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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 design basis accident (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 incident, to scavenge radioactive products, and to return the containment to near-ambient 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, conditions for radiation testing, and procedures for preparing, examining, and evaluating the samples.

1.2 The values stated in inch-pound units are to be regarded as the standard. The 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 4082 Test Method for Effects of Radiation on Coatings Used in Light-Water Nuclear Power Plants[3]

D 5139 Specification for Sample Preparation for Qualification Testing of Coatings to be Used in Nuclear Power Plants[3]

3. Terminology

3.1 *Definitions:*

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

3.1.2 *boiling water reactor (BWR)*—a reactor in which the water moderator-coolant is boiled directly within the reactor core. The pressure in the reactor vessel is only slightly greater than the steam turbine pressure.

3.1.3 *chemical spray*—a solution of chemicals, such as those contained in Table 1, which could be used during a loss of coolant accident (LOCA) to suppress the incident, to scavenge fission products, and to return the facility to near-ambient conditions.

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

3.1.5 *cracking*—a break or a split in the coating (paint) system extending through the film or to the substrate.

3.1.6 *curing*—the transformation of a coating or other material into a solid phase or film.

3.1.7 *DBA*—a generic term for any one of a family of accident conditions which can result from postulated events. These conditions are generally associated with the rupture of high energy piping. The more commonly recognized accident conditions used to evaluate coating systems for primary containment are the LOCA or main steam pipe break.

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

3.1.9 *delamination*—separation of one coat or layer from another coat or layer, or from the substrate.

3.1.10 *engineered safety system*—a system designed to mitigate the effects of a design basis accident.

3.1.11 *irradiation*—exposure to ionizing radiation.

3.1.12 *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

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

[3] *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

self-supporting chain reaction.

3.1.13 *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 environmental parameters described.

3.1.14 *peeling*—separation of one or more coats or layers of a coating from the substrate.

3.1.15 *pressurized-water reactor (PWR)*—a nuclear power reactor design utilizing liquid water under high pressure as moderator-coolant.

3.1.16 *quality assurance*—the verification of the conformance of materials and methods of application to the governing specifications, in order to achieve the desired result.

3.1.17 *reactor containment (containment)*—the enclosure provided to protect the environment from the consequences of a nuclear incident.

4. Significance and Use

4.1 This test method is designed to provide a uniform test to determine the suitability of coatings used inside primary containment of light-water nuclear facilities under simulated DBA conditions. Variations in actual surface preparation and in application and curing of the coating materials may require additional testing as deemed necessary by the specifying or qualifying agency, or both, if it is anticipated that the variations may adversely affect the performance of the coating system during a DBA. This test method is intended only to demonstrate that under DBA conditions, the coatings will remain intact and not become debris which could compromise engineered safety systems.

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 of the liquid phase (if present) can be recorded.

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 curves from the latest Safety Analysis Report (SAR) identified by the owner for the specific containment. Illustrations of time-temperature-pressure test curves that simulate primary containment atmospheres during a DBA are shown in Fig. 1 and Fig. 2.

7.1.2 The curves depicted in Fig. 1 or Fig. 2 may be used if they represent conditions equal to or more severe than those DBA conditions anticipated.

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

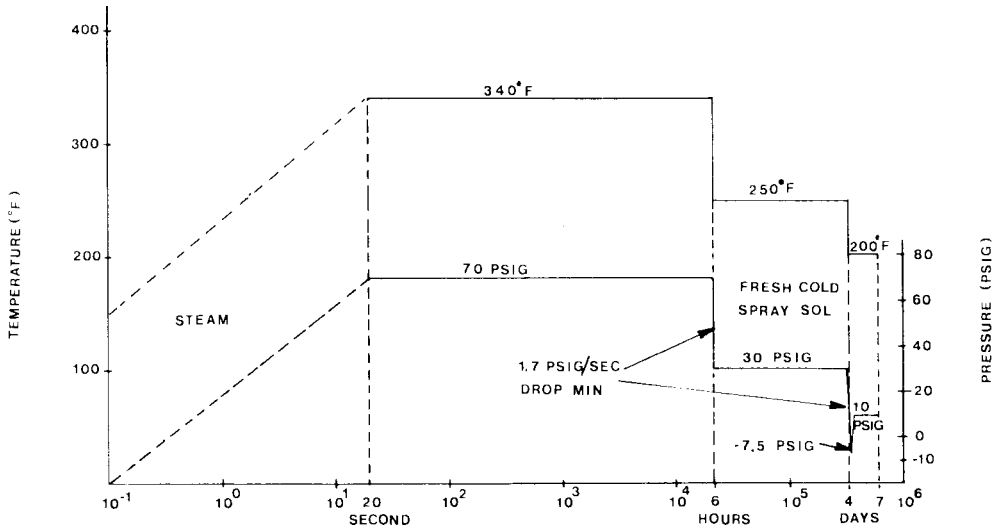

FIG. 1 Typical Design Basis Accident (DBA) Testing Parameters (Temperature-Time-Pressure)—BWR Drywell

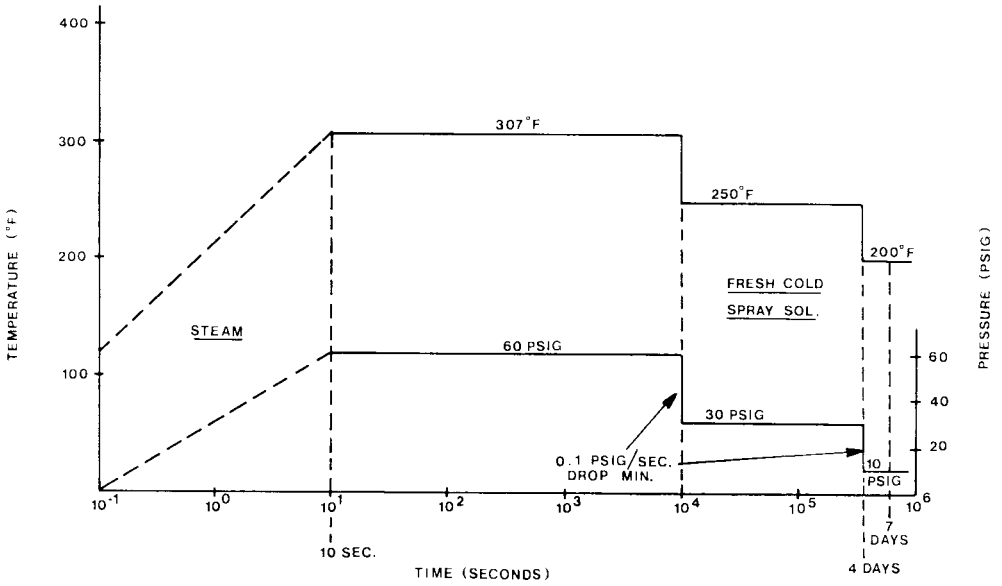

FIG. 2 Typical Design Basis (DBA) Testing Parameters (Temperature-Time-Pressure)—PWR Containment

7.1.4 Steam is used initially to achieve the desired thermal shock and to raise the test chamber and its environment to the prescribed test conditions. After equilibrium is achieved, 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 impringe directly on the test specimen. The duration of steam injection should be minimized, as much as feasible, and the duration shall be recorded. Where inlet steam temperatures exceed 370°F, (188°C) initial steam injection shall be no longer then 15 min.

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. Circulation should start after the first pressure drop.

7.2.4 Make sure that the fresh cold spray solution shown in Fig. 1 and Fig. 2 (pressure drops) is at 70 to 80°F (21.1 to 26.7°C) unless otherwise specified.

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 defects:

8.1.1.1 Delamination and peeling.

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 ¼ in. (6.4 mm) from the edges of the steel or concrete test surfaces, and the top and bottom ends of the concrete surfaces.

8.2 *Report*—Report the following information:

8.2.1 The results of the 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 defect from 8.1. Report “none” if no defects are present.

8.2.3 Any observations of unusual appearances.

9. Acceptance Criteria

9.1 Peeling shall not be permitted.

9.2 Delamination shall not be permitted.

9.3 Cracking is not considered a failure unless accompanied by delamination or loss of adhesion.

9.4 Blisters shall be limited to intact blisters that are completely surrounded by sound coating bonded to the surface.

9.5 An owner may establish acceptance criteria more stringent than above. The above criteria are meant to establish minimum standards only.

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 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.

11.3 Significant areas shall be determined by the specifying or qualifying agency. Nonsignificant areas have been determined as being less than 2 ft^2 (0.19 m^2) in an approximate 2000 ft^2 (185.8 m^2) area; larger areas require a decision regarding significance.

12. Precision

12.1 Test equipment must be demonstrated to have the capability to reproduce the design time/temperature parameters within± 10 s and ±5° F 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; containment; DBA; design basis accident; LOCA-loss of cooling accident; nuclear