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THE CORROSION SOCIETY

Standard
Recommended Practice

Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates

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Foreword

A coating is applied to a substrate to prevent corrosion, reduce abrasion, and/or reduce product contamination. The degree of coating continuity required is dictated by service conditions. Discontinuities in a coating are frequently very minute and not readily visible. This standard recommended practice provides a procedure for electrical detection of minute discontinuities in new coating systems that are applied to conductive substrates. The user should refer to NACE Standards RP0274,[1] RP0490,[2] and/or TM0384[3] for procedures specific to electrical inspection of pipeline coatings. This standard describes procedures for determining discontinuities using two types of test equipment: low-voltage wet sponge testers and high-voltage spark testers.

This standard is intended for reference in coating specifications or other documents and may be used by specifiers, applicators, and coating inspectors if a specification requires holiday detection on conductive substrates. For the purposes of this standard, the term "coating" is defined as a nonconductive film in either atmospheric or immersion service.

This standard was originally prepared in 1988 by Task Group T-6A-37, a component of Unit Committee T-6A on Coating and Lining Materials for Immersion Service. It was reaffirmed without revisions in 1990 and technically revised in 1999. This standard is issued by NACE International under the auspices of Group Committee T-6 on Protective Coatings and Linings. It combines the input of representatives of coating manufacturers, applicators, inspection agencies, architectural engineers, equipment manufacturers, and general consumers.

In NACE standards, the terms *shall*, *must*, *should*, and *may* are used in accordance with the definitions of these terms in the *NACE Publications Style Manual*, 3rd ed., Paragraph 8.4.1.8. *Shall* and *must* are used to state mandatory requirements. *Should* is used to state that which is considered good and is recommended but is not mandatory. *May* is used to state that which is considered optional.

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Section 1: General

1.1 This standard provides procedures for low-voltage wet sponge testing and high-voltage spark testing of new coatings on conductive substrates.

1.2 Electrical testing to determine the presence and number of discontinuities in a coating film is performed on a nonconductive coating applied to a conductive substrate. The allowable number of discontinuities should be determined prior to conducting this test, because the acceptable number of discontinuities varies depending on coating film thickness, design, and service conditions.

1.3 This standard is not intended to provide data on service life, adhesion, or film thickness of an applied coating system. Electrical testing does not detect areas where the coating is thin (even as thin as 25 µm [1.0 mil]).

1.4 This standard is intended for use only with new coatings applied to conductive substrates. Inspecting a coating previously exposed to an immersion condition could result in damage to the coating or could produce an erroneous detection of discontinuities due to permeation or moisture absorption of the coating. Deposits may also be present on the surface, causing telegraphing. The use of a high-voltage spark tester on previously exposed coatings can result in a spark that damages an otherwise sound coating. A low-voltage wet sponge tester may be used without damaging the coating but can produce erroneous readings.

1.5 To prevent damage to a coating film if a high-voltage spark tester is being used, the total film thickness and dielectric strength of the coating system shall be considered in selecting the appropriate voltage for detection of discontinuities.

1.6 The coating manufacturer shall be consulted to obtain the following information, which can affect the accuracy of the tests described in this standard to determine discontinuities:

(a) The length of time required to adequately dry or cure the applied coating film prior to testing. Solvents retained in an uncured coating film may form an electrically conductive path through the film to the substrate.

(b) Whether the coating contains electrically conductive fillers or pigments that may affect the normal dielectric properties.

Section 2: Definitions

Discontinuity: A void, crack, thin spot, foreign material inclusion, or contamination in the coating film that significantly lowers the electrical resistance of the coating. May also be identified as a holiday or pinhole.

Holiday: A discontinuity in a protective coating that exposes unprotected surface to the environment; a term used interchangeably with discontinuity.

Holiday Detector: A device that locates discontinuities in a coating film applied to a conductive substrate.

Pinholes: Small, porelike flaws in the coating which, if extended entirely through the film, are discontinuities. A pinhole in a single coat of a multicoat system might not be detected.

Telegraphing: Current that travels through a moisture patch to a discontinuity, causing an erroneous discontinuity test result.

Section 3: Low-Voltage Wet Sponge Testing

3.1 Equipment

3.1.1 A low-voltage wet sponge tester is an electronic device powered by a self-contained battery with voltages ranging from 5 to 90 V DC, depending on the manufacturer's circuit design. It is used to locate discontinuities in a nonconductive coating applied to a conductive substrate. Operation includes the use of an open-cell sponge electrode saturated with a solution for exploring the coating surface, a ground connection, and an audible and/or visual indicator for signaling a point of coating discontinuity.

3.1.2 The operating voltage of a low-voltage wet sponge tester is a function of the particular electronic circuit design and does not affect the sensitivity of the device.

3.1.3 A number of industry-accepted, low-voltage wet sponge testers are commercially available. The following electronic principles describe two types of devices generally used; others may be available but are not described in this standard.

3.1.3.1 One type of low-voltage wet sponge tester is a lightweight, self-contained, portable device based on the electrical principle of an electromagnetic-sensitive relay or solid-state electronic relay circuit that energizes an audible or visual indicator when a coating discontinuity is detected. Generally, this type of tester can be recalibrated in the field by the user.

3.1.3.2 Another type of low-voltage wet sponge tester is a lightweight, self-contained, portable device based on the principle of an electronic relaxation oscillator circuit that reacts significantly to the abrupt drop in electrical resistance between the high dielectric value of the coating film and the conductive substrate at the point of coating-film discontinuity. This results in a rise in oscillator frequency as well as in the audible signal from the device. Generally, this type of tester cannot be recalibrated in the field by the user.

3.2 Procedures for Use

3.2.1 Sufficient drying or curing of the coating shall be allowed prior to conducting a test. The length of time required for drying or curing shall be obtained from the coating manufacturer. Solvents retained in the coating film could produce erroneous indications.

3.2.2 The film thickness of the coating shall be measured with a nondestructive dry-film thickness gauge. If the coating film exceeds 500 µm (20 mils), the procedures for high-voltage spark testing described in Section 4 shall be used. A low-voltage wet sponge tester shall not be used for determining the existence of discontinuities in coating films having a total thickness greater than 500 µm (20 mils), due to the relative inaccuracy and lack of sensitivity of low-voltage wet sponge testers.

3.2.3 The tester shall be tested for sensitivity in accordance with Paragraph 3.3.

3.2.4 The ground wire from the tester ground output terminal shall be attached to the conductive substrate, and positive electrical contact shall be ensured.

3.2.5 The exploring sponge lead shall be attached to the output terminal.

3.2.6 The sponge shall be saturated with tap water. The sensitivity of the test may be increased by adding a low-sudsing wetting agent (such as that used in photographic film development), combined at a ratio of 30 mL (1 fl oz) wetting agent to 4 L (1 gal) water. The sponge shall be wetted sufficiently to barely avoid dripping while it is moved over the coating.

3.2.7 If a wetting agent is used, it must be completely removed by rinsing the holiday area prior to repair. Additives can leave contaminants on the surface that can interfere with adhesion of topcoats or repair coats and may contaminate stored product.

3.2.8 If a test is conducted between coats of a multicoat system, a wetting agent shall not be used.

3.2.9 Sodium chloride (salt) shall not be added to the water because it can cause erroneous indications of discontinuities. The salt, after drying on the coated surface, can form a continuous path of conductivity. It also interferes with intercoat adhesion of additional coats.

3.2.10 A bare spot on the conductive substrate shall be contacted with the wetted sponge to verify that the tester is properly grounded. This procedure shall be repeated periodically during the test.

3.2.11 The sponge shall be moved over the surface of the coating at a moderate rate of approximately 0.3 m/s (1 ft/s), using a double pass over each area. Sufficient pressure shall be applied to maintain a wet surface. If a discontinuity is detected, the sponge should be turned on end to determine the exact location of the discontinuity.

3.2.12 Discontinuities that require repair shall be identified with a marker that is compatible with the repair coating or one that is easily removable.

3.2.13 To prevent telegraphing, care should be taken to ensure that the solution is wiped dry from a previously detected discontinuity before continuing the test.

3.3 Verifying Sensitivity of Equipment

3.3.1 The tester shall be tested for sensitivity prior to initial use on each project and periodically thereafter during the project, in accordance with the manufacturer's instructions.

3.3.2 The battery shall be tested for proper voltage output according to the manufacturer's instructions.

3.3.3 The ground cable shall be connected to the tester ground output terminal.

3.3.4 The tester shall be switched to the "on" position, if neccessary.

3.3.5 The sponge shall be saturated with a wetting solution consisting of tap water and a wetting agent (see Paragraph 3.2.6).

3.3.6 The ground-cable alligator clip shall be touched to the wetted sponge. The tester signal should actuate in accordance with the manufacturer's instructions.

3.3.7 If the tester fails to signal, it shall be considered inoperative.

3.4 Verifying Tester Calibration or Sensitivity

3.4.1 The following procedures shall be used to verify calibrations of testers having an electromagnetic-sensitive relay or solid-state electronic relay:

3.4.1.1 Test the battery for proper voltage output. Refer to the manufacturer's instructions.

3.4.1.2 Switch the tester to "on" or "calibrate," if neccessary.

3.4.1.3 Connect an 80,000-ohm resistor with an accuracy tolerance of ±5% across the output terminals. The alarm should actuate.

3.4.1.4 Connect a 100,000-ohm resistor with an accuracy tolerance of ±5% across the output terminals. The alarm should not actuate if properly calibrated.

3.4.1.5 If the tester fails to perform as outlined in Paragraphs 3.4.1.3 and 3.4.1.4, adjust the alarm circuit or return it to the manufacturer.

3.4.2 The following procedures shall be used to verify sensitivity of testers having an electronic relaxation oscillator circuit:

3.4.2.1 Test the battery for proper voltage output. Refer to the manufacturer's instructions.

3.4.2.2 Switch the tester to "on."

3.4.2.3 At different intervals, a 10-megohm, 1-megohm, 100,000-ohm, and 10,000-ohm resistor should be connected across the output terminals.

3.4.2.4 A discernible increase in frequency should be detected as the resistance is decreased.

3.4.2.5 If the tester fails to indicate a frequency change, it shall be considered inoperative.

Section 4: High-Voltage Spark Testing

4.1 High-voltage spark testers are suitable for determining the existence of discontinuities in coating films of all thicknesses. The coating manufacturer should be consulted for proper test equipment and inspection voltage. Suggested starting voltages are provided in Table 1.

CAUTION: Coatings that are applied at thicknesses of less than 500 µm (20 mils) may be susceptible to damage if tested with a high-voltage spark tester.

4.2 A high-voltage spark tester may be used to determine discontinuities in coatings on conductive concrete substrates. The conductivity of concrete varies depending on moisture content, type, density, and location of rebars. Conductivity shall be tested by attaching a ground wire to the rebar or another metallic ground permanently installed in the concrete and touching the electrode to the bare concrete. If the metallic ground is not visible, the ground wire shall be placed directly against the bare concrete surface and weighted with a damp cloth or wet sand-filled paper bag. If the test indicates that the concrete is not conductive, determining discontinuities with a high-voltage spark tester will be ineffective.

TABLE 1
Suggested Voltages for High-Voltage Spark Testing

Total Dry Film Thickness (µm)	(mils)	Suggested Inspection (V)
200 to 280	8 to 11	1,500
300 to 380	12 to 15	2,000
400 to 500	16 to 20	2,500
530 to 1,000	21 to 40	3,000
1, 010 to 1,390	41 to 55	4,000
1,420 to 2,000	56 to 80	6,000
2,060 to 3,180	81 to 125	10,000
3,200 to 4,700	126 to 185	15,000

4.3 Equipment

4.3.1 A high-voltage (in excess of 800 V) spark tester is an electronic device used to locate discontinuities in a nonconductive protective coating. It consists of an electrical energy source, an exploring electrode, and a ground connection from the indicator signaling current flow through a coating-film discontinuity to the substrate.

4.3.2 The exploring electrode shall be of the type capable of maintaining continuous contact with the surface being inspected, including bolts, raised areas, etc. It shall be kept clean and free of coating material.

4.3.3 A high-voltage spark tester can be identified as either a pulse-type tester or a direct-current tester. A pulse-type tester discharges a cycling, high-voltage pulse. A direct-current tester discharges continuous voltage.

4.4 Procedures for Use

4.4.1 Sufficient drying or curing of the coating shall be allowed prior to conducting a holiday test. The length of time required for drying or curing shall be obtained from the coating manufacturer. Solvents retained in the coating film could produce erroneous results, as well as an explosive environment.

4.4.2 The thickness of the coating shall be measured with a nondestructive dry-film thickness gauge. If the coating film is less than 500 µm (20 mils), using procedures for low-voltage testing should be considered (see Section 3). Although the high-voltage spark tester is suitable for determining discontinuities in coating films of less than 500 µm (20 mils), it is recommended that the coating manufacturer be consulted before using this test. Certain coatings can be damaged if tested with this equipment.

4.4.3 The high-voltage spark tester shall be calibrated in accordance with Paragraph 4.6.

4.4.4 The high-voltage spark tester shall be adjusted to the proper voltage for the coating thickness being tested. In selecting the inspection voltage, sufficient voltage shall be provided to break the air gap that exists at the holiday. This air gap varies depending on the total applied film thickness. Excessive voltage may produce a holiday in the coating film. The maximum voltage for the applied coating shall be obtained from the coating manufacturer. Table 1 contains suggested voltages that may be used as guides.

4.4.5 The ground wire from the high-voltage spark tester ground output terminal shall be attached to the conductive substrate, and positive electrical contact shall be ensured. When testing concrete surfaces, the ground wire shall be attached to the rebars. If the rebars are not visible, the ground wire shall be placed directly against the bare concrete surface and weighted with a damp cloth or wet sand-filled paper bag.

4.4.6 Contact shall be made with the exploring electrode on the conductive substrate to verify that the tester is properly grounded. This test shall be conducted periodically during the testing of the coating.

4.4.7 The exploring electrode shall be moved over the surface of the dry coating at a rate of approximately 0.3 m/s (1 ft/s) using a single pass. Moisture on the coating surface can cause erroneous indications. If moisture exists, it shall be removed or allowed to dry before the test is conducted.

4.4.8 Discontinuities that require repair shall be identified with a marker that is compatible with the repair coating or one that is easily removable.

4.5 Verifying Operation of Equipment

4.5.1 The following procedures shall be used to verify operation of high-voltage spark testers:

4.5.1.1 Test the energy source (battery) for proper voltage output according to the manufacturer's instructions.

4.5.1.2 Connect the exploring electrode and grounding cable to the terminals of the testers.

4.5.1.3 Switch the tester to the "on" position.

4.5.1.4 Touch the exploring electrode to the ground-cable alligator clip. The tester signal should actuate in accordance with the manufacturer's operating instructions.

4.5.1.5 If the tester fails to signal, it shall be considered inoperative.

4.6 Calibration

4.6.1 Before the initial tests, the tester shall be calibrated to the specified voltage to be used for holiday detection. The tester shall be recalibrated periodically thereafter. The following procedure shall be used:

4.6.1.1 Connect a high-voltage voltmeter between the probe and the ground lead.

4.6.1.2 Switch the tester to the "on" position.

4.6.1.3 Compare the voltage of the voltmeter with the output voltage of the tester. Depending on the type of tester, adjust to the specified voltage (±5%) using either the variable regulator or predetermined selector switch.

4.6.1.4 Switch the tester to the "off" position.

4.6.1.5 Disconnect the voltmeter.

Section 5: Testing of Repaired Area

5.1 Sufficient drying or curing of the repair coating shall be allowed prior to retesting. The length of time required for drying or curing shall be obtained from the coating manufacturer.

5.2 The test shall be conducted following the procedures previously outlined in this standard for the type of tester selected.

5.3 Only those areas that have been repaired shall be retested, unless otherwise specified.

Section 6: Safety

6.1 Precautions shall be taken to prevent electrical shock. This is particularly important if the tester is powered by line voltage. The manufacturer's safety instructions shall be followed to prevent electrical shock.

6.2 Prior to conducting high-voltage tests in an enclosure, an inspection shall be conducted to indicate whether the enclosure is safe for entry, including testing for flammable or explosive gas. Solvents retained in the coating film can produce an explosive environment.

6.3 If testing is being conducted with a high-voltage spark tester, complete, proper electrical grounding (to earth) of the substrate shall be ensured.

References

1. NACE Standard RP0274 (latest revision), "High-Voltage Electrical Inspection of Pipeline Coatings" (Houston, TX: NACE).

2. NACE Standard RP0490 (latest revision), "Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 µm (10 to 30 mils)" (Houston, TX: NACE).

3. NACE Standard TM0384 (latest revision), "Holiday Detection of Internal Tubular Coatings of Less than 250 µm (10 mils) Dry Film Thickness" (Houston, TX: NACE).

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