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Standard Guide for Evaluating Polymeric Lining Systems for Water Immersion in Coating Service Level III Safety-Related Applications on Metal Substrates[1]

This standard is issued under the fixed designation D7230; 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.

1. Scope

1.1 This guide establishes procedures for evaluating lining system test specimens under simulated operating conditions.

1.2 Lining systems to be tested in accordance with this guide are intended for use in both new construction and for refurbishing existing systems or components.

1.3 The lining systems evaluated in accordance with this guide are expected to be applied to metal substrates comprising water-wetted (that is, continuous or intermittent immersion) surfaces in systems that may include:

1.3.1 Service water piping upstream of safety-related components,

1.3.2 Service water pump internals (draft tube, volutes, and diffusers),

1.3.3 Service water heat exchanger channels, pass partitions, tubesheets, end bells, and covers,

1.3.4 Service water strainers, and

1.3.5 Refueling water storage tanks and refuel cavity water storage tanks.

1.4 This guide anticipates that the lining systems to be tested include liquid-grade and paste-grade polymeric materials. Sheet type lining materials, such as rubber, are excluded from the scope of this guide.

1.5 Because of the specialized nature of these tests and the desire in many cases to simulate to some degree the expected service environment, the creation of a standard practice is not practical. This standard gives guidance in setting up tests and specifies test procedures and reporting requirements that can be followed even with differing materials, specimen preparation methods, and test facilities.

1.6 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.

1.7 *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 to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

C868 Test Method for Chemical Resistance of Protective Linings

D115 Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation

D714 Test Method for Evaluating Degree of Blistering of Paints

D2240 Test Method for Rubber Property—Durometer Hardness

D2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

D2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

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

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

D5144 Guide for Use of Protective Coating Standards in Nuclear Power Plants

[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] 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.

D6677 Test Method for Evaluating Adhesion by Knife
D7167 Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant
E96/E96M Test Methods for Water Vapor Transmission of Materials
G14 Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)
G42 Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures

2.2 *Federal Standards*[3]

EPA Method 415.1 Total Organic Carbon in Water

2.3 *NACE International*[4]

RP0394 Application, Performance and Quality Control of Plant-Applied, Fusion Bonded External Pipe Coating
TM0174 Laboratory Methods for the Evaluation of Coating Materials and Lining Material on Metallic Substrates in Immersion Service
TM0404 Offshore Platform Atmospheric and Splash Zone New Construction Coating System Evaluation

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 In addition to the following terms, general terms applicable to this standard are found in Terminology D4538.

3.1.2 *cladding, n*—a thick coating system comprised of a liquid-grade prime coat, a paste-grade intermediate build coat, and a liquid-grade finish coat.

3.1.2.1 *Discussion*—This system is typically applied as a lining to heat exchanger tubesheets and as a repair material in localized areas of metal loss (for example, pump impeller cavitation, pipe wall corrosion) to restore surface contour. A modified (that is, thinner) cladding may be used on the warmer side of heat exchanger pass partitions to prevent "cold wall" blistering.

3.1.3 *Coating Service Level III (CSL III), n*—areas outside the reactor containment where lining (or coating) failure could adversely affect the safety function of a safety-related structure, system, or component (SSC).

3.1.3.1 *Discussion*—This definition is consistent with that found in Guide D5144.

3.1.4 *cold wall effect, n*—propensity for a fluid or vapor to permeate into/through a lining applied to the warmer side of a substrate that serves as a boundary between warmer and cooler fluids.

3.1.5 *lining, n*—particular type of coating intended for protection of substrates from corrosion as a result of continuous or intermittent fluid immersion.

3.1.5.1 *Discussion*—The normal operating service environments to which linings are subject are aggressive. As such, material and application process parameters are specialized and require exacting quality control measures.

3.1.6 *liquid-grade, adj*—lining material that is liquid when mixed and applied.

3.1.6.1 *Discussion*—Liquid-grade polymeric lining materials are typically used as prime and finish coats in a lining system.

3.1.7 *paste-grade, adj*—lining material that, when mixed, results in a paste-like material that is often applied by trowel or squeegee.

3.1.7.1 *Discussion*—Paste-grade polymeric lining materials are often used as the build coat in a lining system and are always incorporated in a cladding system. In addition to imparting thickness and impact resistance, the paste-grade build coat material has the ability to restore an extensively corroded surface to a relative smooth condition by filling corrosion-induced surface porosity, pits, and depressions.

3.1.8 *service water, n*—that water used to cool power plant components or extract heat from systems or components, or both.

3.1.8.1 *Discussion*—Cooling/heat extraction is generally accomplished via heat exchangers, fan coolers, or chillers. Service water may be raw water or water chemically treated to retard corrosion. Service water systems are distinct and separate from the circulating water system used to extract waste heat from the main steam surface condenser.

4. Summary of Guide

4.1 The objectives of the testing set forth in this guide are to evaluate a CSL III lining system's ability to:

4.1.1 Prevent corrosion and erosion of the metallic materials of construction and

4.1.2 Remain intact during design basis conditions.

4.2 *The Tests Outlined Comprise Two Distinct Phases:*

4.2.1 *Phase 1*—Phase 1 includes two primary assessments and certain additional related physical testing. The Phase 1 tests are considered essential to the objective of developing a test database that can be used to rank and otherwise compare candidate-lining systems.

4.2.1.1 *Permeability Testing*—Defined thicknesses of liquid and paste-grade polymeric lining materials are tested to assess their relative imperviousness.

4.2.1.2 *Test (Atlas) Cell "Conditioning" Followed by Destructive Testing*—Test specimens representing thinner and thicker film candidate lining systems are "conditioned" by exposure to test conditions replicating water immersion environments that produce a temperature gradient across the specimen (that is, "cold wall" conditions). Following conditioning, the test specimens are tested for impact resistance, flexibility, adhesion, and hardness.

4.2.2 *Phase 2*—Phase 2 includes additional destructive tests. Phase 2 testing is intended to provide additional performance data that can be used to refine the lining selection process. For instance, Phase 1 tests may be used to evaluate a relatively broad array of candidate materials. Once the field of candidate systems is narrowed via Phase 1 testing, Phase 2 tests can be used to fine-tune the system selection process.

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

[4] Available from NACE International (NACE), 1440 South Creek Dr., Houston, TX 77084-4906, http://www.nace.org.

5. Significance and Use

5.1 Safety-related service water system (SWS) components are designed to provide adequate cooling to equipment essential to the safe operation and shutdown of the plant. Linings in these systems are installed to maintain the integrity of the system components by preventing corrosion and erosion of the metal materials of construction. Linings on SWS surfaces upstream of components, including heat exchangers, orifice plates, strainers, and valves, the detachment of which may affect safe-plant operation or shutdown, may be considered safety-related, depending on plant-specific licensing commitments and design bases.

5.2 The testing presented in this guide is used to provide reasonable assurance that the linings, when properly applied, will be suitable for the intended service by preventing corrosion and erosion for some extended period of time. Additionally, the test data derived allows development of schedules, methods, and techniques for assessing the condition of the lining materials (see Guide D7167). The ultimate objective of the testing is to avoid lining failures that could result in blockage of equipment, such as piping or heat transfer components, preventing the system or component from performing its intended safety function.

5.3 It is expected that this guide will be used by:

5.3.1 Lining manufacturers for comparing specific products and systems and to establish a qualification basis for recommended linings and

5.3.2 End users seeking a consistent design basis for candidate coating systems.

5.4 In the event of conflict, users of this guide must recognize that the licensee's plant-specific quality assurance program and licensing commitments shall prevail with respect to the selection process for and qualification of CSL III lining materials.

5.5 Operating experience has shown that the most severe operating conditions with respect to heat exchanger linings occur on pass partitions. A phenomenon known as the "cold wall effect" accelerates moisture permeation through a coating applied to the warmer side of a partition that separates fluids at two different temperatures. The thickness and permeability of the lining are key variables affecting the ability of a lining to withstand cold wall blistering.

5.5.1 This effect is particularly pronounced when the separated fluids are water, though the effect will occur when only air is on the other side, for example, an outdoor tank filled with warm liquid. A heat exchanger pass partition represents geometry uniquely vulnerable to the water-to-water maximized temperature differentials (ΔTs) that drive the cold wall effect.

5.5.2 Pass partitions separate relatively cold incoming cooling water from the discharge water warmed by the heat exchanger's thermal duty. Improperly designed coatings will exhibit moisture permeation to the substrate accelerated by the cold-wall effect. Many instances of premature pass partition warm-side blistering have been noted in the nuclear industry. Such degradation has also been seen on lined cover plate and channel barrel segments that reflect water-to-air configurations.

5.6 Large water-to-water ΔTs are known to be the most severe design condition. The test device used to replicate ΔT configurations is known as an "Atlas cell." Atlas cell testing is governed by industry standard test methodologies (Test Method C868 and NACE TM0174). A lining proven suitable for the most severe hypothesized ΔT would also be suitable for service on other waterside surfaces.

5.7 Plant cooling water varies in composition and temperature seasonally. For purposes of standardization, demineralized water is used in Atlas cell exposures rather than raw plant water. It is generally accepted in polymeric coatings technology that low-conductivity water (deionized or demineralized) is more aggressive with respect to its ability to permeate linings than raw water. Thus, stipulating use of low-conductivity water as the test medium is considered conservative.

6. Reagents

6.1 Unless otherwise indicated in the project-specific test instructions or under a particular test method described hereinafter:

6.1.1 Reagent water used in conjunction with permeability tests and Atlas cell exposures should have a maximum conductivity of 1.0μ S/cm.

7. Procedure

7.1 The user of this guide is expected to invoke only those tests that are applicable. Refer to Table 1. A test specification should be developed to indicate the particular tests to be used. The test specification should include details on the lining systems to be evaluated.

7.2 For plant-specific applications, design and operating parameters will need to be reviewed. On the basis of that review, the site-specific design objectives for testing can be defined. Test parameters based on water temperatures and ΔTs more severe than the plant-specific normal and upset conditions might also be allowed. The test specimen should replicate the anticipated plant-specific substrate condition to the extent practicable (for example, new, corroded, etc.).

7.3 *Steel Test Specimens*—Duplicate test specimens should be provided fabricated from hot-rolled mild carbon steel conforming to Specification A36/A36M. Thickness and other dimensions are stipulated for each specific test referenced herein.

7.4 *Product Information and Characterization*—Each batch of each component of the lining materials to be used for testing described herein should be identified and "fingerprinted" by means of the data and testing described in Section 3.2 of NACE TM0404, which includes Fourier transform infrared (FTIR) analysis. FTIR testing should be per method #4A of NACE TM0404, that is, the attenuated total reflection method for pigmented samples. Testing should be performed by a laboratory approved by the organization for which the testing is being conducted. Fingerprinting results should be traceable to the respective batch number of each tested component.

TABLE 1 Matrix of Testing Requirements

					Phase 1 Tests									Phase 2 Tests		
Description	FTIR[A]	Permeability E96/ E96M, Procedure BW[B]	Atlas Cell Air-to-Water C868[B]	Atlas Cell Water-to-Water C868[B]	AC Impedance Air-to-Water	AC Impedance Water-to-Water	TOC EPA 415.1	Reverse Impact D2794[B]	Flex NACE RP 0394[B]	Adhesion D4541[B] or D6677	Hardness D2583 or D2240[C]	Cathodic Disbondment G42[D]	Dielectric Strength D115[D]	Radiation Resistance D4082[D]	Direct Impact G14[D]	Abrasion Resistance D4060[D]
Liquid-Grade		X 20 mils										X	X			X
Paste-Grade		X 20 mils										X	X			X
Thinner Film System ≤25 mils	X		X	X	X	X		X	X	X				X	X	
Thicker Film System >25 mils	X		X	X	X	X		X	X	X				X	X	
Each Test Cell Solution							X									

[A] FTIR – Fourier Transform Infrared (spectroscopy).
[B] As modified in accordance with Section 8.
[C] Perform on all water-exposed faces.
[D] As modified in accordance with Section 9.

8. Phase 1 Tests

8.1 *Permeability*—The permeability of the polymeric lining materials should be determined in accordance with Test Method E96/E96M, Procedure BW, modified as follows:

8.1.1 Liquid-grade and paste-grade polymeric lining materials should be tested separately.

8.1.2 The thickness for each type of material should be the intended thickness as defined by the lining manufacturer or the project specifications. Suggested film thicknesses are presented in Table 1. Since test results are reported per unit of thickness, actual test thickness is not considered critical.

8.2 *Immersion Environment Testing*—Test specimens of the lining material should be conditioned in an Atlas cell immersion environment to evaluate the lining material when exposed to immersion service at a stipulated temperature. Both water-to-air and water-to-water heat transfer configurations should be replicated in the test. The evaluation should include visual examination, flex testing, reverse impact testing, adhesion testing and hardness assessment. Test specimen exposure should be performed in accordance with Test Method C868, modified as follows:

8.2.1 At the discretion of the organization responsible for the test program, immersion test panels may be pre-irradiated in accordance with 9.3.

8.2.2 The Atlas cell test duration should be 180 days with interruption at 30-day intervals for examination of the test panels. Exposure should be terminated prior to 180 days if the lining has degraded to the extent that it is on longer viable for the testing described below.

8.2.3 Test panels should be 8 in. (20 cm) square by ⅛-in. (3-mm) thick carbon steel plates. Each panel should be uniquely identified for traceability throughout testing and examination. Panel identification should indicate the following:

8.2.3.1 The top (vapor phase) and bottom (liquid phase) halves of the panel should be differentiated by marking.

8.2.3.2 For those panels exposed to water on both sides, the side exposed to the cooler and warmer water should be differentiated by marking.

8.2.4 Typical Atlas cell configurations are presented in Fig. 1 and Fig. 2. Each Atlas cell should be fitted with the necessary probes and electrodes to evaluate the performance of the lining materials using alternating current (AC) impedance techniques. The Atlas cells shown schematically in Fig. 1 and Fig. 2 involve a single test panel. Combined configurations that accommodate multiple panels may be used. An Atlas cell diameter of at least 5 in. (13 cm) should be used.

8.2.5 When applicable to the intended service condition, the test solution should be constantly agitated with air bubbling as described in Test Method C868.

8.2.6 Test panels of both thinner (for example, ≤25 mils (0.6 mm)) and thicker (for example >25 mils (0.6 mm)) lining systems should be tested. The thinner lining system includes one or more coats of liquid-grade materials. The thicker lining system may also include paste-grade materials. Surface preparation and application of lining materials should be in accordance with the lining manufacturer's instructions and the requirements of the test specification. Panel preparation and lining material application should be fully documented in accordance with Specification D5139.

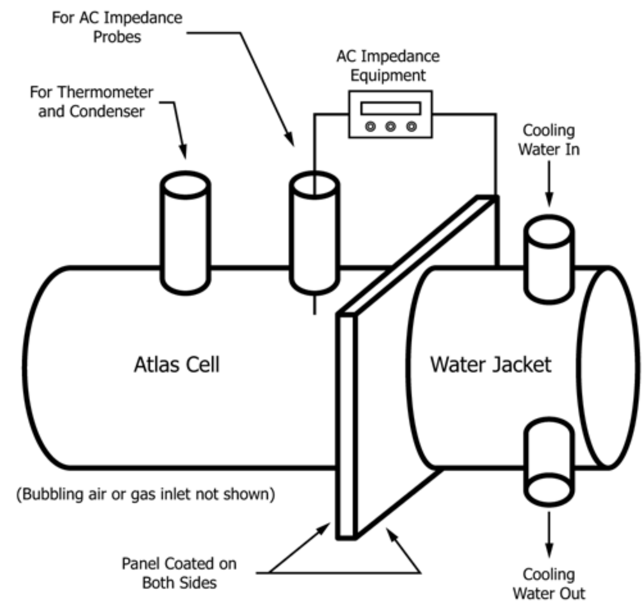

FIG. 1 Atlas Cell—Water to Water

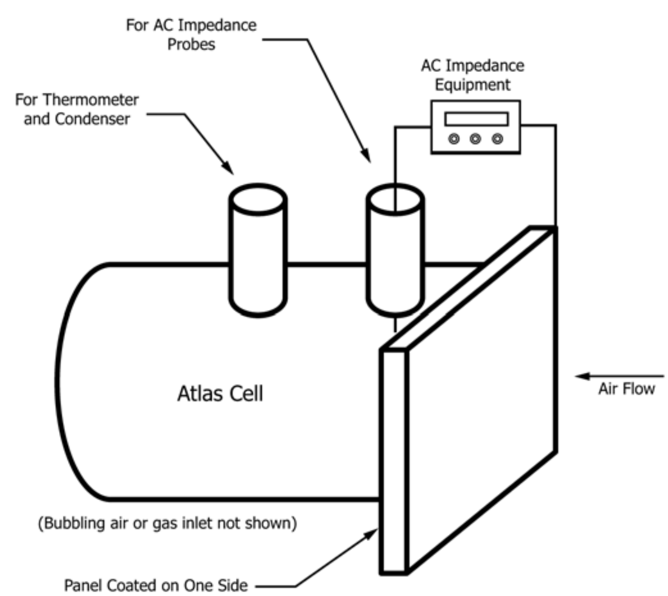

FIG. 2 Atlas Cell—Air to Water

8.2.6.1 For water-to-air testing, the applied lining should be on one side only (the side ultimately exposed to the cell environment). The other side of the panel should be unlined in accordance with Test Method C868.

8.2.6.2 For water-to-water testing, both sides of the panel should be coated with the same system and thickness or as stipulated by the test specification. Different thicknesses on the test plate may influence lining performance in a cell exposure.

8.2.7 Before installation onto the Atlas cell, each panel should be photographed.

8.2.8 The temperature of the solution within the Atlas cell should not exceed 120 ± 4ºF (48.9 ± 2.2ºC). The air-to-water interface differential temperature should be 50 ± 4ºF (10 ±

2.2°C) with the air temperature being at the cooler temperature. The water-to-water interface differential temperature should be 80 ± 4°F (26.7 ± 2.2°C).

8.2.9 The number of required test panels will be dependent upon the scope of the test program. Each test described in the following sections should be carefully reviewed to determine the number of test panels that will be required to allow proper testing. Certain tests such as the flex test will deform the test specimen or damage the lining, or both, thereby preventing other physical tests on that panel.

8.3 *AC Impedance Testing:*

8.3.1 AC impedance measurements should be made initially upon start of the Atlas cell test exposure. Subsequent measurements, at a minimum, should be taken at days 1, 2, 4, and 7 after start of the test exposure and then weekly thereafter until the 30-day examination described in 8.4.

8.3.2 The AC impedance measurement frequency described above should be repeated after each time the solution is replaced in the Atlas cell.

8.3.3 Results of this test method are intended for comparative purposes.

8.4 *Periodic Assessment and Evaluation:*

8.4.1 At 30-day intervals, visually evaluate the exposed surfaces in accordance with Test Method C868.

8.4.2 The outline of the Atlas cell perimeter (outer diameter of flange) should be marked on each test panel with a permanent marker immediately upon disassembly.

8.4.3 The extent of blistering should be determined in accordance with Test Method D714. The total blistered area of each thinner film and thicker film surface also may be measured by quantitative image analysis (QIA).

8.4.4 The lining film should not be marked or disturbed by the visual examination.

8.4.5 The condition of each panel should be photographically recorded.

8.4.6 A sample of the solution should be analyzed for total organic carbon (TOC) in accordance with EPA Method 415.1.

8.5 *Flex Testing:*

8.5.1 Flex testing should be performed following Atlas cell "conditioning." The specimens to be tested should be made by cutting the cell-exposed plate into two separate pieces along the liquid-to-vapor phase interface (marking will have been used to differentiate between the two zones). The plate first should be scored to produce a kerf through the coating using a high speed bit (for example, a router with a guide " fence") to minimize saw trauma.

8.5.2 Each test panel section should be force dried in accordance with Fig. 3 and then allowed to stand at room temperature for 24 h. After drying, the panels should be subjected to flex, reverse impact, adhesion, and hardness testing as described in sections 8.5.3 through 8.8.

8.5.3 Each panel section should be flex tested in accordance NACE RP0394, Appendix H, Procedure B; Four-Point Bend. Reference in that NACE standard to specimen dimensions, freezer cooling and sub-freezing bending do not apply. The flexed panels should be inspected in accordances with Section H4.3.4 of NACE RP0394. Determine and record the deformation strain in accordance with Section H4.4 thereof. Flex testing should be performed on each test panel section.

8.5.4 For test panels lined on both sides, the panel should be oriented so that the side that was exposed to the warmer water is subject to tensile stress when the test specimen is loaded.

8.5.5 Section H4.3.2 of NACE RP0394 applies when bending specimens coated on one side only.

8.5.6 After completion of flex testing, the lining should be forcibly removed from the cell-exposed area of the panel section. A hammer and chisel or other suitable tools should be used to produce a cleavage between the lining and the panel surface.

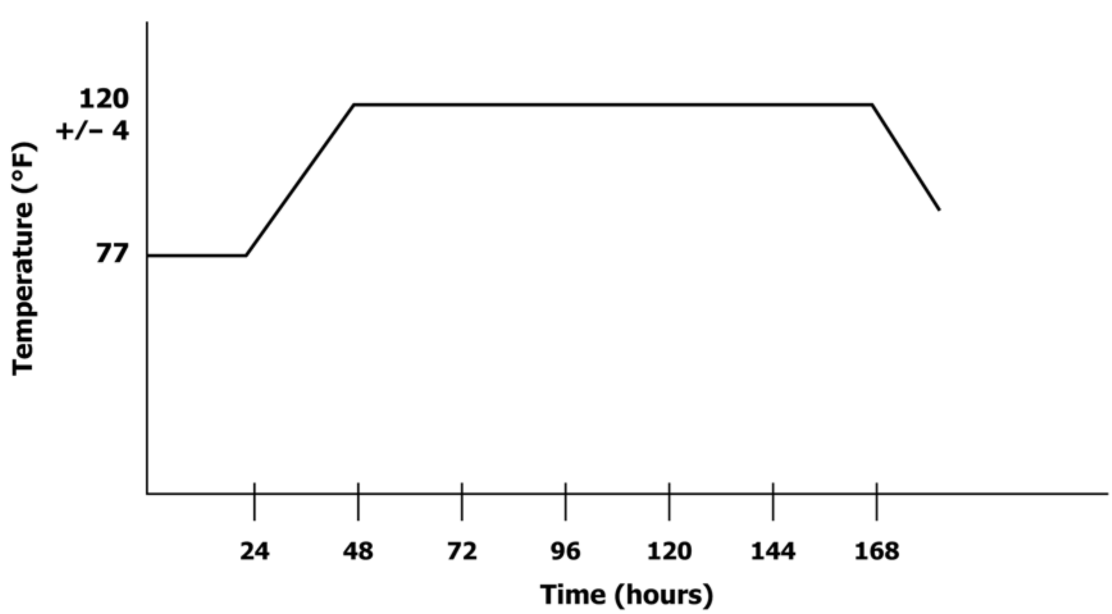

FIG. 3 Lining Force Drying Temperature/Time Curve

8.5.7 The backside of the removed lining and the exposed metal surface should be examined for evidence of corrosion appearing as " leopard spots." All observed conditions should be photographed at 1 and 20× magnifications.

8.6 *Reverse Impact Testing*—Reverse impact testing should be performed on a cell-exposed test panel. An equal number of tests should be performed on the vapor and liquid phases. Reverse impact testing should be in accordance with Test Method D2794, modified as follows:

8.6.1 For test panels used in water-to-water cell exposure and lined on both sides, the lining should be removed locally from the side exposed to the cooler water at the intended impact point(s) over an area sufficiently large to accommodate the punch guide flush with the test panel.

8.6.2 The indenter punch should be 0.625-in. (1.6-cm) diameter.

8.6.3 Baseline reverse impact testing should be performed on a portion of the panel outside of the cell exposed zone.

8.6.4 A minimum of three test values should be obtained in each area.

8.7 *Adhesion Testing*—Adhesion testing should be performed on the vapor and liquid phases. Adhesion testing should be performed in accordance with Test Method D4541 or D6677. When Test Method D4541 is used, it should be modified as follows:

8.7.1 Adhesion testing should be performed using a Type III or V self-aligning adhesion tester. These devices are suited to the relatively small fixture bearing surface available on the sectioned, cell-exposed specimens.

8.7.2 The lining should be pre-scored around the area where the adhesion test dolly will be affixed in accordance with Test Method D4541.

8.7.3 Each test pull should be continued until the bond between the dolly and the panel is broken. A minimum of three adhesion test pulls should be performed on each test panel.

8.7.4 The test results should characterize the percentage of the dolly face representing cohesive and adhesive failure, respectively.

8.8 *Hardness Testing*—Hardness testing should be performed on both the liquid and vapor phase portions of the test panels.

8.8.1 Hardness testing should be performed in accordance with Test Method D2583 (Barcol impressor) or Test Method D2240 (durometer), or any of the hardness tests indicated in Test Method C868.

8.8.2 Baseline hardness testing should be performed on a portion of the panel outside of the cell exposed zone.

8.8.3 When the test panel is used for multiple tests, such as impact and adhesion testing, the amount of surface within the cell exposure area available for assessing hardness will be limited (see 8.2.9). The test panel surface should be visually examined to ensure that impressor contact is at non-disturbed portions of the lining.

9. Phase 2 Tests

9.1 *Cathodic Disbondment*—A lining material's resistance to cathodic disbondment should be determined in accordance with Test Method G42, modified as follows:

9.1.1 Flat, ⅛-in. (0.3-cm) thick carbon steel plates coated on both sides and at the edges can be used in lieu of pipe at the discretion of the organization responsible for the testing program. Triplicate specimens should be used.

9.1.2 The thickness for the thinner liquid-grade lining material should be ≤25 mils (0.6 mm).

9.1.3 The thickness for the thicker lining system should be ≥25 mils (0.6 mm). Include paste-grade material if applicable.

9.1.4 The test should be conducted at a water temperature of 130 ± 4ºF (54.4 ± 2.2ºC).

9.1.5 The test duration should be 30 days for the first of the triplicate specimens, 60 days for the second specimen, and 90 days for the third.

9.2 *Dielectric Strength*—The lining material's dielectric strength should be determined in accordance with Test Methods D115, modified as follows:

9.2.1 Liquid- and paste-grade materials should be tested separately.

9.2.2 The lining materials should be tested on a copper substrate.

9.2.3 Any suitable means of applying a lining film of reasonably uniform thickness is acceptable. The dry film thickness limitations of Test Methods D115 are not required.

9.3 *Radiation Resistance*—The polymeric lining material's resistance to radiation should be determined in accordance with Test Method D4082, modified as follows:

9.3.1 The test specimens should be prepared in accordance with the requirements defined by the organization responsible for the test program.

9.3.2 Specimens of both the thinner film polymeric lining (≤25 mils (0.6 mm)] and thicker cladding (>25 mils (0.6 mm)) systems should be tested. The thinner lining system should include the prime and finish coats. The thicker system should include liquid-grade prime and finish coats, and a paste-grade intermediate coat if applicable.

9.3.3 The total radiation exposure should be at least 8.7×10^7 rads unless otherwise established by the organization responsible for the test program.

9.4 *Abrasion Resistance*—The polymeric lining materials' resistance to abrasion should be determined in accordance with Test Method D4060, modified as follows:

9.4.1 Liquid- and paste-grade polymeric lining materials should be tested separately.

9.4.2 Test panel warping due to curing stresses may affect results. Precautions should be taken to ensure test panel flatness as cured.

9.4.3 Testing should be performed using the CS-17 wheel with a total load of 1000 g. The test should be continued for 1000 revolutions.

9.4.4 Results of the testing should be reported as weight loss.

9.5 *Direct Impact Testing*—The polymeric lining materials should be tested by direct impact in accordance with Test Method G14, modified as follows:

9.5.1 Flat, ¼-in.(6-mm) thick carbon steel plate panels should be used in lieu of the pipe specimen described in Test

Method G14. The number of specimens will be dependent upon panel size and test apparatus configuration.

9.5.2 The test specimens should be prepared in accordance with the requirements established by the organization responsible for the test program.

9.5.3 Specimens of both the thinner (≤25 mils (0.6 mm)) and thicker lining (>25 mils (0.6 mm)) systems, including a cladding if applicable, should be tested.

9.5.4 Impact testing should be performed from one side of the panel only.

9.5.5 An alternate weight or drop height may be required to test the thick film system adequately. Any such changes should be reported with the test results.

10. Keywords

10.1 Coating Service Level III; CSL III; cold-wall effect; lining systems; metal substrates; nuclear; polymeric material; safety-related service water; service water systems