



Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Intermittent Contact¹

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INTRODUCTION

Workers involved in the production, use, and transportation of liquid and gaseous chemicals can be exposed to numerous compounds capable of causing harm upon contact with the human body. The deleterious effects of these chemicals can range from acute trauma such as skin irritation and burn, to chronic degenerative disease such as cancer. Since engineering controls may not eliminate all possible exposures, attention is often placed on reducing the potential for direct skin contact through the use of protective clothing that resists permeation, penetration, and degradation.

This test method is used to measure the resistance to permeation under the condition of intermittent contact of the protective clothing material with liquid or gaseous chemicals. Resistance to permeation and penetration under conditions of continuous contact should be determined by Test Methods F 739 and F 903, respectively. In certain situations, the permeation of liquids through protective clothing materials can be measured using a permeation cup following Method F 1407. An undesirable change in the physical properties of protective clothing materials is called degradation. Methods for measuring the degradation of rubbers, plastics, and coated fabrics are found in Test Methods D 471, Test Method **D 543**, and Test Method **D 751**, respectively. A starting point for selecting the chemicals to be used in assessing the chemical resistance of clothing materials is Guide F 1001.

1. Scope

1.1 This test method measures the permeation of liquids and gases through protective clothing materials under the condition of intermittent contact.

1.2 This test method is designed for use when the challenge chemical is a gas or a liquid; where the liquid is either volatile (that is, having a vapor pressure greater than 1 mm Hg at 25°C) or soluble in water or another liquid that does not interact with the clothing material.

1.3 *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.* Specific hazard statements are given in Section 7.

2. Referenced Documents

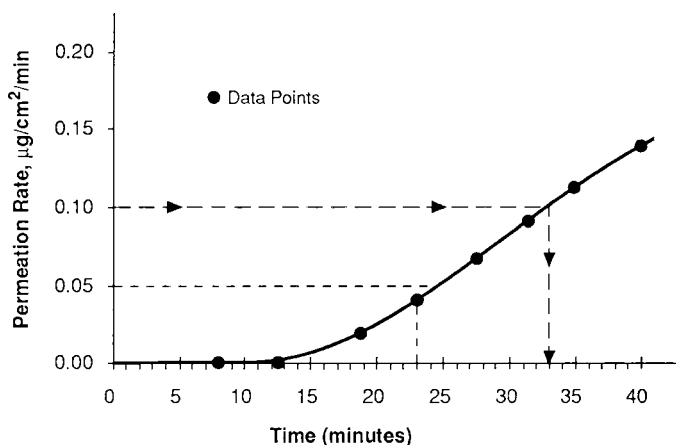
2.1 *ASTM Standards:*²

- D 471 Test Method for Rubber Property—Effect of Liquids
- D 543** Practices for Evaluating the Resistance of Plastics to Chemical Reagents
- D 751** Test Methods for Coated Fabrics
- D 1777** Test Method for Thickness of Textile Materials
- E 105** Practice for Probability Sampling Of Materials
- E 171** Specification for Atmospheres for Conditioning and Testing Flexible Barrier Materials
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- F 739** Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact

¹ This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.30 on Chemicals.

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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.



NOTE—In an intermittent contact test, it is possible that the permeation rate will exceed, go below, and then again exceed a permeation rate of 0.1 µg/cm²/min. If this occurs, the standardized breakthrough time is the first occurrence of the permeation rate exceeding 0.1 µg/cm²/min.

FIG. 1 The Breakthrough Detection Time for a Method Sensitivity of 0.05 µg/cm²/min is 23 min. The Standardized Breakthrough Detection Time is 33 min.

F 903 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids

F 1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials

F 1194 Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing

F 1407 Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method

F 1494 Terminology Relating to Protective Clothing

2.2 ISO Standard:

ISO 6529 Protective Clothing—Determination of Resistance of Protective Clothing Materials to Permeation by Liquids and Gases³

3. Terminology

3.1 Definitions:

3.1.1 *analytical technique, n*—a procedure whereby the concentration of the challenge chemical in a collection medium is quantitatively determined.

3.1.1.1 *Discussion*—These procedures are often specific to individual chemical and collection medium combinations. Applicable techniques can include, but are not limited to flame ionization, photo ionization, electro-chemical, ultraviolet, and infrared spectrophotometry, gas and liquid chromatography, colorimetry, length-of-stain detector tubes, and radionuclide tagging/detection counting.

3.1.2 *breakthrough detection time, n*—the elapsed time measured from the start of the test to the sampling time that immediately precedes the sampling time at which the challenge chemical is first detected. (See Fig. 1.)

3.1.2.1 *Discussion*—The breakthrough detection time is dependent on the sensitivity of the method. (See Appendix X1.)

3.1.3 *challenge chemical, n*—the liquid or gas that is used to challenge the protective clothing material specimen.

3.1.3.1 *Discussion*—The liquid or gas may be either one component (for example, a neat liquid or gas) or have several components (for example, a mixture).

3.1.4 *closed-loop, adj*—refers to a testing mode in which the collection medium volume is fixed.

3.1.5 *collection medium, n*—a liquid, gas, or solid that absorbs, adsorbs, dissolves, suspends, or otherwise captures the challenge and does not affect the measured permeation.

3.1.6 *contact time, n*—in an intermittent contact test, the duration during each cycle that the challenge side chamber of the permeation cell is filled with the challenge chemical.

3.1.7 *cumulative permeation, n*—the total mass of chemical that permeates during a specified time from when the material is first contacted.

3.1.7.1 *Discussion*—Quantification of cumulative permeation enables the comparison of permeation behaviors under different intermittent and continuous contact conditions.

3.1.8 *cycle time, n*—in an intermittent contact test, the interval of time from the start of one contact period to the start of the next contact period.

3.1.9 *minimum detectable mass permeated, n*—the smallest mass of test chemical that is detectable with the complete permeation test system.

3.1.9.1 *Discussion*—This value is not necessarily the sensitivity of the analytical instrument.

3.1.10 *minimum detectable permeation rate, n*—the lowest rate of permeation that is measurable with the complete permeation test system.

3.1.10.1 *Discussion*—This value is not necessarily the sensitivity of the analytical instrument.

3.1.11 *open-loop, adj*—refers to a testing mode in which fresh collection medium flows continuously through the collection chamber of the test cell.

3.1.12 *penetration, n*—for a protective clothing material or item, the process by which a substance moves through closures, seams, interstices, and pinholes or other imperfections on a non-molecular level.

3.1.13 *permeation, n*—the process by which a chemical moves through a protective clothing material on a molecular level.

3.1.13.1 *Discussion*—Permeation involves the following: (1) sorption of molecules of the chemical into the contacted (challenge side) surface of the material, (2) diffusion of the sorbed molecules in the material, and (3) desorption of the molecules from the opposite (collection side) surface of the material.

3.1.14 *protective clothing material, n*—any element, constituent, or substance from which protective clothing is composed or can be made

3.1.15 *purge time, n*—in an intermittent contact test, the time immediately following the termination of the contact time when the challenge chemical is removed from the challenge side chamber and air or nitrogen is blown over the outside surface of the protective clothing material.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

3.1.16 *standardized breakthrough time, n*—the first time at which the permeation rate reaches $0.1 \mu\text{g}/\text{cm}^2/\text{min}$ (see Fig. 1).

4. Summary of Test Method

4.1 The permeation of chemical(s) through a protective clothing material is assessed by measuring the breakthrough detection time, standardized breakthrough time, and subsequent permeation rate through replicate specimens of the material intermittently contacted with the chemical.

4.2 In the permeation test apparatus, the protective clothing material specimen partitions the challenge chemical from the collection medium.

4.2.1 Contact of the challenge chemical with the clothing material's outside surface is made intermittent by periodically adding and removing the test chemical from the challenge chamber of the test cell.

4.2.2 The collection medium is analyzed quantitatively for its concentration of the challenge chemical and thereby the amount of that chemical that has permeated the barrier as a function of time after its initial contact with the material.

4.2.3 By either graphical representation or appropriate calculations, or both, the breakthrough detection time, the standardized breakthrough time, and the cumulative permeation of the challenge chemical are determined.

5. Significance and Use

5.1 This test method is used to measure chemical permeation through specimens of protective clothing under the condition of intermittent contact of a challenge chemical with the specimen. In many applications, protective clothing is contacted intermittently to chemicals, not continuously as is tested by Test Method F 739.

5.2 This test method is normally used to evaluate flat specimens from finished items of protective clothing and of materials that are candidates for items of protective clothing.

5.2.1 Finished items of protective clothing include gloves, arm shields, aprons, suits, hats, boots, respirators, and the like.

5.2.2 The phrase *specimens from finished items* encompasses seamed or other discontinuous regions as well as the usual continuous regions of protective clothing items.

5.3 In some cases, it may be of interest to compare permeation behaviors that occur under conditions of intermittent contact with those that occur during continuous contact. Test Method F 739 is recommended for measuring permeation under the conditions of continuous contact of the challenge chemical with the clothing specimen.

5.4 The breakthrough detection time, standardized breakthrough time, and the cumulative permeation are key measures of the effectiveness of a clothing material as a barrier to the challenge chemical. Such information is used in the comparison of clothing materials during the process of selecting clothing for protection from hazardous chemicals. Long breakthrough detection times and standardized breakthrough times and low cumulative permeation are characteristics of better barriers.

NOTE 1—At present, no quantitative information exists about acceptable levels of dermal contact. Therefore, the data obtained using this test method cannot be used to infer safe exposure levels.

5.5 The sensitivity of the test method in detecting low permeation rates or amounts of the challenge chemical permeated is determined by the combination of: (1) the analytical technique and collection system selected, and (2) the ratio of material specimen area to collection medium volume or flow rate.

5.5.1 The analytical technique employed should be capable of measuring the concentration of the challenge chemical in the collection medium at, or below, levels consistent with standardized breakthrough time value specified in 3.1.16.

5.5.2 Often, permeation tests will require measurement of the challenge chemical over several orders of magnitude in concentration, requiring adjustments in either the sample collection volume or concentration/dilution, or the analytical instrument settings over the course of the test.

5.5.3 Higher ratios of material specimen area to collection medium volume or flow rate permit earlier detection of permeation because higher concentrations of the challenge chemical in the collection medium will develop in a given time period, relative to those that would occur at lower ratios.

5.5.4 The sensitivity of an open-loop system is characterized by its minimum detectable permeation rate. A method for determining this value is presented in Appendix X1.

5.5.5 The sensitivity of a closed-loop system is characterized by its minimum detectable mass permeated.

5.6 Comparison of results of tests performed with different permeation test systems requires specific information on the test cell, procedures, contact and purge times, and analytical techniques. Results obtained from closed-loop and open-loop testing may not be directly comparable.

5.7 A group of chemicals that is recommended for use in permeation testing is given in Guide F 1001.

6. Apparatus

6.1 *Thickness Gauge*, suitable for measuring thicknesses to the nearest 0.02 mm (or the nearest 0.001 in.), as specified in Test Method D 1777, shall be used to determine the thickness of each protective clothing material specimen tested.

6.2 *Analytical Balance*, readable and reproducible to ± 0.5 mg shall be used to determine weight per unit area of each test specimen.

6.3 *Test Cell*—The test apparatus consists of a two-chambered cell for contacting the specimen with the challenge chemical on the specimen's normally outside surface and with a collection medium on the specimen's normal inside surface.

6.3.1 The test cell⁴, as shown in Fig. 2, is constructed of two sections of straight glass pipe, each nominally sized to a 25.4 mm (1.0 in.) diameter.⁵ Materials other than glass may be used. Such materials would be required for tests involving chemicals (for example, hydrofluoric acid), which are incompatible with glass. The section that is designated to contain the challenge chemical is 25.4 mm (1.0 in.) in length. The second section, which is designated to contain the collection medium, is 32 mm (1.2 in.) or less in length.

⁴ The test cell as shown in Fig. 2 is available from Pesce Lab Sales, P.O. Box 235, 226 Birch St., Kennet Square, PA 19348.

⁵ Sections of borosilicate glass pipe, available from Corning Glass, Catalog No. 72-0702 (1-in. length), or equivalent, have been found suitable for this purpose.