



Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes¹

This standard is issued under the fixed designation D6747; 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 guide is intended to assist individuals or groups in assessing different options available for locating leaks in installed geomembranes using electrical methods. For clarity, this document uses the term leak to mean holes, punctures, tears, knife cuts, seam defects, cracks and similar breaches through an installed geomembrane.

1.2 This guide does not cover systems that are restricted to seam testing only, nor does it cover systems that may detect leaks non-electrically. It does not cover systems that only detect the presence, but not the location of leaks.

1.3 **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.**

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D4439 Terminology for Geosynthetics

¹ This guide is 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.

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

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

D7240 Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)

3. Terminology

3.1 *For general definitions used in this document, refer to D4439.*

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *electrical leak location, n*—a method which uses electrical current or electrical potential to detect and locate leaks

3.2.2 *leak, n*—for the purposes of this document, 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. Leaks detected during surveys have been grouped into five categories:

3.2.2.1 *holes*—round shaped voids with downward or upward protruding rims.

3.2.2.2 *tears*—linear or areal voids with irregular edge borders.

3.2.2.3 *linear cuts*—linear voids with neat close edges.

3.2.2.4 *seam defects*—area of partial or total separation between sheets

3.2.2.5 *burned through zones*—voids created by melting polymer during welding.

4. Significance and Use

4.1 Leaks are typically related to the quality of the subgrade material, quality of the cover material, care in the cover material installation and quality of geomembrane installation.

4.2 Experience demonstrates that geomembranes can have leaks caused during their installation and placement of material(s) on the geomembrane.

4.3 The damage to a geomembrane can be detected using electrical leak location systems. Such systems have been used successfully to locate leaks in electrically-insulating geomembranes such as polyethylene, polypropylene, polyvinyl chloride, chlorosulfonated polyethylene and bituminous geomembranes installed in basins, ponds, tanks, ore and waste pads, and landfill cells.

4.4 The principle behind these techniques is to place a voltage across a synthetic geomembrane and then locate areas where electrical current flows through discontinuities in the geomembrane (as shown schematically in Fig. 1). Other electrical leak paths such as prevent pipe penetrations, flange bolts, steel drains, and batten strips on concrete and other extraneous electrical paths should be electrically isolated or insulated to prevent masking of leak signals caused by electrical current flowing through those electrical paths. The only electrical paths should be through leaks in the geomembrane. This electric detection method of locating leaks in geomembranes can be performed on exposed geomembranes, on geomembranes covered with water or on geomembranes covered with an earthen material layer, or both.

5. Developed Systems

5.1 Electrical leak detection systems were developed in the early 1980's and commercial surveys have been available since 1985. A short description of each of these systems is presented in this section.

5.2 *The Water Puddle and Water Lance System*—The technique is appropriate to survey a dry uncovered geomembrane placed directly on a conductive layer below the electrically insulating geomembrane. Practice D7002 is a standard practice describing the water puddle method. The lower conductive material is usually the sub-grade soil and the upper conductive layer being the water in a puddle or a stream of water. One electrode of a low voltage power supply is placed in contact with the lower conductive material and another electrode is placed in a water puddle maintained by a squeegee or in the water stream of a lance (as shown schematically in Fig. 2 and Fig. 3, respectively). Water is usually supplied from a tank or other pressurized water source. For this technique to be

effective in locating leaks, the water in the puddle or stream must come into contact through the leak with the electrical conducting material below the geomembrane. This completes an electrical circuit and electrical current will flow. Detector electronics are used to monitor the electrical current. The detector electronics usually convert a change in the current into a change in an audio tone. Leaks as small as 1 mm in size have been identified with this method; typically by listening to an audio signal or by measuring a current

5.2.1 *Features*—The main advantage of this system is the detection of leaks in geomembrane seams and sheets while the geomembrane installation work progresses during construction. The system does not require covering the geomembrane with water other than the small puddle of water or stream. Procedures can be used to differentiate smaller leaks from larger leaks in their vicinity. The electrical survey rate of approximately 500 m²/h per operator does not affect the installation work schedule and permits a rapid construction quality control of the geomembrane installers' finished work. The approximate setup time varies from 1 to 3 h.

5.2.2 *Limitations*—This technique cannot be used when an earthen material layer is covering the geomembrane. The presence of wrinkles and waves, steep slopes and lack of contact between the geomembrane and the conductive material underneath inhibits the survey from being performed at those locations unless special measures are undertaken. This technique cannot be used during rainy weather or when the membrane is installed on an electrically non-conductive material, typically a desiccated subgrade, and in the near vicinity of conductive structures that cannot be fully insulated or isolated. The detection of leaks in seams of repair patches is difficult and time consuming since it requires a potential lengthy water infiltration time.

5.3 *The Water-Covered Geomembrane System*—This system is to test the geomembrane while it is covered with water, with an electrically conductive material below the geomembrane. Practice D7007 contains a standard practice for this system. An electrical power supply is connected to one electrode which is put in the water and another electrode is

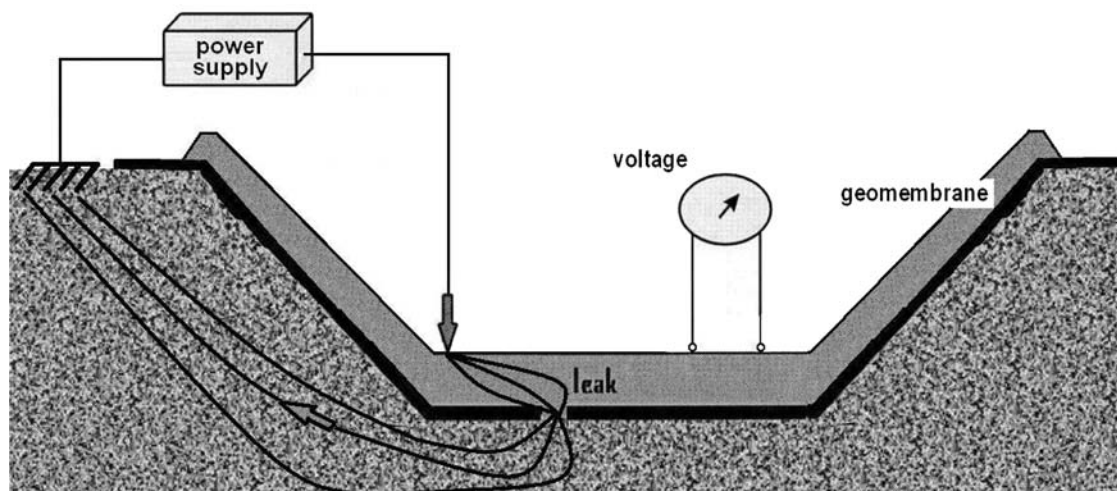


FIG. 1 Schematic of the Electrical Leak Location Method (Earthen material-Covered Geomembrane System is Shown)

Water Puddle

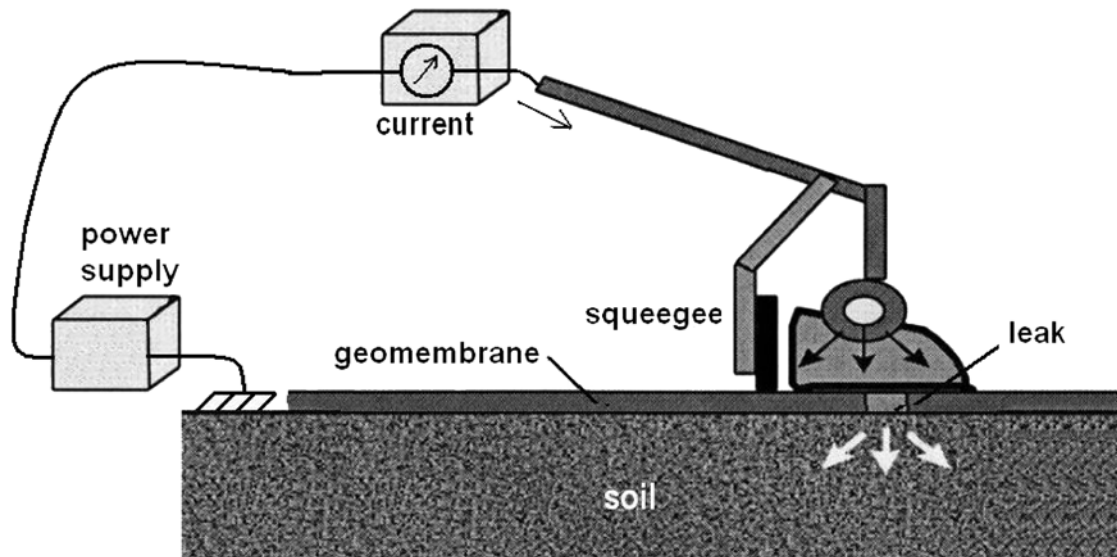


FIG. 2 Schematic of Water Puddle Systems

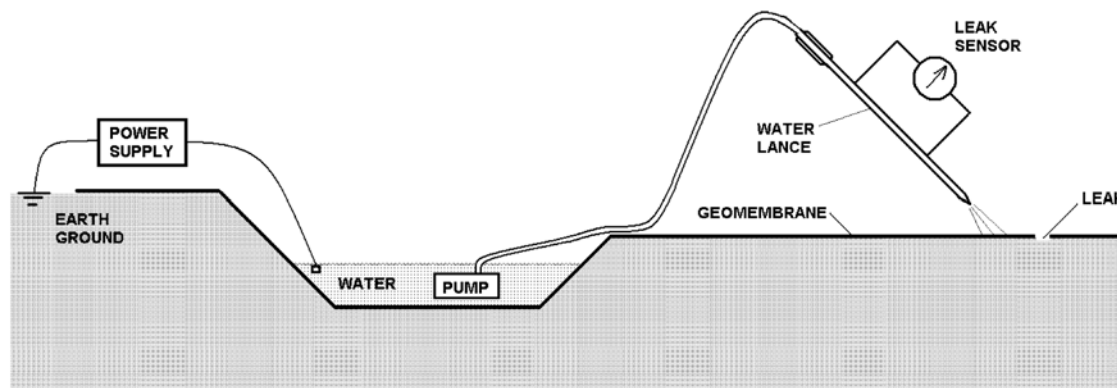


FIG. 3 Schematic of Water Lance System

placed in contact with the electrically conductive material under the geomembrane. The voltage impressed across the geomembrane produces a low current flow and a relative uniform voltage distribution in the material above the geomembrane. An electrical current flowing through the leaks causes localized abnormalities in the electrical potential at the location of the leak as shown schematically in Fig. 4. To maximize the current flowing through the leaks, a high voltage power supply with safety circuits can be used. A hand-held probe or a probe on a long cable is scanned through the water to locate these places where current is flowing through a leak. This technique can locate very small leaks, smaller than 1 mm. The signal amplitude is inversely related to the distance from the leak, so the scanning spatial frequency should be designed to provide the desired leak detection sensitivity.

5.3.1 Features—This system has the advantage of being used to locate leaks in in-service impoundments (assuming the contained liquid is electrically conductive). Primary geomem-

branes can be tested when a conductive material is available underneath the geomembrane. Secondary geomembranes can be tested before the primary geomembrane is installed. The water head on the geomembrane ensures good electrical contact with the conductive material under the geomembrane through any leaks, resulting in optimum leak detection sensitivity. While this technique can be performed in rainy conditions, it is never recommended to do a survey during stormy conditions. The system can also be used for the detection of leaks with an earthen material layer covering the geomembrane (for example after the installation of the drainage layer on the geomembrane). The survey rate depends primarily on the spacing between sweeps and the depth of the water. A close spacing between sweeps is needed to detect the smallest leaks. The survey rate for a survey while wading, sweeping the probe so that it comes within 0.25 m of every point on the submerged geomembrane is 800 to 1200 m²/h per person. For a survey with a towed probe with the probe scanned within 0.4 m of

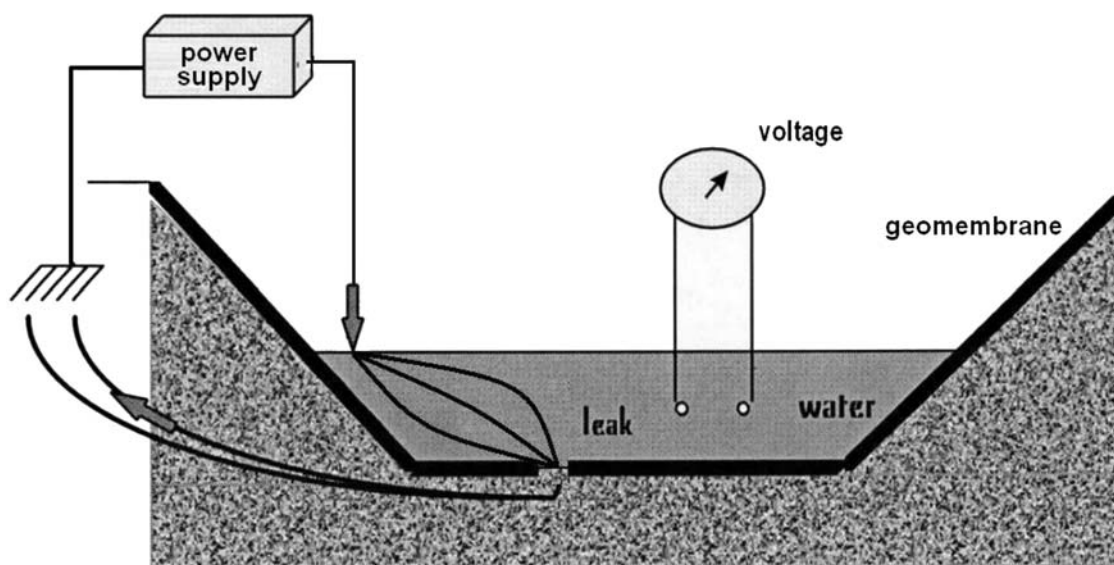


FIG. 4 Schematic of the Water-Covered Geomembrane System

every point, the survey rate is 800 to 1000 m²/h per two persons, including establishing the survey lines. The approximate setup time is 30 to 90 min. These times do not include the time to cover the geomembrane with water.

5.3.2 Limitations—The main disadvantage of this system is that it cannot be applied to detect leaks in geomembrane joints and sheets as work progresses during construction, because of the need to cover the geomembrane with water. The presence of large leaks may interfere with the detection of small leaks in their vicinity. The procedure requires the time and effort to cover the area with water, probing to locate leaks and draining the area to repair any found leaks.

5.4 Spark Testing Electrically Conductive Geomembrane System—CCoextrusion technology made it possible to manufacture a polyethylene geomembrane that can be spark tested. ASTM D7240 is a standard practice for this system. The material has a thin layer of electrically conductive material on one surface as an integral part of the geomembrane. This provides a way to spark test the installed geomembrane. The spark testing that occurs in the field is very similar to the method used in the factory to identify holes during geomembrane manufacturing. The conductive geomembrane is installed such that the conductive surface is against the soil sub-grade and the non-conductive surface is on top. The testing utilizes a voltage source to charge an element such as an electrically conductive neoprene pad. The charge is then transferred to the (underlying) conductive layer of the geomembrane through the capacitance effect. Another conductive element is then swept over the upper surface to inspect for the presence of leaks. Where a leak occurs, a closed circuit is created and a spark is produced as shown in Fig. 5. To facilitate leak location, equipment must include an audible alarm. Different types of equipment are utilized depending on the area to be tested. For example, small, hand-held detectors are used in confined areas and large detectors can be used on large, open areas.

5.4.1 Features—The main advantages of this technique are: this is the only system that utilizes a conductive grounding layer that is an integral part of the geomembrane being tested thus eliminating the issue of inconsistent grounding; it can be performed while construction is ongoing; no water pumping is required; current flow is miniscule; primary and secondary geomembranes can be tested; all slopes can be tested; it can detect leaks smaller than 1 mm. The rate of testing depends on the type of equipment used. Using a 2-m wide brush, travelling at 3 to 5 km/h, the rate can be up to 500–1,500 m²/h. Repairs can be performed immediately upon location of a leak. The setup time required is approximately 30 min.

5.4.2 Limitations—The presence of wrinkles and waves and steep slopes may reduce survey speed. This technique cannot be used during rain events, and it is only applicable to exposed conductive geomembranes that are relatively clean and dry. Other geomembranes in intimate contact with a conductive surface may be tested with this method. It is not the intention of this method to replace traditional non-destructive testing of seams.

5.5 The Earthen material-Covered Geomembrane System—Standard Practice D7007 tests the geomembrane after the earthen material layer is emplaced. As shown in Fig. 6, it is similar to the water-covered geomembrane method except the geomembrane is covered with earthen material, and point-by-point measurements are made on the surface of the earthen material. The earthen material must have adequate moisture, but the earthen material does not have to be saturated with water. It requires an electrically conductive material above and below to test the geomembrane. The most common implementation of this method is to make dipole measurements using two moving electrodes spaced a fixed distance apart. Pole measurements can also be made by making potential measurements on the earthen material cover using one moving electrode referenced to a second distant stationary electrode. The data can be taken on a grid or at regular points along parallel

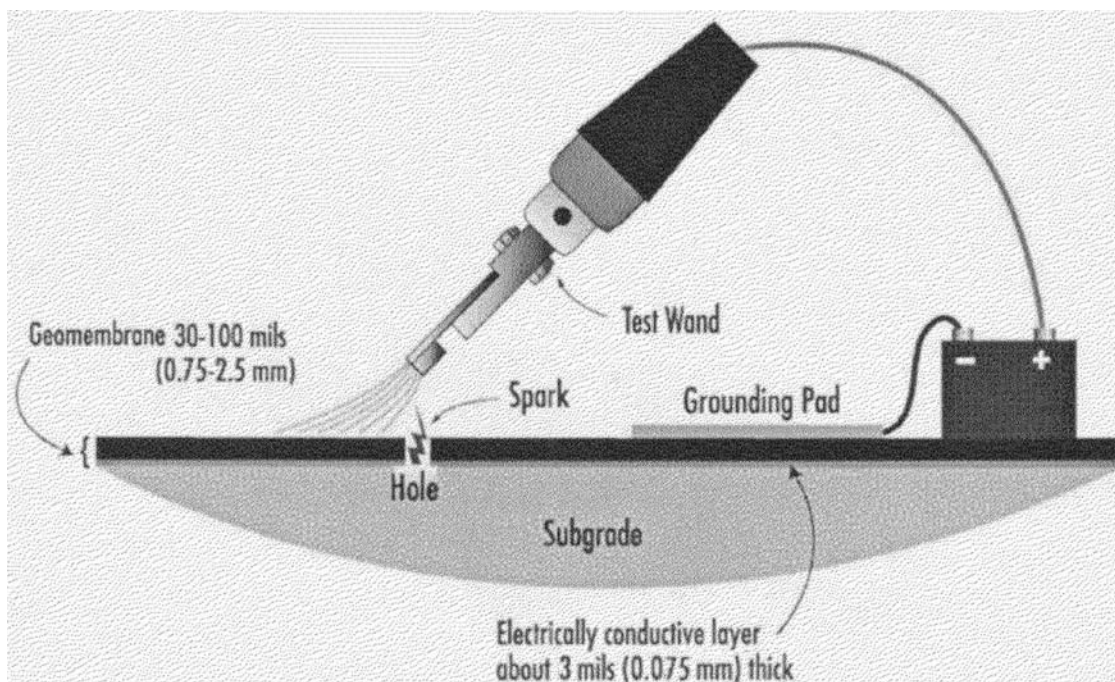


FIG. 5 Schematic of Spark Testing Electrically Conductive Geomembrane System

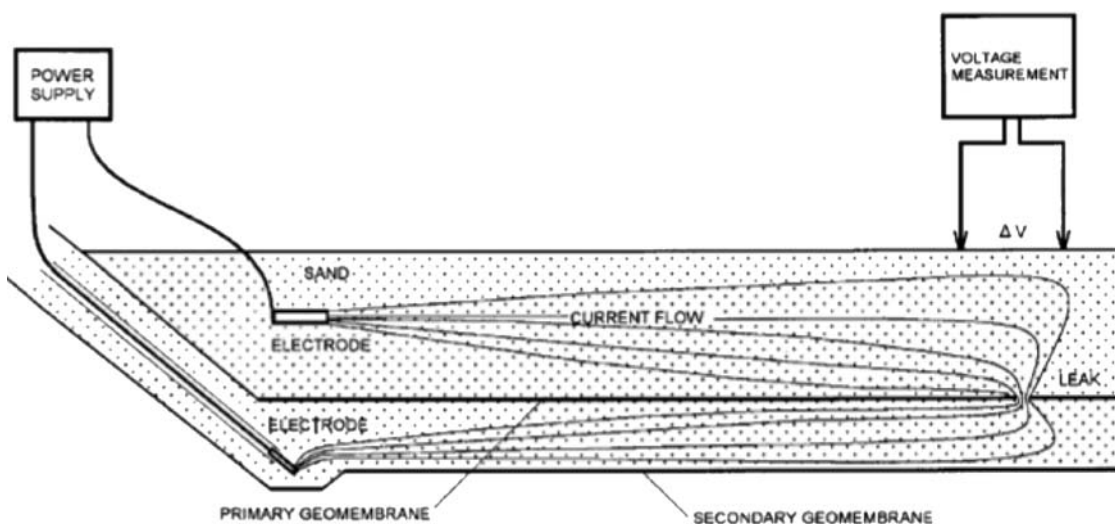


FIG. 6 Schematic of Earthen material-Covered Geomembrane System

survey lines. The data can be plotted in the field and analyzed to locate areas displaying a characteristic leak signal. The data can be analyzed in raster data form or using contour plots.

5.5.1 Features—This method has the distinct advantage of locating leaks that are made during the emplacement of the earthen material layer above the geomembrane. These leaks, due to construction damage, have been found to be the prevalent type of damage to geomembranes that are difficult to witness during construction quality assurance activities. This technique can be used in wet conditions. With proper signal sampling, this technique can locate very small leaks under 600 mm of earthen materials. The survey rate depends on the sampling density of the measurements. The rate of testing also depends on data acquisition methodology and whether the data

interpretation is accomplished in the field. The approximate survey rates for a survey taking one measurement every square meter is 400 to 1,000 m²/h per person; including establishing the survey lines and including data interpretation. Setting up the equipment and electrodes typically requires 1 to 2 h.

5.5.2 Limitations—A limitation of this method is that the overlying and underlying earthen material must have adequate electrical conductivity to perform the leak location survey. In cases where the earthen material is non-conductive (typically because it is desiccated), the earthen material should be wetted with water, or upper layers of the desiccated soil could be scraped away at the measurement points.

5.6 The Grid System—This permanent system has been developed to monitor leaks under bottom liners and lined final

covers of landfills. Fig. 7 shows a diagram of a typical installation. The leaks are located by taking potential measurement via a widely spaced grid of electrodes under the lined area. The collected data are then processed to determine the distribution of the current density that best reproduces the observed voltage data.

5.6.1 Features—The system is used principally as a permanent monitoring system. It can alert an operator on a continuous or periodic basis. The technique permits isolating the general location of a leak. It can be used under cover earthen material and with waste stored in the application. Telemetry can be used for remote and/or ongoing monitoring. The survey time can be very fast and depends on the degree of automation of the data acquisition system.

5.6.2 Limitations—The main limitation is related to the placing of the electrodes under the floor area. Because of the large amount of wire needed for large grids, the system is usually installed in smaller sections. It cannot be used during the construction phase.

6. System Functionality or Calibration

6.1 A realistic test of the leak detection sensitivity should be performed and documented as part of every leak location survey. An actual or artificial leak can be used. The corresponding standard practices for the various leak location systems can be used to determine the size, construction, use, and operation of the actual or artificial leak. A summary of the leak detection sensitivity test follows for each scenario below, specific focus was placed on the artificial leaks.

6.2 For the water puddle and water lance systems, an artificial leak consists of a leak placed in a piece of geomembrane placed on its representative subgrade. Practice D7007 contains relevant details about the use of an artificial leak and an actual leak for the water puddle system. All leak location equipment, personnel, and procedures should demonstrate the ability to detect the artificial or actual leak prior to commencing the leak location survey.

6.3 For a water-covered geomembrane, the artificial leak consists of a leak in an insulating container that is connected to the material under the geomembrane with an insulated wire. Practice D7007 contains the relevant details about the con-

struction and use of an artificial leak as well as for an actual leak. The artificial leak is submerged in the water above the geomembrane. All leak location equipment, personnel, and procedures should demonstrate the ability to detect the artificial or actual leak under the worst case conditions. During the production leak location survey, the spacing of the leak location sensor sweeps should not exceed that used during the leak detection sensitivity test.

6.4 For a soil-covered geomembrane, the artificial leak is a usually a small circular metal electrode about the size of an actual leak. An insulated wire connects the electrode to the conductive material underneath the geomembrane. Practice D7007 contains the relevant details about the construction and use of an artificial leak as well as for an actual leak. The artificial leak is buried in the earthen material cover at the depth of the geomembrane. All the leak location equipment, personnel, and procedures used should demonstrate the ability to detect the artificial or actual leak under worst case conditions. During the production leak location survey, the spacing of the leak location sensor sweeps should not exceed that used during the leak detection sensitivity test

6.5 Spark testing an electrical conductive geomembrane, an actual leak is made on a test piece of geomembrane; the test piece is placed on a large scrap of geomembrane or on the installed geomembrane with the conductive side down. Practice D7240 contains the relevant details about the system functionality test for this system. All the leak location equipment (the mobile brush) and procedures should demonstrate the ability to detect the actual leak made in the test piece of the geomembrane.

7. Considerations

7.1 In selecting one of the many systems described in Section 5, the following considerations should be taken into account:

7.1.1 Subgrade restrictions (conductivity, moisture content, etc.),

7.1.2 Geosynthetics underneath or above the geomembrane,

7.1.3 Uncovered material restrictions (waves, wrinkles, steep slopes, etc.),

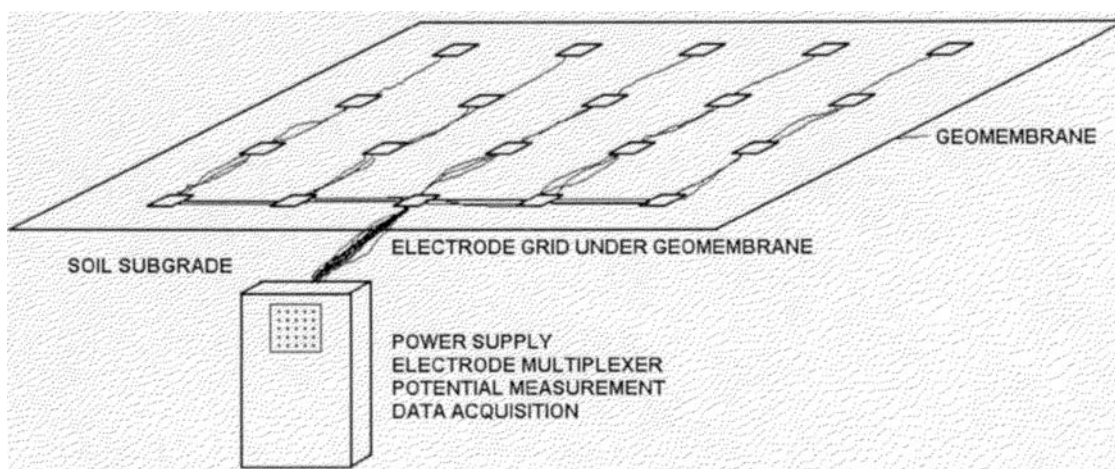


FIG. 7 Schematic of the Grid System

7.1.4 Cover material restrictions (conductivity, water saturation, etc.),

7.1.5 Water requirement (depth necessary, quantity of water needed, bottom slope),

7.1.6 Protruding accessories (pipes, steel bars, access platforms, etc.),

7.1.7 Economic factors, and

7.1.8 Intent of test.

8. Reporting

8.1 A report of electrical leak location survey is usually prepared according to the relevant standard practices: **D7002**, **D7007**, and **D7240**

9. Keywords

9.1 electrical leak location system; geomembrane; leak detection

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