Designation: D8551 – 24

Standard Practices for Permanent Monitoring Systems for Electrical Leak Detection and Location[1]

This standard is issued under the fixed designation D8551; 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 These practices describe standard procedures for using electrical methods to locate leaks in geomembranes covered with liquid, earthen materials, waste, and/or any material deposited on the geomembrane.

1.2 These practices are intended to ensure that permanent leak detection and location systems are effective, which can result in complete containment (no leaks in the geomembrane).

1.3 Not all sites will be easily amenable to this method, but some preparation can be performed in order to enable this method at nearly any site as outlined in Section 6. If ideal testing conditions cannot be achieved (or designed out), the method can still be performed, but any issues with site conditions must be documented.

1.4 Permanent monitoring systems for electrical leak detection and location can be used on geomembranes installed in basins, ponds, tanks, ore and waste pads, landfill cells, landfill caps, and other containment facilities including civil engineering structures. The procedures are applicable for geomembranes made of materials such as polyethylene, polypropylene, polyvinyl chloride, chlorosulfonated polyethylene, bituminous material, and other sufficiently electrically insulating materials.

1.5 Any permanent electrical monitoring system must detect the occurrence of a leak through the geomembrane, and it must last longer than the monitored geomembrane by nature of the concept. Therefore, all buried components and mechanical and electrical connections must be made of material either the same as the geomembrane, in case of sensors situated above geomembrane, or made from a material with a longer lifespan in cases where they are situated under the monitored geomembrane.

1.6 Permanent electrical monitoring systems are comprised of either large mesh pads separated by nominal spaces, or a grid of sensors situated either below the geomembrane or above the geomembrane or in both positions (below and above the geomembrane). In specific cases, sensors may be situated only at the perimeter of the monitored lined facility.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 The electrical methods used for geomembrane leak location should be attempted only by qualified and experienced personnel. Appropriate safety measures should be taken to protect the leak location operators, as well as other people at the site.

1.9 *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.*

1.10 *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]

D4439 Terminology for Geosynthetics

D6747 Guide for Selection of Techniques for Electrical Leak Location of Leaks in Geomembranes

D7002 Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Puddle Method

D7007 Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials

D7703 Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance Method

D7909 Guide for Placement of Intentional Leaks During Electrical Leak Location Surveys of Geomembranes

[1] These practices are under the jurisdiction of ASTM Committee D35 on Geosynthetics and are the direct responsibility of Subcommittee D35.10 on Geomembranes.

Current edition approved Feb. 1, 2024. Published February 2024. DOI: 10.1520/D8551-24.

[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.

D7953 Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing Method
D8265 Practices for Electrical Methods for Mapping Leaks in Installed Geomembranes

3. Terminology

3.1 For general definitions related to geosynthetics, see Terminology D4439.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *actual leak, n*—for the purposes of this standard, the term "actual leak" is used for a leak to distinguish it from an artificial leak.

3.2.2 *anomaly (anomalies, pl), n*—electrical measurement caused by some aberration in the measurement area, which may or may not be a leak.

3.2.3 *artificial leak, n*—for the purposes of this standard, an artificial leak is the temporary use of a sensor electrode or supply electrode, which is used to electrically mimic a leak in the lining system and is used to confirm functionality without creating an actual leak in the lining system.

3.2.4 *blind leak, n*—for the purposes of this standard, a blind leak is a circular hole in the geomembrane intentionally placed by the owner or owner's representative in a location unknown to the leak location practitioner.

3.2.5 *conductive-backed geomembrane, n*—a specialty geomembrane featuring a conductive backing.

3.2.6 *conductive geotextile, n*—a specialty geotextile manufactured to be electrically conductive for use in multilayer geosynthetic arrangements.

3.2.7 *dipole measurement, n*—an electrical measurement made on or in a partially conductive material using closely spaced sensors carried over the covering layer and placed at equal centers to measure the entire surface for evidence of anomalies (see Practices D7007 and D8265).

3.2.8 *earthen material, n*—sand, gravel, clay, silt, combinations of these materials, waste materials, or similar materials with an approximate conductivity <50 kΩ/m.

3.2.9 *electrically isolated conductive-backed geomembrane installation, n*—an installation of conductive-backed geomembrane that achieves a continuously conductive surface on the bottom layer while electrically isolating the bottom conductive layer from the top insulating layer of the entire geomembrane installation.

3.2.10 *known leak, n*—for the purposes of this standard, a known leak is a circular hole in the geomembrane intentionally placed by the owner or owner's representative per Guide D7909.

3.2.11 *leak, n*—for the purposes of this standard, a leak is any opening, perforation, breach, slit, tear, puncture, crack, or seam breach in the lining system. Moisture/humidity or direct mineral contact should be present through a "leak" in order to produce an anomaly. Scratches, gouges, dents, or other aberrations that do not completely penetrate the geomembrane are not considered to be leaks. Types of leaks detected during measurements include but are not limited to: burns, circular holes, linear cuts, seam defects, tears, punctures, and material defects.

3.2.12 *measurement, n*—for the purposes of this standard, a measurement is an electrical evaluation of a geomembrane-lined containment facility to check for leaks in the geomembrane.

3.2.13 *measurement area, n*—the portion of the geomembrane-lined containment facility subjected to an electrical leak location measurement.

3.2.14 *monitoring, n*—for the purpose of this standard, monitoring is a repeated measurement of the measurement area to enable the detection of leaks as and when they occur.

3.2.15 *point sensor, n*—a sensor placed in a discrete location of a gridded network.

3.2.16 *potential, n*—electrical voltage measured relative to a reference point.

3.2.17 *power source, n*—the direct current (DC) power supply used by leak location practitioners and permanent systems in order to create a voltage differential across the geomembrane.

3.2.18 *primary geomembrane, n*—the geomembrane constituting the first containment layer in a lining system containing multiple geomembranes.

3.2.19 *probe(s), n*—a conductive object used to make electrical measurements.

3.2.20 *return electrode, n*—the electrode that is used as reference pole to the current source electrode and it is placed outside of measurement area, or on the opposite side of the geomembrane as the current source electrode.

3.2.21 *sensing electrode(s), n*—see *sensor*; alternative noun used by leak location practitioners.

3.2.22 *sensor(s), n*—the electrodes that are used as receptors of the electric leak location signals for measuring either voltage (V) or current (A). They are placed either below the geomembrane or above the geomembrane or on both sides of geomembrane. These are usually manufactured using conductive and corrosion-resistant material such as 316L stainless steel or titanium, or alternatively of semiconductive HDPE.

3.2.23 *site response current, n*—the value of current, typically expressed in milliamps, resulting from applying a voltage to a current source electrode inserted into the material covering the geomembrane in the measurement area with the current return electrode connected to the underlying conductive layer in case of multiple geomembranes or to the earth in case of single geomembrane construction.

3.2.24 *source electrode, n*—the electrode used to apply current to the material above the geomembrane.

3.2.25 *zonal sensors, n*—a form of sensor that is not a point sensor but instead covers a large area and is formed of electrically conductive mesh, which has a ratio of 1:1 (leak location resolution to physical sensor size).

4. Significance and Use

4.1 Geomembranes are used as impermeable barriers to prevent liquids leaking out of landfills, ponds, and other containment facilities. In addition, geomembranes are also used to prevent external liquids leaking into to these types of facilities (for example, floating covers, landfill caps, and roofs of storage tanks). The liquids may contain contaminants that, if released, can cause damage to the environment or damage to the contents where protection is against leakage into the facility. In the case of a landfill cap, leakage increases the amount of leachate that the landfill can produce. Leaking liquids can erode the subgrade, causing further damage. Leakage can result in product loss or otherwise prevent the installation from performing its intended containment purpose. For these reasons, it is desirable that the geomembrane have as little leakage as practical.

4.2 Geomembrane leaks can be caused by poor quality of the subgrade, poor quality of the material placed on the geomembrane, accidents, poor workmanship, manufacturing defects, and carelessness.

4.3 The most significant causes of leaks in geomembranes that are covered with only water are related to construction activities, including pumps and equipment placed on the geomembrane, accidental punctures, punctures caused by traffic over rocks or debris on the geomembrane or in the subgrade, and ruptures caused by settlement during filling.

4.4 The most significant cause of leaks in geomembranes covered with earthen materials is construction damage caused by machinery that occurs while placing the earthen material on the geomembrane. Such damage also can breach additional layers of the lining system such as geosynthetic clay liners.

4.5 As a practical measure, other electrical leak location methods (see Guide D6747) should be used in conjunction with the permanent monitoring system to eliminate leaks in the installed geomembrane(s) as part of facility construction. Such methods must include testing of the exposed geomembrane before covering and before commissioning a permanent monitoring system. Then the permanent monitoring system can be used in conjunction with other cover geomembrane testing methods to quickly detect and locate all leaks caused by the covering process.

4.6 Permanent electric leak location monitoring methods are used to first detect and then subsequently locate leaks for repair during the whole life of the geomembrane. They are designed to detect and locate leaks at the end of the construction phase and during the operational and closure phases and also to monitor any post-closure phases. These practices can easily achieve a zero-leak condition at the conclusion of the measurement(s) at the end of the construction phase. If any of the requirements for measurement area preparation and testing procedures is not adhered to, however, then leaks can remain in the geomembrane after the construction phase completion measurement. On some sites it may not be practicable to achieve, but the closer the site can be designed (and carefully constructed to that design), the closer it will reach the ideal zero-leak condition.

4.7 Through the life of the facility monitored by an electric leak location system, leaks that are detected can be repaired. Often the difficulties of carrying out a repair are cited as a reason for not applying this method. However, history has shown that it may be better to know, in order to minimize late-life remedial work, by repairing leaks in a sector of a site rather than entirely exhuming and relocating (waste, for example) to a new site.

4.8 A permanent electric leak location monitoring system must last longer than the geomembrane it is designed to monitor, otherwise failure caused by degradation of that material will not be detected. To achieve this, all buried components and the associated electrical connections must be designed in such a way as to achieve this and additionally must avoid metallic corrosion of the buried components and/or critical connections.

5. Summary of the Permanent Electrical Leak Location Methods

5.1 There are three types of measurement employed when monitoring geomembrane integrity:

5.1.1 Voltage measurement (mV and V),

5.1.2 Current measurement (mA), and

5.1.3 Hybrid (current and voltage measurement are both used).

5.2 There are three types of system configurations by which the above mentioned measurements can be taken:

5.2.1 Point sensors (mV, V, and mA),

5.2.2 Zonal sensor (mV, V, and mA), and

5.2.3 Hybrid (zonal sensor and point sensors).

5.3 When there are leaks in the geomembrane, electrical current flows through the leaks, which produces high current density and a localized anomaly in the voltage potential distribution in the material above the geomembrane. Electrical measurements are made to locate those areas of high current density that can correspond to the presence of leaks.

5.4 The electric current is used as a direct testing and monitoring parameter to detect and/or locate position of leaks by the specific technology used.

5.5 Measurements are typically made either pole-pole or pole-dipole array or on a grid pattern. For point sensor systems, they are always recorded and then organized into an electrical map of the measurement area (this is not the case for zonal sensing).

5.6 An electrical map created from the electrical measurements is adjusted in order to clearly display a characteristic leak signal, and the measurement area is analyzed for the presence of any signals characteristic of a leak.

5.7 Electrical measurements can be carried out at any time and it does not depend on thickness of covering material.

5.8 Zonal sensor systems utilize a direct detection method. Each zonal sensor is a known size at a known location, which enables simultaneous detection and location of a leak within a few seconds of the leak occurring in a fully autonomous manner.

5.9 Geomembranes of EPDM are not able to be tested by this or other covered geomembrane electric leak location methods.

6. Design

6.1 The design process should involve the electric leak location system designer who should identify all the areas from the proposed site drawings where there is insufficient conductivity. In addition, all places and points where the electric leak location signals (applied electrical potential or electrical current) can escape via conductive paths should be identified. Once identified, the design should be altered so that these incompatible conditions can be eliminated.

6.2 Different types of sensors can be used for measurements (whether these are point sensors or zonal sensors). They must be made of a material that is demonstrably resistant to the corrosive environment in which they are to be placed and must meet the same requirements for longevity as the geomembrane itself, with a minimum operating life of more than 30 years.

6.3 Point sensors can be placed under or above the geomembrane to be monitored, but should be placed as close as possible to the geomembrane.

6.4 Point sensors can arranged in either a regular or irregular grid or a mixture, however, the whole monitored area needs to be covered, preferably with a margin beyond the perimeter because measurement is taken in pairs so effectively the last measurement by length or width is effectively halfway between the sensors.

6.5 The spacing of point sensors affects the precision of leak location, but most importantly it also greatly affects the sensitivity for detection of any leak. Higher grid density results in greater sensitivity and higher leak location precision, however, there are diminishing returns and the cost curve is exponential. Optimum grid spacing to ensure detection of leaks is always possible and has been found to be 5 m by 5 m for sites with normal electrical properties. Grid spacing of point sensors should therefore always comply with the following table in terms of resistivity of the covering, subgrade, or conductive geosynthetic material (depending on what is in contact with the point sensors):

Less than 5 kOhm	Greater than 5 kOhm
10 m by 10 m	5 m by 5 m

6.6 All types of sensors and electrodes shall have their positions precisely registered as X-Y coordinates.

6.7 Typically the precision associated with the location of leaks is ±10 % of the grid spacing of point sensors when installed in accordance with 6.5.

6.8 The design of the installed grid of sensors must take into consideration the loss of single sensors, whereupon the accuracy of the system does not get fundamentally worse. As a rule, leaks are detected by several sensors so the loss of one sensor can be compensated by the surrounding sensors.

6.9 Zonal sensors have a 1:1 leak resolution, meaning their physical size is the same as their leak location resolution (for example, a 3 m by 3 m zonal sensor will provide a leak position of somewhere within an identified area of 9 m^2).

6.10 In all cases, a power source is provided and connected to a source electrode installed within the material covering the geomembrane. The other output (or opposite pole) of the power source is connected to a return electrode in contact with the subgrade, or electrically conductive material under the geomembrane (in the case of multilayered geomembrane arrangements). This creates a voltage differential between the material over the geomembrane and the material under the geomembrane. There can be one or more source electrodes regularly or irregularly covering the monitored area. The density depends on the conductivity of the cover material and any multiplier used to create redundancy to increase system resilience. Positions of each source electrode must be precisely recorded as X-Y coordinates, preferably using a GPS total station (±5 mm).

6.11 Sufficiently electrically conductive material must be present and in direct contact with the monitored geomembrane (above and below the geomembrane), for example, suitable electrically conductive earthen material, GCL, or liquid. Frozen earthen materials are not sufficiently electrically conductive when the whole cross section is frozen. In the case of bare geomembrane, the measurement area can be flooded with water in order to perform this test method. The geomembrane should be subjected to a hydraulic gradient across the geomembrane so that if a hole or breach exists in the geomembrane it will leak either shortly before or during the testing. The material creating the subgrade of the geomembrane should be as homogenous as possible. Anomalous features such as trenches or pipes are allowed, but may produce anomalous electrical readings. The material covering the geomembrane has no restrictions other than suitable electrical conductivity.

6.12 For single geomembrane installations, the material covering the geomembrane must be completely isolated from the material underneath the geomembrane. This is typically achieved through an isolation trench around the entire perimeter of the measurement area. It can also be achieved with a welded flap of geomembrane that separates the cover material inside the measurement area from the material outside, or the geomembrane can be extended through the anchor trench to daylight above the earthen materials. Any conductive path(s) such as metal pipe penetrations, grounded pumps, and batten strips on concrete must be isolated or insulated from the water or earthen material over the geomembrane. The only path for electrical current flow must be through leaks in the geomembrane under the level of water or earthen materials covering the geomembrane in the measurement area.

6.13 There must be a sufficiently conductive material directly below the electrically insulating geomembrane being tested. Typically, leak location measurements on a properly prepared subgrade will have sufficient conductivity. Under proper conditions and preparations, geosynthetic clay liners (GCLs) are adequate as conductive material. There are some conductive geotextiles or other conductive materials with successful field experience which can be installed beneath the geomembrane to facilitate electric leak location measurement on geomembranes without an underlying conductive layer.

6.14 Leak location sensitivity depends on geoelectrical conditions and the correct density of sensors in point sensor systems. Optimal conditions for single membrane construction include the elimination of electrical bridges from the cover