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Standard Guide for Evaluating Chemical Protective Clothing[1]

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INTRODUCTION

ASTM Committee F23 was established in 1976 for the purpose of producing standards for use in the evaluation of protective clothing. A significant number of these standards have applied to protection against chemicals. Chemical protective clothing ranges from aprons and gloves to totally encapsulating ensembles. Chemical protective clothing is widely used throughout in several different applications including the general industry, the chemical process industry, oil refining, agriculture, hazardous materials remediation, and emergency response.

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. Committee F23 has developed test methods for both types of evaluations.

The successful use of Committee F23'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 aid in the application of standards for the development, specification, and selection of chemical protective clothing with the ultimate goal of maintaining the safety and health of workers who come into contact with hazardous chemicals.

1.2 This guide provides a short description of each referenced standard and then makes specific recommendations for the use of these standards. The referenced standards are organized under the following headings: Material Chemical Resistance, Material Physical Properties, Seam and Closure Performance, and Overall Clothing Performance.

1.3 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.

1.4 The values stated in SI units or in other units shall be regarded separately as standard. The values stated in each system must be used independently of the other, without combining values in any way.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 747 Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam[2]

D 751 Test Methods for Coated Fabrics[3]

D 1630 Test Method for Rubber Property-Abrasion Resistance (Footwear Abrader)[4]

D 2582 Test Method for Puncture-Propagation Tear Resistance of Plastic Film and Thin Sheeting[5]

D 3389 Test Method for Coated Fabrics Abrasion Resistance (Rotary Platform, Double-Head Abrader)[3]

D 4157 Test Method for Abrasion Resistance of Textile

[1] This guide is under the jurisdiction of ASTM Committee F23 on Protective Clothing and is the direct responsibility of Subcommittee F23.30 on Chemicals.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 09.02.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

Fabrics (Oscillatory Cylinder Method)[6]
D 4966 Test Method for Abrasion Resistance of Textile Fabrics (Martindale Abrasion Tester Method)[6]
D 5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)[6]
D 5151 Test Method for Detection of Holes in Medical Gloves[3]
D 5587 Test Method for Tearing Strength of Fabrics by Trapezoid Procedure[6]
D 6413 Test Method for Flame Resistance of Textiles (Vertical Test)[6]
F 392 Test Method for Flex Durability of Flexible Barrier Materials[7]
F 739 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Continuous Contact[8]
F 903 Test Method for Resistance of Materials Used In Protective Clothing to Penetration by Liquids[8]
F 1001 Guide for Selection of Chemicals to Evaluate Protective Clothing Materials[8]
F 1052 Test Method for Pressure Testing Vapor Protective Ensembles[8]
F 1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles[8]
F 1186 Classification System for Chemicals According to Functional Groups[8]
F 1194 Guide for Documenting the Results of Chemical Permeation Testing on Materials Used in Protective Clothing[8]
F 1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin[8]
F 1301 Practice for Labeling Chemical Protective Clothing[8]
F 1342 Test Method for Protective Clothing Material Resistance to Puncture[8]
F 1358 Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance[8]
F 1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin[8]
F 1383 Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Intermittent Contact[8]
F 1407 Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method[8]
F 1461 Practice for Chemical Protective Clothing Program[8]
F 1494 Terminology Relating to Protective Clothing[8]
F 1790 Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing[8]
F 2061 Practice for Chemical Protective Clothing Care and Maintenance Instructions[8]
F 2130 Test Method for Measuring Repellency, Retention, and Penetration of Liquid Pesticide Formulation Through Protective Clothing Materials[8]

2.2 *ANSI Standard:*[9]
ANSI Z41 American National Standard for Personal Protection—Protective Footwear

2.3 *ANSI/ISEA Standard:*[10]
ANSI/ISEA 105 American National Standard for Hand Protection Selection Criteria

2.4 *NFPA Standards:*[11]
NFPA 1991 Standard on Vapor-Protective Ensemble for Hazardous Materials Emergencies
NFPA 1992 Standard on Liquid Splash-Protective Ensemble and Clothing for Hazardous Materials Emergencies
NFPA 1994 Standard on Protective Ensemble for Chemical/Biological Terrorism Incidents

2.5 *Federal Regulations:*[12]
29 CFR Part 1910.120 Hazardous Waste Operations and Emergency Response: Final Rule, *Federal Register*, Vol 54, Mar. 6, 1989, p. 9317, as amended in *Federal Register*, Vol 55, Apr. 13, 1990, p. 14073; *Federal Register*, Vol 56, Apr. 18, 1991, p. 15382 and *Federal Register*, Vol 59, Aug. 22, 1994, p. 43270
29 CFR Part 1910.132 General Requirements, of Subpart I—Personal Protective Equipment, *Federal Register*, Vol 39, Jun. 27, 1974, p. 23502, as amended in *Federal Register*, Vol 59, Apr. 6, 1994, p. 16334 and *Federal Register*, Vol 59, July 1, 1994, p. 33910
29 CFR Part 1910.1000 Air Contaminants, *Federal Register*, Vol. 39, June 27, 1974.

2.6 *American Conference of Governmental Industrial Hygienists:*
TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents; Biological Exposure Indices[13]

3. Terminology

3.1 *Definitions:*

3.1.1 *protective clothing, n*—a product which is specifically designed and constructed for the intended purpose of isolating parts of the body from a potential hazard; or as a barrier to prevent the body from being a source of contamination.

3.1.1.1 *Discussion*—In this guide, protective clothing is intended to provide protection against chemicals.

3.1.2 For definitions of other terms related to protective clothing used in this guide, refer to Terminology F 1494.

4. Significance and Use

4.1 The standards under the jurisdiction of Committee F23 and other technical committees can be used individually or as

[6] *Annual Book of ASTM Standards*, Vol 07.02.
[7] *Annual Book of ASTM Standards*, Vol 15.09.
[8] *Annual Book of ASTM Standards*, Vol 11.03.

[9] Available from National Safety Council (NSC), 1121 Spring Lake Dr., Itasca, IL 60143-3201.
[10] Available from Industrial Safety Equipment Association, 1901 North Moore Street, Suite 808, Arlington, VA 22209.
[11] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.
[12] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.
[13] Available from The American Conference of Governmental Industrial Hygienists, Inc. (ACGIH), 1330 Kemper Meadow Dr., Suite 600, Cincinnati, OH 45240.

part of an integrated protocol in the development, selection, specification, and use of chemical protective clothing.

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

4.3 The suggested evaluation and test methods are recommended guidelines only. Test methods offer procedures for evaluating chemical protective clothing at standardized conditions to allow comparison.

4.4 The information on clothing performance must be combined with professional judgment, and a clear understanding of the clothing application, to provide the best protection to the worker. All chemical protective clothing use must be based on a hazard assessment to determine the risks for exposure to chemicals and other hazards. Conduct hazard assessments in accordance with 29 CFR 1910.132.

4.5 Chemical protective clothing intended for use during hazardous materials emergencies shall be evaluated against and conform to NFPA 1991, Standard on Vapor-Protective Ensemble for Hazardous Materials Emergencies, or NFPA 1992, Standard on Liquid Splash-Protective Ensemble and Clothing for Hazardous Materials Emergencies, as appropriate for the type of emergency. For emergencies involving release of chemical agents during terrorism incidents, chemical protective clothing shall be evaluated against and conform to NFPA 1994, Standard on Protective Ensemble for Chemical/Biological Terrorism Incidents.

4.6 Recommendations for labeling chemical protective clothing are provided in Practice F 1301, recommendations for implementing a chemical protective clothing program are provided in Practice F 1461, and recommendations for preparing care and maintenance instructions are provided in Practice F 2061.

4.7 Appendix X1 is an example of how several of the referenced standards can be combined into a protocol to select the most suitable chemical 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.

4.8 Appendix X2 provides a chart to cross reference U.S. Standards with European and International Standards. This chart shows only analogous standards for measuring the same property or evaluating the similar chemical protective clothing and does not imply that results from different tests will be comparable.

5. Evaluation of Material Chemical Resistance

5.1 *Applicable Standards*:

5.1.1 *Test Method F 739 (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 separates the test chemical from the collection medium. The liquid or gas collection medium is analyzed quantitatively for the challenge chemical concentration that permeates through the test specimen as a function of time after it contacts the material.

5.1.1.2 Test Method F 739 permits several configurations of the test, including the choice of collection media, detection systems, the test temperature, and length of the test.

5.1.2 *Test Method F 1383 (Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Intermittent Contact)*—This test method is a variation of Test Method F 739 and is used to measure breakthrough detection time and permeation rate through specimens of protective clothing under the conditions of intermittent contact of the test chemical with the specimen.

5.1.2.1 Test Method F 1383 is designed to simulate the type of chemical exposures where chemical contact occurs through periodic exposure or through repeated splashes depending on the type of task in which the clothing wearer is involved.

5.1.2.2 Test Method F 1383 permits several options for specifying the frequency and length of chemical contact with the material specimens. Because chemical contact with the specimen is varied, the test method specifies the reporting of cumulative permeation as opposed to permeation rate. One of the options for using Test Method F 1383 is to measure the length of time for a specific chemical to permeate through a candidate clothing material after a single "splash" exposure followed by a saturated vapor exposure. This test protocol can simulate how clothing is exposed during actual use.

5.1.3 *Test Method F 1407 (Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method)*—In this test method, permeation of chemicals through a clothing specimen is measured gravimetrically. The chemical is placed in a shallow cup and the clothing specimen clamped over the top of the cup. The interior 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 degradation.

5.1.3.1 Physical properties of the clothing specimen can be measured before and after the exposure as another means for assessing chemical resistance.

5.1.3.2 Test Method F 1407 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 the permeation of different chemicals from a chemical mixture.

5.1.4 *Test Method F 903 (Resistance of Materials Used In Protective Clothing to Penetration by Liquids)*—This test method is used to evaluate the barrier effectiveness of protective clothing materials against liquids.

5.1.4.1 In penetration resistance testing, 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. Test Method F 903 permits the use of techniques such as the use of blotter paper and dyes to enhance the visual detection of penetration. Results are reported as "pass" or "fail."

5.1.4.2 Test Method F 903 specifies four different time and pressure sequences representing different types of exposure scenarios. The test method also permits the use of a support screen for lightweight or elastomeric films.

5.1.5 *Test Method F 2130 (Measuring Repellency, Retention, and Penetration of Liquid Pesticide Formulation Through Protective Clothing Material)*—This test method measures repellency, retention and penetration of a known volume of liquid pesticide when applied to protective clothing material. No external hydrostatic or mechanical pressure is applied to the test specimen during or after the application of the liquid pesticide. Test Method F 2130 is designed to measure performance of protective clothing materials at two levels of contamination. A low level of contamination is achieved by applying the 0.1 mL liquid formulation and a high level of contamination is achieved by applying 0.2 mL.

5.1.6 *Classification F 1186 (Classification System for Chemicals According to Functional Groups)*—This classification provides a method of categorizing chemicals by their function group, which is helpful in grouping permeation resistance test data for large numbers of chemicals and materials.

NOTE 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, knowledge of the chemical class can sometimes give insight into the expected resistance of prospective clothing material. Hazard analyses must be performed in accordance with 29 CFR 1910.132.

5.1.7 *Guide F 1194 (Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing)*—This guide establishes a format and the details for completely reporting permeation resistance test results. The guide assists with the development of a chemical permeation resistance database. This guide is also intended to encourage thorough and consistent documentation of permeation testing and its results.

5.1.8 *Guide F 1001 (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 liquids and 6 gases representing many different classes of chemicals, such as inorganic acids, bases, ketones, aldehydes, amines, and hydrocarbons. These chemicals serve as a useful means for comparing the performance of protective clothing materials against a common set of chemicals.

5.2 *Recommended Use of Standards*

5.2.1 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 liquids and 6 gases representing many different classes of chemicals, such as inorganic acids, bases, ketones, aldehydes, amines, and hydrocarbons. These chemicals serve as a useful means for comparing the performance of protective clothing materials against a common set of chemicals.

NOTE 2—ANSI/ISEA 105 provides a test method for the evaluation of chemical degradation resistance for glove materials. While chemical degradation resistance information is used extensively for gloves and for some chemical protective splash suits and footwear, chemical degradation resistance information does not provide an assessment of the clothing barrier performance. Rather, chemical degradation resistance information can only be used to exclude a material from further consideration.

5.2.2 The type of chemical resistance testing recommended for evaluating materials used in chemical protective clothing will depend on several factors including:

5.2.2.1 The physical state of the chemical(s).

5.2.2.2 The likelihood for exposure and the exposure scenario (that is, control and extent of exposure, duration, work mission, environmental conditions, other hazards and influences, etc.).

5.2.2.3 The hazards of the chemical and consequences of exposure.

5.2.3 Permeation resistance testing in accordance with Test Method F 739 or Test Method F 1383 is recommended for chemicals which are gases, liquids that produce vapors, or any chemical that presents a high hazard for skin exposure.

5.2.3.1 Permeation resistance testing is generally recommended for evaluating gloves since the hands are most likely to come in contact with chemicals.

5.2.3.2 When the expected exposure to chemicals is continuous, Test Method F 739 should be applied for evaluating protective clothing materials.

5.2.3.3 If exposure is intermittent and no change of clothing occurs, Test Method F 1383 should be applied with a contact time, purge time, and frequency representative of the expected exposure.

5.2.3.4 In specifying permeation resistance testing, the minimum test parameters should include the test chemical, its concentration (if not 100 %), the method of contact (continuous or intermittent), the test temperature, and the duration of the test.

5.2.3.5 Permeation resistance test results should be documented using Guide F 1194.

5.2.4 Permeation resistance testing in accordance with Test Method F 1407 is recommended for field testing or as a preliminary test to the more costly Test Method F 739.

5.2.5 Penetration resistance testing in accordance with Test Method F 903 is recommended when the chemical is a liquid but is not a known or suspected carcinogen, or has a “skin” notation, as indicated in either the American Conference of Governmental Industrial Hygienist TLVs and BEIs (Threshold Limit Values for Chemical Substances and Physical Agents; Biological Exposure Indices) or in 29 CFR 1910.1000.

5.2.5.1 Penetration resistance testing is generally not appropriate for chemicals that are volatile under the conditions of use where contact with the vapor at the exposure concentration is considered unacceptable.

5.2.5.2 Penetration resistance testing is generally appropriate when the exposure to low hazard liquid chemicals is limited and occurs in the form of splashes.

5.2.5.3 In specifying penetration resistance testing, the minimum test parameters should include the test chemical and the time and pressure sequence.

5.2.6 Penetration and repellency testing of protective clothing for use in agricultural operations against pesticide formulations should be evaluated in accordance with Test Method F 2130.

5.2.7 Specimens for chemical resistance testing should be representative of the materials used in the construction of protective clothing.

5.2.7.1 Where practical, specimens should be taken from protective clothing items. Areas that include seams should also be tested.

5.2.7.2 For gloves and footwear, specimens should be taken from the thinnest portion of the gloves and boots that yields the appropriately sized specimens.

5.2.7.3 Where different materials are used in the construction of the protective clothing item, each different material should be tested for chemical resistance.

5.2.8 Protective clothing materials should be evaluated against each chemical of interest.

5.2.8.1 The chemical(s) should be tested in the same state and concentration, and at the same temperature as is expected for the exposure.

5.2.8.2 Chemical exposures that occur in the form of mixtures should involve testing of the mixture itself.

NOTE 3—If permeation testing is conducted using a mixture, a method for separation must be used to determine which chemicals permeate the protective clothing materials and their respective breakthrough times and permeation rates.

5.2.8.3 If a protective clothing material is being evaluated for general chemical resistance, then testing should be performed using the chemicals specified in Guide F 1001. Permeation resistance testing should be performed for all 21 chemicals, while penetration resistance testing should be performed only for the 15 liquid chemicals listed in Guide F 1001.

NOTE 4—NFPA 1992 recommends the use of penetration resistance testing only for those chemicals which do not have a skin notation and which are not actual or suspected carcinogens.

6. Evaluation of Material Physical Properties

6.1 *Applicable Standards*:

6.1.1 *Test Method D 5034 (Breaking Strength and Elongation of Textile Fabrics—Grab Test)*—This test evaluates the tensile (breaking) strength of textile materials and can be applied to many types of protective clothing materials, excluding gloves and other unsupported elastomeric materials. Tensile strength is reported in both directions for anisotropic materials.

6.1.2 *Test Method D 5587 (Tearing Strength of Fabrics by Trapezoid Procedure)*—This test method evaluates the tear strength of textile materials and can be applied to many types of protective clothing materials, excluding gloves and other unsupported elastomeric materials. In this test method, tear strength is measured on a specimen that has a small cut along one side and the tear strength is the average force required to continue the tear of the specimen. Tear strength is reported in both directions for anisotropic materials.

6.1.3 *Test Method D 751 (Methods of Testing Coated Fabrics)*—This standard includes a collection of test methods appropriate for coated fabrics, but which may also be applied to different types of protective clothing fabrics. Test methods of interest include methods for evaluating burst strength, seam strength, and blocking resistance. The burst strength method is conducted using a tensile testing machine and measures the force to push a 25-mm ball through the specimen. Seam strength is conducted in a manner similar to tensile strength testing, but the specimen includes a seam, bisecting the long axis.

6.1.4 *Test Method D 2582 (Puncture-Propagation Tear Resistance of Plastic Film and Thin Sheeting)*—This test method evaluates the resistance of plastic materials to a snagging like puncture and tear. In this test method, the material specimen is clamped onto a holder of a special test apparatus and a weighted carriage including a puncture probe falls by the force of gravity such that the probe strikes the fabric puncturing the material and then causing it to tear. The length of the tear is related to the force that causes the puncture and tear. Puncture propagation tear resistance is reported in both directions for anisotropic materials.

6.1.5 *Test Method D 4157 (Abrasion Resistance of Textile Fabrics—Oscillatory Cylinder Method)*—This test method evaluates the abrasion resistance of textiles using a specified abradant, material specimen tension, abradant pressure, and number of abradant cycles in an oscillatory motion. The test method can be applied to different types of protective clothing materials.

6.1.6 *Test Method D 4966 (Test Method for Abrasion Resistance of Textile Fabrics—Martindale Abrasion Tester Method)*—This test method evaluates the abrasion resistance of textiles using a special abrasion test apparatus, which rubs an abradant under a specified pressure in a highly specific motion against the specimen. The test method can be applied to different types of protective clothing materials.

6.1.7 *Test Method F 392 (Flex Durability of Flexible Barrier Materials)*—This test method evaluates the deterioration of a barrier fabric due to repeated flexing of the material in a special device. The flexing device both compresses and twists the material over a stroke and 440° angle.

6.1.8 *Test Method D 747 (Apparent Bending of Modulus of Plastics by Means of a Cantilever Beam)*—This test method evaluates the stiffness of plastic materials by using a device to measure the bending modulus of a material specimen. The test method can also be applied to different types of protective clothing materials and evaluate stiffness at cold temperatures when the testing is performed in controlled environment.

6.1.9 *Test Method F 1358 (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 bum distance are measured. If the material does not ignite, the test is repeated on the same specimen using a flame exposure period of 12 s. Flame resistance is reported in both directions for anisotropic materials.

6.1.9.1 When flame resistance is the primary protection offered by the protective clothing, Test Method D 6413 should be used.

6.1.10 *Test Method F 1342 (Protective Clothing Material Resistance to Puncture)*—This test method evaluates puncture

resistance against protective clothing materials. It is not intended to measure puncture resistance of all types of punctures encountered using protective clothing materials. The test method involves a procedure where a puncture probe representative of a nail is used for puncturing specimens perpendicular to material surface. There is no supporting structure under the material specimen.

6.1.11 *Test Method F 1790 (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. 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.

6.1.12 *Test Method D 3389 (Coated Fabrics Abrasion Resistance—Rotary Platform, Double-Head Abrader)*—This test method measures the abrasion resistance of rubber-coated fabrics by abrading the material on rotary platform abrader with two abrasion wheels. The test method involves a specified type of abrasion wheel and load for counting the number of abrasion cycles until wearthrough of the coating has occurred.

6.1.13 *ANSI/ISEA 105, American National Standard for Hand Protection Selection Criteria*—This standard addresses the classification and testing of hand protection for specific performance properties related to chemical and industrial applications.

6.1.14 *ANSI Z41, American National Standard for Personal Protection—Protective Footwear*—This standard provides performance requirements and test method for protective footwear, including impact and compression resistance, sole puncture resistance, and other properties.

6.1.15 *Test Method D 1630 (Rubber Property-Abrasion Resistance—Footwear Abrader)*—This test method uses a specific test apparatus, abradant and test conditions to determine the number of revolutions (cycles) to abrade 2.5 mm of thickness from footwear sole materials.

6.2 *Recommended Use of Standards for Protective Garments*:

6.2.1 Materials used in protective garments should be evaluated for tensile strength in accordance with Test Method D 5034, tear strength in accordance with Test Method D 5587 (using the five highest peaks technique for interpreting results), burst strength in accordance with Test Method D 751 (using the tension testing machine with ring clamp), and puncture propagation tear resistance in accordance with Test Method D 2582.

6.2.2 Materials used in protective garments can be evaluated for their durability by subjecting materials specimens to preconditions prior to chemical resistance testing, such as abrasion and repeated flexing.

6.2.2.1 Wear of protective garment materials by abrasion can be simulated using either Test Method D 4157 or Test Method D 4966. In these tests, the number of abrasion cycles with a specific abradant and test conditions should be chosen to simulate the type of abrasion consistent with expected clothing use. Specimens should then be taken from abraded samples for chemical resistance testing.

6.2.2.2 Wear of protective garment materials by repeated flexing can be simulated using Test Method F 392. The number of flexing cycles and flexing condition should be chosen to simulate the type of flexing consistent with expected clothing use. Specimens should then be taken from center of flexed samples for chemical resistance testing.

6.2.3 If concerns exist related to the performance of protective garments in hot environments and the possible melting of the material, evaluate garment materials for blocking resistance in accordance with Test Method D 751.

6.2.4 If concerns exist related to the performance of protective garments in cold environments, evaluate garment materials at the lowest possible use temperature in accordance with Test Method D 747.

6.2.5 If concerns exist related to the performance of protective garments in situations where the potential for flame impingement could occur, evaluate garment materials for flame resistance in accordance with Test Method F 1358.

6.3 *Recommended Use of Standards for Chemical Protective Gloves*:

6.3.1 Glove materials should be evaluated for cut resistance in accordance with Test Method F 1790, puncture resistance in accordance with Test Method F 1342, and abrasion resistance in accordance with Test Method D 3389 using the conditions and system of classifying test results established in ANSI/ISEA 105, American National Standard for Hand Protection Selection Criteria.

6.4 *Recommended Use of Standards for Chemical Protective Footwear*:

6.4.1 Where appropriate, protective footwear upper materials should be evaluated for cut resistance in accordance with Test Method F 1790, puncture resistance in accordance with Test Method F 1342, and abrasion resistance in accordance with Test Method D 3389. Abrasion resistance testing per Test Method D 3389 should be performed using the H-18 calibrase wheel and a load of 1000 g to determine the number of cycles until wearthrough of the barrier layer is noted.

6.4.2 Where appropriate, protective footwear toe sections should be evaluated for impact and compression resistance in accordance with ANSI Z41, American National Standard for Personal Protection—Protective Footwear. The specific class of performance should be indicated.

6.4.3 Where appropriate, protective footwear soles should be evaluated for puncture resistance in accordance with ANSI Z41, American National Standard for Personal Protection—Protective Footwear and abrasion resistance in accordance with Test Method D 1630.

7. Evaluation of Clothing Seam and Closure Performance

7.1 Where chemical protective garments, gloves, or footwear incorporate seams, seams should be evaluated for chemical resistance when warranted by the hazard and risk assessment. Representative seams should be tested when exposure to the clothing wearer can occur due to failure of the seam to provide the same barrier performance as the clothing material.

7.2 Garment seams should be evaluated for strength in accordance with Test Method D 751 using the procedures for seam strength.

7.3 Garment closures should be evaluated for chemical resistance when not covered by a protective flap or other means to prevent chemical exposure.

7.4 Garment closures should be evaluated for strength in accordance with Test Method D 751 using the procedures for seam strength.

8. Evaluation of Overall Clothing Performance

8.1 *Applicable Standards*:

8.1.1 *Test Method F 1052 (Pressure Testing Vapor Protective Ensembles)*—This test method evaluates the integrity of chemical protective suit in maintaining a fixed, positive pressure. This capability is related to the ability of the suit to prevent the inward leakage of gases or vapors.

8.1.1.1 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 vapor-protective ensemble. The pressure is lowered to the test pressure and monitored for 4 min. If the pressure drop is more than 20 %, the suit fails the test and is removed from service.

8.1.1.2 Test Method F 1052 generally only applies to full-body chemical protective clothing that totally encapsulates the wearer in combination with attached gloves and footwear or bootie feet. Test Method F 1052 is useful both as a quality control evaluation in the manufacture of chemical protective suits and in the field testing of chemical protective suits by users to determine their continued integrity.

8.1.2 *Test Method F 1359 (Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin)*—This test method evaluates the ability of protective clothing or protective ensembles to resist liquid penetration. It is suitable for evaluating specific configurations and design features, particularly seams, closures, and interfaces between different clothing items.

8.1.2.1 A test specimen is placed on a mannequin that is dressed in a liquid-absorptive garment covering portions of the mannequin form that are of interest. Water treated with a surfactant 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 min in each of four specimen orientations or other conditions as specified. The test specimen is rated as passing if liquid does not penetrate and as failing if liquid does penetrate.

8.1.2.2 In most cases, the conditions used in Test Method F 1359 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.

8.1.3 *Test Method D 5151 (Detection of Holes in Medical Gloves)*—This test method uses a simple approach to evaluate the integrity of medical gloves for hole by filling the glove with 1000 mL of water and observing for leakage on the surface of the gloves 2 min later. The test method can be adapted for evaluating chemical protective gloves and footwear.

8.1.4 *Practice F 1154 (Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles)*—These practices establish standard procedures for quantitatively evaluating the performance characteristics of chemical-protective suit ensembles in terms of comfort, fit, function, and overall integrity. The procedures involve human test subjects who rate their ability to perform specific exercises. Ensemble or clothing integrity is evaluated both before and after the exercises to determine if any loss of integrity occurs.

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

8.1.4.2 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.

8.1.5 *Test Method F 1291 (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.

8.2 *Recommended Use of Standards*:

8.2.1 Chemical protective clothing intended for protecting against chemicals in the form of gases or vapors, or in situations where extreme hazards exist for any contact with a specific chemical or chemicals, should be evaluated for integrity against gases and vapors. It is further recommended this chemical protective clothing be tested for inward leakage of gases and vapors.

8.2.1.1 Vapor protective suits should be evaluated using Test Method F 1052.

8.2.1.2 Special fixtures may be created to permit the individual evaluation of chemical protective gloves and footwear.

8.2.2 Chemical protective clothing intended to prevent liquid exposure should be evaluated for its integrity to prevent the inward leakage of liquids.

8.2.2.1 Both full-body and partial body chemical protective clothing should be evaluated using Test Method F 1359.

8.2.2.2 Test Method D 5151 can be adapted for the evaluation of chemical protective gloves and footwear by adjusting the amount to fill within 25 mm of the barrier portion of item near its opening and using water that has been treated with a surfactant to achieve a surface tension of 0.032 ± 0.002 N/m (32 ± 2 dynes/cm).

8.2.3 Practice F 1154 should be used to evaluate the impact of the chemical protective clothing or ensemble on the wearer and also assesses how well the clothing or ensemble maintains it integrity after use.

8.2.4 Test Method F 1291 can be used to evaluate the potential for heat stress in the wearing of chemical protective clothing.

9. Keywords

9.1 chemical protective clothing; chemical resistance; closure performance; overall clothing performance; physical properties; protective clothing; seam performance

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF USE OF STANDARDS TO EVALUATE CHEMICAL PROTECTIVE CLOTHING

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 Conduct a hazard assessment of the expected exposure scenario to determine the chemicals that the ensemble may be used to protect against. Identify any other hazards such as flame exposure, generation of static electricity, sharp objects, rough surfaces, or temperature extremes that are associated with the specific application and risks for exposure to both chemicals and other hazards.

X1.1.2 Obtain flat samples of the materials of construction of candidate totally encapsulating ensembles.

X1.1.3 Assess the general chemical resistance of the materials using Test Method F 739 if exposures are unknown or expected to be continuous. Otherwise, use Test Method F 1383 for intermittent exposures using an contact and purge sequence representative of the expected ensemble use. Evaluate the suit materials against each chemical of interest for a minimum of the longest estimated chemical exposure duration for the ensemble. If the chemical(s) for which the ensemble will be used are unknown, select the test chemicals from Guide F 1001 as a starting point. Consider evaluating the ensemble for the properties and requirements provided in NFPA 1991, as recommended in OSHA Regulations 29 CFR 1910.120.

X1.1.4 Subject the most chemically resistant materials to physical property tests, using standard methods for tensile strength (Test Method D 5034), tear strength (Test Method D 5587), burst strength (Test Method D 751) and puncture propagation tear resistance (Test Method D 2582). Consider additional test properties as pertinent to the application. Use the test results to compare against materials with known performance.

X1.1.5 For the subset of materials that exhibit the best combination of chemical resistance, physical properties, weight, thickness, cost, and other factors considered to be important, obtain samples of candidate seams and closures from fabricated garments.

X1.1.6 Subject the candidate seams to the same test method used for evaluating material permeation resistance (Test Method F 739 or Test Method F 1383) and closures to penetration testing in accordance with Test Method F 903.

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 in accordance with 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 the ensemble be labeled in accordance with F 1301, the standard for chemical protective clothing labeling.

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

X2. CORRESPONDING INTERNATIONAL AND EUROPEAN STANDARDS TO U.S. STANDARDS ON CHEMICAL PROTECTIVE CLOTHING

TABLE X2.1 Corresponding International and European Standards to U.S. Standards on Chemical Protective Clothing[A]

NOTE—Note that the listing of standards as corresponding to one another does not imply that the results of tests or classification or products can easily be compared. Standard test methods may differ in the type of specimens, conditions employed, test apparatus, procedures, types of results, and interpretation of results. The classification or minimum performance of chemical protective clothing may differ in the types of tests specified, properties measurements, and in minimum or classification levels that are set.

Property or Evaluation	U.S. Standard	European Standard	International Standard
Chemical Resistance			
Degradation resistance	ANSI/ISEA 105, Section 6[B]	N/A[C]	N/A
Penetration resistance and repellency (general chemicals)	N/A	EN 368	ISO 6530
Penetration resistance and repellency (pesticides)	ASTM F 2130	N/A	ISO 22608[D]
Penetration resistance (with pressure)	ASTM F 903	N/A	ISO 13994
Permeation resistance (continuous contact)	ASTM F 739	EN 369 EN 374-3[B]	ISO 6529
Permeation resistance (intermittent contact)	ASTM F 1383	N/A	ISO 6529
Permeation resistance (gravimetric method)	ASTM F 1407	N/A	N/A
Practice for reporting permeation results	ASTM F 1296	N/A	N/A
Classification of chemicals	ASTM F 1186	N/A	N/A
Standard chemical list	ASTM F 1001	N/A	ISO 6529, Annex A
Physical Properties			
Tensile strength (grab method)	ASTM D 5034	N/A	ISO 13935-1
Tear strength	ASTM D 2261 (tongue tear) ASTM D 5587 (trapezoid tear)	EN 388 (trouser tear)[B]	ISO 4674 (trouser tear) ISO 9073-4 (trapezoid tear)
Burst strength	ASTM D 751 (ring and clamp)	N/A	ISO 2960 (pneumatic)
Puncture propagation tear resistance	ASTM D 2582	N/A	ISO 13995
Blocking (heat resistance)	ASTM D 751	N/A	ISO 5978
Stiffness (cold temperature)	ASTM D 747	N/A	ISO 9073-7
Flame impingement	ASTM F 1358	EN 532	ISO 15025
Cut resistance	ASTM F 1790	EN 388[B]	ISO 13996
Puncture resistance	ASTM F 1342	EN 388[B]	ISO 13997
Abrasion resistance	ASTM D 3389 (rotary platform) ASTM D 4157 (oscillatory) ASTM D 4966 (Martindale)	EN 388 (Martindale)[B]	ISO 5470 (rotary platform) ISO 12947 (Martindale)
Flex fatigue resistance	ASTM F 392	N/A	ISO 7854
Seam and Closure Performance			
Seam strength	ASTM D 751	N/A	ISO 13935-2
Overall Clothing Performance			
Pressure testing (gas/vapor integrity)	ASTM F 1052	EN 464	ISO 17491, Method A
Gas/vapor integrity—dynamic inward leakage	N/A	EN 943-1 (within standard)	ISO 17491, Method B
Liquid integrity (long duration spray with manikin)	ASTM F 1359	N/A	ISO 17491, Method E
Jet integrity (human subject)	N/A	EN 463	ISO 17491, Method C
Spray integrity (human subject)	N/A	EN 468	ISO 17491, Method D
Liquid integrity (gloves)	ASTM D 5151	EN 374-2	ISO 22613[D], Annex
Particulate inward leakage	N/A	N/A	ISO 13982-2
Overall functionality, fit, comfort, and integrity	ASTM F 1154	EN 943-1 (within standard)	ISO 16602 (within standard)[D]
Comfort (manikin-based)	ASTM F 1291	N/A	N/A
Clothing Standards and Specifications			
Vapor protective clothing	NFPA 1991[E]	EN 9431 EN 943-2	ISO 16602[D]

TABLE X2.1 *Continued*

Property or Evaluation	U.S. Standard	European Standard	International Standard
Liquid splash protective clothing	NFPA 1992[E]	EN 465 EN 466 EN 467 EN 13034	ISO 16602[D]
Protective ensembles for protection against chemical and biological agents during terrorism incidents	NFPA 1994[E]	N/A	N/A
Glove requirements (chemical)	ANSI/ISEA 105	EN 374-1 EN 420	ISO 22613[D]
Footwear requirements	ANSI Z41	EN 344-1 EN 344-2 EN 345-1 EN 345-2	N/A

[A] While analogous standards are shown, it is difficult to make direct comparison with test data because of significant differences in the type of specimens, test apparatus, test procedures, and test conditions.
[B] Pertains only to gloves.
[C] N/A—not known or applicable.
[D] Draft standard at the time this Guide was prepared (not yet approved).
[E] Intended for emergency applications only.