Designation: E2945 − 14

Standard Test Method for Film Permeability Determination Using Static Permeability Cells[1]

This standard is issued under the fixed designation E2945; 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 test method covers the measurement of the transmission of a gas through plastic membranes, sheeting, films, and fabric materials using a static sealed diffusion chamber. The test method monitors gas diffusion across a film membrane and provides measurements of *(1)* gas concentrations on each side of the film membrane and *(2)* estimates of the mass transfer coefficient (MTC) for the tested gas and film material. The MTC represents the film permeability and is independent of the concentration gradient used during testing, which simplifies some aspects of the experimental design.

1.2 This test method permits the loading of mixed vapors and simultaneous determination of the permeability of one film to various gases.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

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:*[2]

D618 Practice for Conditioning Plastics for Testing

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *concentration, C, n*—chemical mass divided by the chamber volume.

3.1.1.1 *Discussion*—C_o is the initial ($t = 0$) concentration in the source chamber. The SI unit of concentration is μg/cm^3.

3.1.2 *concentration gradient, n*—difference in the concentration of gases across the film membrane divided by the transport distance between the source and collection chambers (for example, usually considered to be the film thickness).

3.1.2.1 *Discussion*—The SI unit of the concentration gradient is μg/cm^3-cm.

3.1.3 *mass transfer coefficient, MTC, n*—gas diffusion rate constant that relates the mass transfer rate, distance, and concentration gradient as the driving force through a film membrane under the test conditions.

3.1.3.1 *Discussion*—The SI unit of the MTC is cm/hour. The MTC expresses the ease of transmission of a gas through a membrane under test conditions. The test conditions shall be stated, which include the ambient temperature, relative humidity, film conditioning, sampling, and handling.

3.1.4 *mass transfer rate, J, n*—mass transfer rate, or flux density, of a gas diffusing through a film membrane is the mass of gas passing through a unit area (for example, 1 cm^2) of film membrane per unit time interval (for example, 1 h). The SI unit of J is μg/cm^2 hour.

4. Summary of Test Method

4.1 This test method uses a static sealed apparatus consisting of two chambers separated by the test-film membrane. The test chemical in the vapor phase is added to the chamber on one side of the film and the apparatus is incubated at constant temperature during which the chemical diffuses through the test membrane. This test method requires determination of the relative chemical concentrations on both sides of the membrane at several time points during the incubation. Concentrations are monitored until equilibrium is reached or some other practical stoppage time. For permeable films, more frequent sampling is necessary because equilibrium may be reached within minutes or hours. For films with very low permeability, longer incubation times (weeks) may be necessary to reach

[1] This test method is under the jurisdiction of ASTM Committee E35 on Pesticides, Antimicrobials, and Alternative Control Agents and is the direct responsibility of Subcommittee E35.22 on Pesticide Formulations and Delivery Systems.

Current edition approved Feb. 1, 2014. Published April 2014. DOI: 10.1520/E2945-14.

[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.

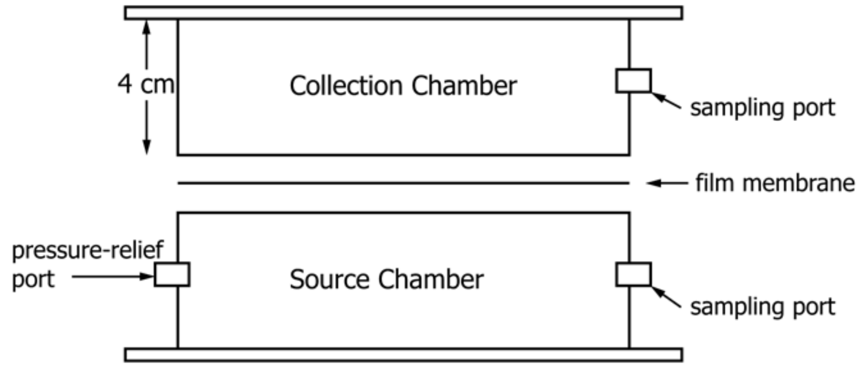


FIG. 1 Schematic of Static Film Permeability Apparatus Consisting of Two Parts: A Source and Collection Chamber with a Film Membrane between Them

equilibrium. Linear regression of data may be used to calculate the mass transfer coefficient (MTC). Alternatively, an analytical solution to a mathematical model may be used to calculate MTC (see Appendix X1) for which a nonlinear least-square algorithm is available to fit concentrations derived from the mathematical model to the observed concentrations. See Papiernik et al[4,5] for additional details.

5. Significance and Use

5.1 This test method provides a simple approach for determining the transmission properties of film membranes and sheeting over a range of permeability exceeding four orders of magnitude. This test method is described here to measure the permeability of films used in soil fumigation, but it is also appropriate for other gases and membranes if the analytical methods are appropriately modified.

5.2 This test method can be used for single or mixed compounds. This test method uses small quantities of test chemicals in vapor form, and microgram to milligram quantities of each chemical may produce a sufficient amount of vapor for each test depending on the analytical methods.

5.3 Interlaboratory testing showed that the MTC estimated by this test method is relatively insensitive to the laboratory procedures. The interlaboratory testing involved measuring the MTC for several soil fumigant compounds and a wide range of film permeability. Analysts with prior experience handling and analyzing gaseous fumigant compounds had lower coefficients of variation (10 to 20 %) compared to less experienced analysts (20 to 50 %) based on triplicate tests. The coefficient of variation between laboratories was higher for less permeable film materials than for films with high MTC. This was attributed to the additional length of the experiments and potential for increased leakage from the apparatus and was most pronounced for less experienced analysts.

6. Apparatus

6.1 A sealed apparatus is constructed of inert and impermeable material (for example, stainless steel) such that a sample of test membrane is held between the two chambers in a closed system. The selection of material is dependent on the gases being considered. The apparatus (see Fig. 1) enables sampling of the time rate of change in the gas concentration in each chamber and the mass transfer coefficient. The apparatus is configured as shown in Fig. 1.

6.1.1 *Permeability Apparatus*—Stainless steel pipe (for example, 0.3 to 0.6 cm thick, 10- to 15-cm diameter) is cut to form cylinders with height 2 to 6 cm. The volume of the chamber affects the time to reach equilibrium; therefore, taller cylinders are appropriate for testing permeable films, shorter cylinders for less permeable films. The ends of the pipe are trued and the mating surfaces smoothed. Each cylinder is welded to a flat steel plate (for example, 0.3 cm thick) at one end, as shown in Fig. 2.

6.1.2 *Sampling Ports*—Holes are drilled and threaded on the side of each cylinder to allow installation of sampling ports. The holes should be located near the mid-point height of the cylinder (Figs. 1 and 2).

6.1.3 The purpose of the ports is to allow access to the inside of the chamber for spiking and sampling. During other times, ports should be sealed to prevent leakage. This can be accomplished using a septum port or sampling valve as described in 6.1.3.1 and 6.1.3.2.

6.1.3.1 *Septum Port*—A 1.6-mm steel (or brass) union connector is installed in each hole. Before installation, the threads of the union are coated with epoxy to ensure a gastight seal. One port is installed in the collection chamber and two ports (on opposite sides of the cylinder) are installed in the source chamber. The second port is used to vent the source chamber during spiking. A septum and threaded nut are installed onto the 1.6-mm union and the union threads coated with epoxy. The threaded nut is covered by a Swagelok[6] cap and a septum (Fig. 3A). Samples are collected with a syringe by removing the outer septum and cap and piercing through the

[4] Papiernik, S. K., Yates, S. R., and Gan, J., "An approach for estimating the permeability of agricultural films," *Environmental Science and Technology*, Vol 35, 2001, pp. 1240-1246.

[5] Papiernik, S. K., Ernst, F. F., and Yates, S. R., "An apparatus for measuring the gas permeability of films," *Journal of Environmental Quality*, Vol 31, 2002, pp. 358-361.

[6] Swagelok is a registered trademark of the Swagelok Company, Cleveland, Ohio.

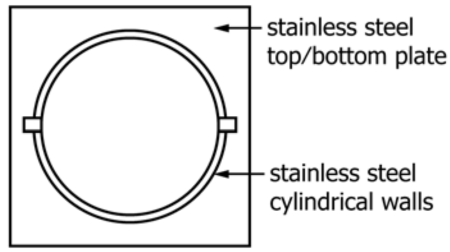
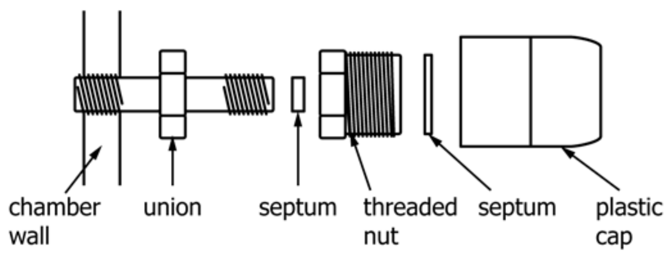
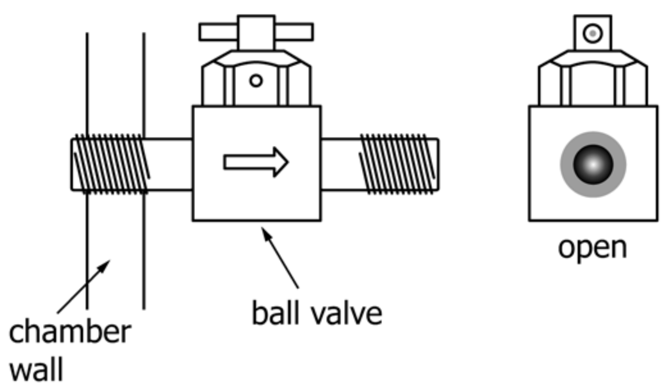


FIG. 2 Top View of the Source Chamber—A Stainless Steel Cylinder Is Welded to the Stainless Steel Bottom Plate Leaving One End of the Cylinder Open



3A Sampling Port Design



3b Sampling Port Design

FIG. 3 Sampling Port Design

septum behind the threaded nut (Fig. 3A). Between sampling, the nonpunctured septum and cap should be tightened over the threaded nut to prevent leakage from the pierced septum between sampling times.

6.1.3.2 *Sampling Valve Port*—A gastight sampling valve is screwed onto the union (Fig. Fig. 3A) or directly into the chamber wall and the threads sealed with epoxy (Fig. Fig. 3B). One valve is installed in the collection chamber and one valve is installed in the source chamber. The valve shall be made of inert and impermeable material and produce a gastight connection to the cylinder wall. A polytetrafluoroethylene stopcock screwed onto the union allows sample introduction or removal. A stainless steel two-way valve (1.6 mm) screwed directly into the drilled hole could also be used to allow sample introduction or removal (Fig Fig. 3B). The air volume within the valve should be minimized.

NOTE 1—Other configurations for the chamber access ports are possible, but design criteria and testing should demonstrate that they: *(1)* are constructed of inert materials, *(2)* are non-leaking between sampling times, *(3)* minimize leaking during sampling, and *(4)* maintain integrity during routine laboratory handling.

7. Materials

7.1 The apparatus can be used to measure diffusion of an arbitrary gas through a film membrane. The specifics of the methodology described in the following relate to fumigant gases and fumigation films, but the test method can be modified to allow measuring the MTC for other gases and other membranes.

7.2 *Fumigant Chemicals*—Iodomethane, 1,3-dichloropropene (mixture of cis and trans isomers), dimethyl disulfide, methyl isothiocyanate (transformation product of metam sodium or dazomet during fumigation), chloropicrin, methyl bromide, and sulfuryl fluoride.

7.3 *Gas-Mixing Chamber*—Gastight 1-L glass container with valves on both ends and a side sampling port. Other types of gastight containers with sampling ports may be used. If a clear glass container is used, it is recommended that the glass