Designation: ~~F739 – 12ε1~~ F739 – 20

Standard Test Method for Permeation of Liquids and Gases Through Protective Clothing Materials Under Conditions of Continuous Contact[1]

This standard is issued under the fixed designation F739; 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.

~~ε1 NOTE—Editorially corrected 8.8.1 in February 2015.~~

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 health effects of these chemicals can range from acute trauma such as skin irritation and burn, to chronic degenerative disease ~~such as~~ and mutagenic conditions, including 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 permeation of liquids and gases through protective clothing materials under the conditions of continuous contact of the clothing material by the test chemical. Resistance to permeation under the condition of intermittent contact with the test chemical should be determined by Test Method F1383. In certain situations, the permeation of liquids through protective clothing materials can be measured using a permeation cup following Test Method F1407. Penetration of liquids should be determined by Test Method F903. An undesirable change in the physical properties of protective clothing materials is called degradation. Procedures for measuring the degradation of rubbers, plastics, and coated fabrics are found in Test Method D471, ~~Test Method~~ Practice D543, and Test Method D751, respectively. A starting point for selecting the chemicals to be used in assessing the chemical resistance of clothing materials is Guide F1001.

1. Scope

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

1.2 This test method is designed for use when the test 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)~~25 °C) or soluble in water or another liquid that does not interact with the clothing material.

1.3 Values states in SI units are to be regarded as standard. Values given in parentheses are not exact equivalents and are given for information only.

[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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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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 7.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D471 Test Method for Rubber Property—Effect of Liquids
D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D751 Test Methods for Coated Fabrics
D1777 Test Method for Thickness of Textile Materials
E105 Practice for Probability Sampling of Materials
~~E171~~E171/E171M Practice for Conditioning and Testing Flexible Barrier Packaging
~~E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods~~
~~E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method~~
F903 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids
F1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials
F1194 Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing
F1383 Test Method for Permeation of Liquids and Gases Through Protective Clothing Materials Under Conditions of Intermittent Contact
F1407 Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method
F1494 Terminology Relating to Protective Clothing
F2815 Practice for Chemical Permeation Through Protective Clothing Materials: Testing Data Analysis by Use of a Computer Program (Withdrawn 2019)[3]

~~2.2 *ISO Standard:*~~
~~ISO 6529 Protective Clothing—Determination of Resistance of Protective Clothing Materials to Permeation by Liquids and Gases~~[4]

3. Terminology

3.1 *Definitions:*

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

3.1.1.1 *Discussion*—
These techniques are often specific to individual chemical and collection medium combinations. Applicable techniques include, but are not limited ~~to,~~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 initial exposure to the test chemical to the sampling time that immediately precedes the sampling time at which the test chemical is first detected.

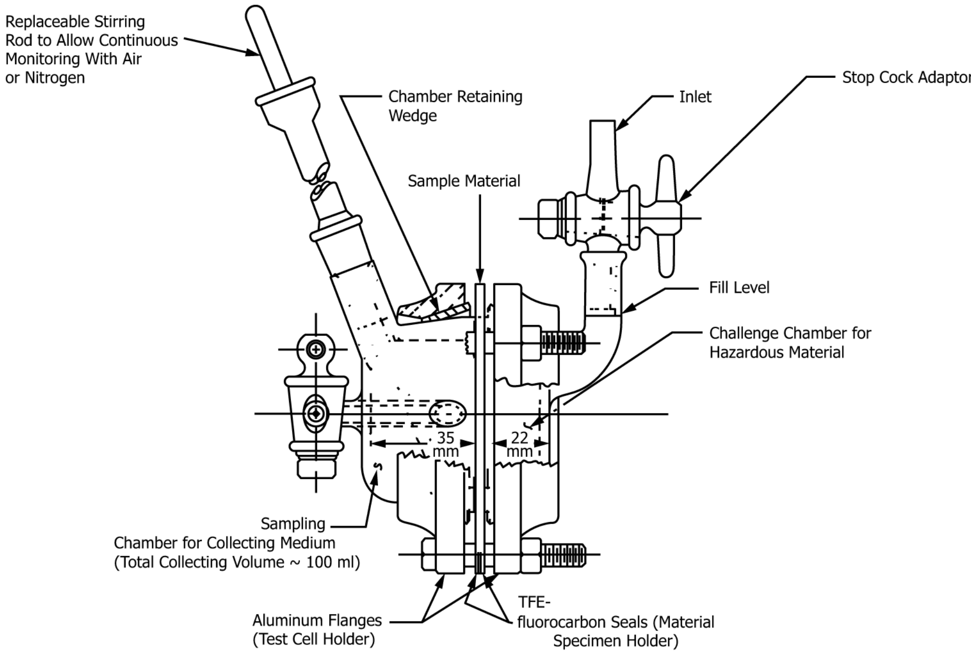
3.1.2.1 *Discussion*—
(See Fig. ~~6~~1.) The breakthrough detection time is dependent on the sensitivity of the method (see Appendix X1).

3.1.3 *closed-loop, adj*—refers to a testing mode in which there is no change in the volume of the collection medium except for sampling.

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

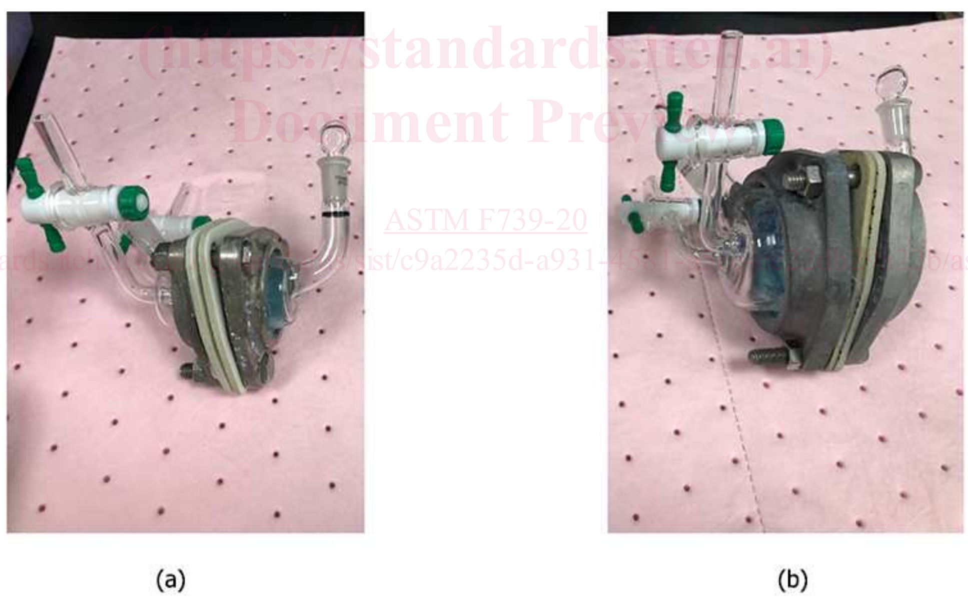
3.1.5 *cumulative permeation, n*—the total mass of chemical that permeates a specific area of protective clothing material during a specified time from when the material is first contacted by the test chemical.

[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.



NOTE 1—Cell can be reconfigured for gas challenges. Collection chamber can be used in open- or closed-loop mode. Closed chamber is to right of sample material; flow chamber to left.

FIG. ~~1~~3 ~~ASTM Permeation Test Cell~~Standard Cell Configured for Liquid Challenges



NOTE 1—In each image, the closed chamber is on the right and the flow chamber is on the left of the assembly.

FIG. 2 ~~Alternative Permeation Test Cell Design~~Test Cell Setup—(a) 1 in. Diameter Cell; (b) 2 in. Diameter Cell

3.1.6 *degradation, n*—a deleterious change in one or more properties of a material.

3.1.6.1 *Discussion*—

For protective clothing materials, changes in physical properties are typically of most interest.

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

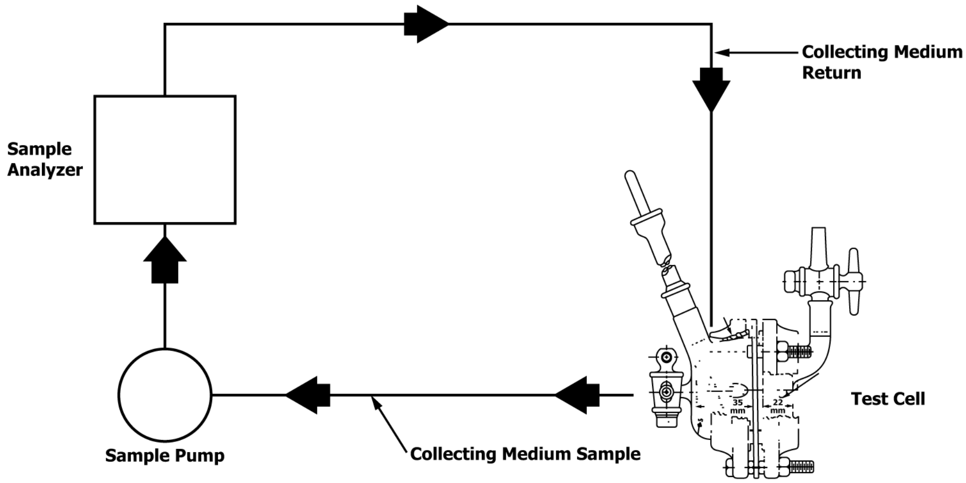


FIG. ~~3~~4 Example ~~Set-up~~Setup for Continuous Collecting Medium Sample Withdrawal, Analysis, and Return

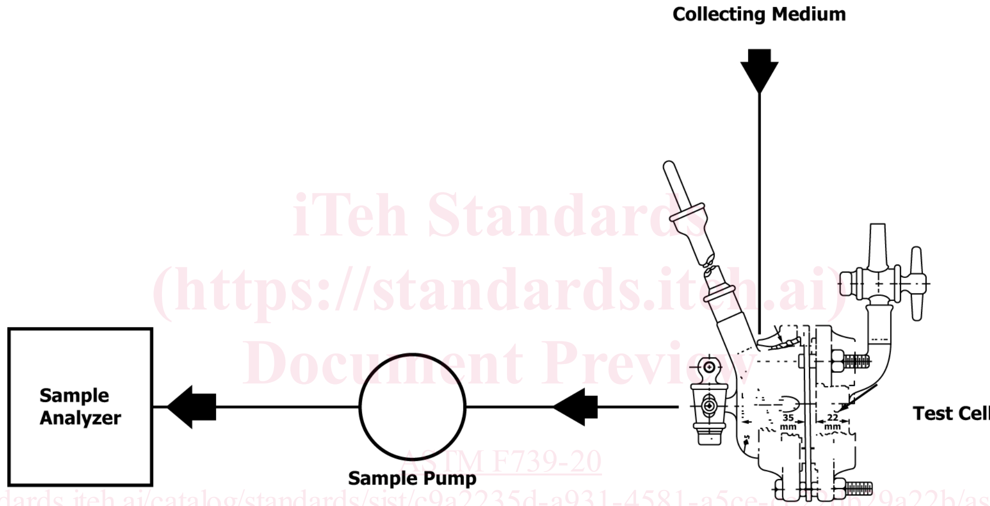


FIG. 4~~~~5 Example ~~Set-up~~Setup for Continuous Flow of Fresh Collecting Medium

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

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

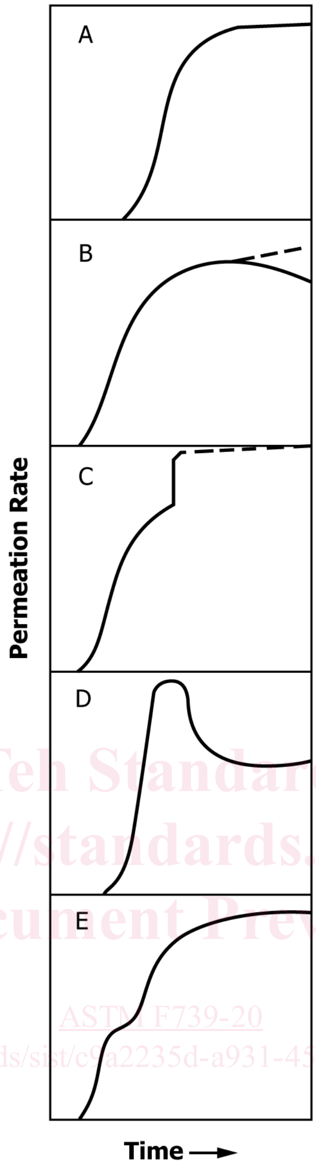
3.1.8.1 *Discussion—*
This value is not necessarily the sensitivity of the analytical instrument.

3.1.9 *normalized breakthrough time, n*—the time at which the permeation rate reaches 1.0 µg/cm^2/min.

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

3.1.11 *penetration, n*—for chemical protective clothing, the movement of substances through voids in protective clothing materials or items on a non-molecular level.

3.1.11.1 *Discussion—*
Voids include gaps, pores, holes, and imperfections in closures, seams, interfaces, and protective clothing materials. Penetration does not require a change if state; solid chemicals move through voids in materials as solids, liquids as liquids, and gases as gases. Penetration is a distinctly different mechanism from permeation.



NOTE 1—Fig. 56 shows five types of permeation behavior. Type A, the most typical, where the permeation rate stabilizes at a "steady state" value. Type B behavior is due to the material specimen being structurally modified by the chemical, resulting in an increase or decrease in permeation rate. Type C behavior occurs when the material specimen exhibits a sudden, very large increase in rate. Type D response happens when there is moderate to heavy swelling of the material specimen, although the permeation rate eventually stabilizes. Type E response can occur when there is a high degree of swelling.

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FIG. 56 Five Types of Permeation Behavior

3.1.12 *permeation, n*—for chemical protective clothing, the movements of chemicals as molecules through protective clothing materials by the processes of (*1*) absorption of the chemical into the contact surface of the materials, (*2*) diffusion of the absorbed molecules throughout the material, and (*3*) desorption of the chemical from the opposite surface of the material.

3.1.12.1 *Discussion*—
Permeation is a distinctly different mechanism from penetration.

3.1.13 *protective clothing, n*—item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the wearer of the clothing.

3.1.14 *seam, n*—a line along which two pieces of material are joined together in protective clothing.

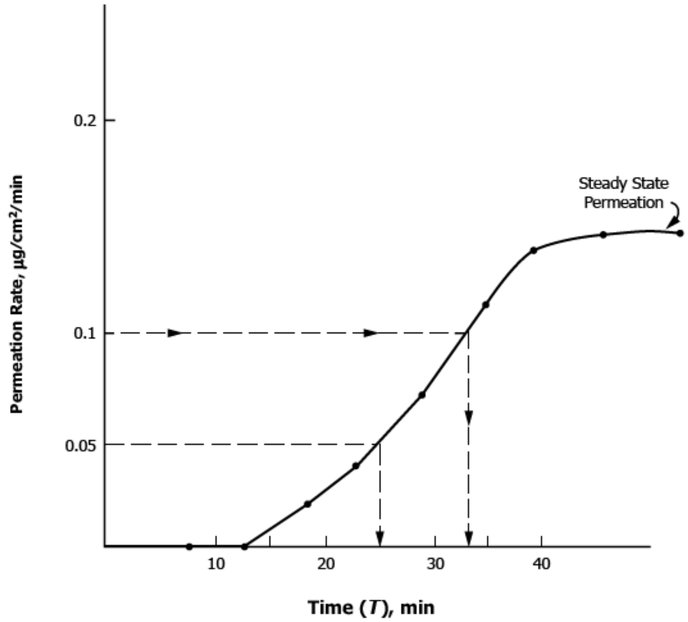

FIG. ~~6~~1 The Breakthrough Detection Time for a ~~method sensitivity~~Method Sensitivity of 0.05 µg/cm^2/min is ~~23 minutes.~~25 min. The Standardized Breakthrough Detection Time is 33 ~~minutes.~~min. The ~~Steady State~~ Steady-State Permeation Rate is ~~approximately~~Approximately 0.15 µg/cm^2/min.

3.1.14.1 *Discussion—*
Common ways that seams are constructed include sewing with thread, welding with heat, taping, and gluing.

3.1.15 *standardized breakthrough time, n*—the time at which the permeation rate reaches 0.1 µg/cm^2/min.

3.1.16 *steady-state permeation, n*—the constant rate of permeation that occurs after breakthrough when the chemical contact is continuous and all forces affecting permeation have reached equilibrium.

3.1.17 *test chemical, n*—the solid, liquid, gas, or mixture thereof, used to evaluate the performance of a protective clothing material.

3.1.17.1 *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).

3.1.18 *volatile liquid, n*—a liquid with a vapor pressure greater than 1 mm Hg at 25 °C.

3.2 For other protective clothing definitions, refer to Terminology F1494.

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, normalized breakthrough time, subsequent permeation rate, and cumulative permeation over a period of time through replicate specimens of the material.

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

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

4.2.2 By either graphical representation, appropriate calculations, or both, the breakthrough detection time, standardized breakthrough time, ~~and the permeation rate~~ normalized breakthrough time, permeation rate, and cumulative permeation of the test chemical are determined.

5. Significance and Use

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

5.1.1 Finished items of protective clothing include gloves, ~~arm shields,~~ sleeves, aprons, suits, ~~hats,~~ coveralls, hoods, boots, respirators, and the like.

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

5.1.3 Selected seams for testing are representative of seams used in the principal construction of the protective clothing item and typically include seams of both the base material and where the base material is joined with other types of materials.

5.2 The breakthrough detection time, standardized breakthrough time, permeation rate, and cumulative permeation are key measures of the effectiveness of a clothing material as a barrier to the test 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, long standardized breakthrough detection times, low amounts of cumulative permeation, and low permeation rates are characteristics of ~~better barriers.~~more effective barrier materials than materials with higher permeation characteristics.

NOTE 1—At present, only limited quantitative information exists about acceptable levels of dermal contact with most chemicals. Therefore, the data obtained using this test method cannot be used to infer safe exposure levels.

5.2.1 The reporting of a standardized breakthrough time greater than a specific time period means that the test chemical has not permeated the specimen at a rate exceeding ~~0.1~~ 0.1 µg ~~µg/cm~~cm^2/min in the designated time. Permeation may or may not have occurred at a lower rate during this time interval.

5.2.2 The reporting of cumulative permeation over a specified test period is another means to report barrier performance of protective clothing for resistance to permeation. This measurement quantifies the total amount of chemical that passed through a known area of the material during the specified test period.

NOTE 2—It is possible to relate cumulative permeation test results to the total amount of chemical to which an individual wearer may be exposed by accounting for the exposed surface area and the underlying air layer. This information has value when there are known maximum permitted skin exposure doses for specific chemicals.

5.3 The sensitivity of the test method in detecting low permeation rates or amounts of the test chemical that permeate is determined by the combination of the analytical technique and collection system selected, and the ratio of material specimen area to collection medium volume or flow rate.

5.3.1 The analytical technique employed ~~should~~shall be capable of measuring the concentration of the test chemical in the collection medium ~~at,~~at or ~~below, levels~~below 0.05 µg⁄cm^2 ~~consistent with the standardized breakthrough time value specified in~~ /min, ~~3.1.13~~and ~~at,~~at or ~~above,~~above the steady-state permeation rate.

5.3.2 Often permeation tests will require measurement of the test 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.

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

5.4 Comparison of results requires specific information on the test cell, procedures, and analytical techniques. Results obtained from closed-loop and open-loop testing may not be directly comparable.

5.4.1 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.

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

5.5 A group of chemicals for use in permeation testing is given in Guide F1001.

5.6 ~~These test procedures are also a part of ISO 6529. ISO 6529 provides a harmonized standard that also permits~~While this method specifies standardized breakthrough time as the time at which the permeation rate reaches 0.1 µg/cm^2 ~~using some practices commonly followed in Europe for permeation testing, for example, using a breakthrough time normalized~~ /min, it is acceptable to continue the testing and also report a normalized breakthrough time at a permeation rate of ~~1.0~~ 1.0 µg ~~µg/cm/~~cm^2~~/min instead of 0.1µg/cm/~~min.~~^{2}/min as used in this method. For this reason, the reporting of all permeation data must include the method that is used in the testing. Guide F1194 provides guidance on reporting permeation test results.~~

5.7 It is recommended that the test be continued for the measurement of maximum or steady-state permeation rate or for the duration specified for the determination of cumulative permeation.

5.7.1 It is permitted to terminate tests early if there is catastrophic permeation of the chemical through the protective clothing material and the rate of permeation could overwhelm the capability of the selected analytical technique.

5.8 Guide F1194 provides a recommended approach for reporting permeation test results.

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 D1777, 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,~~ ±0.5 mg, shall be used to determine weight per unit area of each test specimen.

6.3 *Test ~~Cell,~~ Cell*—~~the~~The test apparatus consists of a two-chambered cell for contacting the specimen with the test chemical on the specimen's normally outside surface and with a collection medium on the specimen's normally inside surface. See Fig. 2.

NOTE 3—Use of a 2 in. (50 mm) diameter cell (Fig. 2(b)) is preferred over a 1 in. (25 mm) diameter cell (Fig. 2(a)) due to higher ratios of material specimen surface area to collection medium volume.

6.3.1 ~~*Liquid Test Chemical,* for liquid chemicals, the test cell,~~The chambers are ~~shown in Fig. 1, is constructed of two sections of straight glass pipe, each nominally sized to a 25.4-mm (1.0-in.) diameter.~~of two types: ~~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 test 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.~~

6.3.1.1 *Closed Chamber*—The closed chamber contains a fixed volume of liquid and a straight bore, standard taper spout for adding challenge chemical or collection medium. Small volumes of collection medium may be removed with or without replacement for analysis. The 1 in. closed chamber is 23 mm (0.917 in.) in length and 25.3 mm (1.0 in.) internal diameter (see Fig. 2(a)). The internal volume of the closed chamber is 17.1 mL. The 2 in. closed chamber is 22.0 mm (0.87 in.) in length and 50 mm (2.0 in.) internal diameter (see Fig. 2(b)). The internal volume of the closed chamber is 48 mL.

6.3.1.2 *Flow Chamber*—The flow chamber has inlet and outlet ports with valves through which a challenge chemical or a collection medium flows during the test. The flow chamber is used for continuously passing a gaseous challenge over the normally outside surface of the test specimen, or continuously passing a gaseous or liquid collection medium over the normally inside surface of the test specimen. The 1 in. flow chamber is 31 mm (1.25 in.) in length and 25.3 mm (1.0 in.) internal diameter. The inlet and outlet ports have 4 mm (0.19 in.) internal diameters (see Fig. 2(a)). The internal volume of the flow chamber is 17.8 mL. The 2 in. flow chamber is 35 mm (1.38 in.) in length and 50 mm (2.0 in.) internal diameter. The inlet and outlet ports have 4 mm (0.16 in.) internal diameters (see Fig. 2(b)). The internal volume of the flow chamber is 68.7 mL.

6.3.1.3 The ~~open~~ open, circular end of each chamber is flared to create a flange that facilitates clamping the chambers together.

6.3.1.4 ~~Inlet and outlet ports, with stopcock valves, if desired, are added to each chamber to enable the introduction and withdrawal of test chemical and collection medium, if appropriate. The collection medium inlet tube should direct the collection medium directly towards the center of the clothing material specimen. The inside diameter of tubing, ports, stopcocks, etc. should be at least 2 mm (0.08 in.) to prevent undesirable pressure differences in the system.~~Use chemically inert and non-absorptive test cell parts that contact the test chemical.

NOTE 4—The standard closed and flow chambers are made of glass.[4] Test chemicals (for example, hydrofluoric acid) that are corrosive to glass require chambers constructed of alternative materials.

~~6.3.1.3 Each chamber may also be equipped with a straight bore, standard taper spout. This spout may be useful for adding and removing test chemical and collection medium. The spouts may also be used to introduce stirrers into the chambers.~~

~~6.3.1.4 Upon assembly, the clothing material is clamped between the two chambers by means of a yoke having at least three bolts.[7] Two PTFE gaskets having smooth, rounded edges are used at the joint, with the clothing material between them.[8]~~

6.3.2 Select the test cell configuration based on the challenge chemical and most appropriate analytical method.

NOTE 5—The configuration can be of two closed chambers, two flow chambers, or one closed and one flow chamber.

6.3.2.1 When the flow chamber contains the challenge chemical, the chemical is introduced through the longer stem that goes all the way to the end of the chamber. A shorter stem on the side of the test chamber provides the challenge chemical a means of exit from the test chamber. This mode of entry and exit of the challenge chemical aids in mixing of the chemical inside the test chamber. Flow of the challenge chemical must be regulated such that its composition and the concentration does not change over time.

6.3.3 The test specimen is sandwiched between two PTFE or butyl gaskets and the assembly is clamped between the two chambers.

NOTE 6—Butyl gaskets can become contaminated and contaminate future tests.

NOTE 7—Adequate seal of elastomeric specimens may be achieved without use of gaskets.

6.3.4 ~~*Discussion—*~~*Additional Information:* ~~The bolts shall be tightened with sufficient torque to prevent leakage of the test chemical or the collection medium but avoid damage to the clothing material or the test cell.~~

6.3.4.1 ~~Leak-tight~~ Make leak-tight connections to the collection chamber inlet and outlet ~~tube must be made.~~ tube. In addition, ~~all tubing coming into~~ use tubing which is in contact with the test chemical ~~should be~~that is made from material that does not absorb or react with the test chemical. Glass, PTFE, or stainless steel ~~can be used~~are appropriate choices in most cases. ~~Connections~~ It is recommended to make connections of external tubing to the glass inlet and outlet ports of the test cell chambers ~~can be made~~ via PTFE pressure-fit union connectors.

6.3.4.2 In non-flow tests where increased analytical sensitivity is required, use a closed chamber to reduce the volume of the collection medium. This increases the sensitivity of the method by increasing the ratio of material specimen area to the collection medium volume. Similarly, use a lower volume test chamber for a high hazardous chemical to minimize the amount of chemical being used for testing

6.3.4.3 In ~~closed-loop tests where increased analytical sensitivity is required, a shorter length chamber may be used to reduce the volume of the collection medium. This increases the sensitivity of the method by increasing the ratio of material specimen area to the collection medium volume. In~~ open-loop tests, lower collection medium flow rates ~~will~~ increase the system sensitivity by lowering the minimum detectable permeation rate. However, these approaches to increasing sensitivity must be achieved within the constraints of having sufficient volumes and mixing rates so as not to interfere with the permeation process.

NOTE 8—A flow rate of 0.1 L/min has been found to achieve the required analytical sensitivity for minimum detectable permeation rate with an optimal mixing efficiency.

[4] The ~~test cell as shown is~~closed and flow chambers are available from Pesce Lab Sales, ~~P.O. Box 235, 226 Birch St.,~~ 355 N. Lincoln St, Kennett Square, PA 19348.

~~6.3.2.3 Liquid test chemicals that are mixtures must be stirred to minimize concentration gradients. Stirring may be effected by a stirring rod inserted through the fill spout or a magnetic stirrer. If there is not a good seal of the shaft of the rod and the spout, evaporation of the chemical can occur, reducing its volume and potentially changing its composition.~~

~~6.3.2.4 For a liquid collection medium that is not circulated, the two chambers of the test cell must permit the mixing, withdrawal and replenishment of the collection medium during the test.~~

6.3.5 ~~For gaseous test chemicals, the test cell can consist of two chambers one of which allows the gaseous test chemical to be circulated from its reservoir. Flow must be such that the composition and concentration of the gas in the test chamber does not change with time, and the test gas in the chamber is well mixed.~~Special considerations with liquids that are mixtures:

6.3.5.1 In case of liquids that are mixtures and for liquid collections, minimize concentration gradients by mounting the test cell setup on a rocker table in a vertical orientation to ensure both surfaces of the specimen are fully contacted by liquids. Set the table rocker to be continuous with lowest speed sufficient to promote uniform mixing.

6.3.5.2 Alternatively, liquid test chemicals that are mixtures can be stirred to minimize concentration gradients. Use a stirring rod inserted through the fill spout or a magnetic stirrer.

6.3.5.3 If a stirrer is used, do not let it contact or damage the specimen.

NOTE 9—If there is a poor seal of the shaft of the rod with the spout, evaporation of the chemical can occur, reducing its volume and potentially changing its composition.

6.3.5.4 For a liquid collection medium that is not circulated, use a test cell design and permeation test setup that permits the mixing, withdrawal, and replenishment of the collection medium during the test.

6.4 *Alternative Test ~~Cell—~~Cells—*Alternative permeation test cells ~~may be~~ shall be permitted to be used, provided ~~that the results are~~ the type of test cell used is reported as prescribed in Section 12. The ~~cells~~cell and configuration described above and shown in ~~Fig. 1~~Figs. 2 and 3, however, ~~are~~is the ~~standards.~~standard. If ~~a different~~an alternate cell is used, ~~it~~ the equivalence of the alternative test cell must be documented as described in Section 12. ~~An alternative design that has been documented is shown in Fig. 2.~~

6.5 *~~Constant Temperature~~ Constant-Temperature Chamber or Bath,* used to maintain the test cell within ~~±1.0°C~~±1.0 °C of the test temperature. The standard temperature ~~for this test is 27°C.~~is 27 °C. Condition all test materials, including the test cells and chemicals, in the chamber(s) ~~of~~or bath(s) prior to testing.

6.6 *Circulating Pump,* if appropriate, is used to transport the collection ~~medium,~~medium or test chemical, or both, through the test cell. All parts contacting the test chemical ~~or fluid containing it~~ must be chemically inert and non-absorptive to the test chemical. The flow rate must be sufficiently high to provide adequate ~~mixing,~~mixing or dilution, or both, within the test cell.

NOTE 10—If a circulating pump is used, care should be taken to avoid inducing pressure which may deform or damage the test specimen.

6.7 *Flow Meter,* used to measure the flow rate of the collection medium through the collection chamber. A calibrated rotameter, or similarly accurate device, ~~may~~shall be used. The flow rate shall be measured in-line with all system components in place at the start of each test.

6.8 *Thermometer or Thermocouple,* used to measure the temperature of the constant-temperature chamber (or bath), or the collection chamber of the test cell, or both. A calibrated ~~device,~~device accurate to ~~±0.5°C must~~±0.5 °C shall be used.

7. Safety Precautions

7.1 Before this test method is carried out, safety precautions recommended for handling any potentially hazardous chemical should be identified and reviewed to provide full protection to all personnel.

7.1.1 For carcinogenic, mutagenic, teratogenic, and other toxic (poisonous) chemicals, the work area should be isolated, ~~well-ventilated,~~ well ventilated, and meticulously clean. Involved personnel should be outfitted with protective clothing and equipment.

7.1.2 For corrosive or otherwise hazardous chemicals, involved personnel ~~should, as a minimum,~~ should be outfitted with protective clothing and equipment.

7.2 Emergency equipment, such as a safety shower, eye wash, and self-contained breathing apparatus, should be readily accessible from the test area.

7.3 Appropriate procedures for the disposal of the chemicals should be followed.

8. Testing and Analytical Technique Consideration

8.1 Each protective clothing material specimen ~~may~~ shall be permitted to consist of either a single layer or a composite of multiple layers that is representative of ~~an~~ actual protective clothing construction, with all layers arranged in proper order. In each test, the specimen's normally outer surface shall contact the test chemical.

8.1.1 ~~If,~~If in a ~~proposed~~ design of ~~an item of protective clothing,~~protective clothing different materials or thicknesses of materials are specified at different locations, specimens from each location shall be tested.

8.1.2 ~~If,~~If in a ~~proposed design,~~ design of protective clothing seams are ~~specified,~~used, additional specimens containing such seams shall be tested. Care must be taken to ensure that the test cell can be properly sealed when specimens of nonuniform thickness are tested.

NOTE 11—Use of a 2 in. (50 mm) diameter cell is preferred over a 1 in. (25 mm) diameter cell for this reason.

8.2 ~~Each material specimen to be tested shall have a minimum cross dimension of 43 mm (1.7 in.). A 51-mm (2-in.) diameter circle is convenient.~~Sample size is dependent on test cell dimensions.

8.2.1 For a 2 in. (50 mm) diameter cell, each material specimen to be tested shall have a minimum cross dimension of 68.6 mm (2.7 in.). A 76.2 mm (3 in.) diameter circle is convenient.

8.2.2 For a 1 in. (25 mm) diameter cell, each material specimen to be tested shall have a minimum cross dimension of 43 mm (1.7 in.). A 51 mm (2 in.) diameter circle is convenient.

8.2.3 Specimens are permitted to extend beyond the edge of the sealing surface if the larger specimen does not interfere with the ability to seal the test cell.

8.3 A minimum of three random specimens shall be tested. Random specimens shall be generated as described in Practice E105.

8.4 To avoid incidental contamination of exposed surfaces, clean gloves ~~may~~shall be worn when handling specimens.

8.5 To avoid affecting permeation ~~measurements, a~~quantification, the collection medium should not interact with the test ~~material,~~material and must have adequate capacity for the permeant. To have adequate capacity for the permeant, the collection medium should not exceed ~~20%~~20 % of its saturation concentration from the permeant at any time during the test. For a liquid collection medium, saturation is the maximum solubility or miscibility of the permeant in the liquid at the test temperature. For a gaseous collection medium, saturation is determined by the vapor pressure of the permeant.

8.6 Under conditions in which the test chamber or bath is at a temperature significantly different from that of the test chemical or collection medium that is being introduced into the test cell, the temperature in the test chemical chamber ~~and/or~~or the collection ~~chamber~~ chamber, or both, should be measured. It may be necessary to ~~pre-condition~~precondition the test chemical or collection medium before it enters into the test cell. Similarly, it may be necessary to maintain the temperature of the collection medium after it leaves the test cell to prevent condensation or precipitation.