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Standard Specification for Air-Fed Protective Ensembles¹

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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, health, and environmental 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](#)

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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.

- 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
- 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:Standards*:⁵
- NFPA ~~1991:2012~~1991:2016 Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents
- 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-air line 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

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>.

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 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~~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~~ and NFPA 1994 ~~standards, which establish~~ 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. NFPA 1994 establishes requirements for a protective ensemble under Class 1 requirements that in some configurations 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~~air line 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.”~~“air line 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.”~~“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~~ blood-borne (or liquidborne) liquid-borne) 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. The requirements in the certification section are based on the recommendations provided for conformity assessment example category B in Annex A2 of Guide F3050 and other National Fire Protection Association product standards for emergency services protective clothing and equipment. This category specifies that the supplier provides a declaration of conformity with testing conducted at an independent laboratory that is accredited to ISO 17025 and manufacturer quality management system that is registered to ISO 9001 with the appropriate scope for air-fed ensembles, and with manufacturer/supplier periodic monitoring of continuing conformity. The manufacturer is permitted to exceed these requirements.~~

5. Classification

5.1 Protective ensembles shall be classified as either an ~~“Airline Protective Ensemble”~~ or a ~~“PAPR-Based Air-Fed Protective Ensemble”~~ “air line 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 ~~specifies~~ specified 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~~, 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-air line 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, 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**, with the exception of the man-in-simulant test (MIST), which is considered optional.

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:

TABLE 1 Protective Ensemble Performance Requirements

Performance Property	Test Method (paragraph)	Criteria
Maintenance of positive pressure	ASTM F1052 (11.1)	Ending pressure \leq 80 mm water gauge pressure
Ergonomic impact on wearer	ASTM F1154 (11.2)	Test subjects complete all tasks 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
Air flow capacity	(11.3)	Test subjects are able to execute emergency doffing within 60 seconds Ensemble internal pressure \leq 100 mm water gauge pressure <u>Airflow capacity</u>
Ending pressure after evaluation \geq 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
<u>Man-in-Simulant Test (MIST)</u>	<u>NFPA 1994:2018 (Class 1)</u>	<u>PPDF_i \geq 871 PPDF_{sys} \geq 441</u>
<u>Man-in-simulant test (MIST)^A</u>	<u>NFPA 1994:2018 (Class 1)</u>	<u>PPDF_i \geq 871 PPDF_{sys} \geq 441</u>

^AOptional test.