



Designation: F903 – 18

Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids¹

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INTRODUCTION

Workers involved in the production, use, and transportation of liquid 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 determines resistance of protective clothing materials, seams, and closures to liquid penetration only. Resistance of protective clothing materials to permeation is determined by Test Method F739 or F1383. While degradation resistance is not directly determined by this test method, the degradation of a material can be a contributing factor to the observed penetration of a liquid.

Test Method F1359 assesses the liquid penetration of full protective clothing items or ensembles of clothing and equipment.

1. Scope

1.1 This test method is used to test specimens of protective clothing materials, assemblies such as seams and closures, or interfaces used in the construction of protective clothing. The resistance to visible penetration of the test liquid is determined with the liquid in continuous contact with the normally outside (exterior) surface of the test specimen.

1.2 This test method includes different procedures for maintaining the liquid in contact with the test specimen in terms of the length of exposure and the pressure applied. Suggestions are provided for how to select an appropriate procedure for liquid contact.

1.3 In some cases, significant amounts of hazardous materials will permeate specimens that pass the penetration tests. For more sensitive analyses, use either Test Method F739 or F1383 to determine permeation.

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 test method does not address penetration of vapors through protective clothing materials.

1.5 This test method is not applicable to non-planar protective clothing materials, interfaces, or assemblies such as the fingertips or crotch areas of gloves, which are possible failure points.

1.6 This test method does not address the liquid penetration resistance of full protective clothing items or ensembles. Use Test Method F1359 for this purpose.

1.7 The values as stated in inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use. Specific hazards are given in Section 7.*

1.9 *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

- D1777 Test Method for Thickness of Textile Materials
- D3776 Test Methods for Mass Per Unit Area (Weight) of Fabric
- E105 Practice for Probability Sampling of Materials
- F104 Classification System for Nonmetallic Gasket Materials
- F739 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact
- F1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin
- F1383 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Intermittent Contact

2.2 NFPA Standards:³

- NFPA 1951 Standard on Protective Ensembles for Technical Rescue Incidents
- NFPA 1952 Standard on Surface Water Operations Protective Clothing and Equipment
- NFPA 1971 Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting
- NFPA 1991 Standard of Vapor-Protective Ensembles for Hazardous Materials Emergencies
- NFPA 1992 Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies

2.3 Military Standard:⁴

- MIL-STD-105E Sampling Procedures and Tables for Inspection by Attributes

2.4 ANSI/ASQ Standard:⁵

- ANSI/ASQ Z1.4 Sampling Procedures and Tables for Inspection by Attributes

2.5 ISO Standard:⁶

- ISO 2859-1 Sampling Plans for Inspection by Attributes

3. Terminology

3.1 Definitions:

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

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 Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

⁴ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://quicksearch.dla.mil>.

⁵ Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, <http://www.asq.org>.

⁶ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

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

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

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

3.1.3.1 *Discussion*—Permeation is a distinctly different mechanism from penetration and does not require a void in the material to occur.

3.1.4 *protective clothing, n*—an 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.

3.1.4.1 *Discussion*—The potential hazard addressed by this test method is penetration by liquids.

4. Summary of Test Method

4.1 A protective clothing specimen is placed in a specialized test cell where its normal exterior side is contacted by a liquid. The interior side of the specimen is open to viewing and is observed for evidence of visible penetration of the liquid.

4.2 This test method provides different procedures for length of times and pressures applied by the liquid during its contact with the specimen. For most procedures, the observation of visible liquid penetration is indicated as a failing result. In one procedure, the pressure is sequentially increased to specified levels and the test result is the specific pressure when visible liquid penetration was observed. This test method also allows for other methods of liquid contact.

5. Significance and Use

5.1 This test method is normally used to evaluate the barrier effectiveness against penetration of liquids through materials, seams, closures, or other planar assemblies used in protective clothing and specimens from finished items of protective clothing.

5.1.1 Finished items of protective clothing include gloves, arm protectors, aprons, coveralls, suits, hoods, boots, and similar items.

5.1.2 The phrase “specimens from finished items” is permitted to include continuous regions of protective clothing items as well as seamed or other discontinuous regions of protective clothing.

5.1.3 The types of specimens are limited to those that are relatively flat (planar) that are capable of being sealed in the test cell specified in this test method without peripheral leakage.

5.2 A substitute challenge liquid (for example, water or isopropanol) is appropriate in some cases to generalize material penetration resistance to liquids. However, it is possible that differences in chemical and molecular properties (for example, surface tension) may lead to different results.

5.3 In addition to the failure mode where a liquid finds a pathway for penetration through a void, imperfection, or defect in material or clothing subassembly, some selected chemicals cause degradation of barrier material, film, or coating, leading to penetration over extended periods of contact.⁷

TABLE 1 Pressure/Time Sequences and Conditions for Selected Circumstances

Procedure	Pressure/Time Sequence ^A	Circumstance
A	0 psig for 5 min followed by 2 psig (13.8 kPa) for 10 min	Used for selecting protective clothing materials, seams, and closures to limit exposure to liquid splashes.
B	0 psig for 5 min followed by 1 psig (6.9 kPa) for 10 min	Used for selecting extensible protective clothing materials (such as gloves) to limit exposure to liquid splashes.
C ^B	0 psig for 5 min followed by 2 psig (13.8 kPa) for 1 min followed by 0 psig for 54 min	Used for selecting protective clothing materials, seams, and closures to limit exposure of fire-service personnel to liquid splashes during emergency responses.
D	0 psig to 10 psig (68.9 kPa) in 0.5-psig (3.5-kPa) increments at 60-s intervals	Used when the pressure where penetration occurs is sought without a set pressure pass/fail criteria limit. Can also be used for quality control purposes on the assurance of material or seam liquid holdout.
E	Include in the report the time and pressure sequence used if different from Procedure A, B, C, or D	Used for other specified needs or circumstance.

^A Use of a retaining screen is optional. If a retaining screen is used, indicate its use in the report.

^B Procedure C is specified in several standards for emergency response protective clothing, including NFPA 1951, NFPA 1952, NFPA 1971, NFPA 1991, and NFPA 1992, available from NFPA, Batterymarch Park, Quincy, MA 02269.

5.4 Five different procedures for how the specimen is exposed to the liquid are provided in **Table 1**. In this test method, all procedures involve liquid exposure that is continuous over the duration of the test. These procedures entail different hydrostatic pressures and durations of liquid exposure.

5.4.1 Procedures A, B, and C apply a set pressure (6.9 or 13.8 kPa [1 or 2 psig]) for a specified period of time (1 or 10 min) over a 15- or 60-min liquid exposure time.

5.4.2 Procedures A and B represent the originally established methods of liquid contact developed by the National Institute for Occupational Safety and Health, where Procedure A involves the application of a test pressure (13.8 kPa [2 psig])

that has been found to discriminate the liquid barrier performance of materials, while a lower pressure (6.9 kPa [1 psig]) is used for Procedure B to accommodate materials that exhibit ballooning or extension when the 13.8 kPa (2 psig) pressure is applied.^{8,9} Both procedures entail exposure of the specimen for 5 min at ambient pressure followed by 10 min of exposure of the specimen to the test pressure.

5.4.3 Procedure C was developed to account for potentially longer exposures where failure may also occur as the result of material or assembly degradation. Procedure C uses a 13.8 kPa (2 psig) test pressure for a portion of the test where the specimen is first exposed to the liquid at ambient pressure for 5 min, followed by 1 min at 13.8 kPa (2 psig), and continuing for 54 additional minutes at ambient pressure.

5.4.4 Procedure D involves the sequential increase of pressure from ambient (0 kPa [0 psig]) to 68.9 kPa (10 psig) in increments of 3.5 kPa (0.5 psig) in 1-min intervals until liquid penetration is observed at a specific test pressure. The time interval between changes in pressure is set at 1 min to coincide with the time of applied pressure in Procedure C.

5.4.5 Procedure E permits the test method user to specify the pressures and duration of the specimen's exposure to the liquid.

5.5 Different results are reported by the different procedures.

5.5.1 Procedures A, B, and C results are reported as "pass" or "fail" for each replicate. Passing results indicate that no liquid penetration was observed over the duration of the test exposure.

5.5.2 Procedure D results are reported as the test pressure at which liquid penetration was observed for each replicate.

5.6 The choice of pressure/time sequence and type of test result are dependent on the objectives of the testing.

5.6.1 Procedure C is specified in several different National Fire Protection Association standards for establishing the minimum barrier performance of protective clothing materials, seams, and closures of first responder protective clothing.

5.6.2 Procedure D may be used when the pressure where penetration occurs is sought without a set pressure pass/fail criterion. Procedure D also has utility for assessing the robustness of protective clothing materials and assemblies as part of quality systems. It is also possible to use Procedure D to supplement the pass/fail results provided by Procedures A, B, and C.

5.6.3 Procedure E permits setting a specific sequence of pressure/time exposures based on the specific needs for the testing.

5.6.4 In this test method, a hydrostatic pressure is applied but does not necessarily correlate with a mechanical pressure against a semi-rigid or rigid surface.

⁷ Stull, J. O., White, D. F., and Greimel, T. C., "A Comparison of the Liquid Penetration Test with Other Chemical Resistance Tests and its Application in Determining the Performance of Protective Clothing," *Performance of Protective Clothing: Fourth Volume*, ASTM STP 1133 (J. McBriarity and N. Henry, Eds.), ASTM International, West Conshohocken, PA, 1992, pp. 123–140.

⁸ Mansdorf, S. Z., and Berardinelli, S. P., "Chemical Protective Clothing Standard Test Method Development Part 1: Penetration Test Method," *American Industrial Hygiene Association Journal*, Vol 49, No. 1, 1988, pp. 21–25.

⁹ Berardinelli, S. P. and Cottingham, L., "Evaluation of Chemical Protective Garment Seams and Closures for Resistance to Liquid Penetration," *Performance of Protective Clothing*, ASTM STP 900 (R. L. Barker and G. C. Coletta, Eds.), ASTM International, West Conshohocken, PA, 1986, pp. 263–275.

5.6.5 It is recommended that a human factors investigation, hazard/risk exposure assessment, or similar study be conducted to determine the most suitable procedure for relating the choice of a specific procedure for measuring protective clothing material liquid penetration resistance to the intended protective performance of the clothing material.

5.7 This test method permits the use of a retaining screen for preventing the overextension of a specimen as pressure is applied. However, it is important that the selected retaining screen does not interfere with the observation of liquid penetration or affect the sealing of the specimen in the test cell.

5.8 A critical feature of the test is how the specimen is sealed in the test cell. Inadequate sealing of the specimen can lead to a false result (observed liquid penetration that is due to the method of sealing rather than penetration through the specimen). It is recommended that any special means used to seal specimens in the test cell be validated for providing sufficient integrity of the specimen in the test cell, not contribute to specimen damage, and not interfere with the observation of liquid penetration. Special means used to seal specimens in the test cell should be documented in the report.

5.9 A minimum number of three test specimens is established for this test method. However, it is also appropriate to establish sampling plans based on a specific acceptable quality limit using a larger number of specimens, depending on the application of the test method. Potential sampling plans for this approach are found in MIL-STD-105E, ANSI/ASQC Z1.4, and ISO 2859-1.

5.10 This test method does not address the liquid penetration of full protective clothing or ensembles. Use Test Method F1359 to provide a complete evaluation of the liquid integrity of protective clothing or ensembles, particularly areas of the clothing or ensembles that cannot be directly assessed by this test method, such as interface areas between different items of clothing and equipment.

6. Apparatus

6.1 *Thickness Gage*, suitable for measuring thickness to the nearest 0.001 in. (or nearest 0.01 mm), as specified in Test Method D1777.

6.2 *Liquid Penetration Tester*, as shown in Figs. 1-10. See Table 2 for parts and materials.

NOTE 1—A 5-psig pressure gage is acceptable for use with Procedures A, B, and C. Digital and other automated pressurization and monitoring systems may also be acceptable.

6.2.1 *Test Cell*, consisting of a chamber for the challenge liquid and a restraining ring which holds the outside surface of the specimen in contact with the challenge liquid on the open side of the chamber and which allows observation of the specimen's inside surface through a viewing port. A transparent cover is optional.

6.2.2 *Safety Shield*, transparent and shatter resistant, to separate the liquid penetration test unit from the observer (see Fig. 1).

6.2.3 *Screen*, retaining, optional, composed of 316 stainless steel hexagonal 6 by 6 mesh encapsulated in TF1620 PTFE

(Polytetrafluoroethylene), conforming to USP class VI and having 79 % open area. A carbon black dot indicates the smooth side to contact the test specimen. (See Fig. 10.)¹⁰

NOTE 2—It is important that the screen does not cause damage to the specimen when clamped on top of the specimen in the test cell.

6.2.4 *Gasket*—A variety of materials and closed-cell foams are acceptable, such as polyethylene, silicone, buna-n, neoprene, or PTFE, provided that the material is confirmed not to leach or degrade when exposed to the challenge liquid for a period lasting longer than the test exposure time.

7. Hazards

7.1 Before carrying out this test method, identify and review safety precautions recommended for handling each chemical of interest to provide appropriate protection to all personnel.

7.1.1 For carcinogenic, mutagenic, teratogenic, and other toxic (poisonous) chemicals, isolate the work area under adequate exhaust ventilation and keep it meticulously clean. Outfit involved personnel with appropriate protective clothing and equipment and train in use as required by federal, state, and local regulations.

7.1.2 For corrosive or otherwise hazardous chemicals, outfit involved personnel, as a minimum, with protective clothing and equipment and train in use as required by federal, state, and local regulations.

7.2 Keep emergency equipment, such as a safety shower, eye wash, and self-contained breathing apparatus readily accessible to the test area.

7.3 Use a transparent safety shield (6.2.2) between the test cell and the observer.

7.4 Dispose of hazardous chemicals according to federal, state, and local regulations.

8. Test Specimen

8.1 Specimens consist of either a single layer or a composite of multiple layers which is representative of an actual protective clothing material or construction, with all layers arranged in proper order.

NOTE 3—The use of canning wax, flowable silicone rubber, and other materials has been found effective to seal the edges of multi-layer samples prior to testing. This can reduce the occurrence of challenge liquid wicking at the edges. Validation of sealing material performance is recommended to ensure the sealing material does not impact testing.

8.1.1 If in the design of an item of protective clothing different materials or thickness of materials are used at different locations, select and test specimens from each location.

8.1.2 If in the design of an item of protective clothing stitched-through or other type seams are used, select and test additional specimens containing such seams.

8.2 Use material specimens that have a minimum dimension of 2.75 in. (70 mm).

8.2.1 For seam specimens, position the seam in the center of the specimen to be tested.

¹⁰ The retaining screens, Model #6771, available from Mastco Inc., Holmdel, NJ 07733 (email: GeorgeWei@Mastco.net or Karlwade@Mastco.net) have been found suitable.

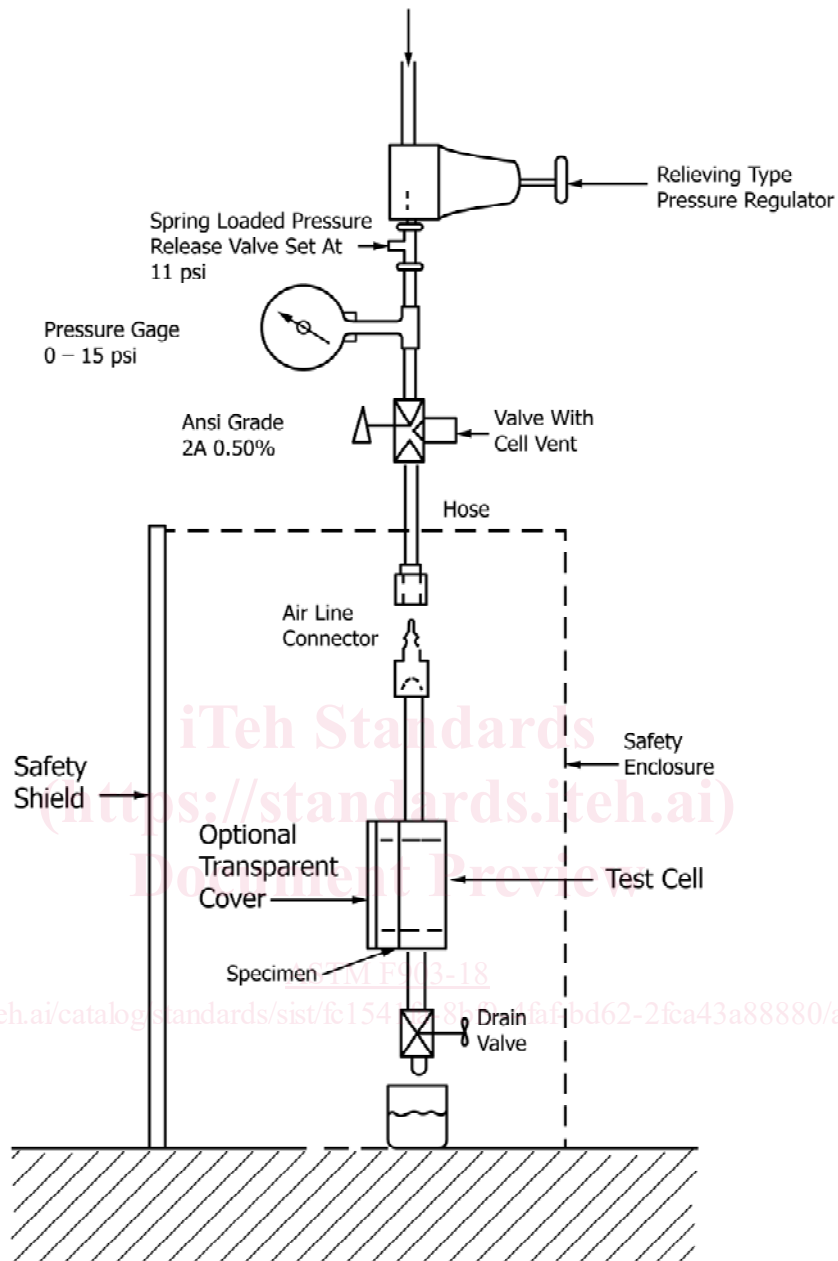


FIG. 1 Liquid Penetration Tester

8.3 Test a minimum of three random specimens for each material, composite, area (in the case of a heterogeneous design), or other conditions specified by the test requestor. Generate random specimens as described in Practice E105.

9. Procedure

9.1 Using Test Method D1777, measure the thickness of each specimen to the nearest 0.001 in. (or nearest 0.02 mm) and record. Measure the unit area weight of each specimen in

g/m^2 (oz/yd^2) in accordance with Test Methods D3776. For nonuniform samples, record the lowest values.

9.2 Place a droplet of the challenge liquid on the normally inside surface of an extra piece of the material to be tested to predetermine the visual appearance of end point penetration. The droplet must remain easily visible to ensure that any droplet that penetrates the material will be seen. If the droplet is not easily visible, one of the following methods may be

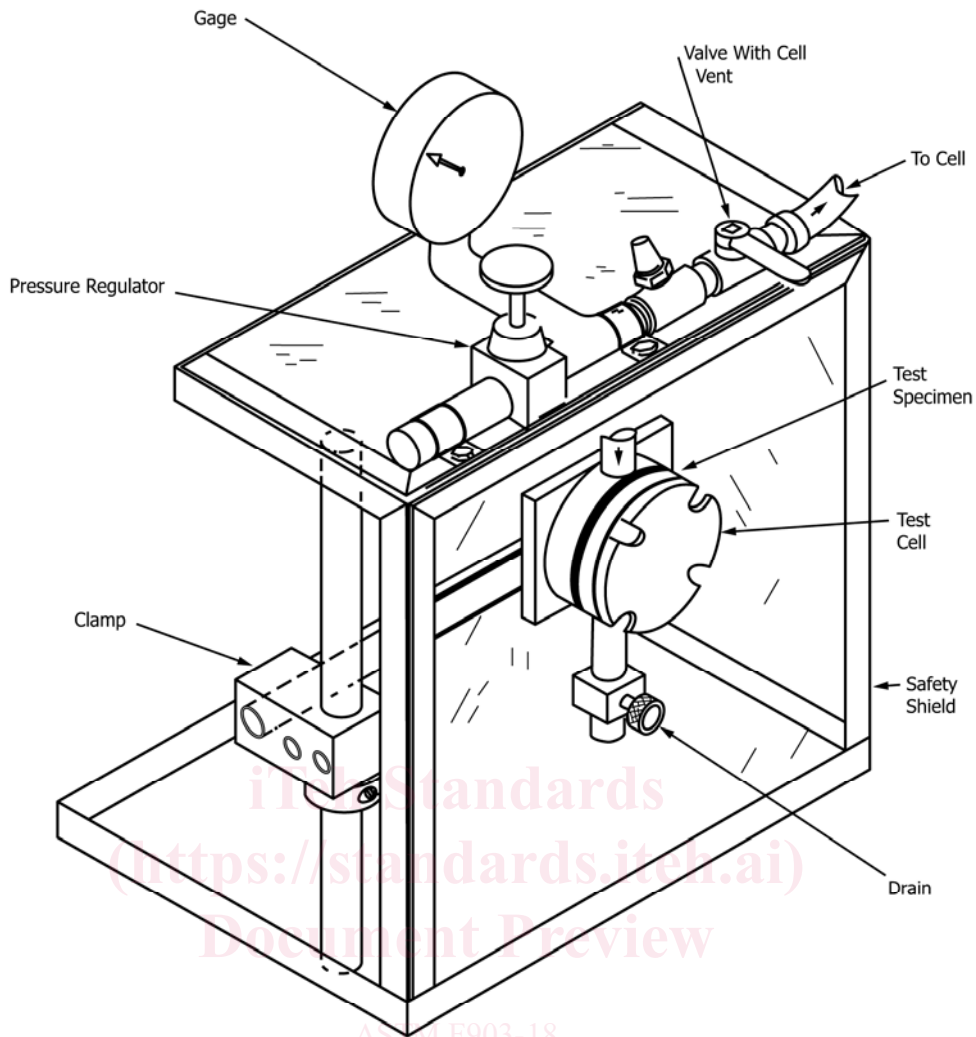


FIG. 2 Three-Dimensional Side View of the Test Apparatus

effective in enhancing droplet visibility by producing a characteristic discoloration:

9.2.1 Apply talcum powder on the normally inside surface of the specimen.

9.2.2 Add food coloring, an acid-base indicator, or Oil Red to the challenge liquid.

9.2.3 Apply food coloring or Oil Red to the normally inside surface of the specimen.

9.2.4 Add a fluorescent dye to the challenge liquid.

9.2.5 Record the amount and type of additive used to enhance droplet visibility.

NOTE 4—Contaminants in the colorant may change the surface energy of the challenge liquid and affect the test results. Use as little an amount as required to achieve required droplet visibility.

9.3 Mount the first specimen in the test cell with the normally outside surface toward the chemical chamber and assemble it as shown in Fig. 1. A transparent cover (see Fig. 3) is optionally mounted directly on the test cell as long as it does not alter the test results.

TABLE 2 Parts and Materials for Liquid Chemical Penetration Test Equipment for Protective Clothing Material (See Figs. 1-10)^A

Quantity	Description
1	Air pressure regulator ¼ NPT, adjustable 0 – 10 psig relieving type
1	Adjustable relief valve with 0 – 30 psi range, set at 11 psig
1	Pressure gage 0 – 15 psig 4½-in. (115-mm) diameter ANSI Grade A 1 % (a magnehelic-type pressure gage is preferred.)
1	¼ NPT 3-way cock with wrench
3	¼ NPT × 1½-in. (38-mm) No. 316 pipe nipples
1 set	¼ NPT air line speed coupler, plug, and socket
3 ft	¼-in. (6-mm) rubber air hose with ¼ NPT female coupling
2	½-in. (13-mm) split shaft collars
	Miscellaneous ¼ NPT galvanized pipe fittings and fasteners, readily available at most hardware stores have not been specified
	Gasket material—closed-cell foam has been found useful
1	Ball Valve, ¼ NPT Type 316 stainless steel
1	½-in. (13-mm) diameter 2-piece Shaft Collar

^A Penetration test apparatus, available from Wilson Road Machine Shop, 1170 Wilson Road, Rising Sun, MD 21911 and the Kent Machine Co., 4445 Allen Rd., Stow, OH 44224, have been found suitable.

NOTE 5—The use of the transparent cover may permit the condensation of vapor that permeates but does not penetrate the specimen, leading to