Geosynthetic membranes or geomembranes are 0.5 to 2.5 mm (0.02 to 0.1 in.) thick sheets of plastic that are used to prevent liquid leakage to the environment primarily in landfills, ponds, mining leach pads, and tanks (Fig. 1). They are also used in wastewater treatment plants, potable water reservoirs, dams, canals and as floating covers. Leakage in geomembranes can cause pollution of groundwater, product loss, and even failure of containment systems. Leaks can easily occur because of inadequate installation, damage from construction activities, and damage while placing a protective layer of earth on the geomembrane. Nondestructive testing techniques are used for preservice testing of the seams and sheets for leaks. Often when a leakage problem is experienced, nondestructive leak location techniques are used to locate the leaks for repair.

Some flexible types of geomembranes are custom-made to fit an installation, but the more rigid geomembranes are deployed in rolls and seamed together in the field. The seams can be extrusion welds, fusion welds, and sometimes solvent welds (Fig. 2). Often the geomembranes are covered with a layer of earth materials.

Although not discussed in this article, destructive testing is also performed on the material and particularly on the geomembrane seams to test the physical characteristics. Destructive testing of seams requires cutting out a large section of the seam, requiring large patches at the sample location.

Figure 1. Nondestructive testing techniques are used to locate leaks in geomembranes such as the one shown in this large pond.
Nondestructive testing of geomembranes can be divided into two general categories. The first is testing as part of construction quality control, specifically the testing of the seams and patches. The other category is leak location methods for locating leaks in the geomembrane panels as well as in the seams.  

**Nondestructive Testing of Seams**

Nondestructive methods used to test the seams during the installation of the geomembranes include vacuum box testing, air channel pressure testing, air lance testing, and spark testing.

**Vacuum Box Testing.** Vacuum box testing is primarily used to test extrusion welds on rigid geomembranes. A rigid rectangular box with an open bottom with rubber seals and a clear plastic window on top is placed on a section of extrusion weld that has been wetted with a soap solution. A vacuum pump is used to draw a partial vacuum on the box. Leaks are visually indicated by bubbling in the soap film. Because of the labor involved, this method is primarily used only on patches. Some skill is needed to be able to get a good seal and to visually recognize leaks through the window, which is usually obscured with soap solution. It is only applicable on relatively flat surfaces. ASTM D5641 is a standard practice for vacuum box testing.

**Pressure Testing of Seams.** Double track fusion welders produce two closely-spaced seams at the same time. This allows the ends of the seams to be sealed for pressure testing. An air pump is connected to a hose with a valve, pressure gauge and hollow needle at the end of the hose. The top layer of the seam is punctured with the hollow
needle and the air pump pressurizes the seam to the specified level. The valve is closed and the pressure is monitored for a prescribed time. A specified pressure drop indicates a leak in the seam. Air pressure testing of double seams is conducted in accordance with ASTM D5820. Pressure testing of dual-track seams in polyvinyl chloride (PVC) geomembranes is conducted in accordance with ASTM D7177.

**Air Lance Testing.** Flexible geomembrane seams can be tested using an air lance. An air lance is a hollow tube with an ell and orifice at the end. A suitable air compressor is connected to the air lance with an air hose. The orifice of the air lance is directed towards the edge of the upper flap of the seam. Unbonded areas are indicated when the air flow causes a vibration of the geomembrane. ASTM D4437 describes the air lance test as well as other nondestructive tests for flexible geomembranes.

**Spark Test.** Applied in accordance with ASTM D6365, the spark test is used particularly for seams that cannot be tested using the other nondestructive tests, specifically for curved surfaces, corners, and penetrations through the geomembrane. A wire or other conductive strip is embedded at the edge of the top sheet of an extrusion weld. The end of the wire is grounded. A holiday tester with a current-limited voltage of several thousand volts is used with a conductive probe or brush. The probe or brush is passed along the weld bead and a spark discharge will occur if there is an air channel or void between the probe and the grounded wire.

**Leak Location Testing**

Imagine the task of locating a small leak in a geomembrane-lined pond as large as the one shown in Fig. 1. The second category of nondestructive testing of geomembranes routinely accomplishes that. Leak location testing using electrical methods is sometimes called **electrical leak location testing** or **geoelectric leak location**. It goes without saying that the most important test of a geomembrane, whose only function is to prevent liquid leakage, is to test for leaks. Geoelectric methods test for leaks in the seams and patches as well as in the geomembrane panels.

Figure 3 shows the basic geomembrane leak location method is to connect a direct current power supply to one electrode in contact with a conductive material under the geomembrane and another electrode in contact with conductive material above the geomembrane. Although the two media are actually resistive, they are electrically conductive compared to the electrical resistance of a leak. Because the geomembrane is an electrical insulator, with no leaks no electrical current will flow, and the resulting electrical potentials on the geomembrane are uniform. But if the geomembrane has leaks, electrical current will flow through the leaks, causing a characteristic anomaly in the potential at the leaks. Various probes are used to detect or map these anomalies to locate the leaks.

Various implementations have been developed to test bare geomembranes, geomembranes covered with shallow and deep water, and geomembranes covered with earth materials. There is no standardization of the equipment used for the leak location testing. Instead, performance-based standards are used. The equipment and survey parameters are tested to determine the leak detection distance using a simulated or actual leak of a specified size. Simulated leaks are electrical equivalents of a leak in a geomembrane. Leak location measurements are made to determine the maximum leak detection distance for the specified artificial or actual leak size. The leak location surveys are conducted so that measurements are made within that distance of every point on the geomembrane. The various methods and the advantages and limitations of each are presented in ASTM D6747.

**Water Puddle Method for Bare Geomembranes**

For bare geomembranes, leaks are detected by pushing a puddle of water over the geomembrane using a squeegee or other device. A low voltage electrical power supply is connected to a conductive media under the geomembrane such as earth ground. The other output of the power supply is connected through an electronic current monitoring detector to the squeegee in contact with a puddle of water. The puddle of water is pushed ahead of the squeegee and when the water puddle passes over a leak in the geomembrane, the water flows through the leak and contacts earth ground. This completes a circuit and the resulting current is monitored by the electronic detector. The detector typically converts the increase in the current to an audible tone indication and a meter reading.

Figure 4 shows the operation of a water puddle system. Leaks with a diameter of 1 mm (0.04 in.) are routinely detected.

![Figure 4. Water puddle system used to detect leaks in bare geomembrane.](image-url)
A similar method uses a stream of water or water lance that is scanned over the geomembrane instead of pushing a puddle.\(^9\)

**Spark Testing of Conductive Geomembrane**

A proprietary geomembrane is available with a conductive surface layer that is installed with the conductive layer downward. The geomembrane is tested in accordance with ASTM D7240 using a holiday tester similar to that described for the spark testing of seams above.\(^10\) In this case a wide metallic brush is used to sweep the geomembrane. When a leak is encountered, a spark discharge indicates a leak.

**Leak Location with Water on the Geomembrane\(^11\)**

ASTM D7007 contains standard practices for performing leak location surveys with water on the geomembrane. Leaks are detected using one of several dipole probes. One type is a 2.5 m (8 ft) probe that is used while wading in the water (Fig. 4). Another wading implementation uses two electrodes on two arms that are hinged together. Other probes include a towed probe for deep water and a plumb bob probe for vertical walls.

Typically the power supply provides 100 to 400 volts across the geomembrane. The probes are scanned on the geomembrane. An electronic detector measures the voltage and sometimes polarity of the voltage on the probes. Typical detectors convert the signal to a meter reading and an audible tone that increases with leak signal amplitude. When a leak signal is detected, the probes are maneuvered to obtain the maximum signal, which corresponds to the exact location of the leak. With wading surveys the leaks are typically marked with small sand bags connected to a float with a string. Typically, leaks with a diameter of 1.3 mm (0.05 in.) and even smaller can be easily detected.

**Leak Location with Earth Materials on Geomembrane\(^11\)**

Geomembranes are often covered with earth materials for protection, particularly for landfills. Leak location testing is used to detect the major damage that can be caused by heavy machinery placing the earth materials on the geomembrane. Instead of scanning the measurement probe along the geomembrane, measurements are made on the surface of the earth material (Fig. 6) using two electrodes spaced a fixed distance apart. This implementation is sometimes called the *dipole method*. Point-by-point potential measurements are made with the dipole probe and a portable digital data acquisition system along equally spaced survey lines. The data is downloaded to a computer for storage, plotting and analysis. When a suspect area is indicated in the data, manual measurements are made to further pinpoint the leak position. Typically, leaks with a diameter of 6.4 mm (0.25 in.) are routinely detected, and much smaller leaks are detected depending on how close the survey line happens to be from the leak.

**Conclusion**

Nondestructive testing of geomembrane seams is an important part of construction quality control of geomembrane installations. Several states are requiring geomembrane leak location testing for landfills and ponds on new installations and periodically when in service. Leak location testing is also widely applied as part of construction quality assurance and to solve leakage problems. Engineers, owners, and regulators understand the importance of testing the only function of a geomembrane, which is to prevent leakage.
References


