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Standard Specification for Air-Fed Protective Ensembles[1]

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1. Scope

1.1 This specification establishes design, performance, classification, documentation, labeling, and certification requirements for protective ensembles that deliver air to the wearer by means of an air line or powered air purifying respirator (PAPR).

1.2 As a prerequisite to this specification, regulations within Title 42 Federal Code of Regulations, Part 84 are used to establish the conformance of the air-fed protective ensemble to respiratory protection requirements.

1.3 This specification addresses protective ensembles used for environments involving chemical, biological, and radiological/nuclear particulate hazards.

1.4 This specification sets specific criteria for air-fed protective ensembles used to prevent exposure to substances such as, but not limited to, chemical hazards, infectious microorganisms requiring Biosafety Level 4 (BLS4) protection, and environments where it is possible radiological or nuclear particulates will be found.

1.5 This specification is further used for classification of the protective ensemble as limited use or multiple use.

1.6 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.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 *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]

D751 Test Methods for Coated Fabrics
D1776 Practice for Conditioning and Testing Textiles
D2582 Test Method for Puncture-Propagation Tear Resistance of Plastic Film and Thin Sheeting
D3787 Test Method for Bursting Strength of Textiles—Constant-Rate-of-Traverse (CRT) Ball Burst Test
D3884 Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)
D4157 Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)
D5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
D5151 Test Method for Detection of Holes in Medical Gloves
D5587 Test Method for Tearing Strength of Fabrics by Trapezoid Procedure
F392 Test Method for Flex Durability of Flexible Barrier Materials
F739 Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact
F903 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids
F1052 Test Method for Pressure Testing Vapor Protective Suits
F1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Durability of Protective Ensembles and Ensemble Components
F1342 Test Method for Protective Clothing Material Resistance to Puncture
F1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

F1494 Terminology Relating to Protective Clothing
F1671 Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood-Borne Pathogens Using Phi-X174 Bacteriophage Penetration as a Test System
F1790 Test Method for Measuring Cut Resistance of Materials Used in Protective Clothing with CPP Test Equipment
F2010 Test Method for Evaluation of Glove Effects on Wearer Hand Dexterity Using a Modified Pegboard Test
F2061 Practice for Chemical Protective Clothing: Wearing, Care, and Maintenance Instructions
F2413 Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear
F2913 Test Method for Measuring the Coefficient of Friction for Evaluation of Slip Performance of Footwear and Test Surfaces/Flooring Using a Whole Shoe Tester
F3050 Guide for Conformity Assessment of Personal Protective Clothing and Equipment

2.2 *Federal Standards:*[3]
42 CFR Part 84 Approval of Respiratory Protective Devices

2.3 *ISO Standards:*[4]
ISO 4649:2010 Rubber, Vulcanized or Thermoplastic – Determination of Abrasion Resistance Using a Rotating Cylindrical Drum Device

2.4 *NFPA Standard:*[5]
NFPA 1991:2012 Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies
NFPA 1994:2018 Standard on Protective Ensembles for First Responders to Hazardous Materials Emergencies and CBRN Terrorism Incidents

3. Terminology

3.1 *Definitions:*

3.1.1 *airborne pathogen, n*—an infectious bacterium or virus, or other disease-inducing microbe that is suspended in air.

3.1.2 *air-fed protective ensemble, n*—a protective ensemble with respiratory protective equipment that provides a source of air directly into the ensemble without the use of a tight-fitting facepiece worn by the individual inside the ensemble.

3.1.2.1 *Discussion*—The respiratory protective equipment is either an airline that is connected to the suit wall of the ensemble that can include a distribution means inside the ensemble or a powered air-purifying respirator that is connected to the suit wall and that can also have a means for distributing air inside the ensemble.

3.1.3 *approved, v*—acceptable to the authority having jurisdiction.

3.1.4 *authority having jurisdiction, n*—an organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.1.5 *barrier material, n*—the layer of a protective clothing item that is designated as providing permeation or penetration resistance against chemicals or other hazardous substances.

3.1.5.1 *Discussion*—In this specification, the barrier material refers to the layer of the protective ensemble element that is designed to act as a barrier to a hazardous substance that the ensemble is intended to protect against.

3.1.6 *blood-borne pathogen, n*—an infectious bacterium or virus, or other disease-inducing microbe carried in the blood or other potentially infectious body fluids (also liquid-borne pathogen).

3.1.7 *labeled, n*—equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.1.8 *listed, n*—equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.1.9 *manufacturer, n*—the entity that directs and controls any of the following: compliant product design, compliant product manufacturing, or compliant product quality assurance; or the entity that assumes the liability for the compliant product or provides the warranty for the compliant product.

3.1.10 *protective ensemble, n*—the combination of protective clothing with respiratory protective equipment, hoods, helmets, gloves, boots, communication systems, cooling devices, and other accessories intended to protect the wearer from a potential hazard when worn together.

3.1.11 *sock, n*—an extension of the garment or suit leg that covers the entire foot and is intended to be worn with a protective outer boot.

3.1.12 *tethered applications, n*—applications in which a hose or line is attached to the garment or hood portion of the ensemble via an external fitting mounted on the garment material that is further connected to a fixed location external to the suit.

3.2 For definitions of other protective clothing-related terms used in this test method, refer to Terminology F1494.

4. Significance and Use

4.1 As with other hazardous materials protective ensembles, air-fed protective ensembles include clothing and equipment

[3] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.
[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[5] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

items needed for dermal and respiratory protection, including protective suits, gloves, footwear, and eye/face protection. Unlike other protective ensembles, air-fed protective ensembles do not use separate respiratory protective devices such as self-contained breathing apparatus (SCBA) or non-powered air-purifying respirators (APRs).

4.1.1 Those types of respirators normally have a tight-fitting face piece that provides inhalation hazard protection and dermal exposure protection to the face, eyes, nose, and mouth.

4.1.2 Air-fed protective ensembles are worn without the use of a separate respirator. The entire suit serves as the respiratory protective device and also provides dermal exposure protection. The wearer breathes supplied air or filtered air pumped into the protective suit.

4.2 Air-fed protective ensembles are used to protect workers in a number of applications.

4.2.1 These include, but are not limited to: chemical and pharmaceutical manufacturing, remediation of hazardous materials sites, use against highly infectious biological agents in BioSafety Level 4 laboratories, and for protection of workers involved in nuclear and radiological facilities, where it is possible radioactive particles will be encountered.

4.3 The requirements of this specification have been partly based on the NFPA 1991 standard, which establishes criteria for vapor-protective ensembles used in hazardous materials emergencies. NFPA 1991 establishes requirements for a protective ensemble that encapsulates the wearer and the breathing apparatus.

4.3.1 In this specification, a breathing apparatus is not worn inside the suit, but instead breathing air is connected to the suit either via an external airline or respiratory protective equipment that is externally connected to the suit wall. Extensive criteria for the integrity of the overall ensemble are applied through design and performance requirements. This allows for different configurations of a protective ensemble that incorporates a hooded visor, protective gloves, protective footwear, and the respiratory protective equipment.

4.4 The qualification of the respiratory protective equipment is addressed by the applicable requirements for respirators established in 42 CFR Part 84. As such, the entire air-fed ensemble is subject to certification by NIOSH in addition to meeting the requirements in this specification.

4.5 This specification establishes classifications for the protective ensemble. The classifications include one that is determined by the configuration of the protective ensemble and one that concerns the use of the protective ensemble.

4.5.1 A protective ensemble can be classified as an “Airline Protective Ensemble” or a “PAPR-Based Air-Fed Protective Ensemble.” Under each of these classifications, protective ensembles can be further classified as “Limited Use” and “Multiple Use.”

4.5.2 These classifications account for differences in the configuration of the air supply and material strength and durability. These classifications do not account for the decontamination effectiveness of multiple-use ensembles.

4.6 In recognition of the potential diverse applications to which the protective ensemble can be used, documentation requirements are provided for manufacturers to base claims for permeation resistance of ensemble materials against specific chemicals or for claims of ensemble material performance against bloodborne (or liquidborne) pathogens. Similar requirements are established for the respiratory protective equipment, when this equipment is based on the use of filters, cartridges, or canisters.

4.7 An extensive section is provided in the specification addressing the certification of air-fed protective ensembles. This certification section is based on provisions established in NFPA 1991 and other National Fire Protection Association product standards for emergency services protective clothing and equipment.

5. Classification

5.1 Protective ensembles shall be classified as either an “Airline Protective Ensemble” or a “PAPR-Based Air-Fed Protective Ensemble” depending on the type of respiratory protective equipment that is provided with the ensemble.

5.2 Protective ensembles shall additionally be classified as limited use or multiple use.

5.2.1 Limited-use protective clothing items shall be subject to the labeling requirement in 12.6.1. Multiple-use garments shall be subject to additional conditions as part of testing as specified in Sections 10 and 11, labeling requirements as specified in 12.6.2, and technical information requirements as specific in 14.1.6 and 14.1.7. In order to qualify as a multiple-use ensemble, all elements of the ensemble shall meet every applicable multiple-use requirement.

5.3 All protective ensembles classified to this specification shall meet the applicable design requirements specified in Section 6, performance requirements specified in Section 7, documentation requirements as specified in Section 8, applicable labeling requirements specified in Section 12, user information requirements specified in Section 13, and technical information requirements in Section 14.

6. Design Requirements

6.1 *Protective Ensembles and Suits:*

6.1.1 *Ensemble Coverage:*

6.1.1.1 Air-fed protective ensembles shall be designed and configured to protect the wearer’s torso, head, arms, legs, hands, and feet, and shall completely enclose the wearer.

6.1.2 *Ensemble Components:*

6.1.2.1 Air-fed protective ensembles shall consist of a suit with hood, gloves, footwear, and respiratory protective equipment.

6.1.2.2 The suit hood shall be provided with a visor that is designed to allow the wearer to see outside the air-fed protective ensemble.

6.1.2.3 The visor shall be constructed of a transparent material that qualifies as a barrier layer.

6.1.2.4 Air-fed protective ensembles shall be permitted to be constructed using an outer garment designed to be worn over the suit element where such additional garments are necessary to meet the suit and ensemble requirements of this standard.

6.1.2.5 Air-fed protective ensembles shall be permitted to be constructed using an outer glove designed to be worn over the glove element where such additional gloves are necessary to meet the glove requirements of this standard.

6.1.2.6 Air-fed protective ensembles shall be permitted to be constructed using an outer boot designed to be worn over a footwear element or sock where such additional boots are necessary to meet the footwear requirements of this standard.

6.1.2.7 Other than outer gloves and outer boots, air-fed protective ensembles shall be designed so that all separate ensemble components necessary to meet the applicable requirements of this specification, are attached and provided as delivered by the manufacturer as a single and integrated unit.

6.1.3 *Respiratory Protective Equipment and Exhaust Valves:*

6.1.3.1 Air-fed protective ensembles shall be provided with respiratory protective equipment that includes either an airline connection to the suit and associated components for the distribution of air to the suit interior, or a powered air-purifying respirator that is connected to the ensemble with pass-throughs into the ensemble to enable the distribution of air inside the ensemble.

6.1.3.2 Respiratory equipment used as part of the air-fed protective ensemble shall meet the applicable requirements in 42 CFR Part 84.

6.1.3.3 Areas of connection or pass-throughs to the suit or ensemble shall be reinforced with additional material for a minimum of 50 mm (2 in.) away from the outer edge of the connection or pass-through.

6.1.3.4 Air-fed protective ensembles shall be equipped with one or more one-way exhaust valve(s).

6.1.3.5 The one-way exhaust valves shall be designed to release exhaust air from the inside of the air-fed protective ensemble to the outside environment through the exhaust valve, and shall prevent entry of contaminated air into the air-fed protective ensemble from the outside environment through the exhaust valve.

6.1.3.6 The mounting mechanism of exhaust valves that are intended to be removable and are not permanently attached to the suit shall be designed to allow their removal for inspection and reinstallation or replacement.

6.1.3.7 Protective covers or pockets constructed shall be provided to protect the exhaust valves from direct chemical or other hazardous liquid splashes to the seat of the exhaust valve(s). The pockets or covers shall allow access to the valves for inspection and removal when the valves are not permanently attached to the suit.

6.1.4 *Materials of Construction:*

6.1.4.1 The air-fed protective ensemble suit with hood and visor, gloves, and footwear shall be constructed of materials that shall provide the protection from contamination and physical hazards. These materials shall be configured as a separate layer or as a composite.

6.1.4.2 The materials used in the construction of the air-fed protective ensemble shall include a barrier material.

6.1.4.3 The barrier layer shall be designed to prevent the permeation or penetration of outside contaminants and provide overall integrity of the protective ensemble.

6.1.4.4 The barrier material shall be permitted to depend on the other materials to provide the physical protection.

6.1.5 *Sizing:*

6.1.5.1 Air-fed protective ensembles shall be offered in at least four unique and different sizes.

6.1.6 *Hardware Quality:*

6.1.6.1 All external hardware and fittings shall be free of rough spots, burrs, or sharp edges that could tear materials.

6.2 *Protective Gloves:*

6.2.1 Gloves shall be designed and configured to protect the wearer's hands and wrists.

6.2.2 Gloves shall provide protection from the finger tips to at least 25 mm (1 in.) beyond the wrist crease.

6.2.3 Gloves shall be permitted to be either single gloves or a glove system consisting of multiple gloves.

6.2.4 Where single gloves are used, the gloves shall be constructed of a barrier material.

6.2.5 Glove systems shall be permitted to be constructed using an outer glove designed to be worn over the primary glove where such additional gloves are necessary to meet the glove requirements of this standard.

6.2.6 Where glove systems are used, one of the gloves shall be constructed of a barrier material to prevent the permeation or penetration of outside contaminants and provide overall integrity of the protective ensemble.

6.2.7 Gloves shall be attached to the sleeve of the suit in the air-fed ensemble using interface components or directly welded to the suit to provide overall integrity of the protective ensemble.

6.2.8 The interface of glove to air-fed protective suit sleeve shall be designed to permit its removal and replacement of the gloves attached to each suit sleeve within 5 min unless the gloves are permanently attached to the suit.

6.2.9 Gloves or glove systems shall be offered in a minimum of four unique sizes.

6.2.10 All external hardware and fittings used in the glove to suit interface shall be free of rough spots, burrs, or sharp edges that could tear materials.

6.3 *Protective Footwear:*

6.3.1 Footwear shall be designed and configured to provide protection to the feet and ankles.

6.3.2 Footwear shall be permitted to be either a single boot, a footwear system consisting of a sock attached to the suit and an outer boot, or a footwear system consisting of an inner boot with a boot cover.

6.3.3 The footwear or footwear system shall provide protection not less than 200 mm (8 in.) in height when measured from the plane of the sole bottom.

6.3.4 The footwear or footwear system shall be constructed using materials that shall provide the protection from chemical and physical hazards. These materials shall be configured as a separate layer or as a composite.

6.3.5 The footwear or footwear system shall be attached to the air-fed protective ensemble using either a seam or interface components to provide overall integrity of the protective ensemble.

6.3.6 *Single Boot Footwear:*

6.3.6.1 Where the footwear is designed as a single boot, the boot shall be constructed of a barrier material that is designed to prevent the permeation or penetration of outside contaminants and provide overall integrity of the protective ensemble.

6.3.7 *Sock and Outer Boot Footwear System:*

6.3.7.1 Socks, where provided, shall be designed as an extension of the protective suit leg, shall cover the entire foot and ankle, and shall provide protection to the feet when worn in conjunction with an outer boot.

6.3.7.2 Where the footwear is designed as a sock in combination with an outer boot, the sock shall be constructed of barrier material that is designed to prevent the permeation or penetration of outside contaminants and provide overall integrity of the protective ensemble.

6.3.8 *Inner Boot and Boot Cover Footwear System:*

6.3.8.1 Boot covers, where provided, shall be designed to provide coverage of the entire inner boot.

6.3.8.2 Where the footwear is designed as an inner boot with a boot cover, the inner boot shall be constructed of barrier material that is designed to prevent the permeation or penetration of outside contaminants and provide overall integrity of the protective ensemble.

6.3.9 *Footwear or Footwear System Hardware:*

6.3.9.1 All external hardware and fittings used in the footwear, footwear system, and interface with the suit shall be free of rough spots, burrs, or sharp edges that could tear materials.

6.3.9.2 Metal parts shall not penetrate from the outside into the lining or insole at any point.

6.3.9.3 No metal parts, including but not limited to nails or screws, shall be present or utilized in the construction or attachment of the sole (with heel) to the puncture-resistant device, if present, insole, or upper.

7. Performance Requirements

7.1 *Protective Ensemble:*

7.1.1 Complete air-fed protective ensembles, consisting of suit with hood, gloves, footwear, and respiratory protective equipment shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 1.

7.1.2 Exhaust valves installed in air-fed protective ensembles shall be tested for mounting strength as specified in 11.6 and shall have a failure force greater than 135 N (30 lbf).

7.1.3 External fittings installed in air-fed protective ensembles that are used for tethered applications shall be tested for pullout strength as specified in 11.7 and shall have a failure force greater than 1000 N (225 lbf).

7.1.4 External fittings installed in air-fed protective ensembles that are used for non-tethered applications shall be tested for pullout strength as specified in 11.7 and shall have a failure force greater than 135 N (30 lbf).

7.2 *Protective Suit:*

7.2.1 Suit materials and seams joining suit materials used in the construction of the suit, including the hood but excluding the visor, shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 2.

7.2.2 Visor materials and seams joining the visor material to suit materials used in the construction of the suit shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 3.

7.2.3 Where a visor is rigid that cannot be tested for burst strength or puncture propagation tear resistance, the tests for burst strength and puncture propagation tear resistance shall not be required.

7.3 *Protective Gloves:*

7.3.1 Gloves and glove materials shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 4.

7.4 *Protective Footwear:*

7.4.1 *Single Boot Footwear:*

7.4.1.1 The boot shall be optionally classified for impact resistance, compression resistance, and puncture resistance as specified in Specification F2413.

7.4.1.2 The boot shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 5.

7.4.2 *Sock and Outer Boot Footwear System:*

7.4.2.1 The outer boot shall be optionally classified for impact resistance, compression resistance, and puncture resistance as specified in Specification F2413.

7.4.2.2 The outer boot shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 5.

7.4.2.3 The sock shall be tested for the performance properties and shall meet the criteria for the respective ensemble

TABLE 1 Protective Ensemble Performance Requirements

Performance Property	Test Method (paragraph)	Criteria
Maintenance of positive pressure	ASTM F1052 (11.1)	Ending pressure ≤80 mm water gauge pressure Test subjects complete all tasks
Ergonomic impact on wearer	ASTM F1154 (11.2)	Test subjects are able to read eye chart to 20/35 through visor Test subjects are able to withdraw and reinsert hands into gloves or glove system Test subjects are able to execute emergency doffing within 60 seconds
Air flow capacity	(11.3)	Ensemble internal pressure ≤100 mm water gauge pressure Ending pressure after evaluation ≥80 mm water gauge pressure
Liquid inward leakage	ASTM F1359 (11.4)	No liquid penetration to interior of ensemble No liquid accumulation in outer gloves or outer boots
Man-in-Simulant Test (MIST)	NFPA 1994:2018 (Class 1)	PPDFi ≥871 PPDFsys ≥441

TABLE 2 Protective Suit Material and Seam Performance Requirements

Performance Property	Test Item	Test Method (paragraph)	Limited Use	Multiple Use
Liquid penetration resistance	Material and seams[A]	ASTM F903 (11.8)	Pass	Pass
Tensile strength	Material only[B]	ASTM D5034 (11.9)	≥ 100 N	≥ 225 N
Tear resistance	Material only[B]	ASTM D5587 (11.10)	≥ 20 N	≥ 40 N
Burst strength	Material only[C]	ASTM D3787 (11.11)	≥150 N	≥300 N
Puncture Propagation Tear resistance	Material only[C]	ASTM D2582 (11.12)	≥ 5 N	≥ 12 N
Abrasion resistance	Material only[C]	ASTM D3884 (11.13)	≥ 500 cycles	≥ 2,000 cycles
Seam strength	Seams only[B]	ASTM D751 (11.14)	≥ 40 N	≥ 100 N
Closure strength	Closure only	ASTM D751 (11.14)	≥ 100 N	≥ 225 N

[A] Applied to the barrier material and seams only; different preconditions applied to limited-use and multiple-use materials.
[B] Applied to each material layer or material layer seam used in the construction of the suit and hood.
[C] Where combinations of materials are used as a composite, applied to the combination of the layers in the order as found in the construction of the suit or hood.

TABLE 3 Protective Suit Visor Material and Seam Performance Requirements

Performance Property	Test Item	Test Method (paragraph)	Limited Use	Multiple Use
Liquid penetration resistance	Material and seams[A]	ASTM F903 (11.8)	PASS	PASS
Burst strength	Material only[B]	ASTM D3787 (11.11)	≥ 150 N	≥ 300 N
Puncture Propagation Tear resistance	Material only[B]	ASTM D2582 (11.12)	≥ 5 N	≥ 10 N
Seam strength	Seams only[C]	ASTM D751 (11.14)	≥ 40 N	≥ 100 N

[A] Applied to the barrier material and seams only; different preconditioning applied to limited-use and multiple-use materials.
[B] Where combinations of materials are used as a composite in the construction of the suit visor, applied to the combination of the layers in the order as found in the construction of the suit visor.
[C] Applied to each material layer or material layer seam used in the construction of the suit and hood.

TABLE 4 Protective Glove, Glove Material, and Glove Seam Performance Requirements

Performance Property	Test Item	Test Method (paragraph)	Limited Use	Multiple Use
Liquid leakage	Whole gloves[A]	ASTM D5151 (11.15)	PASS	PASS
Liquid penetration resistance	Seams only[B]	ASTM F903 (11.8)	PASS	PASS
Cut resistance	Material only[C]	ASTM F1790 (11.17)	≥50 g	≥200 g
Puncture resistance	Material only[C]	ASTM F1342 (11.16)	≥8 N	≥30 N
Abrasion resistance	Material only[C]	ASTM D3884 (11.13)	≥500 cycles	≥2000 cycles
Hand function	Whole gloves[D]	ASTM F2010 (11.18)	≤150%	≤300%

[A] Where a glove system is used consisting of two or more gloves, applied only to the glove providing the barrier material.
[B] Applied to the barrier material and seams only.
[C] Where a glove system is used consisting of two or more layers, applied to all glove materials in the order as found in the construction of the glove system.
[D] Applied to the whole glove system.

TABLE 5 Protective Footwear Performance Requirements

Performance Property	Test Item	Test Method (paragraph)	Limited Use	Multiple Use
Liquid leakage	Whole footwear[A]	ASTM D5151 (11.15)	PASS	PASS
Liquid penetration resistance	Seams only[B]	ASTM F903 (11.8)	PASS	PASS
Cut resistance	Upper material only	ASTM F1790 (11.17)	≥200 g	≥400 g
Puncture resistance	Upper material only	ASTM F1342 (11.16)	≥20 N	≥50 N
Abrasion resistance	Upper material only	ASTM D3884 (11.13)	≥1000 cycles	≥4000 cycles
Sole slip resistance	Sole material only	ASTM F2913 (11.20)	≥0.40	≥0.40
Sole abrasion resistance	Sole material only	ISO 4649:2010 (11.19)	≤250 mm^3	≤250 mm^3

[A] Where a footwear system is used, applied to the outer boot for a footwear system consisting of sock with outer boot or applied to the boot cover for a footwear system consisting of inner boot with boot cover.
[B] Applied to the barrier material and seams of the footwear cover only when the footwear system consists of an inner boot with boot cover.

class as specified in Table 2. The sock shall be permitted to have a lower classification than the suit material.

7.4.3 *Inner Boot and Boot Cover Footwear System:*

7.4.3.1 The inner boot shall be optionally classified for impact resistance, compression resistance, and puncture resistance as specified in Specification F2413.

7.4.3.2 The inner boot shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 5.

7.4.3.3 The boot cover shall be tested for the performance properties and shall meet the criteria for the respective ensemble class as specified in Table 2. The boot cover shall be permitted to have a lower classification than the suit material.

8. Documentation Requirements

8.1 *Chemical Protection:*

8.1.1 Where the manufacturer makes specific claims for permeation resistance of materials used in the construction of air-fed protective ensembles against specific chemicals, testing shall be performed on the suit material, suit seams, hood material (if different), visor material and visor seams, glove or

glove system material and seams, and footwear system materials as specified in 11.21 for each chemical. Acceptable minimum performance for basing claims against each chemical shall be a standardized breakthrough time that is 30 min or greater.

8.1.2 Where the manufacturer makes specific claims of protection against specific chemicals and the respiratory protection equipment uses filters, cartridges, or canisters to remove chemical contaminants from external air, the manufacturer shall demonstrate NIOSH certification of filter or cartridge service life of 30 min or greater.

8.2 *Biological Protection:*

8.2.1 Where a manufacturer makes a specific claim for the penetration resistance of material used in the construction of air-fed protective ensembles against bloodborne pathogens or other potentially infectious materials (OPIM), testing shall be performed on the suit material, suit seams, hood material (if different), visor material and visor seams, glove or glove system material and seams, and footwear system materials as specified in 11.22 for each bloodborne pathogen. Acceptable minimum performance for basing a claim against bloodborne pathogen shall be a result of "pass" for both material and seams.

8.2.2 Where a manufacturer makes a specific claim for the penetration resistance of material used in the construction of air-fed protective ensembles against airborne pathogens, and the respiratory protective equipment uses filters, cartridges, or canisters to remove biological contaminants from external air, the manufacturer shall demonstrate filter performance as being NIOSH certified with a P100 classification established in 42 CFR Part 84.

9. Sampling

9.1 Samples of the primary materials of construction and seams for air-fed protective ensembles shall be randomly selected specimens of protective ensembles that are representative of the portion of the ensemble to be tested.

9.2 Specimens for testing shall be permitted to be performed on material roll goods or fabricated seam samples if it can be demonstrated that the samples are representative of the actual finished air-fed protective ensembles.

10. Conditioning

10.1 *Ambient Conditioning*—All specimens shall be conditioned at a temperature of 21 ± 3 °C (70 ± 5 °F) and relative humidity of 65 ± 5 % for at least 24 h in accordance with Practice D1776, unless otherwise specified by the selected test method.

10.2 *Cleaning and Decontamination Conditioning*—Specimens intended to use in multiple-use ensembles shall be subject to five cycles of simulated cleaning and decontamination in accordance with the manufacturer's instructions for standard cleaning or decontamination of ensembles.

10.3 *Flexing Preconditioning*—Specimens from multiple-use protective ensemble materials shall be subjected to 100 cycles of flexing per Test Method F392 at 45 cycles per minute with each cycle being a full flex and twisting action.

10.4 *Abrasion Preconditioning*—Specimens from multiple-use protective ensemble materials shall be subjected to 25 cycles of abrasion per Test Method D4157, using the following conditions:

10.4.1 A 2.3-kg (5-lb) tension weight shall be used.

10.4.2 A 1.6-kg (3½-lb) head weight shall be used.

10.4.3 An 80 grit abradant trimite D-weight open coat #1A4180, or equivalent, shall be used.

11. Test Methods

11.1 *Maintenance of Positive Pressure*—Determine the ability of the ensemble to maintain positive pressure as specified in Test Method F1052 using the following modifications:

11.1.1 Where ensembles use different pass-throughs or connections to respiratory protective equipment, each type of pass-through or connection shall be evaluated.

11.1.2 A minimum of three different ensembles shall be evaluated for each ensemble configuration.

11.2 *Assessment of Ergonomic Impact on Wearer*—Determine the ergonomic impact of the ensemble on the wearer as specified in Practices F1154 using the following modifications:

11.2.1 A minimum of three different ensembles shall be evaluated for each ensemble configuration with each ensemble worn by a different test subject.

11.2.2 Test subjects use for testing shall have a minimum visual acuity of 20/20 in each eye, uncorrected or corrected with prescription lenses, as determined in a visual acuity test or doctor's examination.

11.2.3 Both exercise Procedures A and B shall be used.

11.2.4 Ensembles tested shall meet the sizing range of the test subject as determined in 14.1.8. The ensemble shall be donned in accordance with the manufacturer's instructions.

11.2.5 Testing shall be conducted at 25 ± 7 °C (77 ± 10 °F) and relative humidity of 50 ± 20 %.

11.2.6 Test subjects shall wear underclothing in accordance with the manufacturer's recommendations, or in lieu of a detailed recommendation, a full-body coverall.

11.2.7 Following the performance of the exercise procedures, visual acuity testing shall be conducted using a standard 6.1-m (20-ft) eye chart, with a normal lighting range of 100 through 150 ft candles at the chart and with the test subject positions at a distance of 6.1 m (20 ft) from the chart.

11.2.8 Each test subject shall read the standard eye chart through the suit visor to determine the ensemble visor's impact on the test subject's visual acuity.

11.2.9 At the end of all testing, each test subject shall be instructed to remove his or her hands from each of the gloves while still wearing the suit, touch his or her waist, and then reinsert his or her hands into the gloves. This action shall be repeated a total of five times.

11.3 *Air Flow Capacity*—Air flow capacity of the ensemble shall be determined using the following procedures:

11.3.1 *Specimens:*

11.3.1.1 A minimum of one ensemble shall be evaluated.

11.3.2 *Test Apparatus:*

11.3.2.1 A suit wall connector capable of accommodating the attachment of an airline hose from a pressurized air source

shall be installed in the back mid-torso region of the ensemble to be tested as indicated in Fig. 1. The connector and airline hose shall allow an airflow rate of 500 L/min. For an ensemble already equipped with an airline, the existing connector and airline hose shall be permitted to be used.

11.3.2.2 A flowmeter capable of measuring airflow rates of 0 to 1000 L/min, ±25 L/min, calibrated for air and the conditions of use, shall be used on the airline hose.

11.3.2.3 A pressure gauge capable of measuring pressures from 0 to 510 mm, ±3 mm water column gauge pressure shall be attached via a second suit wall connector at the very top of the protective ensemble.

11.3.3 *Procedures:*

11.3.3.1 Following the attachment of the two connectors, the gastight integrity of the suit shall be tested as specified in 11.1.

11.3.3.2 During the test, the pressure gauge specified in 11.3.2.3 shall be attached to one bulkhead connector; the other bulkhead connector shall be plugged.

11.3.3.3 During the test, a soapy water solution shall be applied around the edges of the connectors to assure that no leakage occurs through the installed suit wall connectors.

11.3.3.4 The remaining steps of this procedure shall be completed only if the sample ensemble shows an ending pressure of 80 mm water column gauge or higher.

11.3.3.5 The suit shall be connected to a pressurized air source capable of providing 500 L/min by attaching an airline to the installed mid-torso suit wall connector.

11.3.3.6 Beginning at time zero, air shall be flowed into the suit at a rate of 500 L/min.

11.3.3.7 After a period of 5 min, the pressure at the head connector shall be measured.

11.3.3.8 The specialized fittings installed in the suit for this test shall be plugged to prevent air leakage and the suit shall be subjected to a second overall gastight integrity test as specified in 11.1.

11.3.4 *Report:*

11.3.4.1 The maximum internal suit pressure during the airflow period shall be recorded and reported.

11.3.4.2 The ending suit pressure for the gastight integrity tests before and after the airflow period shall be recorded and reported.

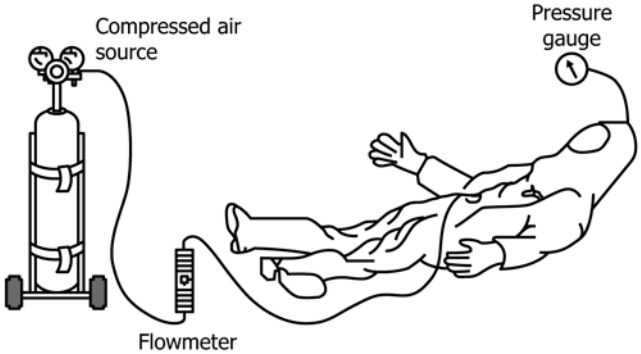

FIG. 1 Test Apparatus Setup for Air Flow Capacity Test

11.4 *Liquid Inward Leakage*—The overall integrity of the ensemble for inward leakage of liquid shall be determined as specified in Test Method F1359, using a minimum of one sample ensemble.

11.5 *Man-in-Simulant Testing (MIST)*—The overall integrity of the ensemble shall be determined using the procedures in 8.2 for Class 1 ensembles in NFPA 1994:2018.

11.6 *Exhaust Value Mounting Strength*—The mounting strength for each type of exhaust value used in the ensemble shall be determined using the following procedures:

11.6.1 *Specimens:*

11.6.1.1 An individual exhaust valve shall be mounted into a piece of suit material having a minimum diameter of 200 mm (8 in.). The means of mounting the exhaust valve shall be representative of the construction practices used in the ensemble.

11.6.1.2 A minimum of three different exhaust valves-suit material assemblies shall be tested.

11.6.2 *Test Apparatus:*

11.6.2.1 A specimen mounting ring that has an inner diameter of 150 mm (6 in.) shall be used for clamping the specimen.

11.6.2.2 The mounting ring shall have a means for tightly clamping the specimen along the circumference of the ring and shall hold the specimen perpendicular to the motion of the pushing force.

11.6.2.3 The mounting ring shall be designed such that a means is provided for affixing it to the fixed (bottom) arm of a tensile testing machine and that a minimum 50 mm (2 in.) unobstructed space is provided under the specimen.

11.6.2.4 A flat plate pushing device shall be 50 mm (2 in.) in diameter. The edge of the flat plate shall be rounded and have no rough or sharp areas.

11.6.2.5 The flat plate shall have a means for being attached to the movable (upper) arm of a tensile testing machine. The flat plate shall be oriented perpendicular to the motion of the pushing force.

11.6.2.6 The tensile testing machine shall meet the following criteria:

(1) It shall be capable of holding the specimen mounting ring securely in the fixed lower arm.

(2) It shall be capable of holding the flat plate pushing device securely in the movable upper arm.

(3) It shall have a calibrated dial, scale, or chart to indicate the applied load and elongation.

(4) The error of the machine shall not exceed 2 % of any reading within its loading range.

(5) It shall be outfitted with a compression cell. The testing machine shall be configured with the compression cell on either the lower or upper arm.

11.6.3 *Procedure:*

11.6.3.1 Specimens shall be clamped into the specimen mounting ring and attached to the fixed arm of a tensile testing machine.

11.6.3.2 The flat plate pushing device shall be attached to the movable arm of a tensile testing machine.

11.6.3.3 The tensile testing machine shall be set in operation but stopped when the exhaust valve either breaks through the material or when the material breaks along the specimen

mounting ring. The flat plate pushing device shall have a velocity of 305 mm/min (12 in./min) under load conditions and shall be uniform at all times.

11.6.3.4 The maximum force registered by the indicating device of the tensile testing machine shall be recorded for each determination.

11.6.4 *Report:*

11.6.4.1 The mounting strength of each specimen shall be recorded and reported to the nearest 1 N (¼ lbf).

11.6.4.2 The average mounting strength shall be calculated, recorded, and reported to the nearest 1 N (¼ lbf).

11.7 *External Fitting Pullout Strength*—The pullout strength for each type of external fitting used in the ensemble shall be determined using the following procedures:

11.7.1 *Specimens:*

11.7.1.1 Specimens shall be an external fitting and suit material assembly representative of the construction practices used to fabricate the ensemble.

11.7.1.2 At least three specimens shall be tested.

11.7.2 *Test Apparatus:*

11.7.2.1 A specimen mounting ring shall be used for clamping the specimen and shall have an inner diameter of 150 mm (6 in.).

11.7.2.2 The mounting ring shall have a means for tightly clamping the specimen along the circumference of the ring and shall hold the specimen perpendicular to the motion of the pushing force.

11.7.2.3 The mounting ring shall be designed such that a means is provided for affixing it to the fixed (bottom) arm of a tensile testing machine.

11.7.2.4 A set of tensile machine jaws shall be used to pull the external fitting perpendicular to the surface of the suit material in which the external fitting is mounted.

11.7.2.5 The tensile testing machine shall meet the following criteria:

(1) It shall be capable of holding the specimen mounting ring securely in the fixed lower arm.

(2) It shall be capable of holding the flat plate pushing device securely in the movable upper arm.

(3) It shall have a calibrated dial, scale, or chart to indicate the applied load and elongation.

(4) The error of the machine shall not exceed 2 % of any reading within its loading range.

(5) It shall be outfitted with a load cell. The testing machine shall be configured with the compression cell on either the lower or upper arm.

11.7.3 *Procedures:*

11.7.3.1 Specimens shall be clamped into the specimen mounting ring and attached to the fixed arm of a tensile testing machine.

11.7.3.2 The jaws of the movable arm of a tensile testing machine shall be clamped onto the body of the external fitting.

11.7.3.3 The tensile testing machine shall be set in operation but shall stop when the external fitting has pulled from the material or when the material breaks along the specimen mounting ring. The tensile testing machine jaws shall have a velocity of 500 mm/min (20 in./min) under load conditions and shall be uniform at all times.

11.7.3.4 The maximum force registered by the indicating device of the tensile testing machine shall be recorded for each determination.

11.7.4 *Report:*

11.7.4.1 The pullout strength of each specimen shall be recorded and reported to the nearest 1 N (¼ lbf).

11.7.4.2 The average pullout strength shall be calculated, recorded, and reported to the nearest 1 N (¼ lbf).

11.8 *Liquid Penetration Resistance*—The penetration resistance of ensemble materials and seams shall be determined as specified using Test Method F903, using the following modifications:

11.8.1 Procedure C shall be used.

11.8.2 The challenge liquid shall be 70 % isopropanol.

11.8.3 For multiple-use protective ensembles, suit, glove, and footwear specimens shall be preconditioned as specified in 10.2, followed by preconditioning as specified in 10.3, followed by preconditioning as specified in 10.4.

11.9 *Tensile Strength*—The tensile strength of each suit material shall be determined as specified in Test Method D5034. Where materials are anisotropic, each material direction shall be tested.

11.10 *Tear Resistance*—The tear resistance of each suit material shall be determined as specified in Test Method D5587. Where materials are anisotropic, each material direction shall be tested.

11.11 *Burst Strength*—The burst strength of suit materials shall be determined as specified in Test Method D3787.

11.12 *Puncture Propagation Tear Resistance*—The puncture propagation tear resistance of each suit material shall be determined as specified in Test Method D2582. Where materials are anisotropic, each material direction shall be tested.

11.13 *Abrasion Resistance*—The abrasion resistance of ensemble materials shall be determined as specified in Guide D3884, using a H-18 wheel and, 500-g load, and end point of cycles to wear through of the barrier material.

11.14 *Seam and Closure Strength*—The strength of suit seams and closures shall be determined as specified in Test Methods D751.

11.15 *Overall Glove and Footwear Integrity*—The integrity of gloves or footwear for liquid leakage shall be determined as specified in Test Method D5151, with the following modifications:

11.15.1 For footwear, a sufficient volume of water shall be used to fill the glove within 50 mm (2 in.) of the lowest part of the top of the boot.

11.15.2 For footwear, use a residence time of 10 min before observing for leakage.

11.16 *Puncture Resistance*—The puncture resistance of the ensemble materials shall be determined as specified in Test Method F1342.

11.17 *Cut Resistance*—The cut resistance of the ensemble materials shall be determined as specified in Test Method F1790.

11.18 *Hand Function*—The dexterity of gloves shall be determined as specified in Test Method F2010.

11.19 *Sole Abrasion Resistance*—The abrasion resistance of footwear soles shall be determined as specified in ISO 4649:2010.

11.20 *Sole Slip Resistance*—The coefficient of friction (slip resistance) of footwear soles shall be determined as specified in Test Method F2913.

11.21 *Permeation Resistance*—For each specific chemical where the manufacturer is making a claim of chemical resistance, the permeation resistance of each barrier material and seams used in the construction of the ensemble shall be determined as specified in Test Method F739 using the following conditions:

11.21.1 For multiple-use protective ensembles, suit, glove, and footwear specimens shall be preconditioned as specified in 10.2, followed by preconditioning as specified in 10.3, followed by preconditioning as specified in 10.4.

11.22 *Viral Penetration Resistance*—Determine garment or glove material and seam viral penetration resistance as specified in Test Method F1671, Procedure A. Seams shall be oriented across the center of the test specimens.

11.22.1 For multiple-use protective ensembles, suit, glove, and footwear specimens shall be preconditioned as specified in 10.2, followed by preconditioning as specified in 10.3, followed by preconditioning as specified in 10.4.

12. Labeling Requirements

12.1 The protective ensemble shall have a product label or labels permanently and conspicuously located inside the ensemble when the ensemble is properly assembled with all layers and components in place.

12.2 Multiple label pieces shall be permitted in order to carry all statements and information required to be on the product label; however, all label pieces that make up the product label shall be located adjacent to each other.

12.3 The certification organization's label, symbol, or identifying mark shall be permanently attached to the product label or shall be part of the product label. All letters shall be at least 2.5 mm (3⁄32 in.) high. The label, symbol, or identifying mark shall be at least 6 mm (1⁄4 in.) in height and shall be placed in a conspicuous location.

12.4 All worded portions of the required product label shall be printed at least in English.

12.5 Symbols and other pictorial graphic representations shall be permitted to be used to supplement worded statements on the product label(s) where the symbols and pictorial graphic representations are clearly explained in the product's user information package.

12.6 The following statement shall be printed legibly on the product label. "THIS {insert either "AIRLINE PROTECTIVE ENSEMBLE" or a "PAPR-BASED AIR-FED PROTECTIVE ENSEMBLE"} MEETS THE REQUIREMENTS OF ASTM F2704. DO NOT REMOVE THIS LABEL."

12.6.1 The following additional statement for ensembles meeting the limited use requirements shall be provided on the product label: "LIMITED-USE ENSEMBLE – SEE USER INFORMATION FOR INSTRUCTIONS ON LIMITATIONS OF USE."

12.6.2 The following additional statement for ensembles meeting the multiple use requirements shall be provided on the product label: "MULTIPLE-USE ENSEMBLE – SEE USER INFORMATION FOR INSTRUCTIONS ON PROPER CARE AND MAINTENANCE, AND CRITERIA FOR REUSE."

12.7 The following information shall also be printed legibly on the product label, and all letters shall be at least 1.6 mm (1⁄16 in.) high:

12.7.1 Manufacturer's name, identification, or designation,

12.7.2 Manufacturer's address,

12.7.3 Country of manufacture,

12.7.4 Manufacturer's garment identification number, lot number, or serial number,

12.7.5 Month and year of manufacture (not coded),

12.7.6 Model name, number, or design,

12.7.7 Size,

12.7.8 Suit, visor, glove, and footwear materials, and

12.7.9 Cleaning and decontamination precautions.

12.8 The air-fed protective ensemble garment elements shall also list those parts and components of the certified ensemble that are required to meet this standard. This list shall be on the product label by manufacturer name and model number after the following statement: FOR COMPLIANCE WITH REQUIREMENTS OF ASTM F2704, THE FOLLOWING PROTECTIVE PARTS AND COMPONENTS MUST BE WORN IN CONJUNCTION WITH THIS ENSEMBLE: [list parts and components here]. All letters shall be at least 2.5 mm (3⁄32 in.) in height.

13. User Information

13.1 The manufacturer shall provide user information, including, but not limited to, warnings, information, and instructions with each ensemble.

13.2 User information shall meet the requirements of Practice F2061 and shall include specific precautions for wearing the protective clothing items during activities specific to the intended protection provided by the air-fed protective ensemble.

13.3 The manufacturer shall attach the required user information or packaging containing the user information to the ensemble in such a manner that it is not possible to use the ensemble without being aware of the availability of the information.

13.4 The required user information or packaging containing the user information shall be attached to the element so that a deliberate action is necessary to remove it. The element manufacturer shall provide notice that the user information is to be removed ONLY by the end user.

14. Technical Information

14.1 When requested by the purchaser, the following technical information shall be provided:

14.1.1 Manufacturer contact information.

14.1.2 The results of the all tests used to demonstrate compliance of the ensemble and its components with this standard.

14.1.3 Where chemical resistance claims are made, the manufacturer shall provide permeation resistance testing results for all ensemble barrier materials and seams for each chemical tested, including the average breakthrough detection time, challenge concentration, description of collection medium, description of analytical detection method, and identification of the laboratory conducting the testing.

14.1.4 Where chemical resistance claims are made, the manufacturer shall provide respiratory protective equipment test results for each chemical tested, including the service life, test conditions for service life testing, and the identification of the laboratory conducing the testing.

14.1.5 Where viral resistance claims are made, the manufacturer shall provide the viral penetration resistance testing results for all ensemble materials and seams.

14.1.6 For multiple-use products, detailed instructions on the cleaning, decontamination, and storage of ensembles,

14.1.7 For multiple-use products, a statement of the number of times that the product can be cleaned and decontaminated and continue to maintain its safety and performance characteristics.

14.1.8 For multiple-use products, instructions on inspections that can be performed by processors to verify the continued safety and effectiveness of the product.

14.1.9 A description of the manufacturer's sizing system indicating the range of wearer dimensions for which the specific size is intended.

NOTE 1—An example of a sizing system for a full-body garment is the list of specific protective clothing item sizes provided by the manufacturer and the respective range in wearer height and girth that is accommodated by each size.

15. Certification

15.1 Air-fed ensembles represented as meeting this specification shall have a conformity assessment meeting the requirements of example conformity assessment program B or higher as defined in Guide F3050.

16. Keywords

16.1 air-fed protective ensemble; biological hazards; Biosafety Level 4; chemical hazards; protective ensemble; radiological particulate hazards; respiratory protective equipment