Designation: D3911 – 16

Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions[1]

This standard is issued under the fixed designation D3911; 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

During a DBA in nuclear power plants, conditions in the reactor containment will be characterized by elevated temperature and pressure, as well as the presence of a radiation environment. Water sprays, with or without chemical additives, may be used in the primary containment to suppress the consequences of the event, to scavenge radioactive products, and to return the containment to near-ambient pressure and temperature conditions.

1. Scope

1.1 This test method establishes procedures for evaluating protective coating systems test specimens under simulated DBA conditions. Included are a description of conditions and apparatus for temperature-pressure testing, and requirements for preparing, irradiating, testing, examining, evaluating, and documenting the samples.

1.2 Consideration should be given to testing using worst case conditions (for example, surface preparation, temperature and pressure profile, irradiation, spray chemistry, chemical resistance, etc.) in an effort to reduce the number of tests required by changing plant accident calculations, changes in coating selection, etc.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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:*[2]

D714 Test Method for Evaluating Degree of Blistering of Paints

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

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

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

3. Terminology

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

4. Significance and Use

4.1 This test method is designed to provide a uniform test to determine the suitability of Coating Service Level 1 coatings used inside primary containment of light-water nuclear facilities under simulated DBA conditions. This test method is intended only to demonstrate that under DBA conditions, the coatings will remain intact and not form debris which could unacceptably compromise the operability of engineered safety systems. Deviations in actual surface preparation and in

[1] This test method 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] 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.

application and curing of the coating materials from qualification test parameters require an engineering evaluation to determine if additional testing is required.

4.2 Since different plants have different tolerance levels for coating conditions, the definition of appropriate acceptance criteria is to be developed by the license holder based on individual plant engineered safety systems operability considerations.

4.3 Use of this standard is predicated on the testing facility having a quality assurance program acceptable to the licensee.

5. Apparatus

5.1 *Environmental Test System, Test Sample Hangers, and Test Sample Identification Tags,* constructed of materials that are corrosion-resistant to the test solutions.

5.2 The test system shall be capable of reproducing and continuously recording the temperature and pressure profiles of the DBA conditions.

5.3 A sufficient number of thermocouples shall be located in the test chamber to assure conformity to the test curve, and so that both the temperature of the vapor phase and, if required, of the liquid phase (if present) can be recorded.

5.4 The thermocouples and test samples shall be positioned to avoid direct steam and spray impingement.

5.5 The test system shall be capable of allowing test samples to be exposed, as specified by the licensee, to total immersion, to liquid-vapor interface, and to spray.

5.6 **WARNING**—It should be noted that high temperature steam is involved and that appropriate safety measures should be taken to protect personnel operating such equipment.

6. Preparation of Test Samples

6.1 Unless otherwise specified, a minimum of five samples, one of which will be a reference (control) sample that will remain unexposed, shall be required to establish conformance of a given coating system on a given substrate, with two of the remaining four samples being irradiated prior to testing in accordance with Test Method D4082. Typical laboratory test samples are 2 by 4 by ⅛ in. (5.1 by 10.2 by 0.32 cm) for steel panels and 2 by 2 by 4 in. (5.1 by 5.1 by 10.2 cm) for concrete blocks.

6.1.1 *Steel Panels*—Prepare in accordance with Specification D5139 or as specified by the licensee. Ensure that all surfaces, including edges, are coated.

6.1.2 *Concrete Blocks*—Prepare in accordance with Specification D5139 or as specified by the licensee.

6.2 Document the sample preparation for metallic and non-metallic substrates in accordance with the requirements of Specification D5139.

6.3 Document the appearance of the test samples (both original and maintenance coating systems, if applicable) prior to testing by photo documentation or equivalent methods in order to provide a basis for post-test comparison. The testing requirements should indicate if this assessment will be done prior to shipping to the test facility.

7. Procedure

7.1 *Test Parameters:*

7.1.1 Test coatings using the applicable time-temperature-pressure curves identified by the plant design basis. Examples of time-temperature-pressure test curves that have been used to simulate primary containment atmospheres during a DBA are shown in Fig. 1 and Fig. 2. These curves may not bound the time-temperature-pressure curves of newer generation nuclear power plants.

7.1.2 The parameters of the curves may be simulated during testing as continuous functions or as an enveloping stepwise function.

7.1.3 Steam shall be generated from deionized or distilled water. Steam is used initially to achieve the desired thermal shock and to raise the test chamber and its environment to the prescribed test conditions. The temperature of the test chamber

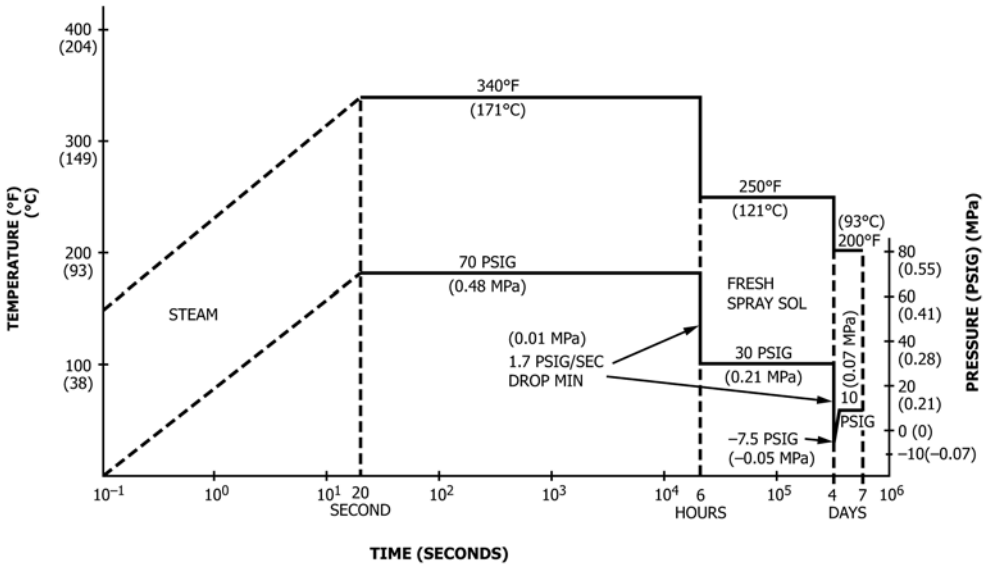

FIG. 1 Example Design Basis Accident (DBA) Testing Parameters (Temperature-Time-Pressure)—BWR Drywell

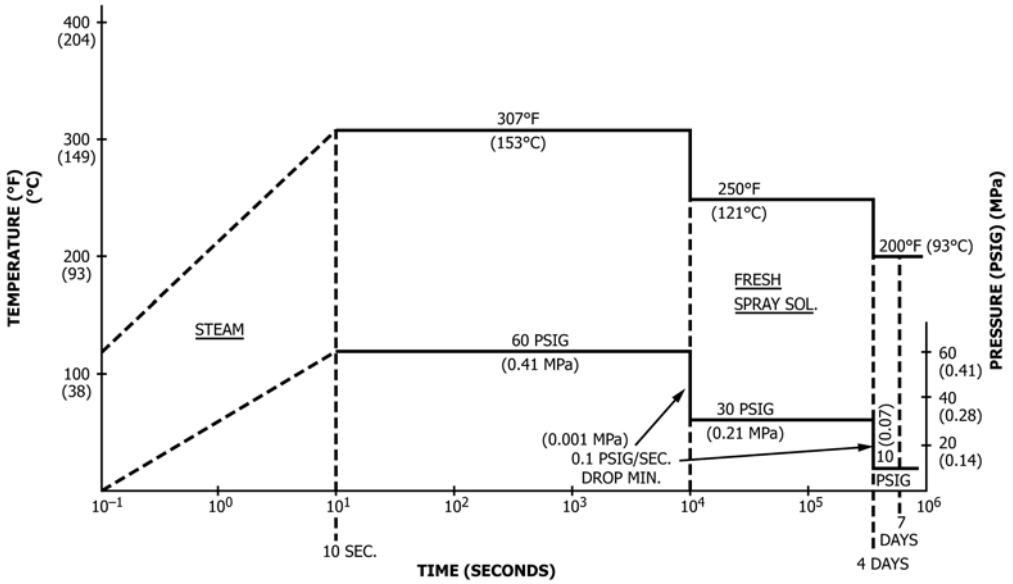

FIG. 2 Example Design Basis (DBA) Testing Parameters (Temperature-Time-Pressure)—PWR Containment

TABLE 1 Typical Spray Solutions

	Composition Chemical Compound	Concentration (in Deionized or Distilled Water)
A	Sodium borate Sodium hydroxide	2000 to 4000 ppm boron adjust solution pH to between 9.0 and 10.0
B	Boric acid Hydrazine Sodium phosphate, dibasic	2000 to 4000 ppm boron 50 ppm unreacted excess adjust solution pH to between 6.8 and 10.0
C	Deionized or distilled water	

is maintained by means of internal or external resistance, or both, heating elements, or other suitable means. The inlet steam shall not impinge directly on the test sample.

7.2 *Spray Solution:*

7.2.1 Unless otherwise specified in the plant design basis, the spray chemistry shall be either Solution A, B, or C as described in Table 1 when testing under simulated DBA conditions.

7.2.2 Record the chemical composition of the spray solution before each test.

7.2.3 The spray solution shall be withdrawn from the bottom of the chamber and recirculated through the spray nozzles.

7.2.4 Fresh spray solution may be added as needed to maintain specified autoclave conditions. If fresh spray solution is added, an equal amount of spray solution shall be removed to maintain the same volume of spray solution in the autoclave when condensate level is to be controlled during the test.

7.2.5 Direct impingement of the spray solution onto the test sample shall be avoided unless otherwise directed by the licensee.

8. Examination and Report

8.1 *Examination:*

8.1.1 Examine and evaluate test samples within 4 h and again after 14 days following removal from the test chamber for the following coating conditions:

8.1.1.1 Delamination.

8.1.1.2 Cracking.

8.1.1.3 Blistering in accordance with Test Method D714.

8.1.2 Unless otherwise instructed, disregard the condition of the edges and plane areas within ¼ in. (6.4 mm) from the edges of the steel or concrete test surfaces, and the top and bottom ends of the concrete blocks.

8.1.3 When directed by the licensee, coated test samples shall be weighed prior to testing and no sooner than 7 days after testing to detect any coating loss.

8.2 *Report*—Report the following information:

8.2.1 The results of the examination and evaluation of each test sample. Report for all sides of concrete blocks and front and back of steel panels.

8.2.2 The extent of each condition from 8.1.

8.2.3 Any observations of unusual appearances.

9. Acceptance Criteria

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.

10. Documentation

10.1 *Testing Procedures*—Document each of the following:

10.1.1 A description of the test apparatus, temperature and pressure profiles, spray solution composition including pH, duration, frequency, and rate of spray solutions, and any other pertinent test conditions.

10.2 *Test Agency:*

10.2.1 The testing agency shall be responsible for the documenting, reporting, and certifying of all tests.

10.2.2 The testing agency shall be responsible for meeting applicable quality assurance requirements.

10.2.3 The testing agency shall be responsible for providing color photographic documentation of the test surfaces as required.

10.2.3.1 Photographs shall reflect the actual size as close as possible of the test samples.

10.2.3.2 As a minimum, photographs of each test sample should be taken before test initiation and in conjunction with the 4-hour and 2-week after DBA testing inspections.

11. Repairability

11.1 Test repair coatings in accordance with the requirements of this standard.

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.

12. Precision

12.1 Calibrated test equipment must have the capability to reproduce the design temperature (±5°F (3°C)) design pressure within (±3 psig) parameters within ±5 seconds of temperature/pressure change.

13. Keywords

13.1 coatings; Coating Service Level I; containment; DBA; design basis accident; LOCA-loss of coolant accident; nuclear

APPENDIXES

(Nonmandatory Information)

X1. COATINGS DEBRIS AND CONDENSATE ANALYSIS

X1.1 Users of this test method should consider collection and analysis of any residues remaining in the autoclave chamber and associated piping. These residues (soluble and non-soluble) are representative of coatings debris which might be produced in primary containment during an actual DBA (LOCA) event. Coatings debris, in combination with fibrous debris, has been shown in certain instances to result in degradation (clogging) of ECCS suction strainers and potentially to adversely affect downstream equipment by abrasion and/or wear (commonly referred to as “downstream effects”).

Particulate coatings debris has been collected in DBA testing using this test method by installation of 10 μm filtration in the autoclave recirculation spray piping. Chemical (soluble) debris produced by dissolution of coating components during DBA testing has been detected by chemical analysis of the condensate remaining in the autoclave after test completion.

X2. WITNESS COUPONS IN PRIMARY CONTAINMENT

X2.1 Users of this test method involved in design and construction of new nuclear power plants should consider installation of coated “witness panels” at various locations in primary containment. This practice has been used by Electricité de France (EdF) in many of its nuclear power plants.

The coated “witness panels” would be representative of the aged condition of the similar coatings on permanent systems, structures and components within the primary containment of a given nuclear power plant. The “witness panels” could be used for coating condition analysis and aging studies during the commercial life of the nuclear power plant.