



Standard Guide for Selection of Test Methods to Determine Rate of Fluid Permeation Through Geomembranes for Specific Applications¹

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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.*

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. Referenced Documents

2.1 ASTM Standards:²

- D471 Test Method for Rubber Property—Effect of Liquids
- D814 Test Method for Rubber Property—Vapor Transmission of Volatile Liquids
- D815 Test Method for Testing Coated Fabrics Hydrogen Permeance (Withdrawn 1987)³
- D1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheet
- D4439 Terminology for Geosynthetics
- D4491 Test Methods for Water Permeability of Geotextiles by Permittivity
- E96/E96M Test Methods for Water Vapor Transmission of Materials
- F372 Test Method for Water Vapor Transmission Rate of Flexible Barrier Materials Using an Infrared Detection Technique (Withdrawn 2009)³
- F739 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact

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 D4439.)

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 The last approved version of this historical standard is referenced on www.astm.org.

3.1.2.1 *Discussion*—In geotechnical engineering, essentially impermeable means that no measurable liquid flows through a geosynthetic when tested in accordance with Test Methods [D4491](#).

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 [D4439](#).)

3.1.4 *permeability, n*—the rate of flow under a differential pressure, temperature, or concentration of a gas, liquid, or vapor through a material. (Modified from Test Methods [D4491](#).)

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,

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	D815 D1434-V D1434-P
Water vapor	H ₂ O	Moisture vapor barriers, water reservoir covers	E96/E96M , D653
Liquid water	H ₂ O	Liners for reservoirs, dams, and canals	Soil-type permeameter with hydraulic pressure
Organic vapor	Organic species	Secondary containment for organic solvent and gasoline	D814 , E96/E96M , F372
Organic liquid	Organic solvents species	Containers, tank liners secondary containment	D814 , E96/E96M
Multicomponents Fluids:			
Gases	CO ₂ /CH ₄	Barriers, separation of gases	F372 , 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	E96/E96M with headspace, GC
Aqueous solutions of organics	Organic species, H ₂ O	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 ₂ O, organic species, dissolved salts	Liners for waste disposal	Pouch, Multi-compartment cell, osmotic cell, analysis by head-space GC

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:

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:

$$Q = kiA \quad (1)$$

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,