Designation: D 3911 – 03

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 D 3911; 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 The values stated in inch-pound and degrees F units are to be regarded as the standard. The SI values given in parentheses are for information only.

1.3 *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:*

D 714 Test Method for Evaluating Degree of Blistering of Paints[2]

D 1193 Specification for Reagent Water[3]

D 4082 Test Method for Effects of Radiation on Coatings Used in Light-Water Nuclear Power Plants[4]

D 4538 Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities[4]

D 5139 Specification for Sample Preparation for Qualification Testing of Coatings to be Used in Nuclear Power Plants[4]

D 5144 Guide for Use of Protective Coating Standards in Nuclear Power Plants[4]

3. Terminology

3.1 *Definitions*—Definitions for use with this standard are shown in Terminology D 4538 or other applicable standards.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *blistering*—the formation of bubbles in a coating (paint) film.

3.2.2 *chemical spray*—a solution of chemicals, such as those contained in Table 1, which could be used during a DBA to suppress the incident, to scavenge fission products, and to return the facility to near-ambient pressure and temperature conditions.

3.2.3 *coating system*—a protective film consisting of one or more coats applied in a predetermined order by prescribed methods to a defined substrate.

3.2.4 *coating service Level 1*—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.

3.2.5 *curing*—the transformation of a coating or other material into a solid phase or film such as through chemical reaction, heat, evaporation, or hydrolysis.

3.2.6 *design basis accident (DBA)*—a generic term for any one of a family of accident conditions which can result from postulated events. The more commonly recognized accident

[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] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

TABLE 1 Typical Spray Solutions

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

conditions used to evaluate coating systems for primary containment are the loss of coolant accident (LOCA) and main steam pipe break.

3.2.7 *deionized water*—water prepared by an ion exchange process meeting the requirements of Specification D 1193, Types II and III.

3.2.8 *delamination*—separation of one coat from another coat in a coating system (adhesion), or within a coat (cohesion), or from the substrate (adhesion).

3.2.9 *engineered safety system*—a system designed to mitigate the effects of a DBA.

3.2.10 *irradiation*—exposure to ionizing radiation.

3.2.11 *light-water nuclear reactor*—an apparatus, using light water as a moderator, in which fissionable material is arrayed so that controlled nuclear fission may be sustained in a self-supporting chain reaction.

3.2.12 *LOCA*—the specific conditions anticipated following a loss of coolant accident that would expose the coated surface of the containments of a light-water nuclear power facility to the temperature-pressure-radiological environmental parameters described.

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 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.

5. Apparatus

5.1 *Environmental Test Chamber*, constructed of materials that are corrosion-resistant to the test solutions.

5.2 The equipment 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 specimens shall be positioned to avoid direct steam impingement.

5.5 The equipment shall be constructed so as to allow test specimens to be exposed to total immersion, to liquid-vapor interface, and to spray as appropriate.

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 Specimens

6.1 Determine the appearance of the test panels 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.

6.2 Unless otherwise specified, a minimum of four samples shall be required to establish conformance of a given coating system on a given substrate, with two of the four samples being irradiated prior to testing in accordance with Test Method D 4082. Typical laboratory test specimens 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.

6.2.1 *Steel Panels*—Prepare in accordance with Specification D 5139 or as necessary to duplicate actual conditions.

6.2.2 *Concrete Blocks*—Prepare in accordance with Specification D 5139 or as necessary to duplicate actual conditions.

7. Procedure

7.1 *Test Parameters*:

7.1.1 Test coatings using the applicable time-temperature-pressure curves identified by the license holder. Illustrations 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.

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 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 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 specimen. The duration of steam injection should be minimized, as much as feasible, and the duration shall be recorded.[5]

7.2 *Spray Solution*:

7.2.1 Unless otherwise specified, use deionized water 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.

[5] Where the inlet steam temperatures exceed 370°F, (188°C), initial steam injection shall be no longer than 15 min.

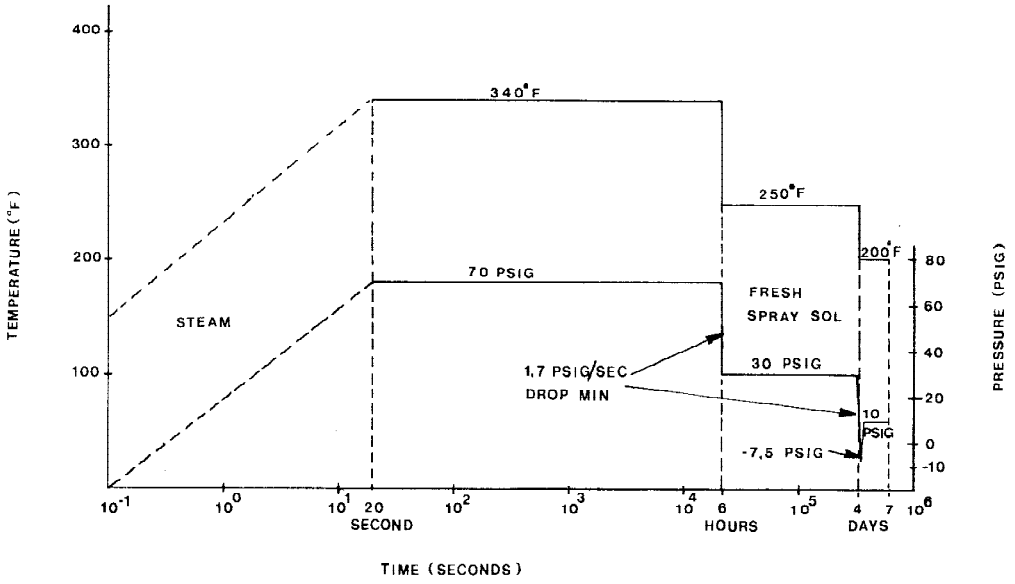

FIG. 1 Typical Design Basis Accident (DBA) Testing Parameters (Temperature-Time-Pressure)—BWR Drywell

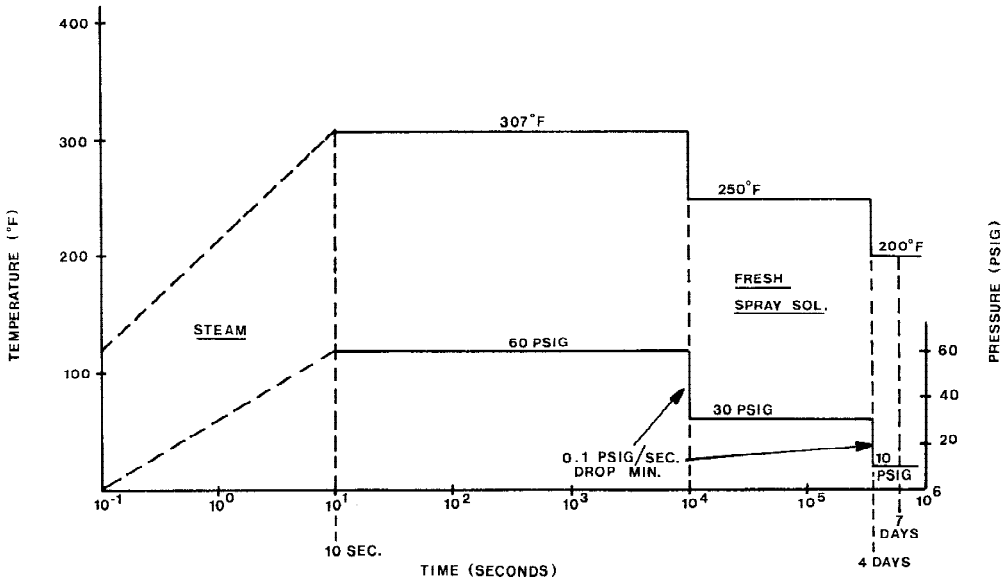

FIG. 2 Typical Design Basis (DBA) Testing Parameters (Temperature-Time-Pressure)—PWR Containment

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.

8. Examination and Report

8.1 *Examination*:

8.1.1 Examine and evaluate test specimens 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 D 714.

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

8.2 *Report*—Report the following information:

8.2.1 The results of the examination and evaluation of each test specimen. 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 license holder shall review the report generated in 8.2 for coating acceptability. The license holder 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 specimens.

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 Test equipment must be demonstrated to have the capability to reproduce the design time/temperature parameters within ±0 s and ±5°F (3°C) and the design pressure within ±3 psig. In any test where the test equipment imposes variances in the pressure/temperature parameters that are outside this range, an analysis of the validity of these test results should accompany the test data.

13. Keywords

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