Designation: D4787 – 13

Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates[1]

1. Scope

1.1 This practice covers procedures that may be used to allow the detection of discontinuities in nonconductive linings or other non-conductive coatings applied to concrete substrates.

1.2 Discontinuities may include pinholes, internal voids, holidays, cracks, and conductive inclusions.

1.3 This practice describes detection of discontinuities utilizing a high voltage spark tester using either pulsed or continuous dc voltage.

NOTE 1—For further information on discontinuity testing refer to NACE Standard SP0188-2006 or Practice D5162.

1.4 This practice describes procedures both with and without the use of a conductive underlayment.

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

1.6 *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.* For a specific hazard statement, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D5162 Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates

G62 Test Methods for Holiday Detection in Pipeline Coatings

2.2 *NACE Standards:*[3]

SP0188-2006 Discontinuity (Holiday) Testing of Protective Coatings

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *conductive underlayment, n*—a continuous layer applied to the prepared concrete surface prior to the application of a nonconductive lining layer(s) that will allow high voltage spark testing for discontinuities in the lining, as it will conduct the current present when the spark is generated.

3.1.2 *current sensitivity, n*—some high voltage testers have adjustable current sensitivity that can be used to prevent low levels of current flow activating the audible alarm. The alarm sensitivity control sets the threshold current at which the audible alarm sounds. If the high voltage can charge the lining, a small amount of current will flow while this charge is established. If the lining contains a pigment that allows a low-level leakage current to flow from the probe while testing the threshold current can be set so that the alarm does not sound until this current is exceeded, that is, when a holiday or 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.

3.1.3 *discontinuity, n*—a localized lining site that has a dielectric strength less than a determined test voltage.

3.1.4 *high voltage spark tester, n*—an electrical device (producing a voltage in excess of 500 V) used to locate discontinuities in a nonconductive protective coating applied to a conductive substrate. The high voltage is applied to the coating or lining using an exploring electrode and any current resulting from the high voltage passing through a discontinuity in the coating or lining is passed to the device via a signal return cable (also known as a ground or earth wire).

3.1.5 *holiday, n*—small faults or pinholes that permit current to flow through the conductive substrate, also known as a discontinuity.

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[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.

3.1.6 *spark-over, n*—the distance a spark, from a high voltage tester, will jump across a space from a grounded surface at a specific electrical voltage.

3.1.7 *telegraphing, n*—current traveling through a moisture path across the surface of the coating to a discontinuity, giving an erroneous indication of a fault.

3.1.8 *test voltage, n*—that electrical voltage established which will allow a discontinuity at the thickest lining location site to be tested, but which will not damage the lining. Table 1 is based on the minimum voltage for a given thickness determined by the breakdown voltage of air, which is typically 4 kV/mm (~100 V/mil) and the maximum voltage to prevent damage assuming a dielectric strength of 6 kV/mm (~150 V/mil).

Alternatively the test voltage can be calculated using the following expression:

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

TABLE 1 Suggested Voltages for High Voltage Spark Testing

Total Dry Film Thickness		Suggested Inspection, V
mm	mils	
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

where:

V = test voltage,
Tc = coating or lining thickness, 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 lining of 500 µm, Tc = 0.5 and M = 3294

Therefore

$$V = 3294\sqrt{0.5} = 3294*0.707 = 2329 \quad V(3.3\ kV)$$

2) For a lining of 20 mil, Tc = 20 and M = 525

Therefore

$$V = 525\sqrt{20} = 525*4.472 = 2347\ V\ (3.3\ kV)$$

3) For a lining of 1500 µm, TC = 1.5 and M = 7843

Therefore

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

4) For a lining of 60 mil, Tc = 60 and M = 1250

Therefore

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

4. Summary of Practice

4.1 This practice allows for high voltage electrical detection of discontinuities in new linings applied to concrete substrates through the utilization of a continuous conductive underlayment applied to the prepared concrete surface prior to the application of the nonconductive lining layer(s) or by determining the conductivity of the concrete substrate to be tested. The conductivity of concrete varies, depending on moisture content, type, density, and location of rebars. Test the conductivity of the concrete by attaching the signal return cable to rebar or other metallic ground permanently installed in the concrete. If the concrete is sufficiently grounded a signal return cable may be placed with its electrical contact against the structure and held in place using a wet sand bag. If the test indicates the concrete provides an insufficient signal return the test cannot be conducted. A conductive underlayment will be required if a continuity test is to be conducted and it is not practical to add this conductive layer for the purpose of the test.

5. Significance and Use

5.1 The electrical conductivity of concrete is primarily influenced by the presence of moisture. Other factors, which affect the electrical continuity of concrete structures, include the following:

5.1.1 Presence of metal rebars,
5.1.2 Cement content and type,
5.1.3 Aggregate types,
5.1.4 Admixtures,

5.1.5 Porosity within the concrete,
5.1.6 Above or below grade elevation,
5.1.7 Indoor or outdoor location,
5.1.8 Temperature and humidity, and
5.1.9 Age of concrete.

5.2 The electrical conductivity of concrete itself may be successfully used for high-voltage continuity testing of linings applied directly with no specific conductive underlayment installed. However, the voltage required to find a discontinuity may vary greatly from point to point on the structure. This variance may reduce the test reliability.

5.3 Although the most common conductive underlayments are liquid primers applied by trowel, roller, or spray, and which contain carbon or graphite fillers, others may take the form of the following:
5.3.1 Sheet-applied graphite veils,
5.3.2 Conductive polymers,
5.3.3 Conductive graphite fibers,
5.3.4 Conductive metallic fibers, and
5.3.5 Conductive metallic screening.

5.4 Liquid-applied conductive underlayments may be desirable as they can serve to address imperfections in the concrete surface and provide a better base for which to apply the lining.

5.5 This practice is intended for use only with new linings applied to concrete substrates. Inspecting a lining previously exposed to an immersion condition could result in damaging the lining or produce an erroneous detection of discontinuities due to permeation or moisture absorption of the lining. Deposits may also be present on the surface causing telegraphing. The use of a high voltage tester on a previously exposed lining is not recommended because of possible spark through which will damage an otherwise sound lining. A low voltage tester can be used but could produce erroneous readings.

5.6 The user may consider this practice when performance requirements of the lining in a specified chemical environment require assurance of a lining free of discontinuities.

5.7 Factors affecting the dielectric properties and test voltage shall be considered. Some factors are the curing time of liquid-applied linings; the possible presence of electrically conductive fillers or solvents, or both; the possible presence of air inclusions or voids; and the compatibility of conductive underlayments with the specified lining.

5.8 A pulsed dc high voltage may cause a lining to breakdown at a lower voltage than would be the case for a continuous dc voltage.

6. Apparatus

6.1 *High Voltage Spark Tester*—An electrical detector with a voltage rating in excess of 500 V. The detector is to consist of an electrical energy source, an exploring electrode, a signal return cable connection, and wire. The detector shall be equipped with a visual or audible indicator, or both.
6.1.1 *Electrical Energy Source*—Either d-c or pulsating d-c type with the appropriate test voltage.
6.1.2 *Exploring Electrode*—A metal brush or conductive rubber strip, the full length of which shall be capable of maintaining continuous contact with the surface being inspected.
6.1.3 *Signal Return Cable, Wire*, typically stranded 14 to 16 gage copper wire.
6.1.4 *Visual or Audible Indicators,* or both, to signal a closed electrical circuit. Such signals shall be essential for testing the underlayment for electrical conductivity and for exposing discontinuities in the lining after it has been applied.
6.1.5 *High Voltage Pulsating DC Spark Tester*—A device used to locate discontinuities where electrical pulses are generating between 20 and 60 cps. Each pulse is on for a period of time between 20 and 200 µs.
6.1.6 *High Voltage Continuous DC Spark Tester*—A device used to locate discontinuities where the voltage is continuously present on the surface of the protective coating.

7. Hazards

7.1 Solvents retained in the applied underlayment or lining may create an explosive environment with the high voltage testers as well as produce an erroneous result.

8. Conductive Underlayments

8.1 The conductive underlayment shall not rely on the concrete substrate's electrical properties.

8.2 The specified lining shall be compatible with the specified conductive underlayment.

8.3 *Application:*
8.3.1 The finished conductive underlayment surface shall be relatively smooth. The conductive underlayment shall be considered part of the lining system and must be installed in accordance with the manufacturer's latest published instructions.
8.3.2 Visually verify that the conductive underlayment covers the entire area to be lined. Breaks at expansion joints and construction joints are allowable unless otherwise specified.

8.4 *Verification of Underlayment Conductivity:*
8.4.1 The surface of the applied conductive underlayment shall be clean, dry, free of oil, grease, dirt, or other contaminants and be sufficiently cured in accordance with the manufacturer's latest published instructions at the time the conductivity testing is performed. (**Warning**—See Section 7.)
8.4.2 Verify the operation of the test instrument in accordance with Section 9.
8.4.3 Adjust the high-voltage test instrument in accordance with Section 11.
8.4.4 Connect the test instrument to the installed underlayment or other appropriate ground using the signal return cable. If electrical isolation across an expansion joint is encountered, the signal return cable must be moved to an appropriate ground in the same section being tested.
8.4.5 Place the exploring electrode on a nonconductive spacer so that an air gap between the surface of the underlayment and the electrode is equal to the maximum thickness of the lining.
8.4.6 The underlayment is conductive if the visual or audible indicator, or both, on the test instrument is activated.

8.5 *Test Sampling:*

8.5.1 A minimum of four test points shall be used for the first 10 m^2 (100 ft^2). Test points shall be approximately equally spaced within the test area. At least one additional test point shall be used for every 50 m^2 (500 ft^2) thereafter.

8.5.2 Test points most distant from the signal return connection shall be included in the test sampling.

8.5.3 The specified lining shall not be applied until the conductivity of the underlayment or concrete has been verified.

9. Verifying Operation of High Voltage Testers

9.1 Test electrical source for proper voltage output of high voltage testers.

9.2 Follow the equipment manufacturer's operating instructions for verifying the operation of the tester.

9.3 If the testers fail to signal, they shall be considered defective.

10. Adjustment of High-Voltage Spark Tester for Verifying Conductivity of Underlayment

10.1 Establish the test voltage based on the maximum specified thickness of the nonconductive lining, its dielectric strength and the lining manufacturer's recommendations, also see 3.1.8.

10.2 Following the equipment manufacturer's instructions, set and check the test voltage established in 10.1.

11. Adjustment of High Voltage Spark Tester for Verifying Conductivity of the Applied Lining

11.1 Select the proper test voltage to provide reliable spark-over to locate a holiday under normal test conditions. The voltage selected must jump an air gap equal to the maximum specified dry film thickness of the lining being tested and not arc through the lining at the minimum specified dry film thickness, see 3.1.2.

11.2 Adjust the tester to the test voltage established in 11.1 as follows:

11.2.1 Connect a high-impedance, high-voltage voltmeter or a spark-gap calibrator between the electrode and the signal return cable. Ensure that the input impedance of the voltmeter is sufficiently high so that the high voltage power supply is not loaded and current is not drawn. If current is drawn the voltage indication on the voltmeter will be lower than the true test voltage.

11.2.2 Switch the detector to the ON position.

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

11.2.4 If required, compare measured voltage with the selected test voltage. Depending on the type of tester, adjust to the selected voltage ±5 %.

11.2.5 Switch the detector to the OFF position.

11.2.6 Disconnect the voltmeter or spark-gap calibrator.

12. Procedure for Using High Voltage Spark Tester

12.1 Attach the signal return cable to the conductive substrate and ensure a positive connection, see 4.1.

12.2 Ensure that a suitable test electrode is fitted to the high voltage handle.

12.3 Move the test electrode over the surface to be tested at a moderate rate, approximately 0.3 m/s (1 ft/s).

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

13. Testing for Verifying Continuity of Applied Lining

13.1 The surface of the applied lining shall be clean, dry, free of oil, grease, dirt, or other contaminants and be sufficiently cured in accordance with the manufacturer's latest published instructions at the time the testing is performed (**Warning**—See Section 7).

13.2 Attach the signal return cable from the instrument terminal to the conductive underlayment or appropriate ground in the same manner as was required in 8.4.4. Make contact with the exploring electrode at a known discontinuity to verify that the instrument is properly connected. For each contact location, make contact with a known discontinuity. A discontinuity may be produced by drilling a hole through the lining with a 1.6-mm (1⁄16-in.) diameter drill bit. Conduct this test periodically during the test.

13.3 With the exploring electrode in continuous contact with the lining surface, move it over the entire surface of the lining at a rate of 0.3 m/s (1 ft/s) maximum in a sweeping motion with overlapping passes to ensure that the entire surface has been subjected to the test.

13.4 Identify discontinuities that require repair with a compatible marker.

13.5 Completely test the lining one time only. Repair all defects found in the lining and retest only those repaired areas.

14. Keywords

14.1 conductive underlayment; conductivity; discontinuities; high voltage spark testers; low voltage wet sponge testers