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## Standard Guide for Evaluating Chemical Protective Clothing<sup>1</sup>

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### INTRODUCTION

ASTM Committee F-23 was established in 1976 for the purpose of producing standards for use in the evaluation of protective clothing; in particular, clothing that is used for protection from potentially hazardous chemicals. Such clothing ranges from aprons and gloves to totally encapsulating ensembles. The clothing is widely used throughout industry, agriculture, government, and academia in, for example, chemical research, pesticide application, hazardous waste cleanup, and chemical production.

Committee F-23 is also concerned with clothing for protection from molten metals, but that aspect of the committee's activities is not addressed in this guide.

The effective development and selection of chemical protective clothing requires information on several aspects of the clothing, including chemical resistance, physical integrity, comfort, and fit. Some of these characteristics can be evaluated using swatches of the materials from which the clothing is fabricated; other characteristics require testing of the finished items of clothing. Both types of test methods have been addressed by Committee F-23.

The successful use of Committee F-23's standards requires an awareness and understanding of each standard as well as the interrelationship of the standards.

The successful application of chemical protective clothing requires the careful matching of the proper level of protection and performance characteristics of clothing with the potential hazard and the functional requirements of the tasks to be performed while wearing the clothing.

### 1. Scope

1.1 This guide is intended to promote the use of standards in the development, specification, and selection of chemical protective clothing with the ultimate goal of improving the safety and health of workers who come into contact with hazardous chemicals.

1.2 *Proposed standards under development by ASTM Committee F-23:*

1.2.1 Test Methods for Measuring the Performance Characteristics of Exhaust Valves Used in Chemical Protective Suits

1.2.2 Test Method for Measuring the Thermal and Evaporative Resistance of Textile Materials Using a Sweating Hot Plate

1.2.3 Test Method for Testing Protective Clothing Materials for Particle Penetration and Air Flow Resistance

1.2.4 Practice for Protective Clothing Maintenance Instructions

1.3 Standards relevant to the work of Committee F-23 are described along with their key reporting elements and limitations.

1.4 Proposed standards of Committee F-23 are also described to provide insight into possible future products of the committee.

1.5 The standards and proposed standards are organized under the following headings: Physical Properties, Chemical Resistance, Classification, Chemical Protective Suits, and General.

1.6 Appendix X1 is an example of how the standards can be combined into a protocol for selection of the most suitable protective clothing for a given application. Briefly, the process is one of defining the requirements of the application and then (by testing) eliminating those candidates that are unsuitable. No protocol can ensure the selection of protective clothing that *guarantees* worker protection. The purpose of testing is to generate data and information that will allow the selection of the most appropriate clothing. Ultimately, clothing selection is based on technical evaluation of available information and professional assessment of risk.

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

1.8 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and*

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health practices and determine the applicability of regulatory limitations prior to use.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- F 739 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Continuous Contact<sup>2</sup>
- F 903 Test Method for Resistance of Materials Used In Protective Clothing to Penetration by Liquids<sup>2</sup>
- F 1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials<sup>2</sup>
- F 1052 Test Method for Pressure Testing Vapor Protective Ensembles<sup>2</sup>
- F 1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles<sup>2</sup>
- F 1186 Classification System for Chemicals According to Functional Groups<sup>2</sup>
- F 1194 Guide for Documenting the Results of Chemical Permeation Testing on Materials Used in Protective Clothing<sup>2</sup>
- F 1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin<sup>2</sup>
- F 1301 Practice for Labeling Chemical Protective Clothing<sup>2</sup>
- F 1342 Test Method for Protective Clothing Material Resistance to Puncture<sup>2</sup>
- F 1358 Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance<sup>2</sup>
- F 1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin<sup>2</sup>
- F 1383 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Intermittent Contact<sup>2</sup>
- F 1407 Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method<sup>2</sup>
- F 1461 Practice for Chemical Protective Clothing Program<sup>2</sup>
- F 1494 Terminology Relating to Protective Clothing<sup>2</sup>
- F 1790 Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing<sup>2</sup>
- F 1818 Specification for Foot Protection for Chain Saw Users<sup>2</sup>
- F 1819 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Synthetic Blood Using a Mechanical Pressure Technique<sup>2</sup>

## 3. Significance and Use

3.1 The standards under the jurisdiction of Committee F-23 can be used individually or as part of an integrated protocol in the development, selection, specification, and application of chemical protective clothing.

3.2 The standards are intended as a means by which information can be requested, generated, and reported in a consistent, comparable manner.

3.3 The information on clothing performance must be combined, by means of professional judgment, with a clear understanding of the clothing application to provide the best protection to the worker.

## 4. Physical Properties of Clothing Materials

### 4.1 Standards:

4.1.1 *F 1358 Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance*—This test method is intended to determine the ignition resistance and burning characteristics of materials used in protective clothing, where flame resistance is not the primary form of protection designated. A test specimen is exposed to a flame for 3 s. If the material ignites, the after-flame time, afterglow time, and burn distance are measured. If the material does not ignite, the test is repeated using a flame exposure period of 12 s.

4.1.1.1 When flame resistance is the primary protection offered by the protective clothing, alternative test methods should be used.

4.1.2 *F 1342 Test Method for Protective Clothing Material Resistance to Puncture*—This test method evaluates puncture resistance of protective clothing materials that may include plastics or elastomeric films, coated fabrics, flexible materials, laminates, or textile materials.

4.1.2.1 It is not intended to measure puncture resistance of all types of punctures encountered using protective clothing materials. This test method involves a procedure where a puncture probe of specified dimensions is used for puncturing specimens.

4.1.2.2 The method evaluates puncture resistance of protective clothing materials, specifically for puncture forced on specimens perpendicular to material surface. There is no supporting structure under the material specimen.

4.1.3 *F 1790 Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing*—This test method assesses the cut resistance of a material when exposed to a cutting edge under specified loads. Data obtained using this test method can be used to compare the cut resistance of different materials.

4.1.3.1 This test method only addresses that range of cutting hazards that are related to a cutting action across the surface of the material. It is not representative of any other cutting hazard to which the material may be exposed.

### 4.2 Proposed Standards:

4.2.1 *Test Method for Testing Protective Clothing Materials for Particle Penetration and Air Flow Resistance*—The purpose of this test method is to provide a means to compare a fabric's particulate penetration behavior. An aerosol generator is used to generate a uniform aerosol. The generator is coupled to a laser particle counter that counts and records the number of aerosol particles before and after the test fabric at specified air flows.

## 5. Chemical Resistance of Clothing Materials

### 5.1 Standards:

<sup>2</sup> Annual Book of ASTM Standards, Vol 11.03.

5.1.1 *F 739 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Continuous Contact*—The resistance of a protective clothing material to permeation by a test chemical is assessed by measuring the breakthrough detection time, normalized breakthrough detection time, and subsequent permeation rate through replicate specimens of the material.

5.1.1.1 In the permeation test apparatus, the protective clothing material specimens partition the test chemical from the collection medium. The collection medium, which may be liquid or gas, is analyzed quantitatively for its concentration of the chemical and thereby the amount of the chemical that has permeated the test specimen as a function of time after its initial contact with the material.

5.1.2 *F 903 Test Method for Resistance of Materials Used In Protective Clothing to Penetration by Liquids*—This test method is normally used to evaluate the barrier effectiveness against liquids of materials used for protective clothing and specimens from finished items of protective clothing. A material specimen is subjected to a liquid contact for a specified time and pressure sequence and observed for visible penetration of the liquid. If the liquid passes through the material, the material fails the test for resistance to penetration of the liquid.

5.1.3 *F 1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials*—This guide lists recommended challenge chemicals to be used in testing programs to evaluate chemical protective clothing materials. The guide contains a list of 15 liquid and 6 gases representing many different classes of chemicals: acids, bases, ketones, aldehydes, amines, hydrocarbons, and so forth.

5.1.4 *F 1383 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Intermittent Contact*—This test method is used to measure breakthrough detection time and chemical permeation through specimens of protective clothing under the conditions of intermittent contact of a test chemical with the specimen.

5.1.5 *F 1407 Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation - Permeation Cup Method*—Permeation of chemicals through a clothing specimen is measured by gravimetry. The chemical is placed in a shallow cup and the clothing specimen clamped over the top of the cup. The top surface of the clothing surface is left open to air. The cup assembly is weighed periodically, and from the change in weight, the permeation rate calculated and the breakthrough time estimated. The clothing material specimen is also observed for visible changes in appearance that would indicate chemical attack. Physical properties of the clothing specimen can be measured before and after the exposure as another means for assessing chemical resistance. The test may be used in the field or as a preliminary test to the more costly Test Method F 739. The test method is applicable to chemicals with sufficiently high vapor pressure such that they will readily evaporate upon permeation through the clothing material. The test cannot distinguish specific permeants when the liquid has multiple components.

5.2 *Proposed Standards: None*

## 6. Classification

### 6.1 Standards:

6.1.1 *F 1186 Classification System for Chemicals According to Functional Groups*—In many situations where chemicals are interacting with other chemicals or materials, the interaction is strongly dependent and often correlated with the functional group(s) present. For this reason it is useful to have a standard means for classifying chemicals.

6.1.1.1 Chemical resistance data are available for only a very small fraction of the chemicals for which protective clothing is used. However, for chemicals for which no data are available, a knowledge of the chemical class can sometimes give insight into the expected resistance of prospective clothing material.

### 6.2 Proposed Standards: None

## 7. Chemical Protective Suits

### 7.1 Standards:

7.1.1 *F 1052 Test Method for Pressure Testing Vapor Protective Ensembles*—This test method evaluates the gas-tight integrity of a totally encapsulating, chemical protective suit. The test apparatus is attached to the suit to permit inflation to the pre-test suit expansion pressure for removal of suit wrinkles and creases and to equalize/stabilize the air temperatures internal and external to the VPE. The pressure is lowered to the test pressure and monitored for 4 min. If the pressure drop is excessive, the suit fails the test and is removed from service.

7.1.2 *F 1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles*—These practices establish standard procedures designed for quantitatively evaluating the performance characteristics of chemical-protective suit ensembles in terms of comfort, fit, function, and overall integrity.

7.1.2.1 Option A evaluates the integrity of the suit and its materials and seams by subjecting the suit to manned exercise scenarios. The exercise routine includes kneeling, squatting, twisting, reaching overhead, and crawling.

7.1.2.2 Option B evaluates the function of the suit by observing the ability of a test subject to perform routine work tasks while wearing the suit. Routine tasks involve lifting boxes, moving a 55-gal drum, operating an overhead valve, using a wrench, using a screwdriver, and climbing a ladder.

7.1.3 *F 1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin*—This test method can be used to quantify and compare the insulation provided by different garments and clothing systems. For example, variations in the design and fabric used in garments can be evaluated. The effects of garment layering, closure, and fit can be measured for clothing ensembles. The insulation values for ensembles can be used in models that predict the physiological responses of people in different environmental conditions.

7.1.4 *F 1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin*—This test method evaluates the ability of the construction and configuration of protective clothing or protective ensembles to resist liquid penetration. In most cases, the conditions used in this test method will not represent actual end-use conditions. The test is

not intended to simulate user exposure to splashes of liquid chemical but rather to provide sufficient time for enough liquid to penetrate to make visual inspection easier.

7.1.4.1 A test specimen is placed on a mannequin that is already dressed in a liquid-absorptive garment covering portions of the mannequin form that are of interest. Water is sprayed at the test specimen from five nozzles positioned in a specific configuration with respect to the specimen. The specimen is exposed to the liquid spray for a period of 15 minutes in each of four specimen orientations. The test specimen is rated as passing if liquid does not penetrate and as failing if liquid does penetrate.

*7.2 Proposed Standards:*

7.2.1 *Test Methods for Measuring the Performance Characteristics of Exhaust Valves Used in Chemical Protective Suits*—The purpose of these test methods is to evaluate the effectiveness of exhaust valves to eliminate inward flow of external vapors into a suit through the exhaust valve.

7.2.2 *Test Method for Measuring the Thermal and Evaporative Resistance of Textile Materials Using a Sweating Hot Plate*—This test method measures the thermal and evaporative resistance, under steady-state conditions, of fabrics, films, coatings, foams, and leathers, including multi-layer assemblies, for use in protective clothing systems. A heated hot plate maintained at 33 to 36°C is used to measure the following parameters: thermal resistance, isothermal evaporative resistance, total heat loss, insulation value, and permeability index.

**8. General**

*8.1 Standards:*

8.1.1 *F 1194 Guide for Documenting the Results of Chemical Permeation Testing on Materials Used in Protective Clothing*—This guide provides a format for documenting information and performance data from a permeation test. This

guide is intended to encourage thorough and consistent documentation of permeation testing and its results.

8.1.2 *F 1301 Practice for Labeling Chemical Protective Clothing*—This practice covers the informational content of labels in or on chemical protective clothing. This practice details the recommended format and minimal content of the information to be included on the labels used for chemical protective clothing. This practice does not cover user information provided by means other than item labels, such as instructions, informational packets, brochures, or other written means. It is intended to provide the user with some of the basic information necessary for the proper selection and use of the chemical protective clothing when comparing resistance data derived from ASTM performance testing.

8.1.3 *F 1461 Practice for Chemical Protective Clothing Program*—The essential elements and considerations are defined for a program for the use of chemical protective clothing. The elements include program administration, standard operating procedures, psychological and physiological limitations of users, clothing selection, training, and maintenance and storage. The practice contains many insights into the practical aspects of selecting and using chemical protective clothing.

8.1.4 *F 1494 Terminology Relating to Protective Clothing*—This standard defines the specialized terms used in standards developed by Committee F-23 on Protective Clothing.

*8.2 Proposed Standards:*

8.2.1 *Practice for Protective Clothing Maintenance Instructions*—This practice describes the recommended minimum information to be conveyed to protective clothing users for the care and maintenance of protective clothing that could be used for more than one wearing.

**9. Keywords**

9.1 chemical protective clothing; protective clothing

**APPENDIX**

**(Nonmandatory Information)**

**X1. EXAMPLE PROTOCOL FOR APPLICATION OF THE STANDARDS OF COMMITTEE F-23**

X1.1 *Objective*—Select a totally encapsulating ensemble for protection from a chemical for which there is no published clothing compatibility information.

X1.1.1 Obtain flat samples of the materials of construction of candidate totally encapsulating ensembles.

X1.1.2 Assess the general chemical resistance of the materials. If the chemical(s) to which the ensemble are unknown, select as a starting point test chemicals from Guide F 1001.

X1.1.3 Subject the most chemically resistant materials to physical property tests, using standard methods for cut (Test Method F 1790), puncture (Test Method F 1342) flame im-

pingement (Test Method F 1358), and so forth as appropriate for the planned use of the ensemble.

X1.1.4 Subject those materials that exhibit good chemical resistance and the necessary physical properties to permeation testing according to Test Method F 739 (continuous exposure) or Test Method F 1383 (intermittent exposure).

X1.1.5 For the two or three materials that exhibit the best combination of chemical resistance and physical properties, obtain samples of candidate seams and closures from fabricated garments.

X1.1.6 Subject the candidate seams and closures to penetration testing according to Test Method F 903.

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X1.1.7 Specify the fabrication of the ensemble based on the results of the above tests and the experience of the clothing vendor. Obtain complete ensembles.

X1.1.8 Pressure test the complete ensembles according to Practice F 1052. Assess the comfort, fit, function, and integrity of the ensemble following Practice F 1154. Modify the ensemble design as necessary.

X1.1.9 When ordering the ensembles, specify that they be labeled according to F 1301, the standard for chemical protective clothing labeling.

X1.1.10 Use Guide F 1194 to report all test results.

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