Designation: D 5886 – 95

Standard Guide for
Selection of Test Methods to Determine Rate of Fluid Permeation Through Geomembranes for Specific Applications[1]

This standard is issued under the fixed designation D 5886; 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 guide covers selecting one or more appropriate test methods to assess the permeability of all candidate geomembranes for a proposed specific application to various permeants. The widely different uses of geomembranes as barriers to the transport and migration of different gases, vapors, and liquids under different service conditions require determinations of permeability by test methods that relate to and simulate the service. Geomembranes are nonporous homogeneous materials that are permeable in varying degrees to gases, vapors, and liquids on a molecular scale in a three-step process (*1*) by dissolution in or absorption by the geomembrane on the upstream side, (*2*) diffusion through the geomembrane, and (*3*) desorption on the downstream side of the barrier.

1.2 The rate of transmission of a given chemical species, whether as a single permeant or in mixtures, is driven by its chemical potential or in practical terms by its concentration gradient across the geomembrane. Various methods to assess the permeability of geomembranes to single component permeants, such as individual gases, vapors, and liquids are referenced and briefly described.

1.3 Various test methods for the measurement of permeation and transmission through geomembranes of individual species in complex mixtures such as waste liquids are discussed.

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 limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 471 Test Method for Rubber Property—Effect of Liquids[2]
D 814 Test Method for Rubber Property—Vapor Transmission of Volatile Liquids[2]
D 815 Method for Testing Coated Fabrics—Hydrogen Permeability[3]
D 1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting to Gases[4]
D 1653 Test Methods for Water Vapor Permeability of Organic Coating Films[5]
D 4439 Terminology for Geosynthetics[6]
D 4491 Test Methods for Water Permeability of Geotextiles by Permittivity[6]
E 96 Test Methods for Water Vapor Transmission of Materials[7]
F 372 Test Method for Water Vapor Transmission Rate of Flexible Barrier Materials Using an Infrared Detection Technique[4]
F 739 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Continuous Contact[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *downstream*, *n*—the space adjacent to the geomembrane through which the permeant is flowing.

3.1.2 *geomembrane*, *n*—an essentially impermeable geosynthetic composed of one or more synthetic sheets. (See Terminology D 4439.)

3.1.2.1 *Discussion*—In geotechnical engineering, essentially impermeable means that no measurable liquid flows through a geosynthetic when tested in accordance with Terminology D 4491.

3.1.3 *geosynthetic*, *n*—a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering-related material as an integral part of a man-made project, structure, or system. (See Terminology D 4439.)

3.1.4 *permeability*, *n*—the rate of flow under a differential pressure, temperature, or concentration of a gas, liquid, or

---

[1] This guide is under the jurisdiction of ASTM Committee D-35 on Geosyntheticsand is the direct responsibility of Subcommittee D35.10 on Geomembranes.

Current edition approved Dec. 10, 1995. Published February 1996.

[2] *Annual Book of ASTM Standards*, Vol 09.01.

[3] Discontinued; see *1988 Annual Book of ASTM Standards*, Vol 09.02.

[4] *Annual Book of ASTM Standards*, Vol 15.09.

[5] *Annual Book of ASTM Standards*, Vol 06.01.

[6] *Annual Book of ASTM Standards*, Vol 04.09.

[7] *Annual Book of ASTM Standards*, Vol 04.06.

[8] *Annual Book of ASTM Standards*, Vol 11.03.

vapor through a material. (Modified from Terminology D 4491.)

3.1.5 *permeant*, *n*—a chemical species, gas, liquid, or vapor that can pass through a substance.

4. Summary of Guide

4.1 The wide range of uses of geomembranes as barriers in many different environments to many different permeating species requires different test procedures to assess the effectiveness of a given membrane for a given application. The permeating species range from a single component to highly complex mixtures such as those found in waste liquids and leachates. In specialized applications, service it may be important to measure transmission or migration of a species that would take place under specific conditions and environments including temperature, vapor pressure, and concentration gradients. Tests that would be applicable to the measurement of the permeability of a material to different permeants present in various applications are summarized in Table 1.

4.1.1 In the use of geomembranes in service as barriers to the transmission of fluids, it is essential to recognize the difference between geomembranes that are nonporous homogeneous materials and other liner materials that are porous, such as soils and concretes. The transmission of permeating species through geomembranes without holes proceeds by absorption of the species in the geomembrane and diffusion through the geomembrane on a molecular basis. The driving force is chemical potential across the geomembrane. A liquid permeates porous materials in a condensed state that can carry the dissolved constituents, and the driving force for such permeation is hydraulic pressure. Due to the selective nature of geomembranes, the permeation of the dissolved constituents in liquids can vary greatly, that is, components of a mixture can permeate at different rates due to differences in solubility and diffusibility in a given geomembrane. With respect to the inorganic aqueous salt solution, the geomembranes are semipermeable, that is, the water can be transmitted through the geomembranes, but the ions are not transmitted. Thus, the water that is transmitted through a hole-free geomembrane does not carry dissolved inorganics. The direction of permeation of a component in the mixture is determined thermodynamically by its chemical potential difference or concentration gradient across the geomembrane. Thus the water in the wastewater on the upstream side is at a lower potential than the less contaminated water on the downstream side and can permeate the geomembrane into the wastewater by osmosis.

4.1.2 Although inorganic salts do not permeate geomembranes, some organic species do. The rate of permeation through a geomembrane depends on the solubility of the organic in the geomembrane and the diffusibility of the organic in the geomembrane as driven by the chemical potential gradient. Principle factors that can affect the diffusion of an organic within a geomembrane include:

4.1.2.1 The solubility of the permeant in the geomembrane,

4.1.2.2 The microstructure of the polymer, for example, percent crystallinity,

4.1.2.3 Whether the condition at which diffusion is taking place is above or below the glass transition temperature of the polymer,

4.1.2.4 The other constituents in the geomembrane compound,

4.1.2.5 Variation in manufacturing processes,

4.1.2.6 The flexibility of the polymer chains,

4.1.2.7 The size and shape of the diffusing molecules,

4.1.2.8 The temperature at which diffusion is taking place, and

4.1.2.9 The geomembrane.

4.1.3 The movement through a hole-free geomembrane of mobile species that would be encountered in service would be affected by many factors, such as:

TABLE 1 Applicable Test Method for Measuring Permeability of Geomembranes to Various Permeants

Fluid Being Contained	Example of Permeant	Example of Field Application	Applicable Test Method and Permeant Detector and Quantifier
Single-Component Fluids:			
Gas	H_2, O_2 N_2, CH_4 CO_2	Barriers, pipe, and hose liners	D 815 D 1434-V D 1434-P
Water vapor	H_2O	Moisture vapor barriers, water reservoir covers	E 96, D653
Liquid water	H_2O	Liners for reservoirs, dams, and canals	Soil-type permeameter with hydraulic pressure
Organic vapor	Organic species	Secondary containment for organic solvent and gasoline	D 814, E96, F372
Organic liquid	Organic solvents species	Containers, tank liners secondary containment	D 814, E96
Multicomponents Fluids:			
Gases	CO_2/CH_4	Barriers, separation of gases	F 372, GC, GCMS
Aqueous solutions of inorganic, for example, brines, incinerator ash leachates, leach pad leachate	Ions, salts	Pond liners	Pouch, osmotic cell, ion analysis
Mixtures of organics, spills, hydrocarbon fuels	Organic species	Liners for tanks and secondary containment	E 96 with headspace, GC
Aqueous solutions of organics	Organic species, H_2O	Liners for ponds and waste disposal	Pouch, Multi-compartment cell with analysis by GC on GCMS
Complex aqueous solutions of organics and inorganic species	H_2O, organic species, dissolved salts	Liners for waste disposal	Pouch, Multi-compartment cell, osmotic cell, analysis by head-space GC

4.1.3.1 The composition of the geomembrane with respect to the polymer and to the compound,

4.1.3.2 The thickness of the geomembrane,

4.1.3.3 The service temperature,

4.1.3.4 The temperature gradient across the geomembrane in service,

4.1.3.5 The chemical potential across the geomembrane, that includes pressure and concentration gradient,

4.1.3.6 The composition of the fluid and the mobile constituents,

4.1.3.7 The solubility of various components of an organic liquid in the particular geomembrane that increase concentration of individual components on the upstream side of the geomembrane and can cause swelling of the geomembrane resulting in increased permeability,

4.1.3.8 The ion concentration of the liquid, and

4.1.3.9 Ability of the species to move away from the surface on the downstream side.

4.1.4 Because of the great number of variables, it is important to perform permeability tests of a geomembrane under conditions that simulate as closely as possible the actual environmental conditions in which the geomembrane will be in service.

5. Significance and Uses

5.1 The principal characteristic of geomembranes is their intrinsically low permeability to a broad range of gases, vapors, and liquids, both as single-component fluids and as complex mixtures of many constituents. As low permeable materials, geomembranes are being used in a wide range of engineering applications in geotechnical, environmental, and transportation areas as barriers to control the migration of mobile fluids and their constituents. The range of potential permeants is broad and the service conditions can differ greatly. This guide shows users test methods available for determining the permeability of geomembranes to various permeants.

5.2 The transmission of various species through a geomembrane is subject to many factors that must be assessed in order to be able to predict its effectiveness for a specific service. Permeability measurements are affected by test conditions, and measurements made by one method cannot be translated from one application to another. A wide variety of permeability tests have been devised to measure the permeability of polymeric materials; however, only a limited number of these procedures have been applied to geomembranes. Test conditions and procedures should be selected to reflect actual service requirements as closely as possible. It should be noted that field conditions may be difficult to model or maintain in the laboratory. This may impact apparent performance of geomembrane samples.

5.3 This guide discusses the mechanism of permeation of mobile chemical species through geomembranes and the permeability tests that are relevant to various types of applications and permeating species. Specific tests for the permeability of geomembranes to both single-component fluids and multicomponent fluids that contain a variety of permeants are described and discussed.

6. Basis of Classification

6.1 Even though geomembranes are nonporous and cannot be permeated by liquids as such, gases and vapors of liquids can permeate a geomembrane on a molecular level. Thus, even if a geomembrane is free of macroscopic holes, some components of the contained fluid can permeate and might escape the containment unit.

6.2 The basic mechanism of permeation through geomembranes is essentially the same for all permeating species. The mechanism differs from that through porous media, such as soils and concrete, which contain voids that are connected in such a way that a fluid introduced on one side will flow from void to void and emerge on the other side; thus, a liquid can flow through the voids and carry dissolved species.

6.3 Overall rate of flow through saturated porous media follows Darcy's equation that states that the flow rate is proportional to the hydraulic gradient, as is shown in the following equation:

$$Q = kiA \tag{1}$$

where:

Q = rate of flow,

k = constant (Darcy's coefficient of permeability),

A = total inside cross-sectional area of the sample container, and

i = hydraulic gradient.

6.4 With most liquids in saturated media, the flow follows Darcy's equation; however, the flow can deviate due to interactions between the liquid and the surface of the soil particles. These interactions become important in the escape of dissolved species through a low-permeability porous liner system in a waste facility. Dissolved chemical species, either organic or inorganic, not only can permeate such a medium advectively (that is, the liquid acts as the carrier of the chemical species), but also by diffusion in accordance with Fick's two laws of diffusion.

6.5 Even though polymeric geomembranes are manufactured as solid homogeneous nonporous materials, they contain interstitial spaces between the polymer molecules through which small molecules can diffuse. Thus, all polymeric geomembranes are permeable to a degree. A permeant migrates through the geomembrane on a molecular basis by an activated diffusion process and not as a liquid. This transport process of chemical species involves three steps:

6.5.1 The solution or absorption of the permeant at the upstream surface of the geomembrane,

6.5.2 Diffusion of the dissolved species through the geomembrane, and

6.5.3 Evaporation or desorption of the permeant at the downstream surface of the geomembrane.

6.6 The driving force for this type of activated permeation process is the "activity" or chemical potential of the permeant that is analogous to mechanical potential and electrical potential in other systems. The chemical potential of the permeant decreases continuously in the direction of the permeation. Concentration is often used as a practical measure of the chemical potential.

6.7 In the transmission of a permeant through a geomembrane, Step 1 depends upon the solubility of the permeating species in the geomembrane and the relative chemical potential of the permeant on both sides of the interface. In Step 2, the diffusion through the geomembrane involves a variety of factors including size and shape of the molecules of the permeating species, and the molecular characteristics and structure of the polymeric geomembrane. A steady state of the flow of the constituents will be established when, at every point within the geomembrane, flow can be defined by Fick's first law of diffusion:

$$Qi = -Di * \frac{dc_i}{dx} \qquad (2)$$

where:

Q_i = mass flow of constituent "*i*," g cm^2 s^{-1},
D_i = diffusivity of constituent "*i*," cm^2 s^{-1},
c_i = concentration of Constituent "*i*," g cm^3, and
x = thickness of the geomembrane, cm.

6.7.1 It should be noted that the concentration of Constituent“ *i*” referred to in Fick's law is within the mass of the geomembrane.

6.7.2 Step 3 is similar to the first step and depends on the relative chemical potential of the permeant on both sides of the interface at the downstream geomembrane surface.

6.8 Chemical potential is a thermodynamic concept that indicates the direction in which the permeation will go, that is, from high to low potential. To use concentration directly to replace chemical potential requires the individual molecules of the permeating species to neither interact with each other nor with the membrane they are permeating. This condition approximately exists when a permanent or a noncondensable gas, such as oxygen, nitrogen, or helium, permeates a membrane. However, the individual molecules of organic species can interact with each other and with the polymer to increase solubility of the species in the geomembrane.

7. Test Methods

7.1 *Permeability of Geomembranes to Single-Component Fluids*—Many of the applications of geomembranes are for barriers to the permeation of single-component permeants, that is, a single gas, vapor, or liquid. With respect to water, such applications include reservoir liners, moisture vapor transmission barriers, floating covers for reservoirs, canal liners, and tunnel liners; other applications involving single-component fluids would also include liners for secondary containment. Other applications might be methane barriers in tunnels, MSW landfills, and buildings built near methane and hydrocarbon sources. Various tests that are appropriate for assessing barriers to the permeation of different types of single-component fluids are discussed in the following paragraphs.

7.1.1 *Permeability of Geomembranes to Single Gases*:

7.1.1.1 For such applications as linings for waste disposal facilities and methane barriers, the permeability to gases is important in geomembrane selection. The permeability of geomembranes can be assessed by measurement of the volume of the gas passing through the geomembrane under specific conditions or by measurement of the increase in pressure on the evacuated downstream side. Both methods are described in Test Method D 1434. The apparatus used for the volumetric method is shown schematically in Fig. 1 (see Ref **(1)**).[9]

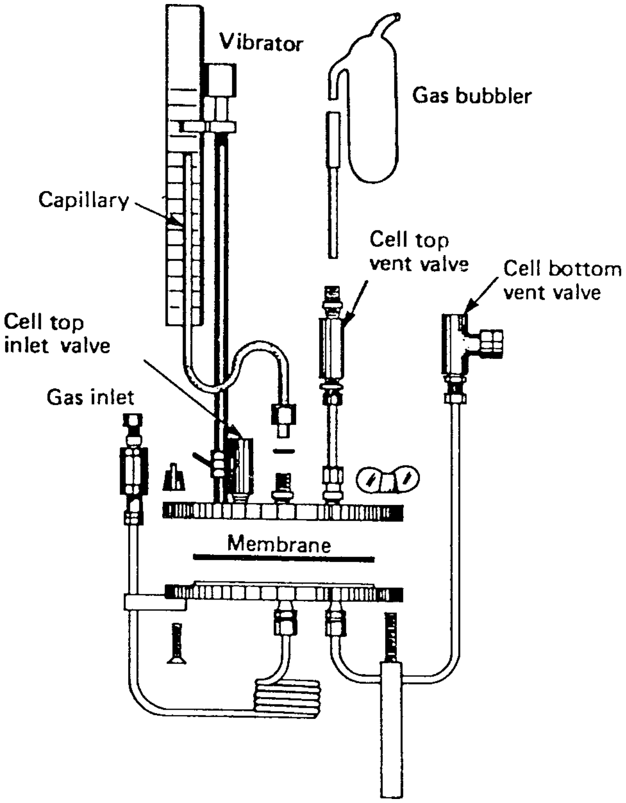


FIG. 1 Gas Permeability Apparatus in Test Method D 1434, Procedure V—Volumetric (1)

7.1.1.2 The volumetric method has been used to measure the permeability of a wide range of geomembranes to methane, carbon dioxide, and nitrogen. In this procedure, the geomembrane is in contact with the gas on both sides, that is, on the upstream side at a pressure greater than atmospheric and on the downstream side at atmospheric pressure to yield a concentration gradient and diffusion of the gas in the geomembrane. Other variables that should be considered in assessing the gas transmission rate (GTR) of a given gas include thickness and such test conditions as temperature and pressure.

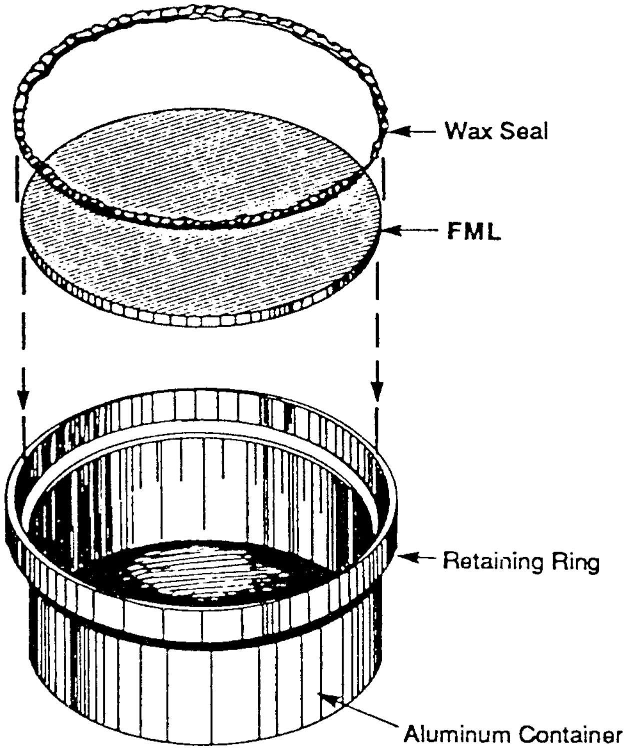
7.1.2 *Permeability of Geomembranes to Water*:

7.1.2.1 *Permeability to Moisture Vapor*—For applications such as reservoir covers and moisture barriers, permeability to moisture vapor can be measured by a variety of methods that reflect the service conditions. Determinations can be made by measuring the change in weight of a small cup that contains either a small amount of distilled water or a desiccant and is sealed at the mouth with a specimen of the geomembrane, for example, Test Methods E 96. An example of the type of cup that is used in this test is shown in Fig. 2 (see Refs **(1)** and **(2)**).

7.1.2.2 *Permeability to Water*—Under a head of water comparable to that encountered in a water reservoir, the pressure on the surface of a geomembrane can cause a small transmission of water through the geomembrane. Various

---

[9] The boldface numbers given in parentheses refer to a list of references at the end of the text.



NOTE 1—In the test procedure, the cup is kept in an inverted position so that water sealed in the cup contacts the FML surface **(1)**.

FIG. 2 Exploded View of Water Vapor Transmission Cup Used in Test Method E 96

measurements of water-permeating geomembranes have been made in which pressure has been applied across a geomembrane with the water on the downstream side at atmospheric pressure. The amount of deaerated water that was transmitted through the membrane was measured on the downstream side. This type of permeability test applies only to water or waters of zero or equal concentration of dissolved constituents on both sides of the geomembrane. A brine or a waste liquid on the upstream side and high-purity water on the downstream side could reverse the direction of permeation of water due to osmotic pressure (see Ref **(3)**).

7.1.3 *Permeability of Geomembranes to Organics*:

7.1.3.1 The moisture vapor transmission type of test can be used to assess the permeability of various membranes to solvent vapors. In this case, the cup that is used in the moisture vapor transmission test is exposed with the solvent vapor contacting the membrane. The vapor concentration inside the cup is that of the vapor pressure at the test temperature and the concentration outside the cup is essentially zero. Therefore, the vapor pressure gradient is the vapor pressure of the solvent at the temperature of test if the vapor concentration is held constant.

7.1.3.2 Another test method that can be used for measuring permeability to organic vapors is Test Method F 739, that is used to measure the resistance of protective clothing materials to the permeation of liquids or gases. In Test Method F 739, an analytical detection system is used to measure the time to breakthrough of the permeant and the equilibrium rate of permeation.

7.1.3.3 For those applications in which geomembranes will be contacted by organic liquids, such as liners for tanks and secondary containment, it is necessary first to determine the compatibility of the specific membrane with the specific organic that is to be contained. This is necessary because of the potential swelling of the geomembrane which can change the permeability.

7.1.3.4 Compatibility testing has been used in the rubber and plastics industries for assessing compatibility of coatings and lining materials for equipment and pipes. A test commonly used for this purpose is Test Method D 471 that will indicate whether the material under test will swell during the test and change the permeability of the test specimen during the test. Once compatibility has been demonstrated, tests such as Test Methods E 96 or D 814, in which the solvent contacts the specimen, can be used and treated in a similar fashion to modified Test Methods E 96 as shown in Fig. 3 (see Ref **(1)**).

7.2 *Permeability of Geomembranes to Multicomponent Fluids*—Many of the applications of geomembranes as barriers involve contact with multicomponent fluids, for example, mixtures of gases, liquids, and aqueous solutions of salts or organics, or both. The most complex of such mixtures are probably leachates from waste disposal facilities. In considering geomembranes for these applications, one must recognize the great differences in the rates of permeation of different chemical species and recognize that the rates depend on solubility, diffusibility, and concentration gradient across the membrane; also, the permeating species may interact differently with each other and with the geomembrane. Though some of the basic test methods described for single-component permeants can be used, they must be supplemented in most cases by a means of identifying and quantifying the species that have permeated the membrane. The analysis of the permeants on the downstream side is needed because of the selective nature of polymeric membranes which results in different

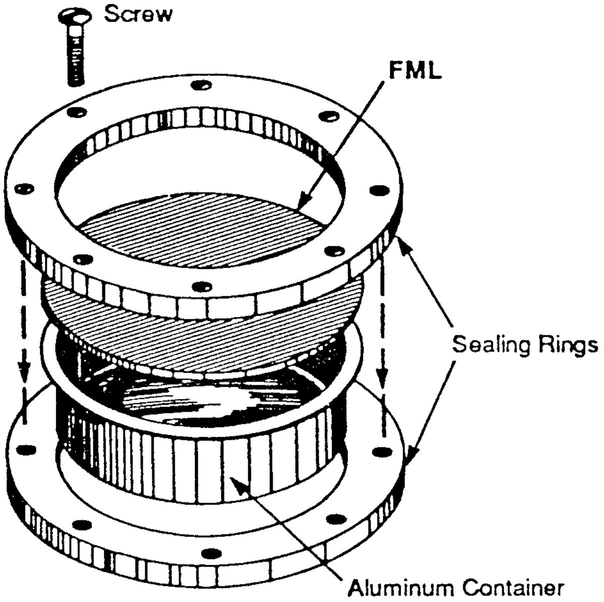


FIG. 3 Exploded View of SVT Cup with Aluminum Sealing Rings (1)

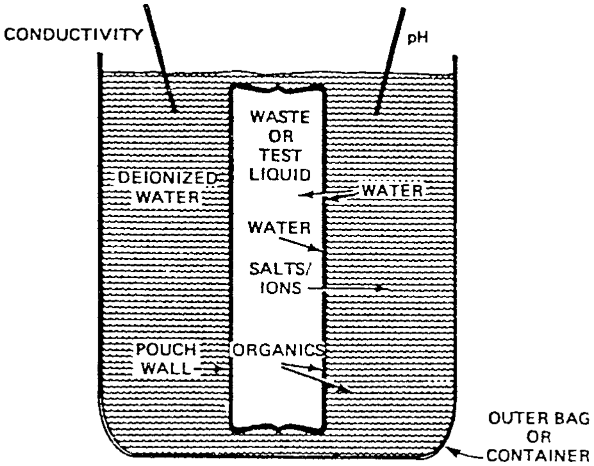
transmission rates for different chemical species. Such analytical tools as gas chromatography (GC) or GC mass spectrography (GCMS) for organics and atomic absorption and analyses the inorganics can be used to detect, identify, and quantify the permeants (see Refs **(3), (4)**, and **(5)**).

7.2.1 *Permeability of Geomembranes to Mixtures of Gases*—In many of the applications as barriers to the migration of gases, the geomembrane will encounter a mixture of two or more gases, that, due to the permselectivity of the geomembrane, will permeate at different rates. Gas chromatography or gas chromatography mass spectrography must be used to analyze the permeating mixtures. Permeating mixture on the downstream side will probably differ in composition from that in the upstream side.

7.2.2 *Permeability of Geomembranes to Aqueous Solutions of Inorganic Salts*:

7.2.2.1 Geomembranes are being used to line wastewater and solid waste storage and disposal facilities that contain aqueous solutions of inorganic salts, for example, leachates from coal-fired power plant wastes. In this example, a geomembrane functions as a semipermeable barrier to the migration of inorganic salts. The permeability of the geomembrane to ions can be measured by separating the solution containing the ions from deionized (DI) water and measuring, as a function of time, the electrical conductivity (EC) of the DI water, or by measuring the concentration of the specific ions. If the geomembranes can be fabricated into pouches, a pouch-type test can be used to assess the permeability of the ions and the water in the liquid as shown schematically in Fig. 4 (see Ref **(1)**).

7.2.2.2 As an example of the measurement of the permeation of ions and water, pouches of PVC were filled with 5 and 10 % solutions of lithium chloride and placed in DI water. The EC of the outer water exhibited almost no change during exposures of up to 600 days. However, as the result of osmotic pressure, the pouches gained in weight. These results show that the ions did not permeate the pouch walls but the water permeated into the pouch from the outer DI water (see Refs **(1)** and **(4)**). Because lithium ions, that are not commonly found in impoundment environments, do not permeate a geomembrane but would pass through a hole, they are potentially useful as a tracer for leaks in a liner.



NOTE 1—In the case illustrated by this drawing, the pouch is filled with an aqueous waste or test liquid and immersed in deionized water. Arrows indicate the flow of specific constituents **(1) (4)**.

FIG. 4 Pouch Assembly Showing the Movement of Constituents During the Pouch Test

7.2.3 *Permeability of Geomembranes to Mixtures of Organics*—For applications of geomembranes that contact mixtures of organics that might affect the geomembrane, such as in secondary containment and tanks, compatibility and permeability tests of the geomembranes with the potential mixture should be performed. Testing of a geomembrane with an individual component of a mixture cannot reflect the potential interaction of the organics and their combined effects on the geomembrane.

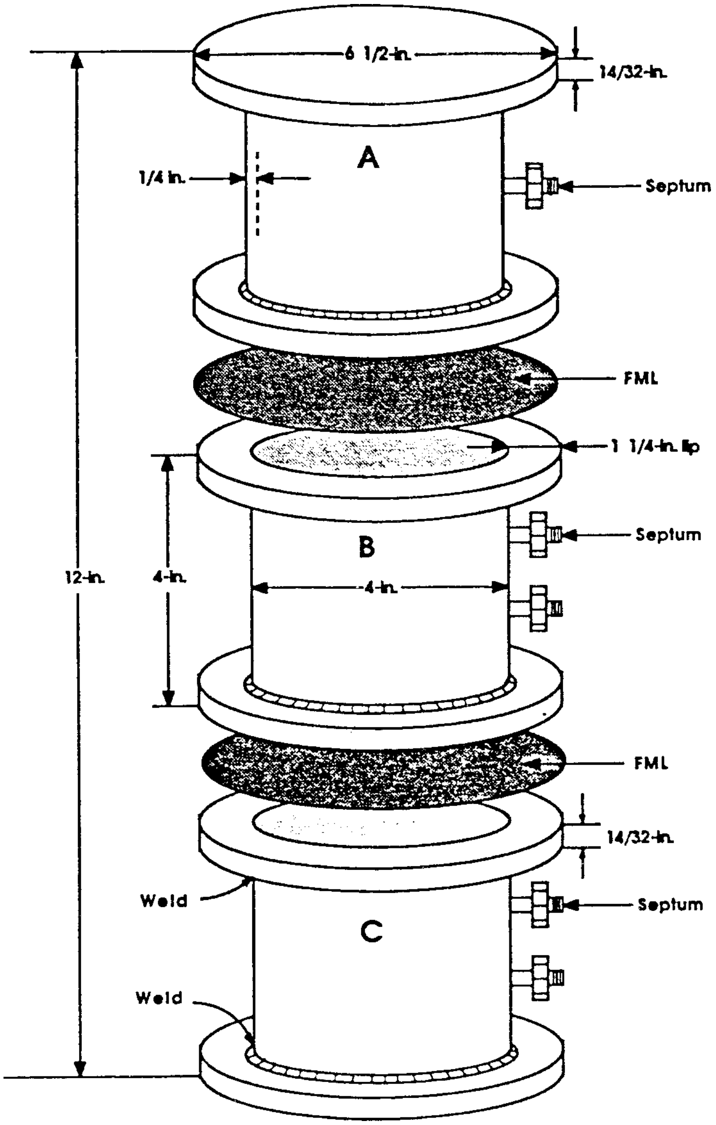
NOTE 1—Results indicate that strong selectivity by the geomembrane causes very different permeation rates for components of mixtures.

7.2.4 *Permeability of Geomembranes to Aqueous Solutions of Organics*—As a barrier material for waste storage and disposal facilities, geomembranes will probably contact dilute aqueous solutions of organics, for example, leachates and waste liquids. Due to the differences in the solubility of individual organics in different geomembranes and in the partitioning coefficients of the permeant between water solutions and the geomembranes, a considerable difference in the permeation rate of a given organic through a geomembrane compared with that obtained on the individual organic can be observed.

NOTE 2—The permeation of organics in dilute aqueous solutions through a variety of geomembranes has been studied (see Refs **(2), (4)**, and **(5)**). The permeation rates of various pure organics and dilute solutions (0.1 to 0.001 weight %) of the same organics through a 1.0-mm HDPE geomembrane were compared. It was shown that the permeation of organics from a dilute solution can be substantially higher than would be expected from the reduced concentration. For example, even though the ratio between the concentrated toluene and the dilute solution was 1000:1, the ratio between permeation rates through the HDPE geomembrane was 20:1. These results indicate that significant quantities of an organic can permeate through a geomembrane due to selective permeation, even when the organics are present at a low concentration.

7.2.4.1 A closed apparatus consisting of three compartments separated by geomembranes (see Fig. 5) was used to assess the permeation of organics from dilute aqueous solutions through polyethylene geomembranes (see Refs **(2)** and **(5)**). The middle compartment was partially filled with the solution, and DI water was placed in the bottom compartment. Thus, the organics could either volatilize into the airspace above the solution and then, permeating through the top geomembrane, enter the top compartment, or they could permeate the lower geomembrane into the bottom compartment. Septums were incorporated in each of the three compartments for withdrawing samples for GC analysis from the aqueous and airspace zones. After the apparatus was dismantled, the two geomembranes were analyzed by headspace GC. The three-compartment apparatus simulated the configuration of a covered landfill, that is:

7.2.4.2 The airspace in the top compartment simulated the airspace over a "cover" liner. The geomembrane specimen between the top and middle compartments simulated a "cover" liner.



NOTE 1—Inside diameter of the compartment was 4 in. **(2)**.

FIG. 5 Schematic of the Three-Compartment Test Apparatus Used in the Study of Water/FML Distribution and Permeation of Organics from Dilute Solutions

7.2.4.3 The airspace in the middle compartment simulates the headspace above a waste liquid, and the dilute solution containing organics serves as the waste liquid. The geomembrane specimen between the middle and bottom compartments simulates the service conditions of a bottom liner.

7.2.4.4 The airspace and the DI water in the bottom compartment simulate, respectively, pore spaces in the soil and the ground water.

7.2.4.5 In an experiment to assess the distribution of organics among water, air, and a geomembrane and to assess the permeation of organics through a geomembrane, a dilute aqueous solution of toluene and trichloroethylene (TCE) was placed in the middle compartment of the test apparatus. An 0.84-mm linear low-density polyethylene (LLDPE) geomembrane separated the three compartments (see Refs **(2)** and **(5)**).

7.2.4.6 The middle compartment was filled with 500 mL of the dilute aqueous solution of toluene and TCE in DI water. The zones containing water or vapor were sampled and analyzed periodically by GC to track the changes in concentrations in the airspaces and water zones. After 256 h, when the concentrations in these zones appeared to approach constant values and equilibrium had been reached, the apparatus was dismantled and the geomembranes were removed and analyzed for the organic species by headspace GC to determine their concentrations in the membrane layers. Data show that at equilibrium the concentration of the respective organic species in the two membrane layers were essentially equal to each other as were the concentrations in the two water zones.

7.2.4.7 The results show that the water in the bottom compartment had absorbed organics. At the end of the test the relative concentrations of the two organics were the same in both aqueous zones, demonstrating the transport of these organics through the geomembrane and the airspace to the water in the bottom compartment. The data also show that, for each of the two organics, the concentrations in the airspaces were similar, as were the concentrations in the two geomembrane specimens.

7.2.5 *Permeability of Geomembranes to Aqueous Solutions of Inorganic and Organic Species*:

7.2.5.1 The pouch test as described in 7.2.2 can be used for assessing the simultaneous permeability of all components in a complex solution of both dilute organics and dilute inorganics. It is necessary to track each component either GC or GCMS for the organics and by EC or specific ion analysis for the inorganics, and the weight of the pouch for the amount of water that has permeated into the pouch. Fig. 2 indicates the direction of migration of individual components from the pouch. If volatile organics are present in the pouch, it is necessary to seal the entire assembly in a closed container to avoid loss of organics and water.

7.2.5.2 The accuracy of the pouch test depends on preparation of durable, leak-free pouches, the seams of which would not allow liquids to bypass the pouch wall and yield high transmission values. In work reported to date, the pouch test was restricted to thermoplastic geomembranes that could be heat-sealed or welded to make non-leaking seams. The test should also apply to vulcanized geomembranes if pouches can be fabricated to yield no leaks in the seams.

8. Keywords

8.1 barriers; diffusion of gases and vapors; flexible membrane liners (FMLs); gas transmission; leachate; organic vapor transmission; permeability; polymeric geomembranes; reservoirs; transport of chemical species; transport of ions; waste disposal; water vapor transmission

REFERENCES

(**1**) Matrecon, Inc., "Lining of Waste Containment and Other Impoundment Facilities," Haxo, H. E. (ed), U.S. Environmental Protection Agency, Cincinnati, OH, *EPA/600/2-88/052*, September 1988.

(**2**) Haxo, H. E., and Lahey, T. P.," Transport of Dissolved Organics from Dilute Aqueous Solutions Through Flexible Membrane Liners," *Hazardous Waste and Hazardous Materials*, Vol 5, No. 4, Mary Ann Liebert, Inc., Publishers, New York, 1988, pp. 275–294.

(**3**) Pierson, P., Pelte, T., Eloy Giomi, C., and Margrita, R., "Water Permeation Through Geomembranes: Mechanism and Measurement," *Proceedings, 5th International Conference on Geotextiles, Geomembranes and Related Products*, Singapore, 1994, pp. 929–932.

(**4**) Haxo, H. E., "Determining the Transport Through Geomembrane of Various Permeants in Different Applications," *Geosynthetic Testing for Waste Containment Applications, ASTM STP 1081*, Robert N. Koerner, ed., ASTM, Philadelphia, 1990.

(**5**) Park, J. K., Satki, J. P., and Hoopes, J. H.," Effectiveness of Geomembranes as Barriers for Organic Compounds," *Proceedings of Geosynthetics 1995 Conference*, Vol 3, Industrial Fabrics Association International, St Paul, MN, 1995, pp. 879–892.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

This standard is copyrighted by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (http://www.astm.org).