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

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

G62 Test Methods for Holiday Detection in Pipeline Coatings

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

2.2 *NACE Standard Practices:*[3]

SP0188–2006 Discontinuity (Holiday) Testing of Protective Coatings

SP0274–2011 High Voltage Electrical Inspection of Pipeline Coatings

SP0490–2007 Holiday Detection of Fusion Bonded Epoxy

2.3 *ISO Standard:*[4]

ISO 29601 Paints and varnishes. Corrosion protection by protective paint systems. Assessment of porosity in a dry film

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

4.2 Electrical testing to determine the presence and number of discontinuities in a coating film is performed on a nonconductive coating 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 coating film thickness, design, and service conditions.

[1] This practice is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

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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.

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

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

4.3 The low voltage wet sponge test equipment is generally used for determining the existence of discontinuities in coating films having a total thickness of 0.5 mm (20 mil) or less. High voltage spark test equipment is generally used for determining the existences of discontinuities in coating films having a total thickness of greater than 0.5 mm (20 mil).

4.4 Coatings that are applied at a thickness of less than 0.5 mm (20 mil) may be susceptible to damage if tested with high voltage spark testing equipment. Consult the coating manufacturer for proper test equipment and inspection voltages.

4.5 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 selecting 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. Suggested starting voltages are provided in Table 1.

4.6 The coating manufacturer shall be consulted to obtain the following information, which would affect the accuracy of this test to determine discontinuities:

4.6.1 Establish 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.

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

4.7 This practice is intended for use with new coatings applied to metal substrates. Its use on a coating previously exposed to an immersion condition has often resulted in damage to the coating and has produced erroneous detection of discontinuities due to permeation or moisture absorption of the coating. 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 due to contamination. The use of a high voltage tester on previously exposed coatings has to be carefully considered because of possible spark-through, which will damage an otherwise sound coating. Although a low voltage tester can be used without damaging the coating, it may also produce erroneous results.

**TABLE 1 Suggested Voltages for High Voltage Spark Testing**

| Total Dry Film Thickness | | Suggested Inspection, V |
|---|---|---|
| mm | mil | |
| 0.500–0.590 | 19.7–23.2 | 2700 |
| 0.600–0.690 | 23.6–27.2 | 3300 |
| 0.700–0.790 | 27.6–31.1 | 3900 |
| 0.800–0.890 | 31.5–35.0 | 4500 |
| 0.900–0.990 | 35.4–39.0 | 5000 |
| 1.000–1.090 | 39.4–42.9 | 5500 |
| 1.100–1.190 | 43.3–46.9 | 6000 |
| 1.200–1.290 | 47.2–50.8 | 6500 |
| 1.300–1.390 | 51.2–54.7 | 7000 |
| 1.400–1.490 | 55.1–58.7 | 7500 |
| 1.500–1.590 | 59.1–62.6 | 8000 |
| 1.600–1.690 | 63.0–66.5 | 8500 |
| 1.700–1.790 | 66.9–70.5 | 9000 |
| 1.800–1.890 | 70.9–74.4 | 10000 |
| 1.900–1.990 | 74.8–78.3 | 10800 |
| 2.000–2.090 | 78.7–82.3 | 11500 |
| 2.100–2.190 | 82.7–86.2 | 12000 |
| 2.200–2.290 | 86.6–90.2 | 12500 |
| 2.300–2.390 | 90.6–94.1 | 13000 |
| 2.400–2.490 | 94.5–98.0 | 13500 |
| 2.500–2.590 | 98.4–102.0 | 14000 |
| 2.600–2.690 | 102.4–105.9 | 14500 |
| 2.700–2.790 | 106.3–109.8 | 15000 |
| 2.800–2.890 | 110.2–113.8 | 15500 |
| 2.900–2.990 | 114.2–117.7 | 16000 |
| 3.000–3.090 | 118.1–121.7 | 16500 |
| 3.100–3.190 | 122.0–125.6 | 17000 |
| 3.200–3.290 | 126.0–129.5 | 17500 |
| 3.300–3.390 | 129.9–133.5 | 18000 |
| 3.400–3.490 | 133.9–137.4 | 18500 |
| 3.500–3.590 | 137.8–141.3 | 19000 |
| 3.600–3.690 | 141.7–145.3 | 19500 |
| 3.700–3.790 | 145.7–149.2 | 20000 |
| 3.800–3.890 | 149.6–153.1 | 21000 |
| 3.900–3.990 | 153.5–157.1 | 21800 |
| 4.000–4.190 | 157.5–165.0 | 22500 |
| 4.200–4.290 | 165.4–168.9 | 23000 |
| 4.300–4.390 | 169.3–172.8 | 24000 |
| 4.400–4.490 | 173.2–176.8 | 25000 |
| 4.500–4.590 | 177.2–180.7 | 25800 |
| 4.600–4.690 | 181.1–184.6 | 26400 |
| 4.700–4.790 | 185.0–188.6 | 26800 |
| 4.800–4.890 | 189.0–192.5 | 27400 |
| 4.900–4.990 | 192.9–196.5 | 28000 |
| 5.000–5.290 | 196.9–208.3 | 28500 |
| 5.300–5.500 | 208.7–216.5 | 29000 |
| 5.600–8.000 | 220.5–307.1 | 30000 |

NOTE 1—Alternative methods for selecting a suitable test voltage are given in Test Methods G62 and NACE RP0188, SP0274, and SP0490.

## 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 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.

5.1.2 Low *Voltage Wet Sponge Tester*—a sensitivity device with the operating voltage being of little importance other than being part of the particular electronic circuit design.

5.1.3 Wet *Sponge Type Instruments*—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.

5.1.3.1 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 coating discontinuity is detected. Generally this equipment is capable of being recalibrated in the field by the user.

5.1.3.2 *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 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 equipment is incapable of being recalibrated in the field by the user.

5.2 Procedure:

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

5.2.2 The surface shall be clean, dry, and free of oil, dirt and other contaminates. Measure the film thickness of the coating with a nondestructive dry film thickness gage. If the coating film exceeds 0.5 mm (20 mil), use the procedures for high voltage spark testing described in Test Method B, High Voltage Spark Testing.

5.2.3 Test the instrument for sensitivity in accordance with 5.3.

5.2.4 Attach the signal return wire from the instrument terminal to the metallic substrate and ensure a good electrical contact.

5.2.5 Attach the exploring sponge lead to the other terminal.

5.2.6 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. An example of a low sudsing wetting agent is one used in photographic development. 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.

5.2.7 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 will also interfere with intercoat adhesion of additional coats.

5.2.8 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 test.

5.2.9 For open areas move the sponge over the surface of the coating at a moderate rate, with a maximum rate of 0.3 m/s (1 ft/s), using a double pass over each area. For internal pipe coatings 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.

5.2.10 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 making tape is acceptable providing the tape adhesive does not affect the subsequent repair.

5.2.11 To prevent telegraphing take care to ensure that the solution is wiped dry from a previously detected discontinuity where possible before continuing the test.

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

5.2.13 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 all residue left by the test water must be completely removed prior to applying additional coats.

5.3 Verifying *Operation of Equipment*:

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

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

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

5.3.4 Wet the sponge with a wetting solution consisting of tap water and a wetting agent (see 5.2.6).

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

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

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

5.4 Verifying *Instrument Calibration*:

5.4.1 Verify instrument calibration in accordance with the manufacturer's latest published instructions. If out of calibration, the instrument shall be calibrated in accordance with the instrument manufacturer's latest published instructions, or returned for calibration. A certificate of calibration, renewed annually, may be required if the quality management system that controls the testing dictates.

## TEST METHOD B—HIGH VOLTAGE SPARK TESTING

5.5 Apparatus:

5.5.1 High *Voltage Detector (in excess of 500 V)*—an electronic device used to locate discontinuities in a nonconductive protective coating 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.

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

5.5.3 High *Voltage Electrical 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.

5.6 Procedure:

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

5.6.2 The surface shall be clean, dry, and free of oil, dirt and other contaminates. Measure thickness of the coating with a nondestructive dry film thickness gage. If the coating film is less than 0.5 mm (20 mil), consider using procedures for low voltage testing (see Test Method A, Low Voltage Wet Sponge Testing). Although the high voltage spark tester is 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 may be damaged if tested with this equipment.

5.6.3 Verify test instrument operation in accordance with 5.7.

5.6.4 Adjust the test instrument to the proper voltage for the coating thickness being tested. 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 applied film 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 film thickness by separating the exploring electrode from the bare metal substrate using a nonconductive spacer equal to the maximum coating thickness. A sheet of plastic film may be used for this purpose. 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 plastic sheet to simulate a defect in a coating. Excessive voltage may cause a holiday to form in the coating film. The maximum voltage for the applied coating shall be obtained from the coating manufacturer. Table 1 contains suggested voltages that can be used as guides. An alternative to Table 1, the test voltage is represented by the expression:

$$V = M\sqrt{Tc} \tag{1}$$

where:

$V$ = test voltage, measured in volts (V),
$Tc$ = coating 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 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 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 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 of 60 mil, Tc = 60 and M = 1250 Therefore

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

5.6.5 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, a small amount of current will flow while this charge is established. If the coating contains a pigment that allows a low-level leakage current 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.

5.6.6 Attach signal return wire from the instrument terminal to the metal substrate and ensure a good electrical contact. In the case of the pulsed type detector, direct contact to the metal substrate is the preferred option, 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.

5.6.7 Make contact with the exploring electrode on 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 5.6.4 shall also be repeated if significant atmospheric changes take place during testing.

5.6.8 Move the exploring electrode 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 may cause erroneous indications. If moisture exists, remove or allow to dry before conducting test.

5.6.9 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.

5.7 Verifying *Operation of Equipment:*

5.7.1 Test the voltage source for proper voltage output. Refer to the manufacturer's instructions.

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

5.7.3 Switch the instrument to the "on" position.

5.7.4 Touch the exploring electrode to the signal return wire alligator clip. The instrument signal should actuate in accordance with the instrument manufacturer' operating instructions.

5.7.5 If the instrument fails to signal, it shall be considered defective.

5.8 Verifying *Instrument Calibration:*

5.8.1 Verify instrument calibration in accordance with the manufacturer's latest published instructions. If out of calibration, the instrument shall be calibrated in accordance with the instrument manufacturer's latest published instructions, or returned for calibration. A certificate of calibration, renewed annually, may be required if the calibration program or the quality management system that controls the testing dictates.

5.8.2 Perform field checking of the test voltage with the electrode placed against the surface of the coating since the exploring electrode voltage may be reduced by the slight current flow of the coating.

5.8.3 If required, compare measured voltage with the selected test voltage. Depending on the type of tester, adjust the selected voltage by up to ±5 %. Adjustment beyond this value indicates that the instrument may be defective.

## 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 discontinuity; high voltage; holiday; holiday detectors; low voltage; new coatings; new linings; spark testers ; wet sponge type instruments