Designation: D 7007 – 03

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

This standard is issued under the fixed designation D 7007; 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 standard practice describes standard procedures for using electrical methods to locate leaks in geomembranes covered with water or earth materials containing moisture.

1.2 This standard practice is 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 This standard practice requires that the leak location equipment, procedures, and survey parameters used are demonstrated to result in an established minimum leak detection sensitivity. 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 earth materials. Separate procedures are given for leak detection sensitivity tests using actual and artificial leaks.

1.5 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.

1.6 **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 earth 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.

1.7 *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]

D 4439 Terminology for Geosynthetics

D 6747 Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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

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

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

3.1.5 *leak*, *n*—any unintended opening, perforation, slit, tear, puncture, crack, hole, cut, or similar breaches through an installed geomembrane. Significant amounts of liquids or solids might or might not flow through a leak. Scratches, gouges, dents, or other aberrations that do not completely penetrate the geomembrane are not considered to be leaks.

3.1.6 *leak detection sensitivity*, *n*—the smallest size leak that the leak location equipment and survey methodology are capable of detecting under a given set of conditions. The leak detection sensitivity specification is usually stated as a diameter of the smallest leak that can be reliably detected.

[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.

3.1.7 *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 *Definitions:*

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

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

4. Summary of the Leak Location Methods

4.1 The principle of the electrical leak location method is to place a voltage across a geomembrane and then locate the points were electrical current flows through discontinuities in the geomembrane.

4.2 *General Principles*:

4.2.1 Figs. 1 and 2 show diagrams of the electrical leak location method for a geomembrane covered with water and for a geomembrane covered with earth 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.

4.2.2 When there are leaks, electrical current flows through the leaks, which produces high current density and a localized abnormality in the potential distribution in the material above the geomembrane. Electrical measurements are made to locate those areas of abnormal signal at the leaks.

4.2.3 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.

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

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

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

4.3.2 For leak location surveys with water on the geomembrane, usually a dipole probe is systematically scanned through the water over the geomembrane to locate the points of abnormal potential distribution. The dipole spacing is typically 0.2 to 1 metre.

4.3.3 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.

4.3.4 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.

4.3.5 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.

4.3.6 The leak detection sensitivity depends on 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, 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.

4.3.7 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.

4.4 *Leak Location Surveys of Geomembranes Covered with Earth Materials*:

4.4.1 For leak location surveys with earth materials covering the geomembrane, point-by-point measurements are made

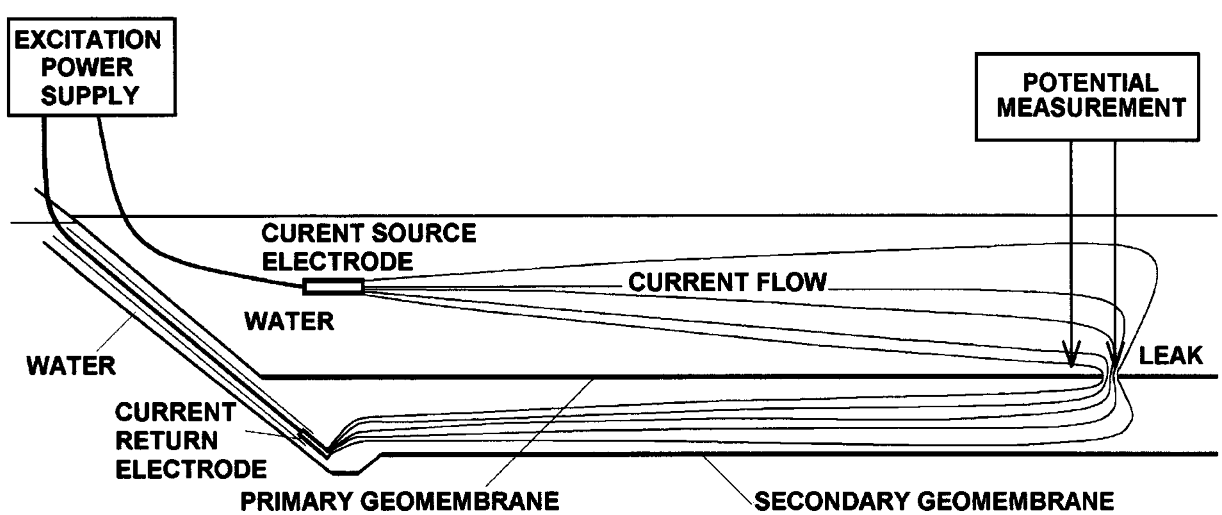


FIG. 1 Diagram of the Electrical Leak Location Method for Surveys with Water Covering the Geomembrane

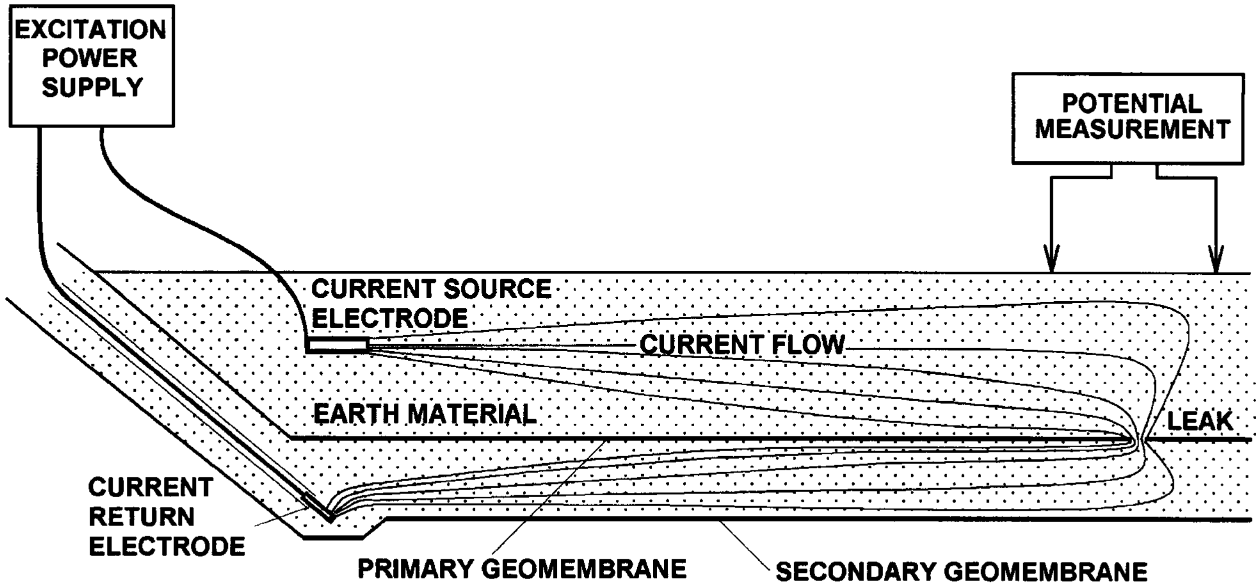


FIG. 2 Diagram of the Electrical Leak Location Method for Surveys with Earth Material Covering the Geomembrane

on the earth material using either dipole measurements or pole measurements. Dipole measurements are typically made with a spacing of 0.5 to 5 metres. Measurements are typically made along parallel survey lines or on a grid pattern.

4.4.2 The survey procedures are conducted in a systematic data collection mode. The measurements and positions are recorded manually or using a digital data acquisition system.

4.4.3 The data is typically downloaded or manually entered into a computer and plotted. Sometimes data is taken along survey lines and plotted in raster. 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.

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

4.4.5 The leak detection sensitivity depends on 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 survey procedures, and data interpretation methods and skill. Leaks as small as 5 mm in diameter can be located under 600 mm of earth material. Leaks larger than 25 mm in diameter can usually be detected from several metres away.

4.4.6 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.

5. Significance and Use

5.1 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.

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

5.3 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.

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

5.5 Electrical leak location methods are an effective final quality assurance measure to locate previously undetected or missed 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 earth material on the geomembrane whenever practical. These conductive paths conduct electricity and mask nearby leaks from detection.

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

6.1.3 There shall be a conductive material below the geomembrane being tested to conduct electrical current through the leaks. The detection of a leak depends on the amount of electrical current flowing through it. The current must flow through the subgrade to complete an electrical circuit. Therefore, the conductive material below the geomembrane must have adequate conductivity. Most earth materials and geosynthetic clay liners will have sufficient conductivity for surveys with water on the geomembrane. This is because water leaking through the leaks will increase the conductivity of the material under the geomembrane. For surveys with earth material on the geomembrane, most earth materials will have sufficient conductivity. Under proper conditions and preparations, geosynthetic clay liners (GCLs) are also adequate for surveys with earth materials on the geomembrane. However, for surveys with earth material on the geomembrane, if the earth materials or GCL below the geomembrane is desiccated, the conductivity may be insufficient to detect leaks.

6.1.4 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 earth 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 earth 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 earth materials on the geomembrane, the survey area can be calculated from the relative density of the earth materials, the thickness of the earth materials and the slope of the geomembrane. Additional area can be surveyed by placing water on the earth material on the primary geomembrane.

6.1.5 For surveys with earth materials on the geomembrane, the earth materials shall have adequate moisture to provide a continuous path for electrical current to flow through the leak. Earth materials usually have sufficient moisture at depth, but sometimes the surface of the earth materials becomes too dry. This dry material shall be scraped away at the measurement points, or the surface shall be wet with water. The earth materials do not have to be saturated with water. The amount of moisture required depends on the earth material, the equipment and procedures. Successful leak location surveys have been conducted on earth materials containing as little as 0.5 percent moisture by weight.

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 sensitivity 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 sensitivity 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 sensitivity tests are also specified.

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

7.3 *Actual Leak Procedures*—Annex A2 contains the procedures for using an actual leak to conduct a leak detection sensitivity 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

TABLE 1 Comparison of Artificial Leaks versus Actual Leaks for Leak Detection Sensitivity 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
Test adequacy of the conductivity of the material under the geomembrane	Yes, could be important for double geomembranes	No, but not critical for single geomembranes because water leaking through any leaks to the material under the geomembrane will provide sufficient conductivity
Signal measurement accuracy during leak detection sensitivity test	Less accurate because increase in signal due to leak must be determined by arbitrarily sweeping the probe near the leak	Accurate because measurements are made while switching the artificial leak on and off
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

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 location survey shall be conducted using procedures whereby the leak location probe is maintained no farther from the current source electrode than that used during the leak detection sensitivity test.

7.6 The percent of full scale criteria used to define the system leak detection sensitivity 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 Sensitivity Test*—The leak detection sensitivity 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 sensitivity 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 sensitivity test shall be repeated.

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

8.1 The leak location survey measurements shall be made on survey lines or on a survey grid. The maximum distance between adjacent survey lines or grid points shall be determined by a leak detection sensitivity 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 sensitivity 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 sensitivity tests are also specified.

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

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

8.4 *Leak Location Survey*—The results of the leak detection sensitivity test shall determine the maximum 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 twice the leak detection distance determined in the leak detection sensitivity test.

8.5 For dipole measurements, the measurement electrode spacing shall be no more than that used for the leak detection sensitivity 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 sensitivity test.

8.7 The leak location survey shall be conducted using procedures whereby the leak location measurements are no farther from the current source electrode than that used during the leak detection sensitivity test.

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.

8.9 Data shall be recorded, plotted and analyzed for leak signals. The positions of these leak signals shall be located and the leaks excavated. The leaks shall be repaired or electrically isolated from the earth material on the geomembrane. The leak location survey shall be repeated on the two closest survey lines for a distance extending five metres before and beyond the leak. If another leak signal is detected, this process shall be repeated until no additional leaks are detected.

8.10 The signal plus noise to noise ratio (R value) used to define the system leak detection sensitivity as required in 8.2 and 8.3 and described in Annex A3 and Annex A4 shall not to

TABLE 2 Comparison of Artficial Leaks versus Actual Leaks for Leak Detection Sensitivity Test with Earth 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	No
Signal measurement accuracy during leak detection sensitivity test	Less accurate because current from excitation power supply flowing through inhomogeneities produce noise, but noise test as detailed in Annex A4 must 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.
Convenience	Must drill hole and take measures to prevent damage to secondary geomembrane.	No drilling of hole or possible damage to secondary geomembrane.

be used as the leak detection criteria. Any definite, repeatable characteristic leak signal indication shall be investigated to be a leak.

8.11 *Periodic Leak Detection Sensitivity Tests*—A partial leak detection sensitivity 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. Each set of equipment used shall be tested on a survey line that passes by the artificial or actual leak. The survey line must pass no closer from the artificial or actual leak than half of the survey line spacing or grid spacing used for the leak location survey. 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 sensitivity test shall produce a signal plus noise to noise ratio, R, greater than 3.0 as described in Annex A3 or Annex A4. If any signal plus noise to noise ratio is smaller, the area surveyed with that set of equipment in the period since the previous leak detection sensitivity test shall be repeated.

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 Climatic 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 sensitivity tests,

9.1.10 Results of periodic leak detection sensitivity 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.

9.2 If specified or requested by the client, ASCII files of the raw data for surveys with earth materials covering the geomembrane shall be provided on a compact disc labeled with the site name, cell name, survey dates, and name of the leak location company.

10. Keywords

10.1 construction quality assurance; electrical leak location method; geomembrane; leak detection; leak location

ANNEXES

(Mandatory Information)

A1. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH WATER COVERING THE GEOMEMBRANE USING AN ARTIFICIAL LEAK

A1.1 *Artificial Leak*—If an artificial leak is used, the artificial leak shall be constructed using an electrically insulating container. Fig. A1.1 shows the construction of the artificial leak that shall be used for the leak detection sensitivity test with water on the geomembrane. The container has a lid with a thickness greater than the geomembrane under test or a means for sealing a disk of geomembrane to the opening of the container. The disk is constructed of geomembrane with the same thickness as the geomembrane to be tested. Initially the lid or disk will have no hole. An insulated wire enters a sealed penetration into the container. The wire is terminated with a metal electrode. A weight should be used in the container so the filled container is not buoyant.

A1.2 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not touch the artificial leak or the end of the artificial leak wire or electrode unless the excitation power supply is turned off. The switch must be properly rated and insulated and it must not be operated by anyone that is in contact with the water. Do not drill a hole in the artificial leak unless the excitation power supply is turned off and disconnected.

A1.3 The other end of the insulated wire shall be connected through a suitable switch to a ground electrode or an electrode between the geomembranes in a double geomembrane installation.

A1.4 The artificial leak shall be filled with some water that is on the geomembrane being tested. The lid or lid with the geomembrane disk (with no hole) shall be sealed onto the container. The artificial leak shall be placed in the water on the geomembrane. If not visible, the artificial leak location shall be adequately marked or its position accurately referenced so its position is known. If a wading survey is to be performed, the artificial leak shall be more than three metres from the edge of the water.

A1.5 The artificial leak switch shall be turned on, the excitation power shall be turned on, and the leak location probe shall be swept within 50 mm of the lid and the sealed penetration. If a signal is detected, either the artificial leak is defective or it happens to be near an actual leak. The artificial leak shall be repaired or replaced, or moved and the test shall be repeated until no signal is measured.

A1.6 When no signal is detected, the excitation power shall be turned off and a circular hole with a diameter no greater than

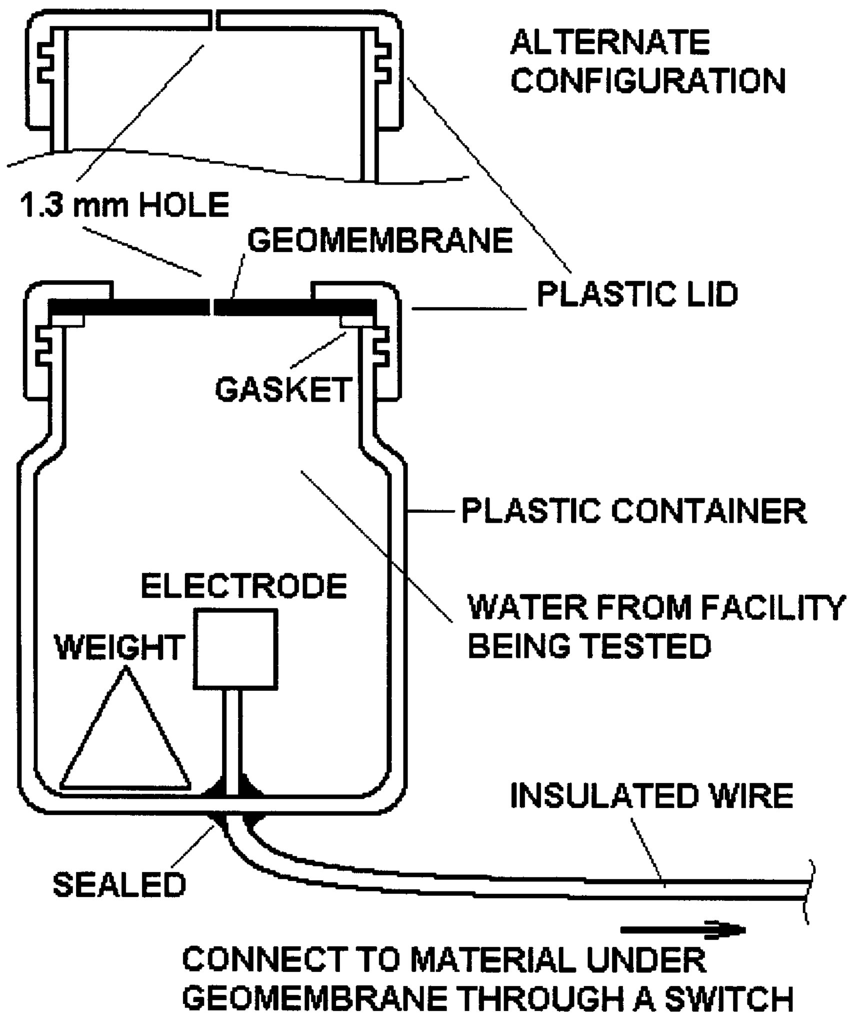


FIG. A1.1 Artificial Leak for Surveys with Water Covering the Geomembrane

1.3 mm shall be placed in the lid or disk without removing the lid or disk or disturbing the seal. (An alternative sized hole may be used if specified.)

A1.7 The artificial leak shall be placed back in the water on the geomembrane at the same position as before.

A1.8 *Leak Detection Sensitivity Test*—The excitation power supply shall be turned on and the leak location probe for each set of equipment shall be slowly moved towards the artificial leak as the switch in the artificial leak wire is turned on and off. The excitation power supply shall remain on during this test. When the signal increases at least 10 percent of the full scale reading of the detection electronics as the switch is turned on, the distance from the probe to the artificial leak shall be measured and recorded. This is the detection distance.

A1.9 If an audio tone is used as an indicator for the leak location survey, the meter on the detector electronics shall move no more than zero to full scale as the audio indicator changes from minimum to maximum indication.

A2. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH WATER COVERING THE GEOMEMBRANE USING AN ACTUAL LEAK

A2.1 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not attempt to drill the actual leak hole or touch the leak when the excitation power supply is turned on.

A2.2 If an actual leak is used, it shall be constructed by drilling a hole with a diameter no greater than 1.3 mm in the installed geomembrane that is to be tested. For a double geomembrane system, measures shall be taken to ensure that the drill bit does not damage the secondary geomembrane. The hole shall be drilled, and the drill bit moved forward and backward in the hole so the geomembrane material is removed rather than displaced. The leak location shall be adequately marked or its position referenced so its position will be known when the actual leak is covered with water.

A2.3 *Leak Detection Sensitivity Test*—The excitation power supply shall be turned on and the leak location probe for each set of equipment shall be scanned in the vicinity of the leak. The scans shall be made in the manner that the actual leak location survey will be conducted. The probe shall be scanned at various distances from the leak to determine the distance where the signal increases at least 10 percent of the full scale reading of the detection electronics. This distance to the actual leak shall be measured and recorded. This is the detection distance.

A2.4 If an audio tone is used as an indicator for the leak location survey, the meter on the detector electronics shall move no more than zero to full scale as the audio indicator changes from minimum to maximum indication.

A3. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH EARTH MATERIAL COVERING THE GEOMEMBRANE USING AN ARTIFICIAL LEAK

A3.1 *Artificial Leak*—If an artificial leak is used, the artificial leak shall be a circular metal surface on a flat, electrically insulating substrate. An insulated wire is connected to the metal surface. The artificial leak shall have no sharp edges that could damage the geomembrane. Fig. A3.1 shows the maximum dimensions and typical construction for the artificial leak for surveys with earth materials covering the geomembrane. The diameter of the metal surface shall be no greater than 6.0 mm unless a geometry or size or both are specified otherwise. This artificial leak size is intended for leak location surveys with up to 600 mm of earth materials on the geomembrane. If the thickness of the earth material is greater, a larger artificial leak size should be specified.

A3.2 **Warning**—Because of the high voltage that could be involved, and the shock or electrocution hazard, do not touch the artificial leak or the end of the artificial leak wire or electrode, or pour water on it when the excitation power supply is turned on. The switch described below must be properly rated and insulated.

A3.3 The other end of the insulated wire shall be connected through a suitable switch to a ground electrode or an electrode between the geomembranes in a double geomembrane installation.

A3.4 The artificial leak shall be buried to within 25 mm of the geomembrane. The artificial leak shall be at least 10 m from any edge of the survey area. The artificial leak shall be backfilled with at least 50 mm of earth material and then no more than 250 mL of water should be poured over the partially buried artificial leak. The excavation shall then be backfilled. The location of the artificial leak shall be clearly marked on the surface.

A3.5 *Leak Detection Sensitivity Test*—Closely-spaced measurements shall be taken to determine the leak signal and background noise signal as follows:

A3.5.1 With the switch in the artificial leak wire turned off, and the excitation power supply turned on, a line of data shall be taken and recorded over the artificial leak to measure and

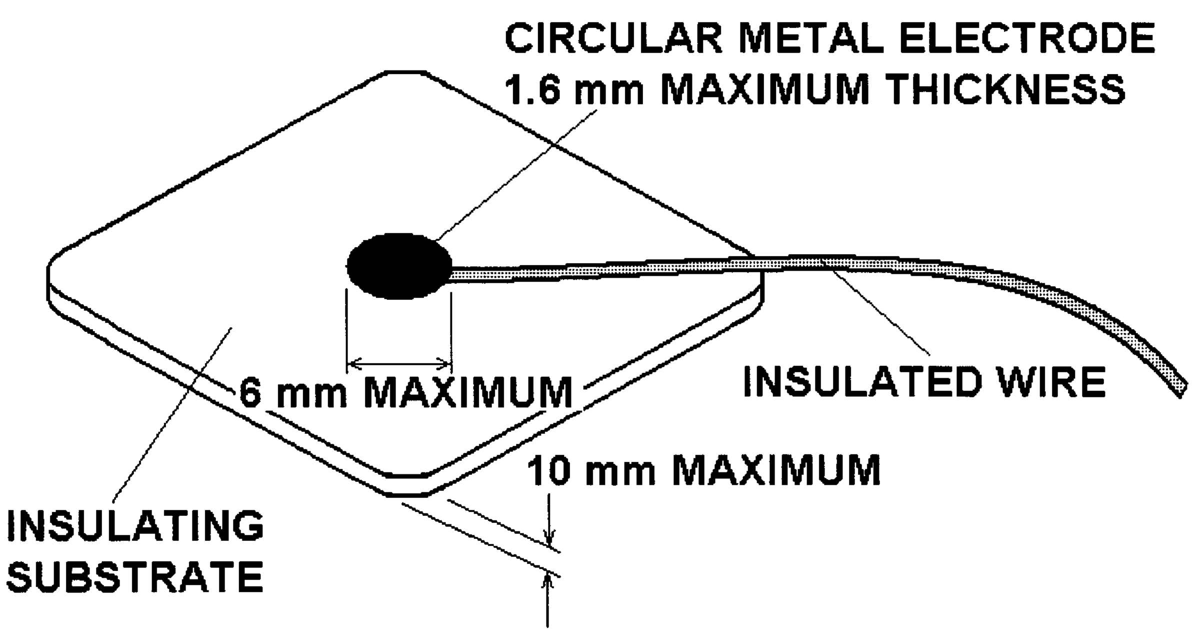


FIG. A3.1 Artificial Leak for Surveys with Earth Materials Covering the Geomembrane quantify the background noise level (N). Measurements shall be taken on a line that extends at least five metres in front of and in back of the artificial leak. The spacing of the measurements shall be the same as that planned for the leak location survey.

A3.5.2 The background noise level (N) shall be defined as the difference between the maximum and minimum measured potential with the artificial leak turned off and the excitation power supply turned on.

A3.5.3 With the switch in the artificial leak wire turned on, and the excitation power supply turned on, leak location measurements shall be made and recorded along closely-spaced parallel lines or on a grid centered on the artificial leak. The distance from each of the parallel lines or grid points to the surface projection of the artificial leak shall be measured. Fig. A3.2 shows the geometry of the measurements. The measurement layout is such that the artificial leak is at the farthest distance from the adjacent measurements. The lines shall be centered on the artificial leak and extend at least 5 metres in front and in back of the artificial leak.

A3.5.4 These signals are the artificial leak signal plus noise ($S + N$). The recorded leak location data shall be examined to determine the peak-to-peak leak signal plus noise to noise ratio $R = (S + N)/N$ for each of the recorded data lines. Fig. A3.3 shows an example of the measurements of N and $S + N$. The measured leak signals shall have the characteristics of a leak. Spurious, false, and unrepeatable data points that deviate from the theoretical leak signal shall not be used to determine R. The leak signal shall be represented by five or more data points in the data.

A3.5.5 The two farthest lateral lines or grid lines of data with an R value greater than 3.0 shall be noted and their distance to the surface projection of the artificial leak shall be recorded. The average of these distances is defined to be the leak detection distance.

A3.5.6 If site conditions prevent an R value greater than 3.0 from being obtained, the leak detection distance shall be defined to be 0.5 metres and the leak location survey shall be conducted with a uniform density of 1 measurement per square metre. These procedures can be followed provided the leak location equipment can be demonstrated to detect a shallower artificial leak from a lesser distance, and that the periodic leak detection sensitivity tests described in 8.11 are made at the lesser distance.

A3.5.7 The distance from the artificial leak to the current source electrode shall be measured and recorded.

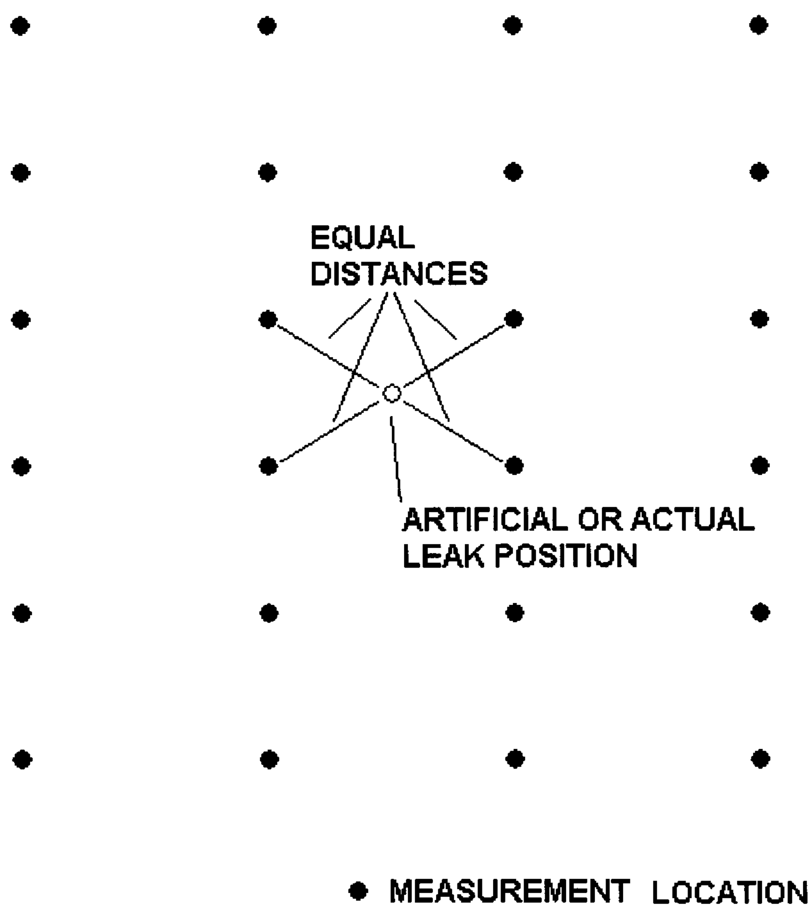
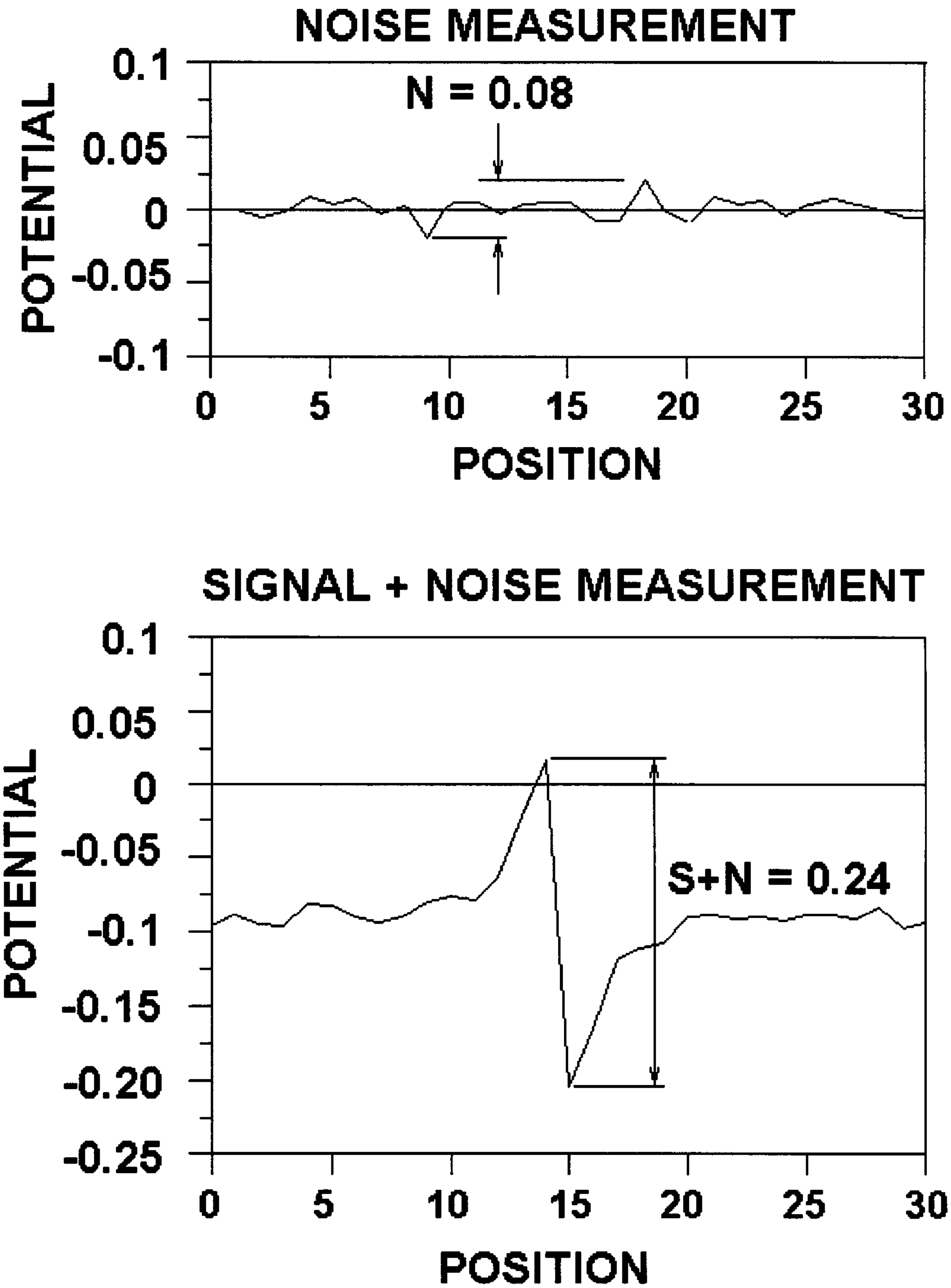


FIG. A3.2 Geometry for Measurements With Artificial or Actual Leak for Surveys with Earth Materials Covering the Geomembrane



$$(S+N) / N = 0.24 / 0.08 = 3.0$$

FIG. A3.3 Example of Determining (*S* + *N*) / *N*

A4. PROCEDURES FOR LEAK DETECTION SENSITIVITY TEST FOR SURVEYS WITH EARTH MATERIAL COVERING THE GEOMEMBRANE USING AN ACTUAL LEAK

A4.1 **Warning—**Because of the high voltage that could be involved, and the shock or electrocution hazard, do not attempt to drill the actual leak hole, or touch the leak, or pour water on it when the excitation power supply is turned on.

A4.2 *Actual Leak*—If an actual leak is used, it shall be constructed by drilling a hole with a diameter no greater than 6.0 mm in the installed geomembrane that is to be tested. For a double geomembrane system, measures shall be taken to ensure that the drill bit does not damage the secondary geomembrane. The hole shall be drilled, and the drill bit moved forward and backward in the hole so the geomembrane material is removed rather than displaced. The leak shall be placed at least 10 m from any edge of the survey area.

A4.3 The leak shall be backfilled with no less than 50 mm of earth material and then no more than 250 mL of water should be poured over the partially buried actual leak. The excavation shall then be backfilled. The location of the actual leak shall be clearly marked on the surface.

A4.4 *Leak Detection Sensitivity Test*—Closely-spaced measurements shall be taken to determine the leak signal and background noise signal as follows:

A4.4.1 With the excitation power supply turned off, a line of data shall be taken and recorded over the actual leak to measure and quantify the background noise level (*N*). Measurements shall be taken on a line that extends at least five metres in front of and in back of the actual leak. The spacing of the measurements shall be the same as that planned for the leak location survey.

A4.4.2 The background noise level (*N*) shall be defined as the difference between the maximum and minimum measured potential with the excitation power supply turned off.

A4.4.3 With the excitation power supply turned on, leak location measurements shall be made and recorded along closely-spaced parallel lines or on a grid centered on the actual leak. The distance from each of the parallel lines or grid points to the surface projection of the actual leak shall be measured. Fig. A3.2 shows the geometry of the measurements. The measurement layout is such that the actual leak is at the farthest distance from the adjacent measurements. The lines shall be centered on the actual leak and extend at least 5 metres in front and in back of the actual leak.

A4.4.4 These signals are the actual leak signal plus noise ($S + N$). The recorded leak location data shall be examined to determine the peak-to-peak leak signal plus noise to noise ratio $R = (S + N)/N$ for each of the recorded data lines. Fig. A3.3 shows an example of the measurements of N and $S + N$. The measured leak signals shall have the characteristics of a leak. Spurious, false, and unrepeatable data points that deviate from the theoretical leak signal shall not be used to determine *R*. The leak signal shall be represented by five or more data points in the data.

A4.4.5 The two farthest lateral lines or grid lines of data with an *R* value greater than 3.0 shall be noted and their distance to the surface projection of the actual leak shall be recorded. The average of these distances is defined to be the leak detection distance.

A4.4.6 If site conditions prevent an *R* value greater than 3.0 from being obtained, the leak detection distance shall be defined to be 0.5 metres and the leak location survey shall be conducted with a uniform density of 1 measurement per square metre. These procedures can be followed provided the leak location equipment can be demonstrated to detect a shallower actual leak from a lesser distance, and that periodic leak detection sensitivity tests described in 8.11 are made at the lesser distance.

A4.4.7 The distance from the actual leak to the current source electrode shall be measured and recorded.