilities. Available from ASTM International.

7. Quality Assurance

7.1 A quality assurance program for Coating Service Level I and III coating work shall be established in accordance with the licensee's licensing commitments. Practice D3843 provides guidance for achieving the objectives of the licensee's quality assurance program with respect to safety-related coatings work. Quality assurance requirements may also be established for Coating Service Level II coating work based on criticality. Coating Service Levels I and III coating work is considered a Special Process as defined in 10CFR50 Appendix B, Criterion IX.

7.2 Contractor quality assurance programs or specific project quality plans, or both, shall be evaluated against licensing requirements of the licensee.

8. Keywords

8.1 ANSI replacement standards; decontamination; Design Basis Accident (DBA); nuclear power plants; protective coating standards; qualification testing; quality assurance Coating Service Level I, Coating Service Level II, and Coating Service Level III; radiation; safety related

APPENDIX

(Nonmandatory Information)

X1. THERMAL CONDUCTIVITY OF TYPICAL COATING SYSTEMS

X1.1 Table X1.1 illustrates thermal conductivity.

TABLE X1.1 Thermal Conductivity of Typical Coating Systems

NOTE 1—Thermal conductivities listed here are indicated for the coating system shown and should not be considered additive.

NOTE 2—To find the thermal conductivity of a coating system 2, 3, 4, etc., mils thick, divide the thermal conductivity for one mil (right-hand column) by 2, 3, 4, etc.

Coating System	Thermal Conductivity (Coefficient)	
	(B.t.u.) (in.)/(h) (ft^2) (°F)	(B.t.u.) (mil)/(h) (ft^2) (°F)
Inorganic zinc primer—no top coat	11 to 18	11 000 to 18 000
Inorganic zinc primer—inorganic top coat	7 to 12	7 000 to 12 000
Inorganic zinc primer—organic top coat	2.5 to 7	2 500 to 7 000
Organic zinc primer—no top coat	2.5 to 5	2 500 to 5 000
Organic zinc primer—organic top coat	1 to 3.5	1 000 to 3 500
Organic primer—organic top coat	1 to 3.5	1 000 to 3 500

SUMMARY OF CHANGES

Committee D33 has identified the location of selected changes to this standard since the last issue (D5144-08$^{\varepsilon 1}$) that may impact the use of this standard. (Approved August 1, 2016.)

(1) Editorial changes were made throughout.