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Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates[1]

This standard is issued under the fixed designation D5162; 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 practice covers procedures for determining discontinuities using two types of test equipment:

1.1.1 *Test Method A*—Low Voltage Wet Sponge, and

1.1.2 *Test Method B*—High Voltage Spark Testers.

1.2 This practice addresses metallic substrates. For concrete surfaces, refer to Practice D4787.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4787 Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates

D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *discontinuity, as used in this standard, n*—a flaw, void, crack, thin spot, foreign inclusion, or contamination in the coating film that significantly lowers the dielectric strength of the coating film; a discontinuity may also be identified as a holiday or pinhole.

3.1.2 *holiday, as used in this standard, n*—a term that identifies a discontinuity.

3.1.3 *holiday detector, as used in this standard, n*—a device that locates discontinuities in a nonconductive coating film applied to an electrically conductive surface.

3.1.4 *pinhole, as used in this standard, n*—a film defect characterized by small pore like flaws in the coating which, when extended entirely through the film, will appear as a discontinuity; a pinhole in the finish coat may not appear as a discontinuity.

4. Significance and Use

4.1 A coating/lining is applied to a metallic substrate to prevent corrosion or reduce product contamination, or both. The degree of coating continuity required is dictated by service conditions. Discontinuities in a coating/lining are frequently very minute and may not be readily visible. This practice provides a procedure for electrical detection of discontinuities in nonconductive coating systems.

4.2 Electrical testing to determine the presence and number of discontinuities in a coating/lining is performed on a nonconductive coating/lining applied to an electrically conductive surface. The allowable number of discontinuities should be determined prior to conducting this test since the acceptable quantity of discontinuities will vary depending on film thickness, design, and service conditions.

4.3 The low voltage wet sponge test equipment is generally used for detecting discontinuities in coatings/linings having a total thickness of 0.5 mm (20 mil) or less. High voltage spark test equipment is generally used for detecting discontinuities in coatings/linings having a total thickness of greater than 0.5 mm (20 mil).

4.3.1 Coatings/linings less than 0.5 mm (20 mil) in thickness may be susceptible to damage if tested with high voltage

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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.

spark testing equipment. However, coatings/linings greater than 0.25 mm (10 mil) and less than 0.5 mm (20 mil) may be tested with high voltage spark test equipment provided the voltage is calculated and set correctly, and the coating manufacturer approves its use.

4.4 To prevent damage to a coating film when using high voltage test instrumentation, total film thickness and dielectric strength in a coating system shall be considered in determining the appropriate voltage for detection of discontinuities. Atmospheric conditions shall also be considered since the voltage required for the spark to gap a given distance in air varies with the conductivity of the air at the time the test is conducted. Table X1.1 in Appendix X1 contains suggested voltages for high voltage spark testing of low dielectric strength coatings/linings.

4.5 The coating manufacturer shall be consulted to obtain the following information that can affect the accuracy of this test to determine discontinuities:

4.5.1 Establish the length of time required to adequately dry or cure the applied coating/lining prior to testing. Solvents retained in an uncured coating/lining may form an electrically conductive path through the film to the substrate and may be a fire hazard.

4.5.2 Determine whether the coating/lining contains electrically conductive fillers or pigments that may affect the normal dielectric properties.

4.6 This practice is intended for use with new coatings/linings applied to metal substrates. Its use on a lining previously exposed to an immersion condition has often resulted in damage to the lining and has produced erroneous detection of discontinuities due to permeation or moisture absorption of the lining. Deposits may also be present on the surface causing telegraphing (current traveling through a moisture path to a discontinuity, giving an erroneous indication) or current leakage across the surface of the coating/lining due to contamination. The use of a high voltage tester on previously exposed coatings/linings must be carefully considered because of possible spark-through that will damage an otherwise sound coating/lining. Although a low voltage tester can be used without damaging the coating/lining, it may also produce erroneous results.

5. Test Methods

TEST METHOD A—LOW VOLTAGE WET SPONGE TESTING

5.1 *Apparatus:*

5.1.1 *Low Voltage Holiday Detector*—An electronic device powered by a self-contained battery with voltages ranging from 5 to 90 V dc, depending on the equipment manufacturer's circuit design. It is used to locate discontinuities in a nonconductive coating/lining applied to a conductive substrate. Operation includes the use of an open-cell sponge electrode wetted with a solution for exploring the coating surface, a signal return connection, and an audible or visual indicator, or both, for signaling a point of coating discontinuity. A number of commercially available, industry-accepted, instruments are available. The following electronic principle describes two types of devices generally used; others may be available but are not described in this practice.

5.1.1.1 *Lightweight, Self-Contained, Portable Devices*—Based on the electrical principle of an electromagnetic sensitive relay or a solid-state electronic relay circuit that energizes an audible or visual indicator when a discontinuity is detected. Generally, this equipment is capable of being adjusted by the user.

5.1.1.2 *Lightweight, Self-Contained, Portable Devices*—Also 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/lining and the conductive substrate at the point of a discontinuity. This results in a rise in oscillator frequency as well as in the audible signal from the device. Generally, this equipment is incapable of being adjusted by the user.

5.1.2 *Low Sudsing, Non-ionic Wetting Agent.*

5.2 *Verifying Operation of Detector (instrument):*

5.2.1 The instrument shall be tested for sensitivity prior to initial use and periodically thereafter, in accordance with the equipment manufacturer's instructions.

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

5.2.3 Switch the instrument to the "on position," if applicable.

5.2.4 Wet the sponge with a wetting solution consisting of tap water and a wetting agent (see 5.4.6).

5.2.5 Connect the signal return wire to the instrument ground output terminal.

5.2.6 Touch the signal return wire clip to the wetted sponge. The instrument should signal in accordance with the instrument manufacturer's instructions.

5.2.7 If the instrument should fail to signal, it shall be considered defective.

5.3 *Instrument Calibration:*

5.3.1 The instrument shall be calibrated by the manufacturer or accredited calibration laboratory at the frequency required by the manufacturer. A certificate of calibration may be required.

5.4 *Procedure:*

5.4.1 Sufficient drying or curing of the coating/lining shall be allowed prior to conducting a test. The length of time required shall be obtained from the coating manufacturer.

5.4.2 The surface shall be dry, and free of oil and other contaminants. Measure the film thickness of the coating with a nondestructive dry film thickness gage in accordance with Practice D7091. If the average thickness of the coating film for the area being inspected exceeds 0.5 mm (20 mil) use the procedures for high voltage spark testing described in Test Method B, High Voltage Spark Testing.

5.4.3 Test the instrument for sensitivity in accordance with 5.3.

5.4.4 Attach the signal return (ground) wire from the instrument terminal to the metallic substrate and ensure a good electrical contact.

5.4.5 Attach the exploring sponge lead to the other terminal.

5.4.6 Wet the sponge with a solution consisting of tap water and a low sudsing wetting agent, combined at a ratio of not more than ½ fluid oz of wetting agent to 1 gal water. Wetting agents are typically supplied by the equipment manufacturer. An example of a low sudsing wetting agent is one used in photographic development. Ionic wetting agents (for example, salt water) should not be used. The sponge shall be wetted sufficiently to barely avoid dripping of the solution while the sponge is moved over the coating. The wetting agent residue must be removed prior to executing repairs to the coating.

5.4.6.1 Sodium chloride (salt) shall not be added to the wetting solution because of the potential erroneous indications of discontinuities. The salt, after drying on the coated surface, may form a continuous path of conductivity across the surface. It may also interfere with adhesion of subsequent coats.

5.4.7 Contact a bare spot on the conductive substrate with the wetted sponge to verify that the instrument is properly connected. This procedure shall be repeated periodically during the testing.

5.4.8 For open areas move the sponge over the surface at a maximum rate of 0.3 m/s (1 ft/s), using a double pass over each area. For internal pipe linings a single pass is appropriate as a double pass could lead to telegraphing and false positives. Apply sufficient pressure to maintain a wet surface. If a discontinuity is detected, turn the sponge on end to determine the exact location of the discontinuity. Improved accuracy of location can be achieved using a corner of the sponge if practical. It should be noted that the detection of pinholes depends on the migration of the moisture in to the holes and therefore the sponge may have to be moved over the surface at a slower rate to maximize detection, particularly for small holes in thicker coatings.

5.4.9 Discontinuities that require repair shall be identified with a marker that is compatible with the repair coating or one that is easily removed. Marking the defects with masking tape is acceptable providing the tape adhesive does not affect the subsequent repair.

5.4.10 To prevent telegraphing wipe dry any solution from a previously detected discontinuity where possible before continuing the test.

5.4.11 The wetting agent must be completely removed by rinsing the area prior to repair.

5.4.12 Wet sponge holiday detection is not recommended between coats of a multicoat system. However, when a test is conducted between coats of a multicoat system, a wetting agent shall not be used and any residue left by the test water must be completely removed prior to applying additional coats.

TEST METHOD B—HIGH VOLTAGE SPARK TESTING

5.5 *Apparatus:*

5.5.1 *High Voltage Detector*—An electronic device used to locate discontinuities in a nonconductive coating/lining applied to a conductive substrate. It consists of an electrical voltage source, an exploring electrode, and a signal return wire connection from the indicator, signaling current flow through a coating film discontinuity, to the substrate. The detector shall be equipped with a visual or audible indicator, or both. The detector can be identified as either a pulse or direct current type. A pulse type detector discharges a cycling, high voltage pulse with a typical voltage repetition rate of between 20 and 60 Hz when a flaw is detected, while a direct current type discharges continuous voltage when a flaw is detected.

5.5.2 *Exploring Electrode,* shall be of the type capable of maintaining continuous contact with the surface being inspected. It shall be kept clean and free of coating material. It is important that the electrode is kept in contact with the coating/lining during the test particularly when testing the internal coating on a pipe.

5.5.3 *Peak Reading Voltmeter.*

5.6 *Verifying Operation of Equipment (detector):*

5.6.1 Connect the exploring electrode and signal return wire to the terminals of the detector.

5.6.2 Adjust the detector to the proper test voltage per 5.8.4.

5.6.3 Place the exploring electrode in contact with the coated surface to be inspected.

5.6.4 Activate the detector high voltage output.

5.6.5 Verify the accuracy of output voltage by comparing the voltage set point to the actual voltage output using a peak reading voltmeter (Note 1). Depending on the type of detector, adjust the selected voltage by up to ±5 %. Adjustment beyond this value indicates that the detector may be defective.

NOTE 1—Some detectors have a built-in peak reading voltmeter. Refer to the instrument manufacturer's instructions.

5.7 *Instrument Calibration:*

5.7.1 The instrument shall be calibrated by the manufacturer or accredited calibration laboratory at the frequency required by the manufacturer. A certificate of calibration may be required.

5.8 *Procedure:*

5.8.1 Sufficient drying or curing of the coating/lining shall be allowed prior to conducting a holiday test. The length of time required shall be obtained from the coating manufacturer.

5.8.2 The surface shall be dry and free of oil, dirt, and other contaminants. Measure thickness of the coating with a nondestructive dry film thickness gage in accordance with Practice D7091. If the average thickness of the coating film for the area being inspected is less than 0.5 mm (20 mil), consider performing low voltage testing (see Test Method A, Low Voltage Wet Sponge Testing). Although the voltage settings on many high voltage spark testers can be finely adjusted and may be suitable for determining discontinuities in coating films of less than 0.5 mm (20 mil), it is recommended that the coating manufacturer be consulted before using this test. Certain coatings/linings less than 0.5 mm (20 mil) may be damaged if tested with high voltage detectors.

5.8.3 Verify test instrument operation in accordance with 5.8.7.

5.8.4 Adjust the test instrument to the proper voltage for the coating/lining thickness being tested (Note 2; Note 3). In selecting the inspection voltage, it is important to provide sufficient voltage to break the air gap that exists at the holiday. The air gap will vary depending on the total coating/lining thickness. The voltage required to break a given air gap may also vary due to atmospheric conditions such as relative humidity and air pressure. Ensure that the voltage is high enough to break the air gap equivalent to the highest coating/lining film thickness by separating the exploring electrode from the bare metal substrate using a nonconductive spacer (with an equivalent dielectric strength to the coating/lining) equal to the maximum coating/lining thickness. The voltage is set high enough to conduct the holiday test only if the spark will jump the gap formed by the spacer. A hole may be deliberately made in the spacer to simulate a defect in a coating/lining. Alternatively, a companion panel containing the same coating/lining applied at a similar average thickness and containing an intentional holiday (for example, created using a 1.6 mm, or 1⁄16-in. drill bit) can be used to adjust the voltage, which eliminates concerns over variations in dielectric strength of the spacer versus the coating/lining and variations in atmospheric conditions. Excessive voltage may cause a holiday to form. The maximum voltage for the applied coating/lining shall be obtained from the coating manufacturer, as the dielectric strength of the coating/lining can influence the voltage setting. Table X1.1 in Appendix X1 contains suggested voltages for high voltage spark testing of low dielectric strength coatings/linings. The test voltage is represented by the expression:

$$V = M\sqrt{Tc} \quad (1)$$

where:

V = test voltage, measured in volts (V),
Tc = coating/lining thickness, measured in either mm or mil, and
M = a constant dependant on the thickness range and the units of thickness as follows:

Coating Thickness Units	Coating Thickness Range	M Value
mm	≤1.00 (1000 µm)	3294
mm	>1.00 (1.000 µm)	7843
mil	≤40.0	525
mil	>40.0	1250

Examples:

(1) For a coating/lining of 500 µm, Tc = 0.5 and M = 3294 Therefore

$$V = 3294\sqrt{0.5} = 3294*0.707 = 2329\ V\ (2.3\ kV)$$

(2) For a coating/lining of 20 mil, Tc = 20 and M = 525 Therefore

$$V = 525\sqrt{20} = 525*4.472 = 2347\ V\ (2.3\ kV)$$

(3) For a coating/lining of 1500 µm, Tc = 1.5 and M = 7843 Therefore

$$V = 7843\sqrt{1.5} = 7843*1.224 \quad = 9599\ V\ (9.6\ kV)$$

(4) For a coating/lining of 60 mil, Tc = 60 and M = 1250 Therefore

$$V = 1250\sqrt{60} = 1250*7.745 = 9681\ V\ (9.7\ kV)$$

NOTE 2—Older models of high voltage detectors may not have the capability of being set to the precise calculated voltage. Contact the manufacturer of the coating/lining to determine whether the voltage setting should be rounded up or down from the calculated setting.

NOTE 3—Some equipment manufacturers have programmed these formulae into the software so that when the coating/lining thickness is entered into the detector the correct voltage setting is established.

5.8.5 Adjust the test instrument for alarm sensitivity if this feature is available. The alarm sensitivity sets the threshold current at which the audible alarm sounds. If the high voltage can charge the coating/lining, a small amount of current will flow while this charge is established. If the coating/lining contains a pigment that allows a low-level current leakage to flow from the probe while testing, the current can be set so that the alarm does not sound until this current is exceeded, that is, when a flaw is detected. Increasing the current threshold setting makes the instrument less sensitive to this low-level current flow; decreasing the current threshold setting makes the instrument more sensitive to current flow.

5.8.6 Attach the signal return wire from the instrument terminal to the metal substrate and ensure electrical contact. In the case of the pulsed type detector, direct contact to the metal substrate is the preferred option but it is not essential. Due to the pulsing of the voltage, a capacitance connection through the coating is sufficient for flaw detection. A conductive rubber mat over the coating or a trailing bare wire on a pipe coating for example, makes a capacitive connection to the metal substrate allowing current flow when a flaw is detected.

5.8.7 Make contact with the exploring electrode to the conductive substrate to verify that the instrument is properly grounded. This test shall be conducted periodically during the test. The spacer test described in 5.8.5 shall also be repeated if significant atmospheric changes occur during testing.

5.8.8 Move the exploring electrode over the surface of the dry coating at a rate not to exceed 0.3 m/s (1 ft/s) using a single pass. Moisture on the coating/lining surface may cause erroneous indications. If moisture exists, remove it or allow the surface to dry before conducting testing.

5.8.9 Discontinuities that require repair shall be identified with a coating-safe marker that is compatible with the repair coating or one that is easily removed. Marking the defects with masking tape is acceptable providing the tape adhesive does not affect the subsequent repair.

6. Testing of Repaired Area

6.1 Repaired areas should be tested in the same manner as used for the original system test unless otherwise agreed by the interested parties. The following aspects must be considered:

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

6.3 Conduct the test following the procedures as previously outlined in this practice for the test instrument selected.

6.4 Retest only those areas that have been repaired, unless otherwise specified.

7. Keywords

7.1 coatings; discontinuity; high voltage; holiday; holiday detectors; linings; low voltage; pinhole; spark testers; wet sponge