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Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earthen Materials[1]

This standard is issued under the fixed designation D7007; 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 cover standard procedures for using electrical methods to locate leaks in geomembranes covered with water or earthen materials. For clarity, this practice uses the term "leak" to mean holes, punctures, tears, knife cuts, seam defects, cracks, and similar breaches in an installed geomembrane (as defined in 3.2.5).

1.2 These practices are intended to ensure that leak location surveys are performed with demonstrated leak detection capability. To allow further innovations, and because various leak location practitioners use a wide variety of procedures and equipment to perform these surveys, performance-based operations are used that specify the minimum leak detection performance for the equipment and procedures.

1.3 These practices require that the leak location equipment, procedures, and survey parameters used are demonstrated to result in an established minimum leak detection distance. The survey shall then be conducted using the demonstrated equipment, procedures, and survey parameters.

1.4 Separate procedures are given for leak location surveys for geomembranes covered with water and for geomembranes covered with earthen materials. Separate procedures are given for leak detection distance tests using actual and artificial leaks.

1.5 Examples of methods of data analysis for soil-covered surveys are provided as guidance in Appendix X1.

1.6 Leak location surveys can be used on geomembranes installed in basins, ponds, tanks, ore and waste pads, landfill cells, landfill caps, and other containment facilities. The procedures are applicable for geomembranes made of materials such as polyethylene, polypropylene, polyvinyl chloride, chlorosulfonated polyethylene, bituminous material, and other electrically-insulating materials.

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 (**Warning—**The electrical methods used for geomembrane leak location could use high voltages, resulting in the potential for electrical shock or electrocution. This hazard might be increased because operations might be conducted in or near water. In particular, a high voltage could exist between the water or earthen material and earth ground, or any grounded conductor. These procedures are potentially VERY DANGEROUS, and can result in personal injury or death. The electrical methods used for geomembrane leak location should be attempted only by qualified and experienced personnel. Appropriate safety measures must 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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

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

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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. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *artificial leak, n*—an electrical simulation of a leak in a geomembrane.

3.2.2 *current source electrode, n*—the electrode that is placed in the water or earthen material above the geomembrane.

3.2.3 *dipole measurement, n*—an electrical measurement made on or in a partially conductive material using two closely-spaced electrodes.

3.2.4 *earthen material, n*—sand, gravel, clay, silt, combinations of these materials, and similar materials with at least minimal moisture for electrical current conduction.

3.2.5 *leak, n*—for the purposes of these practices, a leak is any unintended opening, perforation, breach, slit, tear, puncture, crack, or seam breach. Significant amounts of liquids or solids may or may not flow through a leak. Scratches, gouges, dents, or other aberrations that do not completely penetrate the geomembrane are not considered to be leaks. Types of leaks detected during surveys include, but are not limited to: burns, circular holes, linear cuts, seam defects, tears, punctures, and material defects.

3.2.6 *leak detection distance, n*—The distance that a leak location equipment and survey methodology are capable of detecting a specified leak. The leak is usually specified as a circular leak with a specified diameter. For surveys with earthen materials on the geomembrane, the leak detection distance is usually measured from the surface projection of the leak.

3.2.7 *noise, n*—the unwanted part of a measured signal contributed by phenomena other than the desired signal.

3.2.8 *pole measurement, n*—an electrical measurement made on or in a partially conductive material using one measurement electrode and a remote reference electrode.

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

4. Significance and Use

4.1 Geomembranes are used as impermeable barriers to prevent liquids from leaking from landfills, ponds, and other containments. The liquids may contain contaminants that, if released, can cause damage to the environment. 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, and punctures caused by traffic over rocks or debris on the geomembrane or in the subgrade.

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 Electrical leak location methods are an effective final quality assurance measure to detect and locate leaks.

5. Summary of the Electrical Leak Location Methods for Covered Geomembranes

5.1 The principle of the electrical leak location method is to place a voltage across a geomembrane and then locate the points of anomalous potential distribution where electrical current flows through leaks in the geomembrane. Additional information can be found in Guide D6747.

5.2 *General Principles:*

5.2.1 Figs. 1 and 2 show diagrams of the electrical leak location method for a geomembrane covered with water and for a geomembrane covered with earthen materials respectively. One output of an electrical excitation power supply is connected to a current source electrode placed in the material covering the geomembrane. The other output of the power supply is connected to an electrode in contact with electrically conductive material under the geomembrane.

5.2.2 When there are leaks, 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 anomalous signal at the leaks.

5.2.3 Measurements are made using a dipole or pole measurement configuration. Various types of data acquisition are used, including audio indications of the signal level, manual measurements with manual recording of data, and automated digital data acquisition.

5.2.4 Direct current and alternating current excitation power supplies and potential measurement systems have been used for leak location surveys.

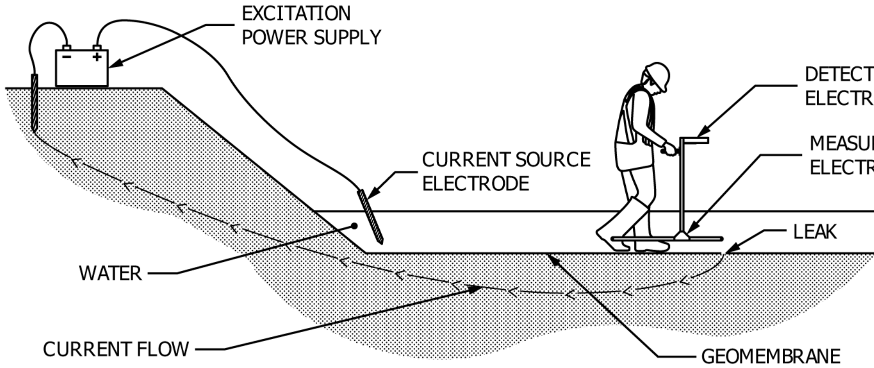

FIG. 1 Diagram of the Electrical Leak Location Method for Surveys with Water Covering the Geomembrane

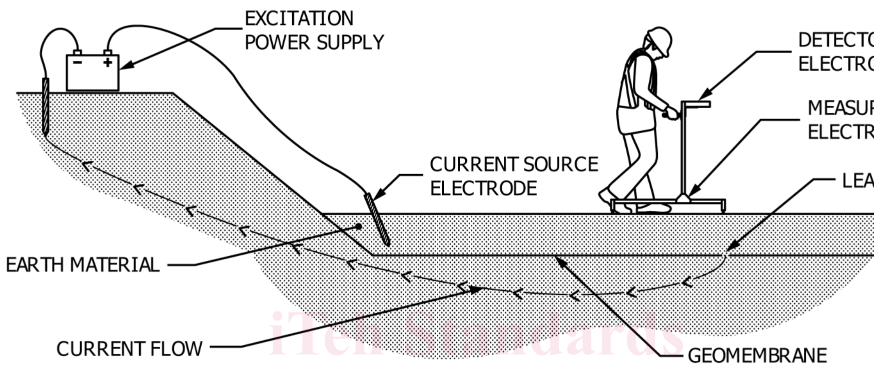

FIG. 2 Diagram of the Electrical Leak Location Method for Surveys with Earthen Material Covering the Geomembrane

5.3 *Leak Location Surveys of Geomembranes Covered with Water:*

5.3.1 Leak location surveys for geomembranes covered with water can be conducted with water on the geomembrane or with water covering a layer of earthen materials on the geomembrane.

5.3.2 For leak location surveys with water on the geomembrane, usually a dipole probe is systematically scanned through the water covering the geomembrane to locate the points of anomalous potential distribution. The dipole spacing is typically 0.2 to 1 m.

5.3.3 Various types of probes can be used to perform the surveys. Some are for when the operator wades in the water; some are for towing the probe back and forth across the geomembrane; and some are for raising and lowering along vertical or sloping walls.

5.3.4 The probe is typically connected to an electronic detector assembly that converts the electrical signal from the probe to an audible signal that increases in pitch and amplitude as the leak signal increases.

5.3.5 When a leak signal is detected, the point with the maximum signal is then determined. This point of maximum signal corresponds to the location of the leak. The location of the leak is then marked or measured relative to fixed points.

5.3.6 The leak detection distance depends on the leak size, the conductivity of the materials within, above, and below the leak, the electrical homogeneity of the material above the leak, the output level of the excitation power supply, the design of the measurement probe, the sensitivity of the detector electronics, the ~~distance away from the leak,~~survey area configuration and isolation, and the survey procedures. Leaks as small as 1 mm in diameter have been routinely found, including tortuous leaks through welds in the geomembrane. Leaks larger than 25 mm in diameter can usually be detected from several metres away.

5.3.7 The survey rate depends primarily on the spacing between scans and the depth of the water. A close spacing between scans is needed to detect the smallest leaks.

5.4 *Leak Location Surveys of Geomembranes Covered with Earthen Materials:*

5.4.1 For leak location surveys with earthen materials covering the geomembrane, point-by-point measurements are made on the earthen material using either dipole measurements or pole measurements. Dipole measurements are typically made with a spacing of 0.5 to 3 m. Measurements are typically made along parallel survey lines or on a grid pattern.

5.4.2 The survey procedures are conducted by systematically taking measurements of voltage potential in a grid pattern. Leaks can be located during the performance of the voltage measurements, but the voltage data must be collected for post-survey evaluation. The measurements and positions can be recorded manually or using a digital data acquisition system. Appendix X1 details the two main methods of data analysis and the advantages and disadvantages of each.

5.4.3 The data is typically downloaded or manually entered into a computer and plotted. Sometimes data is taken along survey lines and plotted in graphical format. Sometimes data is taken in a grid pattern and plotted in two-dimensional contour, shade of gray, or color contour plots, or in three-dimensional representations of the contours. The data plots are examined for characteristic leak signals.

5.4.4 The approximate location of the leak signal is determined from the data plots and additional measurements are made on the earthen material in the vicinity of the detected leak signal to more accurately determine the position of the leak.

5.4.5 The leak detection distance depends on the leak size, the conductivity of the materials within, above, and below the leak, the electrical homogeneity of the material above the leak, the design of the measurement electrodes, the output level of the excitation power supply, the sensitivity of the detector electronics, the ~~distance away from the leak, the survey procedures, and~~ survey procedures, the survey area configuration and isolation, and the data interpretation methods and expertise. Usually leaks as small as 5 mm in diameter can be located under 600 mm of earthen material. Leaks larger than 25 mm in diameter can usually be detected from several metres away.

5.4.6 The survey rate depends primarily on the spacing between the measurement points, the type of data acquisition, and whether data interpretation is accomplished in the field. A close spacing between measurement points is needed to adequately replicate the leak signals and to detect smaller leaks.

6. General Leak Location Survey Procedures

6.1 The following measures shall be taken to optimize the leak location survey:

6.1.1 Conductive paths such as metal pipe penetrations, pump grounds, and batten strips on concrete should be isolated or insulated from the water or earthen material on the geomembrane whenever practical. These conductive paths conduct electricity and mask nearby leaks from detection, as well as compromising the overall survey quality.

6.1.2 In applications where a single geomembrane is covered with earthen materials that overlap the edges of the geomembrane, ~~if practical,~~ measures should be taken to isolate the edges. If earthen materials overlap the edges of the survey area to earth ground, electrical current will flow from the earthen material to earth ground, ~~causing a large signal that will mask small leak signals near the edges of the survey area.~~compromising survey sensitivity. Isolation can be accomplished by either: performing the leak location survey before the edges of the geomembrane are covered; removing the earthen materials from a narrow path around the perimeter of the geomembrane; or allowing the edge of the geomembrane to protrude above the earthen materials.

6.1.3 There must be a conductive material directly below the electrically-insulative geomembrane being tested. Typically leak location surveys on a properly-prepared subgrade will have sufficient conductivity. Under proper conditions and preparations, geosynthetic clay liners (GCLs) can be 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 electrical leak location survey (that is, on dry subgrades, or as part of a planar drainage geocomposite).

6.1.4 For lining systems where an electrically-insulative geomembrane is overlain by a drainage geonet geocomposite, if the geocomposite is not saturated or is not manufactured to be conductive, only leaks that penetrate both geosynthetics can be detected; as a dry drainage geonet geocomposite is electrically-insulative.

6.1.5 For lining systems comprised of two geomembranes with only a geonet or only a geocomposite between them, the volume between the geomembranes shall be filled with water to provide the conductive material. The water level in the area between the geomembranes should be limited so that it exerts a pressure less than the pressure exerted by the water and any earthen materials on the primary geomembrane. When the head pressure of the water under the geomembrane exceeds the downward pressure exerted by the weight of the water and any earthen materials on the geomembrane, the primary geomembrane will begin to float. For surveys with only water on the geomembrane, the survey area will be limited to the area of the geomembrane that is covered with water. For surveys with earthen materials on the geomembrane, the survey area can be calculated from the relative density of the earthen materials, the thickness of the earthen materials and the slope of the geomembrane. Additional area can be surveyed by placing water on the earthen material on the primary geomembrane.

6.1.6 For surveys with earthen materials on the geomembrane, the earthen materials shall have adequate moisture to provide a continuous path for electrical current to flow through the leak. Earthen materials usually have sufficient moisture at depth, but sometimes the surface of the earthen materials becomes too dry. This dry material shall be scraped away at the measurement points, or the surface shall be wet with water. The earthen materials do not have to be saturated with water. The amount of moisture required depends on the earthen material, the equipment and procedures.

7. Leak Location Survey Procedures for Surveys with Water Covering the Geomembrane

7.1 The leak location survey shall be performed by scanning the leak location probe along the submerged geomembrane. The maximum distance between adjacent scans shall be determined by a leak detection distance test using an artificial or actual leak. The advantages and disadvantages of using the artificial or actual leak are listed in Table 1. A leak detection distance test shall be conducted on each geomembrane being tested for each set of equipment used before the set is used on that geomembrane. Periodic leak detection distance tests are ~~also specified tests are specified~~ specified in 7.8.

7.2 *Artificial Leak Procedures*—Annex A1 contains the procedures for using an artificial leak to conduct a leak detection distance test and determine the detection distance for surveys with water on the geomembrane.

TABLE 1 Comparison of Artificial Leaks versus Actual Leaks for Leak Detection Distance Test with Water on the Geomembrane

Factor	Actual Leak	Artificial Leak
Repairs	Geomembrane must be repaired after test	No geomembrane repair
~~Mobility~~	~~Moving location requires making another hole in the geomembrane and subsequently repaired~~	~~Can be easily moved without needing geomembrane repair~~
Mobility	Moving location requires another actual leak to be made and repaired.	Can be easily moved without needing geomembrane repair
Test adequacy of the conductivity of the material under the geomembrane	Yes, could be important for double geomembranes	Yes for single geomembranes, yes for double geomembranes if the artificial leak current return path corresponds to actual site survey conditions
Convenience	Must drill hole, sometimes under water, position is difficult to determine	Artificial leak is just placed in the water, can usually see the position

7.3 *Actual Leak Procedures*—Annex A2 contains the procedures for using an actual leak to conduct a leak detection distance test and determine the detection distance for surveys with water on the geomembrane.

7.4 *Leak Location Survey*—The leak location survey shall be conducted using procedures whereby the leak location probe passes within the detection distance of all locations on the geomembrane being surveyed for leaks. Because the probe detects leaks within the detection distance on both sides of the probe, the distance between leak detection sweeps can be no more than twice the detection distance. In addition to these procedures, any seams that can be visually located, or located by feel as the probe is scanned on the geomembrane, shall be surveyed for leaks by passing the probe directly along the seam or seam flap.

7.5 The leak detection distance test shall be conducted at the farthest distance where the leak location survey will be performed from where the current source electrode is located.

7.6 The criteria used to define the system leak detection distance as required in 7.3 and 7.4 and described in Annex A1 and Annex A2 shall not to be used as the leak detection criteria. Any definite, repeatable leak signal indication shall be considered to be a leak.

7.7 The locations of all leaks found shall be marked or measured relative to fixed points.

7.8 *Periodic Leak Detection Distance Test*—The leak detection distance test using the artificial or actual leak shall be conducted for each set of equipment, as a minimum, at the beginning and end of each day of survey. For this test, the current source electrode shall be no closer to the artificial or actual leak than the maximum distance used during the survey. The periodic leak detection distance tests shall produce a leak detection distance larger than the leak detection distance used for the leak location survey. If any leak detection distance is smaller, then the area surveyed with that set of equipment in the period since the previous leak detection distance test shall be repeated.

8. Leak Location Survey Procedures for Surveys with Earthen Material Covering the Geomembrane

8.1 The distance between adjacent survey lines or grid points shall be determined by a leak detection distance test using an artificial or actual leak. The advantages and disadvantages of using the artificial leak and actual leak are listed in Table 2. A leak detection distance test shall be conducted on each geomembrane being tested for each set of equipment used before the set is used on that geomembrane. Periodic leak detection distance tests are also specified in 8.12

8.2 *Artificial Leak Procedures*—Annex A3 contains the procedures for using an artificial leak to conduct a leak detection distance test and determine the detection distance for surveys with earthen materials on the geomembrane.

8.3 *Actual Leak Procedures*—Annex A4 contains the procedures for using an actual leak to conduct a leak detection distance test and determine the detection distance for surveys with earthen materials on the geomembrane.

8.4 *Leak Location Survey*—The results of the leak detection distance test shall determine the measurement spacings for the leak location survey. The leak location data shall be taken on survey lines or on a grid spaced no farther apart than 1.5 times the leak detection distance determined in the leak detection distance test, or 3.05 m, whichever distance is less.

8.5 For dipole measurements, the measurement electrode spacing shall be the same as that used for the leak detection distance test.

8.6 The spacing between measurements along the survey line or longitudinally along the grid shall be no more than that used during the leak detection distance test.

8.7 The leak detection distance test shall be conducted at the farthest distance where the leak location survey will be performed from where the current source electrode is located.

8.8 (**Warning—**Because of the high voltage that could be involved, and the shock or electrocution hazard, do not come in electrical contact with any leak unless the excitation power supply is turned off.)

TABLE 2 Comparison of Artificial Leaks versus Actual Leaks for Leak Detection Distance Test with Earthen Material on the Geomembrane

Factor	Actual Leak	Artificial Leak
Repairs	Geomembrane must be repaired after test. If a geotextile cushion is on the geomembrane, it also must be removed and repaired.	No geomembrane or geotextile cushion repair.
Mobility	Moving location requires another actual leak to be made and repaired.	Can be easily moved without needing geomembrane repair
Test adequacy of the conductivity of the material under the geomembrane	Yes	Yes for single geomembranes, yes for double geomembranes if the artificial leak current return path corresponds to actual site survey conditions
~~Signal measurement accuracy during leak detection distance test~~	~~Less accurate because current from excitation power supply flowing through inhomogeneities produce noise, but noise test as detailed in Annex A4must be conducted with the excitation power supply off. Likewise, any noise in the excitation power supply is not taken into consideration.~~	~~More accurate because current to the artificial leak can be switched off, allowing noise test detailed in Annex A3 to be conducted with excitation power supply on.~~
Effect on survey sensitivity	Affects sensitivity of immediate vicinity of leak; leak must be isolated in order to survey surrounding area.	None when artificial leak is disconnected.
Convenience	Must drill hole and take measures to prevent damage to secondary geomembrane, where applicable.	No drilling of hole or possible damage to secondary geomembrane.

8.9 Leaks can be located as the survey progresses, but the voltage measurements shall be recorded, plotted, and analyzed for leak signals. Appendix X1 details the two main methods of data analysis and the advantages and disadvantages of each. The positions of these leak signals shall be located and the leaks excavated. The leaks shall be repaired or electrically isolated from the earthen material on the geomembrane. The leak signals have a certain spatial distribution that can mask other nearby leaks, therefore, these additional measurements must be taken after the initial pinpointed leaks have been isolated or insulated. In some instances, such as when the leak is under water, it may not be practical to isolate the leak while the leak location crew is on site. In those cases, when the leak is repaired, the earthen materials should be removed from an area corresponding to the spatial distribution of the leak signal and the geomembrane should be visually inspected for leaks.

8.10 The leak location data shall then be re-collected for in an area extending 5 m before and beyond and on both sides of the position of the original leak. If another leak signal is detected, this process shall be repeated until no additional leaks are detected.

8.11 The signal plus noise to noise ratio (*R* value) used to define the system leak detection distance as required in 8.2 and 8.3 and described in Annex A3 and Annex A4 shall not ~~to~~ be used as the leak detection criteria. Any definite, repeatable characteristic leak signal indication shall be investigated to be a leak.

8.12 *Periodic Leak Detection Distance Tests*—A full or partial leak detection distance test shall be conducted according to Annex A3 or Annex A4 for each set of equipment at the beginning and end of each day of survey as a minimum. The periodic leak detection distance tests should show that the artificial or actual leak can be detected with the specified 3:1 (S+N)/N ~~at the leak detection distance.~~from a distance of half the survey line spacing. If they do not, the site conditions shall be modified until the leak detection distance is regained and the area surveyed that lacked adequate sensitivity shall be resurveyed.

9. Reporting Requirements

9.1 The leak location survey report shall contain the following information:

9.1.1 Description of the survey site,

9.1.2 Weather conditions,

9.1.3 Cover material description,

9.1.4 Type of geomembrane,

9.1.5 Liner system layering,

9.1.6 Description of the leak location method,

9.1.7 Survey methodology,

9.1.8 Description of the artificial or actual leak used,

9.1.9 Results of leak detection distance tests,

9.1.10 Results of periodic leak detection distance tests,

9.1.11 Specific parameters of survey including dipole spacing, spacing between measurements or scans, spacing between survey lines, and dipole orientation along survey lines as applicable,

9.1.12 Location of detected leaks,

9.1.13 Where visible, type and size of leaks, and

9.1.14 Map of the surveyed areas showing the approximate locations of the leaks.