NFPA 1991
Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies

2000 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 1991

Standard on

Vapor-Protective Ensembles for Hazardous Materials Emergencies

2000 Edition

This edition of NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies*, was prepared by the Technical Committee on Hazardous Materials Protective Clothing and Equipment, released by the Technical Correlating Committee on Fire and Emergency Services Protective Clothing and Equipment, and acted on by the National Fire Protection Association, Inc., at its November Meeting held November 14–17, 1999, in New Orleans, LA. It was issued by the Standards Council on January 14, 2000, with an effective date of February 11, 2000, and supersedes all previous editions.

This edition of NFPA 1991 was approved as an American National Standard on February 11, 2000.

Origin and Development of NFPA 1991

In 1985, the National Transportation Safety Board (NTSB) issued report I-004-5 on a hazardous material incident that occurred in Benicia, California. In that report, the NTSB recommended that standards be developed for protective clothing for protection from hazardous chemicals. The United States Department of Transportation (DOT) issued a position that requested private sector standards development to undertake the project of writing the standards on hazardous chemical protective clothing and asked other governmental agencies to assist and participate in the private sector standards development system. DOT at this time also directly requested that the NFPA develop documents on hazardous chemical protective clothing. The Environmental Protection Agency (EPA), the United States Coast Guard (USCG), the Federal Emergency Management Agency (FEMA), and the Occupational Safety and Health Administration (OSHA) either adopted position statements modeled after the DOT position or endorsed the DOT position.

During 1985, the NFPA Standards Council approved a project for development of these standards and assigned the project to the Technical Committee on Fire Service Protective Clothing and Equipment. The Technical Committee on Fire Service Protective Clothing and Equipment established a standing Subcommittee on Hazardous Chemicals Protective Clothing, and they began their work in Phoenix, Arizona, in March 1986. Representatives from the USCG, FEMA, and OSHA participated on the subcommittee.

At the same time, ASTM was developing a document on a selection of chemicals for evaluating protective clothing materials that would serve as one of several ASTM testing criteria that would be referenced in the NFPA standards.

The subcommittee met several times over a $2\,^1/_2$-year period at different locations across the country and developed two standards, one for vapor-protection and one for liquid splash-protection.

NFPA 1991 addresses vapor-protective ensembles designed to protect emergency response personnel against exposure to specified chemicals in vapor and liquid splash environments during hazardous materials emergencies. Chemical permeation resistance documentation is required for primary suit materials (garment, visor, gloves, and boots) against each chemical in the NFPA battery of chemicals and any additional chemicals or specific chemical mixtures for which the manufacturer is certifying the suit. The NFPA battery of chemicals consists of 21 chemicals: those specified in ASTM F 1001, *Standard Guide for Chemicals to Evaluate Protective Clothing Materials*. These chemicals were selected because they are representative of the classes of chemicals that are encountered during hazardous chemical emergencies.

The standard includes performance requirements that were established to reflect simulated use conditions. A suit pressurization test is used to check the airtight integrity of each protective suit. Also, an overall suit water penetration test is designed to ensure the suit provides full body

protection against liquid splashes. Primary suit materials must resist permeation for one hour or more by each chemical in the NFPA battery. Manufacturers may certify protective suits for additional chemicals when the same permeation performance is met. Also included are penetration resistance testing of closures, and leak and cracking pressure tests for exhaust valves. These tests allow determination of adequate suit component performance in hazardous chemical environments.

Material testing for burst strength, tear strength, abrasion resistance, flammability resistance, cold temperature performance, and flexural fatigue are required so that materials used for vapor-protective suits will afford adequate protection in the environment where they will be used.

NFPA 1992 addresses liquid splash-protective ensembles and clothing designed to protect emergency response personnel against exposure to specified chemicals in liquid splash environments during hazardous materials emergencies. Chemical penetration resistance documentation of garment material against an NFPA battery of test chemicals and any additional chemicals or specific chemical mixtures for which the manufacturer is certifying the suit is required. The NFPA battery of chemicals was selected from ASTM F 1001, *Standard Guide for Chemicals to Evaluate Protective Clothing Materials*. These do not include liquid chemicals with known or suspected carcinogenicity or skin toxicity because these garments deal with skin exposure and not inhalation. This criterion produces a different subset of ASTM F 1001 chemicals to be certified.

The standard includes performance requirements that were established to reflect simulated use conditions. An overall suit water penetration test is included to ensure the suit provides full body splash protection. Materials testing includes burst strength, tear resistance, flammability resistance testing, abrasion resistance, cold temperature performance, and flexural fatigue testing. These tests are required so that garment materials will provide adequate protection in the environment in which they will be used.

The first edition of NFPA 1991 was voted on by the Association at the 1989 Fall Meeting in Seattle, Washington, on November 15, 1989, and had an effective date of February 5, 1990.

The Subcommittee on Hazardous Chemicals Protective Clothing began an early revision (4-year cycle) of the 1990 edition of NFPA 1991 in December 1991. During 1993, the NFPA restructured the manner in which committees were organized, and all standing subcommittees were eliminated. Within the Technical Committee on Fire Service Protective Clothing and Equipment, the former standing subcommittees were reorganized as task groups to address specific technical issues, and the technical committee assumed the entire responsibility for NFPA 1991.

The second edition of NFPA 1991 encompassed revised scope and purpose sections to include optional components for enhanced protection and replacement items. Test methods were updated and refined to better ensure repeatability of testing results. Extensive changes were made to the product labels to better accommodate the optional and replacement items.

The second edition was acted on by the membership of the Association at the NFPA Annual Meeting in San Francisco, California, on May 18, 1994, and was issued with an effective date of August 5, 1994.

Since the second edition, the entire project for fire service protective clothing and equipment was reorganized, in January 1995, by the Standards Council. The new project has a Technical Correlating Committee on Fire and Emergency Services Protective Clothing and Equipment and seven technical committees operating within the project.The former standing Subcommittee on Hazardous Chemicals Protective Clothing was established as the new Technical Committee on Hazardous Materials Protective Clothing and Equipment and has the responsibility for NFPA 1991.

This third edition, with the new title of *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies*, represents a complete revision to the second edition and addresses the protection as an ensemble rather than as separate items, but does provide for replacement elements for gloves and footwear. This third edition was presented to the Association membership at the 1999 November Meeting in New Orleans, Louisiana, on November 17, 1999, and issued by the Standard Council with an effective date of February 11, 2000.

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This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the design, performance, testing, and certification of protective clothing and protective equipment manufactured for fire and emergency services organizations and personnel, to protect against exposures encountered during emergency incident operations. This Committee shall also have the primary responsibility for documents on the selection, care, and maintenance of such protective clothing and protective equipment by fire and emergency services organizations and personnel.

Technical Committee on Hazardous Materials Protective Clothing and Equipment (FAE-HAZ)

Committee Scope: This Committee shall have primary responsibility for documents on protective clothing and protective equipment, except respiratory protective equipment, that provides hand, foot, torso, limb, and head protection for fire fighters and other emergency services responders during incidents that involve hazardous materials operations. These operations involve the activities of rescue; hazardous material confinement, containment, and mitigation; and property conservation where exposure to substances that present an unusual danger to responders are present or could occur due to toxicity, chemical reactivity, decomposition, corrosiveness, or similar reactions. Additionally, this Committee shall have primary responsibility for documents on the selection, care, and maintenance of hazardous materials protective clothing and protective equipment by fire and emergency services organizations and personnel.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 7 and Appendix B.

Chapter 1 Administration

1-1 Scope.

1-1.1* This standard shall specify minimum design, performance, certification, and documentation requirements; and test methods for vapor-protective ensembles and individual elements for chemical vapor protection; and additional optional criteria for chemical flash fire escape protection and liquefied gas protection.

1-1.2* This standard shall also specify additional optional criteria for vapor-protective ensembles and individual elements that will provide protection from chemical and biological warfare agents and chemical and biological terrorism incidents.

1-1.3 This standard shall apply to the design, manufacturing, and certification of new vapor-protective ensembles and new individual elements. This edition of this standard shall not apply to vapor-protective ensembles and individual elements manufactured to previous editions of NFPA 1991, *Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies*.

1-1.4* This standard shall not apply to protective clothing for *any* fire fighting applications and shall not provide criteria for protection from radiological or cryogenic liquid hazards, or from explosive atmospheres. This standard shall not apply to vapor-protective ensembles for protection from biological hazards unless the ensemble is certified as compliant with the additional requirements for chemical and biological terrorism incidents.

1-1.5 This standard shall not specify the respiratory protection that is necessary for proper protection with the protective ensemble.

1-1.6 This standard shall not apply to use requirements for vapor-protective ensembles or individual elements as these requirements are specified in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*.

1-1.7 Certification of compliant vapor-protective ensembles and compliant individual elements to the requirements of this standard shall not preclude certification to additional appropriate standards where the ensemble or individual elements meet all the applicable requirements of each standard.

1-1.8 The requirements of this standard shall not apply to accessories that might be attached to a vapor-protective ensemble, to an ensemble element, or to an individual element unless specifically addressed herein.

1-1.9 Nothing herein shall restrict any jurisdiction or manufacturer from exceeding these minimum requirements.

1-2 Purpose.

1-2.1 The purpose of this standard shall be to establish a minimum level of protection for emergency services personnel against adverse vapor, liquid-splash, and particulate environments during hazardous materials emergency incidents.

1-2.1.1 The purpose of this standard shall also be to establish a minimum level of *limited* chemical flash fire protection, *for escape only* in the event of a chemical flash fire, as an option for compliant vapor-protective ensembles and compliant individual elements.

1-2.1.2 The purpose of this standard shall also be to establish a minimum level of liquefied gas protection as an option for compliant vapor-protective ensembles and compliant individual elements.

1-2.1.3 The purpose of this standard shall also be to establish a minimum level of *limited* chemical flash fire protection, *for escape only* in the event of a chemical flash fire, combined with a minimum level of liquefied gas protection as an option for compliant vapor-protective ensembles and compliant individual elements.

1-2.1.4 The purpose of this standard shall also be to establish a minimum level of protection for emergency response personnel from specified chemical and biological warfare agents in vapor, liquid splash, and particulate environments during chemical and biological terrorism incidents as an option for compliant vapor-protective ensembles and compliant individual elements.

1-2.1.5 The purpose of these options shall be to provide users with the flexibility to choose the combination of features that match the anticipated exposure and expected needs.

1-2.2* Controlled laboratory tests used to determine compliance with the performance requirements of this standard shall not be deemed as establishing performance levels for all situations to which personnel can be exposed.

1-2.3 This standard is not intended to be utilized as a detailed manufacturing or purchase specification, but shall be permitted to be referenced in purchase specifications as minimum requirements.

1-3 Definitions.

1-3.1 Accessories. Those items that are attached to a vapor-protective ensemble that are not necessary to meet the requirements of this standard. Such accessories include, but are not limited to, harnesses, cooling systems, and communications devices.

1-3.2 Afterflame Time. The length of time for which a material, component, or chemical-protective suit continues to burn after the simulated chemical flash fire has ended.

1-3.3* Approved. Acceptable to the authority having jurisdiction.

1-3.4* Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

1-3.5 Biological Agents. Biological materials that are capable of causing an acute disease or long-term damage to the human body.

1-3.6 Biological Warfare Agent. A biological substance intended to kill, seriously injure, or incapacitate humans through physiological effects. *(See also definitions 1-3.12, Chemical and Biological Terrorism Incidents and 1-3.16, Chemical Warfare Agent.)*

1-3.7 Boot. See definition 1-3.71, Vapor-Protective Footwear.

1-3.8 Bootie. A sock-like extension of the chemical protective suit leg that covers the entire foot.

1-3.9 Care. Procedures for cleaning, decontamination, and storage of vapor-protective ensembles.

1-3.10 Certification/Certified. A system whereby a certification organization determines that a manufacturer has demonstrated the ability to produce a product that complies with the requirements of this standard, authorizes the manufacturer to use a label on listed products that comply with the requirements of this standard, and establishes a follow-up program conducted by the certification organization as a check on the methods the manufacturer uses to determine continued compliance with the requirements of this standard.

1-3.11 Certification Organization. An independent, third-party organization that determines product compliance with the requirements of this standard with a labeling/listing/follow-up program.

1-3.12 Chemical and Biological Terrorism Incidents. Situations involving the release of chemical or biological warfare agents in civilian areas by terrorists. *(See also definitions 1-3.6, Biological Warfare Agent and 1-3.16, Chemical Warfare Agent.)*

1-3.13 Chemical and Biological Terrorism Vapor-Protective Ensemble. See definition 1-3.67, Vapor-Protective Ensemble with Additional Chemical and Biological Terrorism Protection.

1-3.14* Chemical Flash Fire. The ignition of a flammable and ignitible vapor or gas that produces an outward expanding flame front as those vapors or gases burn. This burning and expanding flame front, a fireball, will release both thermal and kinetic energy to the environment.

1-3.15 Chemical-Protective Layer. The material or composite that is intended to provide permeation resistance to chemicals and gastight integrity for the vapor-protective ensemble and individual elements. The chemical-protective layer is considered as "primary material" and can be configured as a separate layer or as a composite with other primary materials. The chemical-protective layer can depend on the other primary material to provide the physical protection.

1-3.16 Chemical Warfare Agent. A chemical substance intended to kill, seriously injure, or incapacitate humans through physiological effects. *(See also definitions 1-3.6, Biological Warfare Agent and 1-3.12, Chemical and Biological Terrorism Incidents.)*

1-3.17 Compliance/Compliant. Meeting or exceeding all applicable requirements of this standard.

1-3.18 Component. A vapor-protective ensemble element; the suit, glove, and footwear subassemblies. *(See also definitions 1-3.23, Element(s), 1-3.35, Individual Elements, and 1-3.66, Vapor-Protective Ensemble.)*

1-3.19 Component Part(s). Any material(s) or part(s) used in the construction of a vapor-protective ensemble, ensemble element, or an individual element.

1-3.20 Composite. Any layering of chemical-protective layers or components as they appear in the final vapor-protective ensemble or individual element construction.

1-3.21 Cracking Pressure. The pressure at which the suit exhaust valve begins to open, releasing exhaust air to the outside suit environment.

1-3.22* Cryogenic Liquid. A refrigerated liquid gas having a boiling point below −130°F (−90°C) at atmospheric pressure.

1-3.23* Element(s). The parts or items of clothing and equipment that provide vapor protection. The vapor-protective elements are the suit, gloves, and footwear.

1-3.24 Emergency Response Personnel. Personnel assigned to organizations that have the responsibility for responding to hazardous materials emergencies.

1-3.25 Ensemble. See definition 1-3.66, Vapor-Protective Ensemble.

1-3.26 Exhaust Valve. One-way vent valves that release exhaust air from the inside of the protective suit to the outside environment and prevent entry of contaminated air into the protective suit from the outside environment.

1-3.27* External Fittings. Any fitting or connection externally located on, and part of, the vapor-protective ensemble that is not part of the chemical-protective material, visor material, gloves, footwear, seams, or closure assembly.

1-3.28 Flammable or Explosive Atmospheres. Atmospheres containing chemical vapors or gases at concentrations that will burn or explode if ignited.

1-3.29 Follow-Up Program. The sampling, inspections, tests, or other measures conducted by the certification organization on a periodic basis to determine the continued compliance of labeled and listed products that are being produced by the manufacturer to the requirements of this standard.

1-3.30 Footwear. See definition 1-3.71, Vapor-Protective Footwear.

1-3.31 Footwear Upper. That portion of the footwear element above the sole.

1-3.32 Glove. See definition 1-3.72, Vapor-Protective Gloves.

1-3.33 Hazardous Material. Any solid, liquid, gas, or mixture thereof that can potentially cause harm to the human body through respiration, ingestion, skin absorption, or contact.

1-3.34* Hazardous Materials Emergencies. Incidents involving the release or potential release of hazardous materials into the environment that can cause loss of life, personnel injury, or damage to property and the environment.

1-3.35 Individual Elements. Vapor-protective gloves or vapor-protective footwear that are individually certified as compliant with the applicable requirements of this standard and are not ensemble elements (components or subassembly) of the vapor-protective ensemble. *(See definitions 1-3.18, Component, 1-3.23, Element(s), and 1-3.66, Vapor-Protective Ensemble.)*

1-3.36 Labeled. 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.

1-3.37 Ladder Shank. Reinforcement to the shank area of footwear; designed to provide additional support to the instep when standing on a ladder rung.

1-3.38* Liquefied Gas. A gas that, under its charged pressure, is partially liquid at 21°C (70°F).

1-3.39 Liquid Splash-Protective Ensemble. A protective ensemble that is certified as compliant with NFPA 1992, *Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies*.

1-3.40* Listed. 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.

1-3.41 Maintenance. Procedures for inspection, repair, and removal from service of vapor-protective ensembles.

1-3.42 Manufacturer. The entity that assumes the liability and provides the warranty for the compliant product.

1-3.43 Model. The collective term used to identify a group of individual vapor-protective ensembles or individual elements of the same basic design and components from a single manufacturer produced by the same manufacturing and quality assurance procedures that are covered by the same certification.

1-3.44 Outer Boot. A secondary boot worn over the footwear ensemble element or bootie for the purpose of providing physical protection to meet the requirements of this standard.

1-3.45 Outer Garment. A secondary garment worn over the suit ensemble element for the purpose of providing physical protection to meet the requirements of this standard.

1-3.46 Outer Glove. A secondary glove worn over the glove ensemble element for the purpose of providing physical protection to meet the requirements of this standard.

1-3.47 Particulate. Solid matter that is dispersed in air as a mixture. For the purpose of this standard, particulates do not include aerosol, or suspended liquid droplets in air. Aerosols are considered liquids.

1-3.48 Primary Materials. Vapor-protective ensemble and individual element materials limited to the suit material, hood and visor material, glove material, and footwear material that provide protection from chemical and physical hazards. This includes, in addition to the above materials, the wearer's respiratory protective equipment when designed to be worn outside the vapor-protective ensemble, the umbilical air hose, and includes all other exposed respiratory protective equipment materials designed to protect the wearer's breathing air and air path. The chemical-protective layer is considered as primary material and can be configured as a separate layer or as a composite Primary materials can be either single layers or composites.

1-3.49 Product Label. A label or marking affixed to each compliant vapor-protective ensemble and compliant individual elements by the manufacturer. Such labels contain compliance statements, certification statements, general information, care, maintenance, or similar data. The product label is not the certification organization's label, symbol, or identifying mark; however, the certification organization's label, symbol, or identifying mark is a part of the product label. *(See also definition 1-3.36, Labeled.)*

1-3.50 Protective Ensemble. See definition 1-3.66, Vapor-Protective Ensemble.

1-3.51 Protective Footwear. See definition 1-3.71, Vapor-Protective Footwear.

1-3.52 Protective Gloves. See definition 1-3.72, Vapor-Protective Gloves.

1-3.53 Protective Suit. See definition 1-3.73, Vapor-Protective Suit.

1-3.54 Radiological Agents. Radiation associated with x-rays, alpha, beta, and gamma emissions from radioactive isotopes, or other materials in excess of normal background radiation levels.

1-3.55 Recall System. The action taken by which a manufacturer identifies an element, provides notice to the users, withdraws an element from the marketplace and distribution sites, and the element is returned to the manufacturer or other acceptable location for corrective action.

1-3.56 Respiratory Equipment. A positive pressure, self-contained breathing apparatus (SCBA) or combination SCBA/supplied-air breathing apparatus certified by the National Institute for Occupational Safety and Health (NIOSH) and certified as compliant with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*.

1-3.57 Seam. Any permanent attachment of two or more chemical-protective clothing materials, excluding external fittings, gaskets, and suit closure assemblies, in a line formed by joining the separate material pieces.

1-3.58 Shall. Indicates a mandatory requirement.

1-3.59 Shank. See definition 1-3.37, Ladder Shank.

1-3.60 Should. Indicates a recommendation or that which is advised but not required.

1-3.61 Storage Life. The date to remove from service a vapor-protective ensemble or individual element that has undergone proper care and maintenance in accordance with manufacturer's instructions but has not been used either in training or at actual incidents.

1-3.62 Suit See definition 1-3.73, Vapor-Protective Suit.

1-3.63 Suit Closure. The component that allows the wearer to enter (don) and exit (doff) the vapor-protective suit element.

1-3.64 Suit Closure Assembly. The combination of the suit closure and the seam attaching the suit closure to the suit, excluding any protective flap or cover.

1-3.65 Suit Material. The principal material used in the construction of the vapor-protective suit.

1-3.66 Vapor-Protective Ensemble. The combination or assembly of multiple elements that are compliant with at least all base requirements of this standard and that are designed to provide a degree of protection from chemical vapors, gases, liquids, and particulates encountered during hazardous materials emergency incidents. The ensemble elements of the vapor-protective ensemble are the suit, gloves, and footwear. *(See also definitions 1-3.18, Component, 1-3.23, Element(s), and 1-3.35, Individual Elements.)*

1-3.67 Vapor-Protective Ensemble with Additional Chemical and Biological Terrorism Protection. A compliant vapor-protective ensemble that is also certified as compliant with the additional requirements for protection against chemical and

biological warfare agents such as vapors, gases, liquids, and particulate.

1-3.68* Vapor-Protective Ensemble with Additional Chemical Flash Fire Escape Protection. A compliant vapor-protective ensemble that is also certified as compliant with the additional requirements for *limited* protection against chemical flash fire *for escape only*.

1-3.69* Vapor-Protective Ensemble with Additional Liquefied Gas Protection. A compliant vapor-protective ensemble that is also certified as compliant with the requirements for protection against liquefied gases.

1-3.70 Vapor-Protective Ensemble with Additional Chemical Flash Fire Escape and Liquefied Gas Protection. A compliant vapor-protective ensemble that is also certified as compliant with the requirements for both *limited* protection against chemical flash fire *for escape only* and for protection against liquefied gases.

1-3.71 Vapor-Protective Footwear. An ensemble element or an individual element that provides chemical and physical protection for the feet, ankles, and lower legs. Footwear includes boots, or outer boots in conjunction with booties. *(See also definitions 1-3.18, Component, 1-3.23, Element(s), and 1-3.35, Individual Elements.)*

1-3.72 Vapor-Protective Gloves. An ensemble element or an individual element that provides chemical and physical protection for the hands and wrists. *(See also definitions 1-3.18, Component, 1-3.23, Element(s), 1-3.35, Individual Elements.)*

1-3.73 Vapor-Protective Suit. An ensemble element that provides chemical protection for the upper and lower torso, head, arms, and legs.

1-3.74 Visor. The portion of the suit hood that permits the wearer to see outside the chemical-protective suit.

1-4* Units.

1-4.1 In this standard, values for measurement are followed by an equivalent in parentheses, but only the first stated value shall be regarded as the requirement.

1-4.2 Equivalent values in parentheses shall not be considered as the requirement, as these values might be approximate.

Chapter 2 Certification

2-1 General.

2-1.1* All vapor-protective ensembles, ensemble elements, and individual elements that are labeled as being compliant with this standard shall meet or exceed all applicable requirements specified in this standard and shall be certified. Manufacturers shall not claim compliance with a portion(s) or segment(s) of the requirements of this standard and shall not use the name or identification of this standard, NFPA 1991, in any statements about their respective products unless the product is certified to this standard.

2-1.2 All certification shall be performed by a certification organization that meets at least the requirements specified in Section 2-2 and that is accredited for personal protective equipment in accordance with ANSI Z34.1, *Standard for Third-Party Certification Programs for Products, Processes, and Services.*

2-1.3 Compliant vapor-protective ensembles and compliant individual elements shall be labeled and listed. Such vapor-protective ensembles and individual elements shall also have a product label. The product label shall meet the requirements specified in Section 3-1.

2-1.3.1 Glove ensemble elements and footwear ensemble elements that are provided, sold, or distributed as part of a specific ensemble shall not be required to be separately labeled and listed but shall be included as a part of the ensemble product label and listing.

2-1.3.2 Ensemble elements and individual elements that are manufactured as separate items and are not intended to be provided, sold, or distributed as part of a complete ensemble shall be certified as an element for a specific ensemble or ensembles. The designation of which elements are certified as compliant with a specific ensemble(s) shall be clearly indicated on the product labels of both the element and the ensemble.

2-1.3.3 Ensemble elements and individual elements that are tested for gastight integrity as specified in 2-3.1.1 shall be certified as an element for a specific ensemble or ensembles. The designation of which elements are certified as compliant with a specific ensemble(s) shall be clearly indicated on the product labels of both the element and the ensemble.

2-1.4 Where vapor-protective ensembles and individual elements are certified for additional chemicals and chemical mixtures as provided for in 5-2.1, they shall also meet or exceed all applicable requirements specified in this standard.

2-1.5 The certification organization shall not certify any vapor-protective ensembles or any individual elements to the 1994 edition of this standard on or after 1 September 2000.

2-1.6 The certification organization shall not permit any manufacturer to label any vapor-protective ensembles or any individual elements to the 1994 edition of this standard on or after 1 September 2000.

2-1.7 The certification organization shall require manufacturers to remove all certification labels and product labels indicating compliance with the 1994 edition of this standard from all vapor-protective ensembles and individual elements that are under the control of the manufacturer on 1 September 2000. The certification organization shall verify this action is taken.

2-1.8* The certification organization's label, symbol, or identifying mark shall be part of the product label.

2-2 Certification Program.

2-2.1* The certification organization shall not be owned or controlled by manufacturers or vendors of the product being certified. The certification organization shall be primarily engaged in certification work and shall not have a monetary interest in the product's ultimate profitability.

2-2.2 The certification organization shall refuse to certify products to this standard that do not comply with all requirements of this standard.

2-2.3* The contractual provisions between the certification organization and the manufacturer shall specify that certification is contingent on compliance with all applicable requirements of this standard. There shall be no conditional, temporary, or partial certifications. Manufacturers shall not be authorized to use any label or reference to the certification

organization on products that are not manufactured in compliance with all applicable requirements of this standard.

2-2.4* The certification organization shall have laboratory facilities and equipment available for conducting proper tests, a program for calibration of all instruments shall be in place and operating, and procedures shall be in use to ensure proper control of all testing. Good practice shall be followed regarding the use of laboratory manuals, form data sheets, documented calibration and calibration routines, performance verification, proficiency testing, and staff qualification and training programs.

2-2.5 The certification organization shall require the manufacturer to establish and maintain a program of production inspection and testing that at least meets the requirements of Section 2-5 or Section 2-6. The certification organization shall ensure that the audit assurance program provides continued product compliance with this standard.

2-2.6 The certification organization and the manufacturer shall evaluate any changes affecting the form, fit, or function of the certified product to determine its continual certification with this standard.

2-2.7* The certification organization shall have a follow-up inspection program of the manufacturing facilities of the certified product, with at least two random and unannounced visits per 12-month period. As part of the follow-up inspection program, the certification organization shall select sample product at random from the manufacturer's production line, from the manufacturer's in-house stock, or from the open market. The certification organization shall have a statistically validated process for determining the critical inspections and tests to be conducted through this follow-up program to verify the continued compliance of the product or component.

2-2.8 The certification organization shall have a program for investigating field reports alleging malperformance or failure of listed products.

2-2.9* The certification organization shall require the manufacturer to have a product recall system as part of the manufacturer's quality assurance program.

2-2.10 The operating procedures of the certification organization shall provide a mechanism for the manufacturer to appeal decisions. The procedures shall include the presentation of information from both sides of a controversy to a designated appeals panel.

2-2.11 The certification organization shall be in a position to use legal means to protect the integrity of its name and label. The name and label shall be registered and legally defended.

2-3 Inspection and Testing.

2-3.1 For both initial certification and recertification of ensembles, ensemble elements, and components, the certification organization shall conduct both inspection and testing as specified in this section.

2-3.1.1 The certification organization shall ensure that the manufacturer tests each vapor-protective ensemble, each ensemble element, and each individual element for gastight integrity as specified in Section 6-2, Gastight Integrity Test. Each ensemble, ensemble element, and individual element shall show an ending pressure of at least 80 mm ($3\ ^{5}/_{32}$ in.) water gauge pressure. The date of the test shall be placed on the product label.

2-3.2 All inspections, evaluations, conditioning, and testing for certification or for recertification shall be conducted by the certification organization or a facility accredited by the certification organization for inspections, evaluations, conditioning, and testing in accordance with all requirements pertaining to testing laboratories in ISO Guide 25, *General Requirements for the Competence of Calibration and Testing Laboratories.*

2-3.3 All inspections, evaluations, conditioning, or testing conducted by a product manufacturer shall not be used in the certification or recertification process unless the facility for inspections, evaluations, conditioning, or testing has been accredited by the certification organization in accordance with all requirements pertaining to testing laboratories in ISO Guide 25, *General Requirements for the Competence of Calibration and Testing Laboratories.*

2-3.4 The certification organization shall test individual elements with the specific ensemble(s) they are to be certified with in accordance with the requirements of 2-1.3.

2-3.5 Sampling levels for testing and inspection shall be established by the certification organization and the manufacturer to assure a reasonable and acceptable reliability at a reasonable and acceptable confidence level that products certified to this standard are compliant unless such samples levels are specified herein. This information shall be included in the manufacturer's technical data package.

2-3.6 Inspection by the certification organization shall include a review of all product labels to ensure that all required label attachment, compliance statements, certification statements, and other product information are at least as specified in Section 3-1, and that the requirements of 2-1.3.2 and 2-1.3.3 are complied with where applicable.

2-3.7 Inspection by the certification organization shall include a review of any graphic representations used on product labels, as permitted by 3-1.1.4, to ensure that they are consistent with the worded statements.

2-3.8 Inspection by the certification organization shall include a review of the user information required by Section 3-2 to ensure that the information has been developed and is available.

2-3.9 The certification organization shall review the technical data package to determine compliance with the requirements of Section 3-3.

2-3.10 Inspection by the certification organization for determining compliance with the design requirements specified in Chapter 4 shall be performed on whole or complete products. The certification organization shall report on the compliance of each element to each design requirement specified in Chapter 4 for that element.

2-3.11 Testing conducted by the certification organization, in accordance with the testing requirements of Chapter 6, for determining product compliance with the applicable requirements specified in Chapter 5 shall be performed on samples representative of materials and composites used in the actual construction of the vapor-protective ensembles and individual elements. The certification organization shall also be permitted to use sample materials cut from a representative product.

2-3.12* Any change in the design, construction, or material of a compliant product shall necessitate new inspection and test-

ing to verify compliance to all applicable requirements of this standard that the certification organization determines can be affected by such change. This recertification shall be conducted before labeling the modified products as being compliant with this standard.

2-3.13 The certification organization shall not allow any modifications, pretreatment, conditioning, or other such special processes of the product or any product component prior to the product's submission for evaluation and testing by the certification organization. The certification organization shall not allow test specimens that have been conditioned and tested for one test method to be reconditioned and tested for another test method unless specifically permitted in the test method.

2-3.14 Any combination of materials or multipiece element that is needed to meet any of the performance requirements specified in Chapter 5 of this standard shall also be required to meet all the requirements for that particular segment of the vapor-protective ensemble or individual element, unless otherwise specified herein.

2-3.15 The manufacturer shall maintain all design and performance inspection and test data from the certification organization used in the certification of the manufacturer's compliant product. The manufacturer shall provide such data, upon request, to the purchaser or authority having jurisdiction.

2-4 Recertification.

2-4.1 All vapor-protective ensemble models and all individual element models that are labeled as being compliant with this standard shall undergo recertification on an annual basis. This recertification shall include inspection and evaluation to all design requirements and testing to all performance requirements as required by this standard on all manufacturer's models and components as required by 2-4.3.

2-4.1.1 Any change that affects the ensemble or element performance under design or performance requirements of this standard shall constitute a different model.

2-4.1.2 For the purpose of this standard, models shall include each unique pattern, style, or design of the individual element.

2-4.2 Samples of manufacturer's models and components for recertification shall be acquired from the manufacturer or component supplier during random and unannounced visits as part of the follow-up inspection program. For recertification, the certification organization shall acquire at least one complete vapor-protective ensemble sample outfitted with all manufacturer-provided external fittings. The certification organization shall also acquire a sufficient quantity of component samples to be tested for recertification as required by 2-4.3.

2-4.3 Sample vapor-protective ensembles and components shall be inspected, evaluated, and tested as follows.

2-4.3.1 Each vapor-protective ensemble shall be inspected and evaluated to each of the design requirements specified in Chapter 4.

2-4.3.2 Each vapor-protective ensemble specimen shall be tested for overall performance as specified in Section 5-1 using the following sequence of tests:

(1) The vapor-protective ensemble specimen shall then be tested for gastight integrity in accordance with Section 6-2, Gastight Integrity Test.
(2) The vapor-protective ensemble specimen shall then be tested for liquidtight integrity as specified in Section 6-3, Liquidtight Integrity Test.
(3) The vapor-protective ensemble specimen shall then be tested for overall function and integrity as specified in Section 6-4, Overall Ensemble Function and Integrity Test.
(4) The vapor-protective ensemble specimen shall then be tested for airflow capacity as specified in Section 6-5, Maximum Suit Ventilation Rate Test.
(5) If certified for optional chemical flash fire protection, the vapor-protective ensemble shall then be tested for overall ensemble flash protection as specified in Section 6-27, Overall Ensemble Flash Test.

2-4.3.3 All suit material, visor, glove, footwear, optional chemical flash fire protection, and optional liquefied gas protection performance requirements shall be evaluated as specified in Chapter 5 with the following modifications:

(a) Permeation and penetration resistance testing specified in 5-2.1, 5-2.6, 5-2.8, 5-3.1, 5-3.6, 5-4.1, and 5-5.1 shall be performed against each of the following chemicals:

(1) Carbon disulfide
(2) Dichloromethane
(3) Diethylamine
(4) Methanol
(5) Tetrahydrofuran

(b) A total of two specimens shall be permitted for testing requirements. If the testing is specified for both directions of a material, a total of two specimens per material direction shall be permitted for testing requirements.

2-4.4 The manufacturer shall maintain all design, inspection, performance, and test data from the certification organization produced during the recertification of manufacturers' models and components. The manufacturer shall provide such data, upon request, to the purchaser or the authority having jurisdiction.

2-5 Manufacturer's Quality Assurance Program.

2-5.1 The manufacturer shall provide and maintain a quality assurance program that includes a documented inspection and product recall system. The manufacturer shall have an inspection system to substantiate conformance to this standard.

2-5.2 The manufacturer shall maintain written inspection and testing instructions. The instructions shall prescribe inspection and testing of materials, work in process, and completed articles. Criteria for acceptance and rejection of materials, processes, and final product shall be part of the instructions.

2-5.3 The manufacturer shall maintain records of all pass/fail tests. Pass/fail records shall indicate the disposition of the failed material or product.

2-5.4 The manufacturer's inspection system shall provide for procedures that assure the latest applicable drawings, specifications, and instructions are used for fabrication, inspection, and testing.

2-5.5 The manufacturer shall, as part of the quality assurance program, maintain a calibration program of all instruments

used to ensure proper control of testing. The calibration program shall be documented as to the date of calibration and performance verification.

2-5.6 The manufacturer shall maintain a system for identifying the appropriate inspection status of component materials, work in process, and finished goods.

2-5.7 The manufacturer shall establish and maintain a system for controlling nonconforming material, including procedures for the identification, segregation, and disposition of rejected material. All nonconforming materials or products shall be identified to prevent use, shipment, and intermingling with conforming materials or products.

2-5.8 The manufacturer's quality assurance program shall be audited by the third-party certification organization to determine that the program is sufficient to ensure continued product compliance with this standard.

2-6 ISO Registration for Manufacturers.

2-6.1 The manufacturer shall provide and operate a quality assurance program that meets the requirements of this section and that includes a product recall system as specified in 2-2.9.

2-6.2 The manufacturer shall be registered to ISO 9001, *Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation, and Servicing*.

2-6.3 The ISO registration requirements shall have an effective date of 1 March 2002.

2-6.4 Until 1 March 2002, or until the date the manufacturer becomes ISO registered, whichever date occurs first, the manufacturer shall comply with Section 2-5.

Chapter 3 Labeling and Information

3-1 Product Label Requirements.

3-1.1 General.

3-1.1.1 Each vapor protective ensemble shall have a product label permanently and conspicuously attached to the innermost surface of the ensemble when the ensemble is properly assembled with all layers, components and parts in place.

3-1.1.2 Each glove and footwear element shall have a product label attached to the element, or printed upon or inserted in the smallest unit of packaging of that element.

3-1.1.3 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 comprising the entire product label shall be located adjacent to each other.

3-1.1.4 All worded portions of the required product label shall at least be in English.

3-1.1.5 Symbols and other pictorial graphic representations shall be permitted to be used to supplement worded statements on the product label(s).

3-1.1.6 The certification organization's label, symbol, or identifying mark shall be legibly printed on the product label. All letters shall be at least 2.5 mm ($^3/_{32}$ in.) high.

3-1.1.7 The compliance statements and information specified in 3-1.2 and 3-1.3, as applicable for the specific ensemble or individual element, shall be legibly printed on the product label. All letters shall be at least 3 mm ($^1/_8$ in.) high.

3-1.1.8 In addition to the compliance statements and information specified in 3-1.1.6, at least the following information shall also be printed legibly on the product label(s). All letters shall be at least 1.6 mm ($^1/_{16}$ in.) high.

(1) Manufacturer's name, identification, or designation
(2) Manufacturer's address
(3) Country of manufacture
(4) Suit model, style, or serial number
(5) Date of compliance testing to ASTM F 1052, *Standard Test Method for Pressure Testing of Vapor-Protective Ensembles*
(6) Size
(7) Suit, glove, footwear material(s), as applicable
(8) Visor material(s) for suits
(9) Glove component for ensemble
(10) Footwear component for ensemble

3-1.1.9* Where detachable components of a vapor-protective ensemble or an individual element, including but not limited to such components as outer garments, outer gloves, or outer boots, *must* be worn with a vapor-protective ensemble or individual element in order for the ensemble or individual element to be compliant with this standard, at least the following statement and information shall also be printed legibly on the product label of the ensemble and the product label for each glove and footwear. All letters shall be at least 2.5 mm ($^3/_{32}$ in.) high. The appropriate term "ensemble" or "individual element" shall be inserted where indicated in the label text. The detachable component(s) shall be listed following this statement by type, identification, and how properly worn.

"FOR COMPLIANCE WITH NFPA 1991, THE FOLLOWING ADDITIONAL COMPONENTS MUST BE WORN IN CONJUNCTION WITH THIS VAPOR-PROTECTIVE (insert the term 'ENSEMBLE' or 'INDIVIDUAL ELEMENT' here):"

(List detachable components here.)

3-1.1.10 Detachable components specified in 3-1.1.8 shall meet the label requirements specified in ASTM F 1301, *Standard Practice for Labeling Chemical Protective Clothing*. The label shall also meet the requirements of 3-1.1.1 through 3-1.1.5.

3-1.2 Ensemble Compliance Statements.

3-1.2.1 Each vapor-protective ensemble shall have at least the following compliance statement and information on the product label.

"THIS VAPOR-PROTECTIVE ENSEMBLE MEETS THE BASIC REQUIREMENTS OF NFPA 1991, STANDARD ON VAPOR-PROTECTIVE ENSEMBLES FOR HAZARDOUS MATERIALS EMERGENCIES, 2000 EDITION, AND ANY ADDITIONAL REQUIREMENTS AS NOTED BELOW.

ADDITIONAL REQUIREMENTS	YES	NO
CHEMICAL AND BIOLOGICAL TERRORISM INCIDENTS FOR THE FOLLOWING CHEMICAL WARFARE AGENTS: Cyanogen Chloride, Lewisite, Sarin, V-agent, and Sulfur mustard, distilled.		
***LIMITED* CHEMICAL FLASH FIRE PROTECTION FOR *ESCAPE ONLY* IN THE EVENT OF A CHEMICAL FLASH FIRE**		
LIQUEFIED GAS PROTECTION		

THE TECHNICAL DATA PACKAGE CONTAINS INFORMATION ON CHEMICALS AND SPECIFIC CHEMICAL MIXTURES FOR WHICH THIS SUIT IS CERTIFIED. CONSULT THE TECHNICAL DATA PACKAGE AND MANUFACTURER'S INSTRUCTIONS BEFORE USE.

DO NOT REMOVE THIS LABEL."

3-1.2.2 Where the ensemble provides one or more of the optional additional protection, the YES or NO box shall be marked as appropriate for each of the three additional requirements.

3-1.2.3 Where the ensemble does not provide any of the optional additional protection above the basic requirements of this standard, the NO boxes shall be marked for each of the three additional requirements.

3-1.3 Individual Element Compliance Statements.

3-1.3.1 Each individual element shall have at least the following compliance statement and information on the product label. The appropriate term "glove" or "footwear" shall be inserted where indicated in the label text.

"THIS (insert the element name 'GLOVE' or 'FOOTWEAR' here) INDIVIDUAL ELEMENT MEETS THE BASIC REQUIREMENTS OF NFPA 1991, STANDARD ON VAPOR-PROTECTIVE ENSEMBLES FOR HAZARDOUS MATERIALS EMERGENCIES, 2000 EDITION, AND ANY ADDITIONAL REQUIREMENTS AS NOTED BELOW.

ADDITIONAL REQUIREMENTS	YES	NO
CHEMICAL AND BIOLOGICAL TERRORISM INCIDENTS FOR THE FOLLOWING CHEMICAL WARFARE AGENTS: Cyanogen Chloride, Lewisite, Sarin, V-agent, and Sulfur mustard, distilled.		
***LIMITED* CHEMICAL FLASH FIRE PROTECTION FOR *ESCAPE ONLY* IN THE EVENT OF A CHEMICAL FLASH FIRE**		
LIQUEFIED GAS PROTECTION		

THE TECHNICAL DATA PACKAGE CONTAINS INFORMATION ON CHEMICALS AND SPECIFIC CHEMICAL MIXTURES FOR WHICH THIS (insert the element name 'GLOVE' or 'FOOTWEAR' here) IS CERTIFIED. CONSULT THE TECHNICAL DATA PACKAGE AND MANUFACTURER'S INSTRUCTIONS BEFORE USE.

DO NOT REMOVE THIS LABEL."

3-1.3.2 Where the individual element provides one or more of the optional additional protection, the YES or NO box shall be marked as appropriate for each of the three additional requirements.

3-1.3.3 Where the individual element does not provide any of the optional additional protection above the basic requirements of this standard, the NO boxes shall be marked for each of the three additional requirements.

3-2* User Information.

3-2.1 The manufacturer shall provide user information including, but not limited to, warnings, information, and instructions with each vapor-protective ensemble and each individual element.

3-2.2 The manufacturer shall attach the required user information, or packaging containing the user information, to the vapor-protective ensemble or individual element in such a manner that it is not possible to use the ensemble or element without being aware of the availability of the information.

3-2.3 The required user information, or packaging containing the user information, shall be attached to the vapor-protective ensemble or individual element so that a deliberate action is necessary to remove it. The manufacturer shall provide notice that the user information is to be removed ONLY by the end user.

3-2.4 The manufacturer shall provide at least the following instructions and information with each vapor-protective ensemble and individual element:

(1) Pre-use information:
   a. Safety considerations
   b. Limitations of use
   c. Marking recommendations and restrictions
   d. A statement that most performance properties of the vapor-protective ensemble or individual element cannot be tested by the user in the field
   e. Closure lubricants, if applicable;
   f. Suit visor antifog agents or procedures
   g. Recommended undergarments
   h. Shelf life
   i. Warranty information
(2) Preparation for use:
   a. Sizing/adjustment
   b. Recommended storage practices
(3) Inspection frequency and details
(4) Don/doff:

a. Donning and doffing procedures
b. Sizing and adjustment procedures
c. Interface issues

(5) Proper use consistent with NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and 29 *CFR* 1910.132.
(6) Maintenance and cleaning:

a. Cleaning instructions and precautions with a statement advising users not to use garments that are not thoroughly cleaned and dried
b. Inspection details
c. Maintenance criteria and methods of repair, where applicable
d. Decontamination procedures for both chemical and biological contamination

(7) Retirement and disposal criteria and consideration

3-2.5* Vapor-protective ensemble and individual element manufacturers shall furnish a log book with each ensemble and individual element along with instructions on the log book's proper completion and maintenance.

3-2.6 The manufacturer shall state the storage life for each vapor-protective ensemble and individual element.

3-3 Technical Data Package.

3-3.1 General.

3-3.1.1* The manufacturer shall furnish a technical data package with each vapor-protective ensemble and individual element.

3-3.1.2* The technical data package shall contain all documentation required by this standard and the data showing compliance with this standard.

3-3.1.3 In the technical data package, the manufacturer shall describe the vapor-protective ensemble or individual elements in terms of manufacturer trade name, model number, manufacturer replaceable components and component parts, and available options such as accessories, testing devices, and sizes.

3-3.1.4* In the technical data package, the manufacturer shall describe the available sizes of the vapor-protective ensemble. Descriptions of sizes shall include the range in height and weight for persons fitting each particular size and shall provide information to the wearer as to whether these sizes apply to persons wearing SCBA, hard hats, communications devices, structural fire-fighting protective clothing, and other similar clothing or equipment.

3-3.2 Material and Component Descriptions.

3-3.2.1 Where specific clothing items, equipment, or component parts are required for certifying the vapor-protective ensemble or individual element as compliant with this standard, the manufacturer shall list these clothing items, equipment, or component parts in the technical data package.

3-3.2.2 The manufacturer shall provide, in the technical data package, the list and descriptions of the following ensemble or individual element materials and component parts, where applicable:

(1) Suit material
(2) Visor material
(3) Glove material and type of attachment
(4) Footwear material and type of attachment
(5) Zipper/closure type and materials
(6) Material seam types and composition
(7) Exhaust valve types and material(s)
(8) External fitting types and material(s)
(9) External gasket types and material(s)
(10) Outer suit, glove, or boot material(s)
(11) Type or style of head protection accommodated within the suit

3-3.2.3 All descriptions of material composition shall specify either the generic material names or trade names if the composition of the material is proprietary.

3-3.2.4 Where applicable, the descriptions of respective vapor-protective ensemble materials, individual element materials, and component part materials shall include the following information:

(1) Visor material:

a. The availability of any permanent detachable covers and films

(2) Gloves:

a. Type of linings or surface treatments
b. Available glove sizes and sizing information

(3) Footwear:

a. Type of linings or surface treatments
b. Type of soles or special toe reinforcements
c. Available footwear sizes

(4) Suit zipper or closure:

a. The material(s) of construction for the closure (including chain, slide, pull, and tape for zippers)
b. The location and the length of the completed closure assembly
c. A description of any protective covers for flaps

(5) Suit exhaust valves or ports:

a. Type, such as flapper, pressure demand
b. Number and method of attachment to the suit
c. A description of any protective covers or pockets

(6) Other clothing items (e.g., outer garments):

a. Type and how used with protective suit

3-3.2.5 The manufacturer shall describe, in the technical data package, the type of seams or methods of attachment for the following ensemble material and component combinations:

(1) Suit material–suit material
(2) Suit material–visor
(3) Suit material–glove
(4) Suit material–footwear
(5) Suit material–suit closure
(6) Outer cover–outer cover

Chapter 4 Design Requirements

4-1 Ensemble Requirements.

4-1.1 Vapor-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.

4-1.2 Vapor-protective ensembles shall consist of a suit with hood, gloves, and footwear. The suit hood shall be provided with a visor that is designed to allow the wearer to see outside the chemical protective ensemble. The visor shall be constructed of a transparent material that qualifies as a chemical-protective layer.

4-1.2.1 Vapor-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 ensemble element requirements of this standard.

4-1.2.2 Vapor-protective ensembles shall be permitted to be constructed using an outer glove designed to be worn over the glove ensemble element where such additional gloves are necessary to meet the glove ensemble element requirements of this standard.

4-1.2.3 Vapor-protective ensembles shall be permitted to be constructed using an outer boot designed to be worn over a footwear ensemble element or bootie where such additional boots are necessary to meet the footwear ensemble element requirements of this standard.

4-1.3 Other than outer gloves and outer boots, vapor-protective ensembles shall be designed so that all separate components are securely attached and provided as a single and integrated unit.

4-1.4 Vapor-protective ensembles shall be offered in at least four unique and different sizes.

4-1.5* Vapor-protective ensembles shall be equipped with an exhaust valve(s). The exhaust valve(s) shall be one-way valve(s). The one-way valves shall be designed to release exhaust air from the inside of the vapor-protective ensemble to the outside environment through the exhaust valve, and shall prevent entry of contaminated air into the vapor-protective ensemble from the outside environment through the exhaust valve.

4-1.6 The mounting mechanism of exhaust valves shall be designed to allow their removal and reinstallation or replacement, for inspection, from the vapor-protective ensemble.

4-1.7 The vapor-protective ensemble suit with hood and visor, glove and footwear shall be constructed using primary material that shall provide the protection from chemical and physical hazards. The primary material shall include the chemical-protective layer that can be configured as a separate layer or as a composite.

4-1.8 The chemical-protective layer shall be designed to provide permeation resistance to chemicals and gastight integrity for the vapor-protective ensemble. The chemical-protective layer shall be considered as primary material and shall be permitted to be configured as a separate layer or as a composite with other primary materials. The chemical-protective layer shall be permitted to depend on the other primary material to provide the physical protection.

4-1.9 Protective covers or pockets constructed using the suit primary material shall be provided to protect the exhaust valves from direct chemical splashes to the seat of the exhaust valve(s). The pockets or covers shall allow access to the valves for removal and inspection.

4-1.10 All external hardware and fittings shall be free of rough spots, burrs, or sharp edges that could tear materials.

4-2 Glove Requirements.

4-2.1 Vapor-protective gloves shall be designed and configured to protect the wearer's hands and wrists.

4-2.2 Vapor-protective gloves shall provide protection from the finger tips to at least 25 mm (1 in.) beyond the wrist crease.

4-2.3 Vapor-protective gloves shall be constructed using primary material that shall provide the protection from chemical and physical hazards. The primary material shall include the chemical-protective layer that can be configured as a separate layer or as a composite.

4-2.4 The chemical-protective layer shall be designed to provide permeation resistance to chemicals and gastight integrity for the vapor-protective glove. The chemical-protective layer shall be considered as primary material and shall be permitted to be configured as a separate layer or as a composite with other primary materials. The chemical-protective layer shall be permitted to depend on the other primary material to provide the physical protection.

4-2.5 Vapor-protective gloves 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.

4-2.6 The interface of vapor-protective glove to vapor-protective suit sleeve interface shall be designed to permit removal and replacement of the gloves attached to each suit sleeve within 30 minutes.

4-2.7 All external hardware and fittings shall be free of rough spots, burrs, or sharp edges that could tear materials.

4-3 Footwear Requirements.

4-3.1 Vapor-protective footwear shall be designed and configured to provide protection to the feet and ankles.

4-3.2 Vapor-protective footwear shall provide protection for an area of not less than 200 mm (8 in.) in height when measured from the plane of the sole bottom.

4-3.3 Booties, where provided, shall be designed as an extension of the chemical 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.

4-3.4 Vapor-protective footwear shall be constructed using primary material that shall provide the protection from chemical and physical hazards. The primary material shall include the chemical-protective layer that can be configured as a separate layer or as a composite.

4-3.5 The chemical-protective layer shall be designed to provide permeation resistance to chemicals and gastight integrity for the vapor-protective footwear. The chemical-protective layer shall be considered as primary material and shall be permitted to be configured as a separate layer or as a composite with other primary materials. The chemical-protective layer shall be permitted to depend on the other primary material to provide the physical protection.

4-3.6 Vapor-protective footwear shall be permitted to be constructed using an outer boot designed to be worn over the primary footwear or bootie where such additional boots are necessary to meet the footwear requirements of this standard.

4-3.7 All external hardware and fittings shall be free of rough spots, burrs, or sharp edges that could tear materials.

4-4 Accessories.

4-4.1 Any accessories attached to a vapor-protective ensemble or any individual element shall not interfere with the function of the ensemble or individual element or with the function of

any of the ensemble's or individual element's component parts.

4-4.2 Where a vapor-protective ensemble or any individual element is provided with an accessory or accessories that are attached to or integrated with the ensemble or individual element, the ensemble or individual element shall meet all of the design and performance requirements of this standard with accessories installed. In all cases, such accessories shall not degrade the performance of the vapor-protective ensemble or individual element.

Chapter 5 Performance Requirements

5-1 Ensemble Requirements.

5-1.1 Vapor-protective ensembles shall be tested for liquidtight integrity as specified by Section 6-3, Liquidtight Integrity Test, and shall not allow any water penetration.

5-1.2 Vapor-protective ensembles shall be tested for overall function and integrity as specified in Section 6-4, Overall Ensemble Function and Integrity Test, and shall meet the following performance criteria:

(1) Ensembles shall have an ending pressure of at least 80 mm ($3\,^5/_{32}$ in.) water gauge pressure.
(2) Ensembles shall allow the test subject to complete all tasks.
(3) Ensembles shall accommodate heat protection devices meeting the requirements for Type I, Class G helmets of ANSI Z89.1, *Standard for Industrial Head Protection*.
(4) Ensembles shall permit the test subject to see through the visor with a visual acuity of 20/35 or better.
(5) Ensembles shall permit the test subject to remove and reinsert their hand into the glove system.

5-1.3 Vapor-protective ensembles shall be tested for airflow capacity as specified in Section 6-5, Maximum Suit Ventilation Rate Test, and shall exhibit no internal pressures greater than 38 mm ($1^1/_2$ in.) water gauge pressure, and shall show an ending pressure of at least 80 mm ($3\,^5/_{32}$ in.) water gauge pressure after subsequent testing for gastight integrity as specified in Section 6-2, Gastight Integrity Test.

5-1.4 Vapor-protective ensembles, on which external fittings are installed that penetrate any primary materials, shall be tested for gastight integrity as specified in Section 6-2, Gastight Integrity Test, and show an ending pressure of at least 80 mm ($3\,^5/_{32}$ in.) water gauge.

5-1.5 Exhaust valves installed in vapor-protective suits shall be tested for mounting strength as specified in Section 6-9, Exhaust Valve Mounting Strength Test, and shall not have a failure force of less than 135 N (30 lbf).

5-1.6 External fittings installed in vapor-protective ensembles shall be tested for pull-out strength as specified in Section 6-13, Fitting Pull Out Strength Test, and shall not have a failure force of less than 1000 N (225 lbf).

5-1.7 Exhaust valves installed in vapor-protective ensembles shall be tested for inward leakage as specified in Section 6-26, Exhaust Valve Inward Leakage Test, and shall not exhibit a leakage rate exceeding 30 ml/min (1.83 $in.^3$/min).

5-2 Suit Requirements.

5-2.1 Vapor-protective suit materials shall be tested for permeation resistance after flexing and abrading as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-2.1.1 Vapor-protective suit materials shall be tested for permeation resistance after flexing and abrading as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour of less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-2.2 Vapor-protective suit materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Resistance Test, and shall not ignite during the initial 3 second exposure period, shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 10 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-2.3 Vapor-protective suit material shall be tested for bursting strength as specified in Section 6-10, Burst Strength Test, and shall have a bursting strength of not less than 200 N (45 lb force).

5-2.4 Vapor-protective suit materials shall be tested for puncture propagation tear resistance as specified in Section 6-11, Puncture Propagation Tear Resistance Test, and shall have a puncture propagation tear resistance of not less than 49 N (11 lbf).

5-2.5 Vapor-protective suit materials shall be tested for cold weather performance as specified in Section 6-12, Cold Temperature Performance Test One, and shall not have a bending moment greater than 0.057 N × m (0.5 in.-lbf) at a angular deflection of 60 degrees and −25°C (−13°F).

5-2.6 Vapor-protective suit seams shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-2.6.1 Vapor-protective suit seams shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-2.7 Vapor-protective suit seams shall be tested for seam strength as specified in Section 6-24, Seam/Closure Breaking Strength Test, and shall have a breaking strength of not less than 2.88 kN/m (30 lbf/2 in.).

5-2.8 Vapor-protective suit closure assemblies shall be tested for chemical penetration resistance as specified in Section 6-25, Closure Penetration Resistance Test, and show no penetration for the following list of liquid chemicals:

Acetone	Methanol
Acetonitrile	Nitrobenzene
Carbon disulfide	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Hexane	

5-2.8.1 Vapor-protective suit closure assemblies shall be tested for chemical penetration resistance as specified in Section 6-25, Closure Penetration Resistance Test, and for any additional chemicals or specific chemical mixtures for which the manufacturer is certifying the suit.

5-2.9 Vapor-protective suit closure assemblies shall be tested for closure strength as specified in Section 6-24, Seam/Closure Breaking Strength Test, and shall have a breaking strength of not less than 2.88 kN/m (30 lbf/2 in.).

5-3 Suit Visor Requirements.

5-3.1 Visor materials shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-3.1.1 Visor materials shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit breakthrough detection time of 1 hour or less and shall not exhibit a breakthrough detection time of 1 hour or less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-3.2 Visor materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Resistance Test, and shall not ignite during the initial 3-second exposure period, and shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 10 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-3.3 Visor materials shall be tested for bursting strength as specified in Section 6-10, Burst Strength Test, and shall have a bursting strength of not less than 200 N (45 lbf).

5-3.4 Visor materials shall be tested for puncture propagation tear resistance as specified in Section 6-11, Puncture Propagation Tear Resistance Test, and shall have a puncture propagation tear resistance of not less than 5 kg (11 lb).

5-3.5 Visor materials shall be tested for cold temperature bending as specified in Section 6-14, Cold Temperature Performance Test Two, and shall not crack or show evidence of visible damage.

5-3.6 Visor material seams shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-3.6.1 Visor material seams shall be tested for permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 1 hour or less and shall not exhibit a breakthrough detection time of 1 hour or less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-3.7 Visor material seams shall be tested for seam strength as specified in Section 6-24, Seam/Closure Breaking Strength Test, and shall have a breaking strength of not less than 134 N/50 mm (30 lbf/2 in.).

5-4 Glove Requirements.

5-4.1 Vapor-protective glove materials shall be tested for permeation resistance after flexing and abrading as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-4.1.1 Vapor-protective glove materials shall be tested for permeation resistance after flexing and abrading as specified

in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less and shall not exhibit a breakthrough detection time of 1 hour or less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-4.2 Vapor-protective glove materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Resistance Test, and shall not ignite during the initial 3-second exposure period, and shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 10 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-4.3 Vapor-protective glove materials shall be tested for cut resistance as specified in Section 6-15, Cut Resistance Test, and shall have a cut distance of not more than 25 mm (1 in.).

5-4.4 Vapor-protective glove materials shall be tested for puncture resistance as specified in Section 6-16, Puncture Resistance Test One, and shall have a puncture resistance of not less than 2.3 kg (5 lb).

5-4.5 Vapor-protective glove materials shall be tested for cold weather performance as specified in Section 6-12, Cold Temperature Performance Test One, and shall have a bending moment of 0.057 N × m (0.5 in.-lbf) at an angular deflection of 60 degrees and –25°C (–13°F).

5-4.6* Vapor-protective gloves shall be tested for dexterity as specified in Section 6-17, Glove Hand Function Test, and shall have an average percent increase of barehand control of less than 600 percent.

5-5 Footwear Requirements.

5-5.1 Vapor-protective footwear upper materials shall be tested for permeation resistance after flexing and abrading as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less for the following list of chemicals:

Acetone	Hexane
Acetonitrile	Hydrogen chloride (gas)
Anhydrous ammonia (gas)	Methanol
1,3-Butadiene (gas)	Methyl chloride (gas)
Carbon disulfide	Nitrobenzene
Chlorine (gas)	Sodium hydroxide
Dichloromethane	Sulfuric acid
Diethyl amine	Tetrachloroethylene
Dimethyl formamide	Tetrahydrofuran
Ethyl acetate	Toluene
Ethylene oxide (gas)	

5-5.1.1 Vapor-protective footwear upper materials shall be tested for permeation resistance after flexing and abrading as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a breakthrough detection time of 1 hour or less and shall not exhibit a breakthrough detection time of 1 hour or less for each additional chemical or specific chemical mixture for which the manufacturer is certifying the ensemble.

5-5.2 Vapor-protective footwear upper materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Resistance Test, and shall not ignite during the initial 3-second exposure period, and shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 10 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-5.3 Vapor-protective footwear upper materials shall be tested for cut resistance as specified in Section 6-15, Cut Resistance Test, and have a cut distance of not more than 25 mm (1 in.).

5-5.4 Vapor-protective footwear upper materials shall be tested for puncture resistance as specified in Section 6-16, Puncture Resistance Test One, and have a puncture resistance of not less than 3.6 kg (8 lb).

5-5.5 Vapor-protective footwear toes shall be tested for impact and compression resistance as specified in Section 6-21, Impact and Compression Test, and shall have an impact resistance of not less than 101.7 J (75 ft-lb) and a compression resistance of not less than 11,121 N (2500 lbf).

5-5.6 Vapor-protective footwear soles and heels shall be tested for puncture resistance as specified in Section 6-19, Puncture Resistance Test Two, and shall have a puncture resistance of not less than 123.4 kg (272 lb).

5-5.7 Vapor-protective footwear soles and heels shall be tested for abrasion resistance as specified in Section 6-20, Abrasion Resistance Test, and have an abrasion resistance rating of not less than 65.

5-5.8 Vapor-protective footwear soles or ladder shanks shall be tested for bending resistance as specified in Section 6-22, Ladder Shank Bend Resistance Test, and shall not deflect more than 6 mm ($^1/_4$ in.).

5-5.9 Vapor-protective footwear soles shall be tested for slip resistance as specified in Section 6-23, Slip Resistance Test, and shall have a static coefficient of 0.75 or greater.

5-6 Optional Chemical Flash Fire Protection Requirements.

5-6.1 Vapor-protective ensembles, ensemble elements, and individual elements that will be certified as compliant with the additional criteria for chemical flash fire protection for escape only shall also meet all applicable requirements in Section 5-1 through Section 5-5.

5-6.2 Vapor-protective ensembles, ensemble elements, and individual elements shall be tested for overall ensemble flash protection as specified by Section 6-27, Overall Ensemble Flash Test, shall not have any afterflame times of longer than 2 seconds, shall show an ending pressure of at least 13 mm ($^1/_2$ in.) water gauge in the subsequent gastight integrity testing, and shall permit visual acuity through the visor of 20/100 or better.

5-6.3 Primary suit, glove, and footwear materials shall be tested for thermal protective performance (TPP) as specified in Section 6-28, Thermal Protective Performance Test, and shall have an average TPP rating of not less than 12.

5-6.4 Primary suit, glove, and footwear materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Test, and shall not ignite during the initial 3-second exposure period, shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 2 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-6.5 Suit and glove materials shall be tested for the rate of static electric discharge as specified in Section 6-18, Static Charge Accumulation Resistance Test, and shall show no voltage greater than 350 V at 5 seconds after termination of charge generation.

5-7 Optional Liquefied Gas Protection Requirements.

5-7.1 Vapor-protective ensembles, ensemble elements, and individual elements that will be certified as compliant with the additional criteria for liquefied gas protection shall also meet all applicable requirements in Section 5-1 through Section 5-5.

5-7.2 Primary suit, glove, and footwear materials shall be tested for liquefied gas permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 15 minutes or less for the following list of gaseous chemicals:

Ammonia
Butadiene
Chlorine
Ethylene oxide
Hydrogen chloride
Methyl chloride

5-7.2.1 Primary suit, glove, and footwear materials shall be tested for liquefied gas permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 15 minutes or less and shall not exhibit a normalized breakthrough detection time of 15 minutes or less for each additional liquefied gas that the manufacturer is certifying the ensemble.

5-7.3 Primary suit, glove, and footwear materials shall be tested for permeation resistance after cold temperature embrittlement exposure as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not show signs of damage, and shall not exhibit a normalized breakthrough detection time of 60 minutes or less for the following list of gaseous chemicals:

Ammonia
Butadiene
Chlorine
Ethylene oxide
Hydrogen chloride
Methyl chloride

5-8 Optional Combined Chemical Flash Fire and Liquefied Gas Protection Requirements.

5-8.1 Vapor-protective ensembles, ensemble elements, and individual elements that will be certified as compliant with both the additional criteria for chemical flash fire protection for escape only and with the additional criteria for liquefied gas protection shall also meet all applicable requirements in Section 5-1 through Section 5-5.

5-8.2 Vapor-protective ensembles, ensemble elements, and individual elements shall be tested for overall ensemble flash protection as specified by Section 6-27, Ensemble Flash Test, shall not have any afterflame times of longer than 2 seconds, shall show an ending pressure of at least 13 mm ($^1/_2$ in.) water gauge in the subsequent gastight integrity testing, and shall permit visual acuity through the visor of 20/100 or better.

5-8.3 Primary suit, glove, and footwear materials shall be tested for thermal protective performance (TPP) as specified in Section 6-28, Thermal Protective Performance (TPP) Test, and shall have an average TPP rating of not less than 12.

5-8.4 Primary suit, glove, and footwear materials shall be tested for resistance to flame impingement as specified in Section 6-7, Flammability Resistance Test, and shall not ignite during the initial 3-second exposure period, shall not burn a distance of greater than 100 mm (4 in.), shall not sustain burning for more than 2 seconds, and shall not melt as evidenced by flowing or dripping during the subsequent 12-second exposure period.

5-8.5 Suit and glove materials shall be tested for the rate of static electric discharge as specified in Section 6-18, Static Charge Accumulation Resistance Test, and shall show no voltage greater than 350 V, 5 seconds after termination of charge generation.

5-8.6 Primary suit, glove, and footwear materials shall be tested for liquefied gas permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 15 minutes or less for the following list of gaseous chemicals:

Ammonia
Butadiene
Chlorine
Ethylene oxide
Hydrogen chloride
Methyl chloride

5-8.6.1 Primary suit, glove, and footwear materials shall be tested for liquefied gas permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit a normalized breakthrough detection time of 15 minutes or less and shall not exhibit a normalized breakthrough detection time of 15 minutes or less for each additional liquefied gas that the manufacturer is certifying the ensemble.

5-8.7 Primary suit, glove, and footwear materials shall be tested for permeation resistance after cold temperature embrittlement exposure as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not show signs of damage, and shall not exhibit a normalized breakthrough detection time of 60 minutes or less for the following list of gaseous chemicals:

Ammonia
Butadiene
Chlorine
Ethylene oxide
Hydrogen chloride
Methyl chloride

5-9 Optional Chemical and Biological Terrorism Protection Requirements.

5-9.1 Primary suit, glove, and footwear materials and seams shall be tested for cyanogen chloride [CK (blood agent)] permeation resistance as specified in Section 6-6, Chemical Permeation Resistance Test, and shall not exhibit normalized breakthrough detection times of 1 hour or less.

5-9.2 Primary suit, glove, and footwear materials and seams shall be tested for permeation resistance for 60 minutes as specified in Method 2.2, Liquid Agent Contamination/Vapor Penetration, of CRDC-SP-84010, *Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents;* at 32°C, ±2°C (90°F, ±4°F), closed top; at a contamination density of

100 g/m^2; and shall not exceed a cumulative permeation of 1.25 µg for sarin (GB, or isopropyl methyl phosphonofluoridate) and V-agent (VX, or 0-ethyl S-[2-{diisopropylamino}ethyl]methyl phosphonothiate).

5-9.2.1 Primary suit and glove materials shall be tested for permeation resistance after both flexing and abrading, as specified in 6-1.3 and 6-1.4, respectively.

5-9.2.2 Primary footwear materials shall be tested for permeation resistance after both flexing and abrading, as specified in 6-1.6 and 6-1.4, respectively.

5-9.3 Primary suit, glove, and footwear materials and seams shall be tested for permeation resistance for 60 minutes as specified in Method 2.2, Liquid Agent Contamination/Vapor Penetration, of CRDC-SP-84010, *Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents;* at 32°C, ±2°C (90°F, ±4°F); closed top; at a contamination density of 100 g/m^2; and shall not exceed a cumulative permeation of 4 µg for sulfur mustard, distilled [HD, or bis(2-chloroethyl)sulfide], and lewisite [L, or dichloro(2-chlorovinyl)arsine].

5-9.3.1 Primary suit and glove materials shall be tested for permeation resistance after both flexing and abrading, as specified in 6-1.3 and 6-1.4, respectively.

5-9.3.2 Primary footwear materials shall be tested for permeation resistance after both flexing and abrading, as specified in 6-1.6 and 6-1.4, respectively.

5-9.4 Vapor-protective ensembles shall be tested for inward leakage as specified in Section 6-8, Overall Ensemble Inward Leakage Test, and shall have no inward leakage greater than 0.02 percent.

Chapter 6 Test Methods

6-1 Sample Preparation Procedures.

6-1.1 Application.

6-1.1.1 The sample preparation procedures contained in this section shall apply to each test method in this chapter, as specifically referenced in the sample preparation section of each test method.

6-1.1.2 Only the specific sample preparation procedure or procedures referenced in the sample preparation section of each test method shall be applied to that test method.

6-1.2 Room Temperature Conditioning Procedure.

6-1.2.1 Specimens shall be conditioned at a temperature of 21°C, ±3°C (70°F, ±5°F) and a relative humidity of 65 percent, ±5 percent until equilibrium is reached as determined in accordance with Section 4 of Federal Test Method Standard 191A, *Textile Test Methods*, or for at least 24 hours, whichever is shortest.

6-1.2.2 Specimens shall be tested within 5 minutes after removal from conditioning.

6-1.3 Flexural Fatigue Procedure for Suit Materials.

6-1.3.1 Specimens shall be subjected to flexural fatigue in accordance with ASTM F 392, *Standard Test Method for Flex Durability of Flexible Barrier Materials*, with the following modifications:

(a) In lieu of Flexing Conditions A, B, C, D, or E, test specimens shall have a flex period of 100 cycles at 45 cycles per minute. A cycle shall be full flex and twisting action.

(b) Anisotropic materials shall be tested in both machine and transverse directions.

6-1.3.2 The preconditioning shall be performed according to the sequence specified in the test methods of this chapter.

6-1.4 Abrasion Procedure for Suit Materials.

6-1.4.1 Specimens shall be abraded in accordance with ASTM D 4157, *Standard Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)*, under the following conditions:

(1) A 2.3 kg (5 lb) tension weight shall be used.
(2) A 1.6 kg (3 $^1/_2$ lb) head weight shall be used.
(3) An 80 grit abradant trimite D-weight open coat #1A4180, or equivalent, shall be used.
(4) The specimen shall be abraded for 25 continuous cycles.

6-1.5 Flexural Fatigue Procedure for Gloves. Specimen gloves shall be subjected to one full cycle of dexterity testing as specified in Section 6-17.

6-1.6 Flexural Fatigue Procedure for Footwear. Specimen footwear shall be subjected to 100,000 flexes in accordance with Footwear Industries of America Standard 1209, *Whole Shoe Flex*.

6-1.7 Fatigue Procedure for Suit Closure Assemblies. Specimen suit closure assemblies shall be exercised a total of 50 openings and 50 closings.

6-1.8 Embrittlement Procedure for Suit, Visor and Faceshield, Glove, and Footwear Materials. Specimen suit, visor, glove, and footwear materials shall be embrittled in accordance with ASTM D 2136, *Standard Test Method for Coated Fabrics — Low Temperature Bend Test*, with the following modifications:

(1) Embrittlement shall be conducted in a freezer having a temperature no higher than –25°C (–13°F).
(2) The material specimen shall first be placed on a flat sheet of dry ice with outer surface of the material in contact with the dry ice for a period of 15 minutes under a pressure of 3.5 kPa ($^1/_2$ psi).
(3) The material specimen shall be removed from the dry ice after 15 minutes of contact and immediately placed in the test apparatus.
(4) The bending action of the test apparatus shall be immediately activated while the sample is still in the freezer.

6-1.9 Dry Environment Conditioning Procedure for Suit and Glove Materials.

6-1.9.1 Specimens shall be conditioned at a temperature of 24°C, ±3°C (75°F, ±5°F) and a relative humidity of 45 percent, ±5 percent until equilibrium is reached, as determined in accordance with Section 4 of Federal Test Method Standard 191A, *Textile Test Methods*, or for at least 24 hours, whichever is shortest.

6-1.9.2 Specimens shall be tested within 5 minutes after removal from conditioning.

6-2 Gastight Integrity Test.

6-2.1 Application.

6-2.1.1 This test method shall apply to vapor-protective ensembles and individual glove and footwear elements.

6-2.1.2 Modifications to this test method for testing vapor-protective ensembles shall be as specified in 6-2.7.

6-2.1.3 Modifications to this test method for testing individual glove elements shall be as specified in 6-2.8.

6-2.1.4 Modifications to this test method for testing individual footwear elements shall be as specified in 6-2.9.

6-2.2 Specimens.

6-2.2.1 A minimum of three specimens shall be tested.

6-2.2.2 Where the vapor-protective ensemble consists of multiple separate layers, and outer layers are not considered gastight, then only the portion of the vapor-protective suit that is considered gastight shall be tested.

6-2.3 Preparation.

6-2.3.1 Samples for conditioning shall be complete vapor-protective ensembles, individual glove elements, or footwear elements.

6-2.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-2.4 Procedure.

6-2.4.1 Specimens shall be tested in accordance with ASTM F 1052, *Standard Test Method for Pressure Testing of Vapor-Protective Ensembles.*

6-2.4.2 The following pressures shall be used during testing:

(1) Pre-test expansion pressure of 125 mm (5 in.) water gauge
(2) Test pressure of 100 mm (4 in.) water gauge

6-2.5 Report. The ending pressure shall be reported for each specimen.

6-2.6 Interpretation.

6-2.6.1 Where the ending pressure is less than 80 mm ($3\ ^{5}/_{32}$ in.), the specimen shall be recorded as failing.

6-2.6.2 Any one specimen failing the test shall constitute failure of the test.

6-2.7 Specific Requirements for Testing Vapor-Protective Ensembles.

6-2.7.1 A minimum of one vapor-protective ensemble shall be tested.

6-2.7.2 Where the vapor-protective suit consists of multiple separate layers, and outer layers are not considered gastight, then only the portion of the vapor-protective suit that is considered gastight shall be tested.

6-2.7.3 Ensembles failing the test shall be permitted to be repaired. A report indicating the repairs made shall be provided by the manufacturer.

6-2.8 Specific Requirements for Testing Glove Individual Elements.

6-2.8.1 A minimum of one pair of gloves shall be tested.

6-2.8.2 A test fixture that provides a gastight seal with the cuff of the glove shall be utilized. The fixture shall have a valved port to allow air introduction and pressure measurement. The test fixture shall be permitted to be a vapor-protective suit.

6-2.8.3 Gloves failing this test shall not be permitted to be repaired.

6-2.9 Specific Requirements for Testing Footwear Individual Elements.

6-2.9.1 A minimum of one pair of footwear items shall be used.

6-2.9.2 A test fixture that provides a gastight seal with the footwear shall be utilized. The fixture shall have valved port to allow air introduction and pressure measurement. The test fixture shall be permitted to be a vapor-protective suit.

6-2.9.3 Repairs to footwear failing this test shall not be permitted.

6-3 Liquidtight Integrity Test.

6-3.1 Application.

6-3.1.1 This test method shall apply to complete vapor-protective ensembles.

6-3.2 Specimens.

6-3.2.1 A minimum of one specimen shall be tested. The specimen shall consist of the entire ensemble with all layers assembled that are required for the ensemble to be compliant.

6-3.2.2 The size of the ensembles comprising the specimens shall conform to the size of the mannequin in terms of chest circumference, waist circumference, and inseam height in accordance with the manufacturer's sizing system.

6-3.3 Preparation.

6-3.3.1 Samples for conditioning shall be complete ensembles.

6-3.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-3.4 Apparatus.

6-3.4.1* The apparatus and supplies for testing shall be those specified in ASTM F 1359, *Standard Test Method for Measuring the Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Using a Shower Spray While on a Mannequin*, using the following modifications:

(1) The surface tension of the water used in testing shall be 32 dynes/cm, ±2 dynes/cm (32 N/m, ±2 N/m).
(2) The mannequin used in testing shall have straight arms and legs, with one arm positioned at the mannequin's side and the other arm bent upward at the elbow at a 45 degree angle.
(3) The absorptive garment shall cover all portions of the mannequin that are covered by the test specimen.

6-3.5 Procedure.

6-3.5.1 Liquidtight integrity testing of garments shall be conducted in accordance with ASTM F 1359, *Standard Test Method for Measuring Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Using a Shower Spray While on a Mannequin*, with the following modifications:

(1) The method used for mounting the mannequin in the spray chamber shall not interfere with the water spray.
(2) The suited mannequin shall be exposed to the liquid spray for a total of 1 hour, 15 minutes in each of the four specified mannequin orientations.

(3) At the end of the liquid spray exposure period, excess liquid shall be removed from the surface of the specimen.
(4) The specimen shall be inspected within 5 minutes of the end of the liquid spray exposure period for evidence of liquid penetration.

6-3.6 Report. A diagram shall be prepared for each test that identified the locations of any liquid leakage as detected on the interior of the vapor-protective ensemble or the liquid-absorptive suit.

6-3.7 Interpretation.

6-3.7.1 Any evidence of liquid inside the specimen or on the interior of the vapor-protective ensemble or the liquid-absorptive suit, as determined by visual, tactile, or absorbent toweling, shall constitute failure of the specimen.

6-3.7.2 If outer gloves are to be worn in conjunction with chemical protective suit gloves or if outer boots are to be worn in conjunction with suit booties to meet the glove or foot protection requirements, these items shall not to be permitted to fill with liquid.

6-4 Overall Ensemble Function and Integrity Test.

6-4.1 Application. This test method shall apply to vapor-protective ensembles.

6-4.2 Specimens.

6-4.2.1 A minimum of one complete vapor-protective ensemble shall be evaluated.

6-4.2.2 The test specimen shall include all outer wear and other items required for the vapor-protective suit to be compliant with this standard.

6-4.3 Preparation.

6-4.3.1 Samples for conditioning shall be complete vapor-protective ensembles.

6-4.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-4.4 Procedure.

6-4.4.1 Suit overall function and integrity shall be measured in accordance with ASTM F 1154, *Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical Protective Suit Ensembles*, with the following parameters:

(a) Both exercise Procedures A and B shall be used.

(b) Ensembles tested shall meet the sizing range of the test subject as determined in 3-3.1.4. The suit shall be donned in accordance with the manufacturer's instructions.

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

(d) Gastight integrity shall be measured as specified in Section 6-2.

(e) A determination shall be made that the vapor-protective suit is designed to at least accommodate head protection meeting the dimensional requirements of Type I, Class G helmets of ANSI Z89.1, *Standard for Industrial Head Protection*.

(f) The test subject shall have a minimum visual acuity of 20/20 in each eye, uncorrected or corrected with contact lenses, as determined in a visual acuity test or doctor's examination.

(g) Appropriate underclothing and a self-contained breathing apparatus (SCBA) shall be worn. For consistency in testing, the SCBA shall be compliant with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*.

6-4.4.2 Visual acuity testing shall be conducted using a standard 20-foot eye chart, with a normal lighting range of 100–150 ft candles at the chart and with the test subject positions at a distance of 6.1 m (20 ft) from the chart.

6-4.4.3 The test subject shall then read the standard eye chart through the lens of the SCBA facepiece and suit visor to determine the test subject's visual acuity.

6-4.4.4 At the end of all testing, the test subject shall be instructed to remove his or her hands from each of the gloves while still wearing the suit, touch the bypass valve on the SCBA, and then reinsert his or her hands into the gloves. This action shall be repeated a total of five times.

6-4.5 Report.

6-4.5.1 The end suit pressure shall be reported.

6-4.5.2 The ability of the test subject to satisfactorily complete all exercises shall be reported.

6-4.5.3 The suit accommodation of head protection meeting the dimensional requirements of Type I, Class G helmets of ANSI Z89.1, *Standard for Industrial Head Protection*, shall be reported.

6-4.5.4 The visual acuity of the test subject when in and out of the suit shall be reported.

6-4.5.5 The ability of the test subject to repeatedly remove and reinsert his or her hands completely into the gloves shall be reported.

6-4.6 Interpretation.

6-4.6.1 Following the test subject exercises, an ending suit pressure of less than 80 mm ($3\,^{5}/_{32}$ in.) shall constitute failing performance.

6-4.6.2 The inability of the test subject to satisfactorily complete all exercises shall constitute failing performance.

6-4.6.3 The nonaccommodation of head protection meeting the dimensional requirements of Type I, Class G helmets of ANSI Z89.1, *Standard for Industrial Head Protection*, by the vapor-protective suit shall constitute failing performance.

6-4.6.4 The visual acuity of the test subject when inside the suit shall be used for determining pass/fail.

6-4.6.5 The inability of the test subject to repeatedly remove and reinsert his or her hands completely into the gloves shall constitute failing performance.

6-5 Maximum Suit Ventilation Rate Test.

6-5.1 Application. This test method shall apply to vapor-protective ensembles.

6-5.2 Specimens.

6-5.2.1 A minimum of one complete vapor-protective suit shall be evaluated.

6-5.2.2 The test specimen shall include all outer wear and other items required for the vapor-protective ensemble to be compliant with this standard.

6-5.3 Preparation.

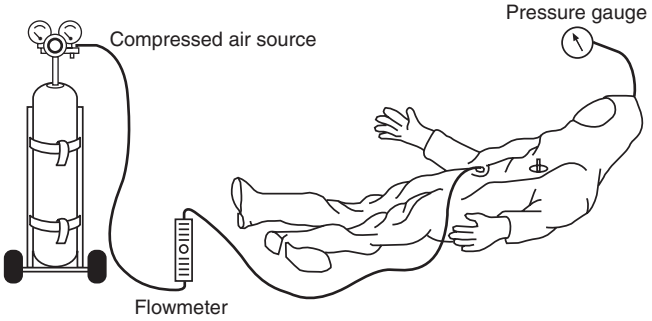
6-5.3.1 Samples for conditioning shall be complete vapor-protective ensembles.

6-5.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-5.4 Apparatus.

6-5.4.1 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 vapor-protective suit to be tested as indicated in Figure 6-5.4.1. The connector and airline hose shall allow an airflow rate of 500 L/min. The connector used in this test shall be permitted to be a standard airline connection that is used with airline respiratory equipment.

FIGURE 6-5.4.1 Configuration of whole suit maximum airflow test.



6-5.4.2 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.

6-5.4.3 A pressure gauge capable of measuring pressures from 0 to 510 mm, ±3 mm (0 to 20 in., $\pm 1/8$ in.) water column gauge pressure shall be attached via a second suit wall connector at the very top of the vapor-protective suit.

6-5.5 Procedure.

6-5.5.1 Following the attachment of the two connectors, the gastight integrity of the suit shall be tested as specified in Section 6-2.

6-5.5.2 During the test, the pressure gauge specified in 6-5.4.2 shall be attached to one bulkhead connector; the other bulkhead connector shall be plugged. 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. The remaining steps of this procedure shall be completed only if the sample suit shows an ending pressure of 80 mm ($3\ 3/16$ in.) water column gauge or higher.

6-5.5.3 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.

6-5.5.4 Beginning at time zero, air shall be flowed into the suit at a rate of 500 L/min.

6-5.5.5 After a period of 5 minutes, the pressure at the head connector shall be measured. A pressure of 38 mm ($1 1/2$ in.) water column gauge or higher shall constitute failing performance.

6-5.5.6 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 Section 6-2.

6-5.6 Report.

6-5.6.1 The maximum internal suit pressure during the airflow period shall be reported.

6-5.6.2 The ending suit pressure for the gastight integrity tests before and after the airflow period shall be reported.

6-5.7 Interpretation.

6-5.7.1 A maximum internal suit pressure of 38 mm ($1 1/2$ in.) water column gauge during the airflow period shall constitute failing performance.

6-5.7.2 Following the maximum airflow test, an ending suit pressure of less than 80 mm ($3\ 5/32$ in.) water column gauge shall constitute failing performance.

6-6 Chemical Permeation Resistance Test.

6-6.1 Application.

6-6.1.1 This test method shall apply to suit materials, visor materials, glove materials, footwear materials, and seams.

6-6.1.2 Modifications to this test method for testing suit materials after flexing and abrading shall be as specified in 6-6.8.

6-6.1.3 Modifications to this test method for testing glove materials after flexing and abrading shall be as specified in 6-6.9.

6-6.1.4 Modifications to this test method for testing footwear materials after flexing and abrading shall be as specified in 6-6.10.

6-6.1.5 Modifications to this test method for testing seams shall be as specified in 6-6.11.

6-6.1.6 Modifications to this test for testing primary materials against liquefied gases shall be as specified in 6-6.12.

6-6.1.7 Modifications to this test for testing suit, visor, glove, and footwear materials following cold temperature embrittlement exposure shall be as specified in 6-6.13.

6-6.2 Samples.

6-6.2.1 Samples for conditioning shall be either vapor-protective ensembles or suit materials, visor materials, gloves, and footwear.

6-6.2.2 For composite materials, only the chemical protection layer shall be the sample for testing for chemical permeation resistance.

6-6.3 Specimens. A minimum of three specimens shall be tested per chemical challenge.

6-6.4 Preparation. Specimens shall be conditioned at least as specified in 6-1.2.

6-6.5 Procedure.

6-6.5.1 Permeation resistance shall be measured in accordance with ASTM F 739, *Standard Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids and Gases*, at 27°C, ±2°C (81°F, ±3°F) for a test duration of at least 3 hours.

6-6.5.2 The minimum detectable permeation rate for the permeation test apparatus shall be measured for each chemical tested. The minimum detectable permeation rate shall be less

than or equal to 0.10 μg/cm^2/min for all permeation resistance tests. When using closed loop systems, the testing laboratory shall assume 1 hour accumulated permeation.

6-6.6 Report.

6-6.6.1 The following information and results shall be reported:

(1) Material type or name
(2) Chemical or chemical mixture (volume composition of mixture)
(3) Permeation normalized breakthrough detection time in minutes calculated at a system detectable permeation rate of 0.10 μg/cm^2/min
(4) Maximum permeation rate (μg/cm^2/min) observed
(5) Minimum detectable rate for test apparatus (μg/cm^2/min)
(6) Detection method
(7) Date of test
(8) Testing laboratory

6-6.6.2 The manufacturer shall report all three measured normalized breakthrough detection times in the technical data package.

6-6.6.3 The manufacturer shall report all three observed permeation rates in the technical data package.

6-6.7 Interpretation.

6-6.7.1 The shortest normalized breakthrough detection time shall be used in determining compliance for the particular material/chemical combination.

6-6.7.2 Any normalized breakthrough detection time of 1 hour or less constitutes failing performance.

6-6.8 Specific Requirements for Testing Suit Materials After Flexing and Abrading.

6-6.8.1 Samples for conditioning shall be 200 mm × 280 mm (8 in. × 11 in.) rectangles and shall consist of all layers as configured in the suit.

6-6.8.2 Two samples shall first be conditioned by flexing as specified in 6-1.3. One sample shall be flexed with the longitudinal axis parallel to the machine direction of the material, and the second sample shall be flexed with the longitudinal axis parallel to the cross machine direction of the material. Following flexing, two samples for abrasion conditioning, each measuring 45 mm × 230 mm (1 $^3/_4$ in. × 9 in.), shall be cut from the center of the flexed samples. At least one specimen for abrasion conditioning shall be taken from a sample flexed in the machine direction, and at least one specimen for abrasion conditioning shall be taken from a sample flexed in the cross machine direction for each chemical tested.

6-6.8.3 These new samples for abrasion conditioning shall then be conditioned by abrading as specified in 6-1.4. Following abrasion, only one specimen for permeation resistance testing shall be taken from each sample subjected to abrasion. The permeation test specimen shall be taken from the exact center of the abraded sample so that the center of the permeation test and the center of the abraded sample coincide.

6-6.9 Specific Requirements for Testing Glove Materials After Flexing and Abrading.

6-6.9.1 Samples for conditioning shall be whole glove components or whole glove individual elements.

6-6.9.2 Samples shall first be conditioned by flexing as specified in 6-1.5. Following flexing, three samples for abrasion conditioning, each measuring 45 mm × 230 mm (1 $^3/_4$ in. × 9 in.), shall be cut from the center of the gauntlet portion of the flexed sample. At least one specimen for abrasion conditioning shall be taken from a sample flexed in the machine direction, and at least one specimen for abrasion conditioning shall be taken from a sample flexed in the cross machine direction for each chemical tested.

6-6.9.3 These new samples for abrasion conditioning shall then be conditioned by abrading as specified in 6-1.4. Following abrasion, only one specimen for permeation resistance testing shall be taken from each sample subjected to abrasion. The permeation test specimen shall be taken from the exact center of the abraded sample so that the center of the permeation test and the center of the abraded sample coincide.

6-6.10 Specific Requirements for Testing Footwear Materials After Flexing and Abrading.

6-6.10.1 This test shall apply to all types of footwear configurations. If the footwear incorporates a bootie constructed of suit material, the suit material flex fatigue resistance test shall be permitted to be substituted for this test.

6-6.10.2 Samples for conditioning shall be whole footwear components or whole footwear individual elements.

6-6.10.3 Samples shall first be conditioned by flexing as specified in 6-1.5. Following flexing, three samples for abrasion conditioning, each measuring 45 mm × 230 mm (1 $^3/_4$ in. × 9 in.), shall be cut from the center of the footwear upper where the greatest flexing occurred, usually at the quarter or vamp of the flexed sample. At least one specimen for abrasion conditioning shall be taken from a sample flexed in the machine direction, and at least one specimen for abrasion conditioning shall be taken from a sample flexed in the cross machine direction for each chemical tested.

6-6.10.4 These new samples for abrasion conditioning shall then be conditioned by abrading as specified in 6-1.4. Following abrasion, only one specimen for permeation resistance testing shall be taken from each sample subjected to abrasion. The permeation test specimen shall be taken from the exact center of the abraded sample so that the center of the permeation test and the center of the abraded sample coincide.

6-6.11 Specific Requirements for Testing Seams.

6-6.11.1 Seam specimens shall be prepared from seam samples that have a minimum of 150 mm (6 in.) of material on each side of the seam center. Permeation test specimens shall be cut such that the exact seam center divides the specimen in half.

6-6.11.2 Seam specimens shall be prepared representing each different of seam or shall be taken from each different type of seam found in the vapor-protective suit, including as a minimum the suit to suit material seams and the suit to visor material seams.

6-6.11.3 Samples for conditioning shall be 600-mm (23 $^9/_{16}$-in.) lengths of prepared seam or cut from vapor-protective ensembles.

6-6.12 Specific Requirements for Testing Primary Materials Against Liquefied Gases.

6-6.12.1 The test cell and test chemical shall be maintained at a temperature sufficient to keep the test chemical as a liquid such that a 13-mm ($^1/_2$-in.) liquid layer is maintained at all times during the test.

6-6.12.2 The permeation test shall be conducted for a minimum of 1 hour.

6-6.13 Specific Requirements for Testing Suit, Visor, Glove, and Footwear Materials Following Cold Temperature Embrittlement Exposure.

6-6.13.1 Samples for conditioning shall be suit material, visor material, glove material from the glove gauntlet, and footwear material from the footwear upper.

6-6.13.2 Specimens shall be conditioned as specified in 6-1.8.

6-6.13.3 Only one specimen for permeation resistance testing shall be taken from each sample subjected to embrittlement conditioning. The permeation test specimen shall be taken from the exact center of the folded sample so that the center of the permeation test and the center of the folded sample coincide.

6-7 Flammability Resistance Test.

6-7.1 Application.

6-7.1.1 This test method shall be apply to suit, visor, glove, and footwear materials.

6-7.2 Sample Preparation.

6-7.2.1 Samples for conditioning shall be at least 1-m (1-yd) squares of material.

6-7.2.2 Samples shall be conditioned as specified in 6-1.2.

6-7.3 Specimens.

6-7.3.1 Five specimens in each of the warp direction, machine or coarse, and filling direction, cross-machine or wales, shall be tested.

6-7.3.2 Where the material is nonanisotropic, then 10 specimens shall be tested.

6-7.4 Procedure. Flame resistance testing shall be conducted in accordance with ASTM F 1358, *Standard Test Method for Resistance of Protective Clothing Materials to Flame Impingement*

6-7.5 Report.

6-7.5.1 Afterflame times and burn distances results shall be reported for each specimen and as the average for each material direction.

6-7.5.2 The burning behavior observations of each specimen shall be reported.

6-7.6 Interpretation.

6-7.6.1 Failure of the material in any direction shall constitute failing performance.

6-7.6.2 Any specimen exhibiting melting as evidenced by dripping or flowing shall constitute failing performance.

6-8 Overall Ensemble Inward Leakage Test.

6-8.1 Application. This test method shall apply to complete vapor-protective ensembles.

6-8.2 Sample. Samples for conditioning shall be complete vapor-protective ensembles.

6-8.3 Specimen Preparation.

6-8.3.1 A minimum of one specimen shall be tested.

6-8.3.2 Specimens shall be conditioned at a temperature of 21°C, ±3°C (70°F, ±5°F) and a relative humidity of 65 percent, ±5 percent until equilibrium is reached, as determined in accordance with Section 4 of Federal Test Method Standard 191A, *Textile Test Methods*, or for at least 24 hours, whichever is shortest. Specimens shall be tested within 5 minutes after removal from conditioning.

6-8.4 Apparatus.

6-8.4.1 Sulfur hexafluoride, CAS No. 2551-62-4, with a minimum purity of 99.8 percent, shall be used as the test agent.

6-8.4.2 The test shall be conducted in a sealed test chamber with minimum volume of 28 m^3 (1000 ft^3). The chamber shall be of sufficient dimensions to permit free movement of the test subject when fully dressed in the vapor-protective ensemble. The chamber shall have a circulating fan or other means to ensure uniform concentration of the test agent throughout the chamber during the test. The exact dimensions of the chamber shall be measured, and shall be used to calculate the total volume of the chamber in order to determine the amount of sulfur hexafluoride gas to be added to achieve the required concentration specified in 6-8.5.6.

6-8.4.3 Two calibrated portable pumps that are capable of maintaining a flow rate of 0.1 L/min, ±0.005 L/min, shall be provided.

6-8.4.3.1 One pump shall be placed in the test chamber, as close as possible to the center of the test chamber, such as on a table or fixture.

6-8.4.3.2 The second pump shall be placed inside the vapor-protective ensemble by the test subject during donning. The pump shall be secured on the test subject's belt or other device in such a manner that the pump does not interfere with the ensemble or with the test subject's free movement during the test.

6-8.4.4 At least eight gastight sampling bags shall be used to collect air samples during testing. Sampling bags shall have a capacity of at least 1 L (33 oz).

6-8.4.4.1 Four gastight sampling bags shall be used to collect air samples inside the test chamber during testing. The sampling bags shall be placed with the second pump in the test chamber.

6-8.4.4.2 Four gastight sampling bags shall be used to collect air samples inside the vapor-protective ensemble during testing. The sampling bags shall be secured on the test subject's belt, other device, or in a pouch or pocket in such a manner that the bags do not interfere with the ensemble or with free movement during the test.

6-8.4.5 All test subjects shall have a medical doctor's certificate that substantiates they are medically and physically suitable to perform these tests without danger to themselves. The medical certificate shall have been issued within 12 months prior to the testing.

6-8.4.6 Test subjects shall be familiar with the use of vapor-protective ensembles and with self-contained breathing appa-

ratus (SCBA). The test subject shall select the appropriate size of the vapor-protective ensemble from available sizes using the manufacturer's sizing chart.

6-8.4.7 For consistency in testing, the SCBA used for all testing with the vapor-protective ensemble shall be certified as compliant with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, and shall be equipped with a fully charged 60-minute breathing air gas cylinder.

6-8.5 Procedure.

6-8.5.1 One portable sampling pump and at least four gastight sampling bags shall be placed inside the test chamber as specified in 6-8.4.3.1 and 6-8.4.4.1.

6-8.5.2 The test subject shall secure the second portable sampling pump and at least four gastight sampling bags inside the ensemble as specified in 6-8.4.3.2 and 6-8.4.4.2 prior to completely donning the SCBA and the vapor-protective ensemble in accordance with the manufacturer's instructions.

6-8.5.3 After sealing the vapor-protective ensemble, the test subject shall enter the test chamber, and the test chamber shall be sealed.

6-8.5.4 At least one baseline sample set shall be taken prior to the addition of test agent to the chamber. A baseline sample set shall consist of one chamber air sample and one ensemble air sample. One sample of chamber air shall be collected for each sample taken inside the vapor-protective ensemble.

6-8.5.4.1 The chamber air sampling shall be collected inside the test chamber, in a position as near as possible to the center of the test chamber, outside of the vapor-protective ensemble.

6-8.5.4.2 The ensemble air sampling shall be collected inside the vapor-protective ensemble. The inlet port of the sampling probe shall be placed near the mid-torso of the test subject.

6-8.5.4.3 Each air test sample shall be collected at a flow rate of 0.1 L/min, ±0.005 L/min, for 8 minutes, ±30 seconds.

6-8.5.5 The baseline chamber air sample shall be initiated by the test subject by connecting a sampling bag to the pump and turning on the pump. Once the chamber air sample is started, the test subject shall initiate the baseline ensemble air sample so as to conduct both air samplings nearly simultaneously.

6-8.5.5.1 To conduct the baseline ensemble air sample, the test subject shall pull his or her hands inside the ensemble, connect the sampling bag to the pump, and turn on the pump.

6-8.5.5.2 At the end of the baseline chamber and ensemble air sampling periods, the sampling bags shall be removed from the pump, sealed, and stored.

6-8.5.6 The test subject shall then remain in the sealed test chamber while sufficient sulfur hexafluoride is added to the test chamber to achieve a concentration of 1000 ppm, ±100 ppm. The air inside the chamber shall be allowed to reach equilibrium for a period of 3 minutes, ±30 seconds, prior to performing the inward leakage detection testing.

6-8.5.7 Following the chamber air reaching equilibrium, the test subject shall perform at least three air test sample sets for inward leakage detection testing. A sample set shall consist of one chamber air sample and one ensemble air sample. One sample of chamber air shall be collected for each air test sample taken inside the vapor-protective ensemble.

6-8.5.7.1 The chamber air sampling shall be collected inside the test chamber, in a position as near as possible to the center of the test chamber, outside of the vapor-protective ensemble.

6-8.5.7.2 The first ensemble air sample shall be taken with the inlet port of the sampling probe secured near the breathing zone of the test subject around the face, outside the SCBA facepiece.

6-8.5.7.3 The second ensemble air sample shall be taken with the inlet port of the sampling probe placed near the exhaust valves of the vapor-protective ensemble.

6-8.5.7.4 The third ensemble air sample shall be taken with the inlet port of the sampling probe placed near the vapor-protective ensemble closure assembly.

6-8.5.7.5 Each air test sample shall be collected at a flow rate of 0.1 L/min, ±0.005 L/min, for 8 minutes, ±30 seconds.

6-8.5.8 The test subject shall perform one series of stationary exercises for each of the three air test sample sets. The stationary exercises shall be as specified in Procedure A of ASTM F 1154, *Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical Protective Suit Ensembles,* as modified by 6-8.5.10.

6-8.5.9 Immediately prior to the start of each exercise series, the chamber air sample for the inward leakage detection testing shall be initiated by the test subject who shall connect a sampling bag to the pump, and turn on the pump. Once the chamber air sample is started, the test subject shall initiate the ensemble air sample so as to conduct both air samplings nearly simultaneously.

6-8.5.9.1 To conduct the ensemble air sample, the test subject shall pull his or her hands inside the ensemble, connect a sampling bag to the pump, and turn on the pump.

6-8.5.9.2 At the end of the chamber and ensemble air sampling periods, the sampling bags shall be removed from the pumps, sealed, and stored.

6-8.5.10 The stationary exercises specified in Procedure A of ASTM F 1154, *Standard Practices for Qualitatively Evaluating the Comfort Fit, Function, and Integrity of Chemical Protective Suit Ensembles*, shall be performed with the following modification: at the conclusion of the "duck squat" exercise specified in paragraph 8.8.2 of ASTM F 1154, the test subject shall remain in a squatting position, and exhaust as much of the internal volume of the suit as possible by placing the hands on top of the head, tucking the arms in toward the body, and gathering as much of the excess ensemble material to the body as possible. The test subject shall then stand quickly with arms stretched overhead to create a possible negative pressure inside the suit. The test subject shall then resume the exercise protocol as specified in Procedure A of ASTM F 1154.

6-8.5.11 At the end of each exercise series, the test subject shall remove the chamber and ensemble air sampling bags, seal and store the sampling bags, attach new sampling bags to each pump, initiate new chamber and ensemble air sampling, and then begin the next exercise series.

6-8.5.12 At the conclusion of the three exercise series and collection of chamber and ensemble air samples, the test subject shall turn off both sampling pumps and shall remain in the

test chamber for 5 minutes, ±1 minute, while the chamber is evacuated. The test subject shall then exit the chamber and doff the vapor-protective ensemble in an area well away from the chamber.

6-8.5.13* All samples collected shall be analyzed using an appropriate analytical technique within 8 hours of collection. The sensitivity of the analytical technique chosen shall provide for a minimum detection limit of at least 0.18 ppm in order to determine compliance with 5-9.4.

6-8.6 Interpretation.

6-8.6.1 The percent inward leakage of sulfur hexafluoride into the ensemble shall be calculated based on the measured concentration inside the ensemble versus measured concentration in the test chamber for each sampling location using the following equation:

$$\text{percent} = \frac{\text{(concentration inside ensemble)} - \text{(baseline inside ensemble)}}{\text{inward leakage} \times [\text{(concentration in text chamber)} - \text{(baseline in text chamber)}]} \times 100$$

6-8.6.2 All calculations shall be reviewed to determine pass/fail in accordance with 5-9.4.

6-8.6.3 Failure at any sampling location shall constitute failure of the test.

6-9 Exhaust Valve Mounting Strength Test.

6-9.1 Application. This test method shall apply to exhaust valves mounted in vapor-protective ensembles.

6-9.2 Sample Preparation.

6-9.2.1 Samples for conditioning shall be exhaust valve and suit material specimens described in 6-9.2.

6-9.2.2 Samples shall consist of an exhaust valve mounted into a piece of garment material having a minimum diameter of 200 mm (8 in.).

6-9.2.3 The means of mounting the exhaust valve shall be representative of the construction practices used to fabricate the vapor-protective suit.

6-9.3 Specimens.

6-9.3.1 A minimum of three specimens shall be tested.

6-9.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-9.4 Apparatus.

6-9.4.1 A specimen mounting ring shall be used for clamping the sample. The mounting ring shall have an inner diameter of 150 mm (6 in.). 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. 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.

6-9.4.2 A flat plate pushing device shall be 50 mm (2 in.) in diameter and 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.

6-9.4.3 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 percent 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.

6-9.5 Procedure.

6-9.5.1 Specimens shall be clamped into the specimen mounting ring and attached to the fixed arm of a tensile testing machine.

6-9.5.2 The flat plate pushing device shall be attached to the movable arm of a tensile testing machine.

6-9.5.3 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.

6-9.5.4 The maximum force registered by the indicating device of the tensile testing machine shall be recorded for each determination.

6-9.6 Report.

6-9.6.1 The mounting strength of each specimen shall be reported to the nearest 1 N ($^1/_4$ lbf).

6-9.6.2 The average mounting strength shall be calculated and reported to the nearest 1 N ($^1/_4$ lbf).

6-9.7 Interpretation. The average mounting strength shall be used to determine pass/fail performance.

6-10 Burst Strength Test.

6-10.1 Application.

6-10.1.1 This test shall apply to suit and visor materials.

6-10.1.2 Where vapor-protective suits are constructed of several separable layers, then all layers, assembled in the order in which they appear in the suit, shall be tested as a composite.

6-10.2 Sample Preparation. Samples for conditioning shall be at least 1-m (1-yd) squares of material.

6-10.3 Specimens.

6-10.3.1 A total of ten specimens shall be tested.

6-10.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-10.4 Procedure. Material burst strength shall be measured in accordance with ASTM D 751, *Standard Methods of Testing Coated Fabrics,* using the tension testing machine with ring clamp.

6-10.5 Report. The burst strength of each specimen shall be reported to the nearest 1 N ($^1/_4$ lbf). The average burst strength of all specimens shall be calculated and reported.

6-10.6 Interpretation. The average burst strength shall be used to determine pass/fail performance.

6-11 Puncture Propagation Tear Resistance Test.

6-11.1 Application.

6-11.1.1 This test shall apply to suit and visor materials.

6-11.1.2 Where the protective suit is constructed of several layers, then all layers, assembled in the order in which they appear in the suit, shall be tested as a composite.

6-11.2 Sample Preparation. Samples for conditioning shall be at least 1-m (1-yd) squares of material.

6-11.3 Specimens.

6-11.3.1 A minimum of five specimens in each of the warp, machine or coarse, and filling, cross-machine or wales, directions shall be tested.

6-11.3.2 If the material is nonanisotropic, then ten specimens shall be tested.

6-11.3.3 Specimens shall be conditioned as specified in 6-1.2.

6-11.4 Procedure. Specimens shall be tested in accordance with ASTM D 2582, *Standard Test Method for Puncture Propagation Tear Resistance of Plastic Film and Thin Sheeting.*

6-11.5 Report.

6-11.5.1 The puncture propagation tear resistance of each specimen shall be reported to the nearest 1 N (0.1 lbf).

6-11.5.2 An average puncture propagation tear resistance shall be calculated for warp and filling directions.

6-11.6 Interpretation.

6-11.6.1 Pass/fail performance shall be based on the average puncture propagation tear resistance in the warp and filling directions.

6-11.6.2 Failure in any one direction constitutes failure for the material.

6-12 Cold Temperature Performance Test One.

6-12.1 Application. This test method shall apply to suit and glove materials.

6-12.2 Specimens.

6-12.2.1 A minimum of five specimens consisting of all layers in each of the warp, machine or coarse, and filling, cross-machine or wales, directions shall be tested.

6-12.2.2 If the material is nonanisotropic, then ten specimens shall be tested.

6-12.3 Preparation.

6-12.3.1 Samples for conditioning shall be at least 1-m (1-yd) squares of material.

6-12.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-12.4 Procedure.

6-12.4.1 Specimens shall be tested in accordance with ASTM D 747, *Standard Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam,* with the following modifications:

(a) The test temperature shall be −25°C (−13°F).

(b) The bending moment shall be that applied when the specimen is bent to a 60 degree angular deflection and shall be calculated in inch-pounds as follows:

$$\text{Bending moment} = \frac{\text{load scale reading} \times \text{moment weight}}{100}$$

$$\text{Bending moment } (N_m) = \text{Bending moment(in.-lb} \times 0.113)$$

6-12.5 Report. Cold temperature performance results shall be reported as the average for each material direction.

6-12.6 Interpretation. Failure of the material in any direction shall constitute failing performance.

6-13 Fitting Pull Out Strength Test.

6-13.1 Application. This test method shall apply to each type of external fitting used in vapor-protective ensembles.

6-13.2 Sample Preparation.

6-13.2.1 Samples for conditioning shall be external fitting and suit material specimens described in 6-13.2.

6-13.2.2 Samples shall consist of the entire external fitting assembly. The means of mounting the external fitting assembly shall be representative of the construction practices used to fabricate the vapor-protective suit.

6-13.3 Specimens.

6-13.3.1 A minimum of three specimens shall be tested.

6-13.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-13.4 Apparatus.

6-13.4.1 A specimen mounting ring shall be used for clamping the sample. The mounting ring shall have an inner diameter of 150 mm (6 in.). 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. 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.

6-13.4.2 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.

6-13.4.3 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 percent 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.

6-13.5 Procedure.

6-13.5.1 Specimens shall be clamped into the specimen mounting ring and attached to the fixed arm of a tensile testing machine.

6-13.5.2 The jaws of the movable arm of a tensile testing machine shall be clamped onto the body of the external fitting.

6-13.5.3 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.

6-13.5.4 The maximum force registered by the indicating device of the tensile testing machine shall be recorded for each determination.

6-13.6 Report.

6-13.6.1 The pull out strength of each specimen shall be reported to the nearest 1 N ($^1/_4$ lbf).

6-13.6.2 The average pull out strength shall be calculated and reported to the nearest 1 N ($^1/_4$ lbf).

6-13.7 Interpretation. The average pull out strength shall be used to determine pass/fail performance.

6-14 Cold Temperature Performance Test Two.

6-14.1 Application. This test method shall apply to visor materials.

6-14.2 Sample Preparation. Samples for conditioning shall be at least 1-m (1-yd) squares of material.

6-14.3 Specimens.

6-14.3.1 A minimum of five specimens consisting of all layers shall be tested.

6-14.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-14.4 Procedure.

6-14.4.1 Specimens shall be tested in accordance with ASTM D 2136, *Standard Test Method for Coated Fabrics — Low Temperature Bend Test*, at a test temperature of −25°C (−13°F).

6-14.4.2 Following this testing, specimens shall be examined for evidence of damage. Damage shall include any breakage, cracks, tears, or separation, but shall not include discoloration along the folded area.

6-14.5 Report. Observations of visible damage shall be reported for each specimen.

6-14.6 Interpretation.

6-14.6.1 Damage of any one specimen shall constitute failing performance.

6-14.6.2 Rigid visors that do not bend but show no evidence of damage shall still be considered to have passed the test.

6-15 Cut Resistance Test.

6-15.1 Application.

6-15.1.1 This test method shall apply to glove materials and footwear upper materials.

6-15.1.2 Modifications to this test method for evaluation of glove materials shall be as specified in 6-15.7.

6-15.1.3 Modifications to this test method for evaluation of footwear upper materials shall be as specified in 6-15.8.

6-15.2 Sample Preparation. Samples for conditioning shall be whole gloves or footwear uppers.

6-15.3 Specimens.

6-15.3.1 A minimum of three specimens, consisting of all layers, shall be tested.

6-15.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-15.4 Procedure. Specimens shall be evaluated in accordance with ASTM F 1790, *Standard Test Methods for Measuring Cut Resistance of Materials Used in Protective Clothing*, with the modification that the specimens shall be tested to a specific load with the measurement of cut distance.

6-15.5 Report.

6-15.5.1 The cut distance shall be reported to the nearest 1 mm ($^3/_{64}$ in.) for each sample specimen.

6-15.5.2 The average cut distance in millimeters (inches) shall be reported for all specimens tested.

6-15.6 Interpretation. The average cut force shall be used to determine pass/fail performance.

6-15.7 Specific Requirements for Testing Glove Materials.

6-15.7.1 Specimens shall be taken from the back and palm of the glove and shall not include seams.

6-15.7.2 Cut resistance testing shall be performed under a load of 400 grams (14 oz).

6-15.8 Specific Requirements for Testing Footwear Upper Materials.

6-15.8.1 Specimens shall be taken from the parts of the footwear upper that provide uniform thickness and shall not include seams.

6-15.8.2 Cut resistance testing shall be performed under a load of 800 grams (28 oz).

6-16 Puncture Resistance Test One.

6-16.1 Application.

6-16.1.1 This test shall be applied to glove and footwear upper materials.

6-16.1.2 Modifications to this test method for testing glove materials shall be as specified in 6-16.7.

6-16.1.3 Modifications to this test method for testing footwear upper material shall be as specified in 6-16.8.

6-16.2 Sample Preparation. Samples for conditioning shall be complete gloves or footwear upper sections.

6-16.3 Specimens.

6-16.3.1 A minimum of three specimens consisting of all layers and each specimen measuring at least 150 mm (6 in.) square shall be tested.

6-16.3.2 Specimens shall be tested after conditioning as specified in 6-1.2.

6-16.4 Procedure. Specimens shall be tested in accordance with ASTM F 1342, *Standard Test Method for Resistance of Protective Clothing Materials to Puncture.*

6-16.5 Report.

6-16.5.1 The puncture force shall be reported for each specimen to the nearest 0.05 kg (0.1 lb) of force.

6-16.5.2 The average puncture force shall be reported for all specimens tested.

6-16.6 Interpretation. The average puncture force shall be used to determine pass/fail performance.

6-16.7 Specific Requirements for Testing Glove Materials.

6-16.7.1 Specimens shall consist of each composite of the palm, palm side of the fingers, and back of the glove used in actual suit glove configuration, with layers arranged in the proper order.

6-16.7.2 Where the specimen composites of the palm, palm side of the fingers, and back of the glove are identical, only one representative composite shall be required to be tested.

6-16.8 Specific Requirements for Testing Footwear Upper Materials.

6-16.8.1 Specimens shall consist of each composite of the footwear item used in the actual suit footwear configuration, with layers arranged in proper order.

6-16.8.2 Specimens shall be taken from the thinnest portion of the footwear upper.

6-17 Glove Hand Function Test.

6-17.1 Application. This test shall apply to gloves.

6-17.2 Specimens.

6-17.2.1 A minimum of one glove pair for each size provided with the suit shall be used for testing.

6-17.2.2 Each glove pair shall be tested as a complete set of gloves in new, as distributed, condition.

6-17.2.3 Glove pair specimens shall not receive special softening or flexing treatments prior to this test.

6-17.3 Sample Preparation.

6-17.3.1 Glove pair specimens shall be preconditioned as specified in 6-1.2.

6-17.3.2 Samples for conditioning shall be whole glove pairs.

6-17.4 Procedures.

6-17.4.1 Each glove size shall be evaluated by a separate test subject.

6-17.4.2 Test subjects shall be selected such that their hand dimensions conform to the manufacturer's sizing information for the glove sizes being evaluated.

6-17.4.3 Each test subject shall be familiarized with the test apparatus and procedure by practicing the test three times before conducting actual testing, but not on the same day of the actual testing.

6-17.5 Pegboard Procedure.

6-17.5.1 A pegboard apparatus that consists of 25 stainless steel pins and a pegboard shall be used. Each stainless steel pin shall have a diameter of 9.5 mm ($^3/_8$ in.) and a length of 38 mm ($1^1/_2$ in.). The pegboard shall have 25 holes, each hole having a diameter of 10 mm ($^{13}/_{32}$ in.) and a depth of 13 mm ($^1/_2$ in.). The holes shall be a 5 by 5 pattern and each hole shall have a separation of 25 mm (1 in.) from any adjacent hole.

6-17.5.2* Before each test, the pegs and pegboard shall be placed on a nominally 610 mm × 915 mm (24 in. × 36 in.) sheet of 1.6-mm (0.0625-in.) Neoprene having a hardness of 50, ±5 Shore A and a thickness of 1.57 mm (0.062 in.) ±10 percent. The pegs shall be randomly scattered in the working area most comfortable to the test subject, such as on the right side for right-handed subjects, left side for left-handed test subjects, or directly in front of the subject.

6-17.5.3 In starting the test, each peg shall be grasped near its end and shall be placed in the pegboard beginning at the upper left corner and proceeding from left-to-right and top-to-bottom. The pegs shall not be picked up from any surface other than the specified test surface, and shall not be picked up by sliding, standing, or otherwise supporting the peg with another object (such as the pegboard, another peg, or the test subject's free hand). Only one hand shall be used during the test, and only one peg shall be grasped at a time. The test subject shall not alternate hands during the test series. The pegboard shall be permitted to be prevented from moving during the test by the test subject's free hand or other means as necessary.

6-17.5.4 The dexterity test time shall be the time it takes from grasping the first peg to placing the last peg in the pegboard.

6-17.5.5 Each test subject shall perform the test without gloves following the steps in 6-17.5.2 through 6-17.5.4 until the variance of the dexterity times of that person's last three repetitions does not exceed 8 percent. Variance shall be calculated by dividing the standard deviation by the average of three repetitions, and multiplying by 100. The average of the three repetitions shall be used as the baseline dexterity test time (Dtt_b), and shall be between 25–45 seconds. The test shall be conducted without the test subject's knowledge of the dexterity test time for each repetition.

6-17.5.6 Each test subject shall then perform the test with one pair of gloves following the steps in 6-17.5.2 through 6-17.5.4 until the variance of the dexterity times of that person's fastest three repetitions does not exceed 8 percent. Variance shall be calculated as in 6-17.5.5. The average of the three fastest repetitions shall be used as the dexterity test time with gloves (DTT_g). The test shall be conducted without the test subject's knowledge of the dexterity test time for each repetition.

6-17.5.7 The dexterity test time with gloves shall be compared with the baseline dexterity test time for each test subject. The percent of bare-handed control shall be calculated for each glove size as follows:

$$\text{Percent of barehanded control} = \frac{DTT_g}{DTT_b} \times 100$$

where:

DTT_g = dexterity test time with gloves

DTT_b = baseline dexterity test time

6-17.6 Report. The average percent of barehanded control for all tests shall be calculated and reported.

6-17.7 Interpretation. The average percent of barehanded control for all tests shall be used to determine pass/fail performance.

6-18 Static Charge Accumulation Resistance Test.

6-18.1 Application. This test method shall apply to suit and glove materials.

6-18.2 Preparation.

6-18.2.1 Samples for conditioning shall be a 200 mm, ±13-mm (8 in., $\pm^1/_2$ in.) square.

6-18.2.2 Samples shall consist of only the exterior layer of suit or glove material composites to be tested.

6-18.3 Specimens.

6-18.3.1 A minimum of five specimens shall be cut from the material to be tested.

6-18.3.2 Specimens shall be conditioned as specified in 6-1.9.

6-18.4 Apparatus.

6-18.4.1 Triboelectric Test Device. The triboelectric test device shall consist of a grounded aluminum frame with two cutouts in the front faceplate.

The lower right cutout shall house the static detector head that is connected to an electrometer.

The upper left cutout shall be for the rubbing wheel used to generate the triboelectric charge.

This rubbing wheel shall be connected to a $^1/_8$ horsepower electric drive motor. A manual lever shall be used to slide the motor/rubbing wheel combination forward so that the wheel gently makes contact with the test specimen at the proper time.

The test pressure shall be held constant during the test by means of a weight and cord system. In this system, a cord shall be attached to the motor assembly, shall run over a pulley wheel, and a 1.4 kg, ±0.05 kg (3 lb, ±0.2 lb) weight shall be attached to the end of the cord.

The test specimen shall be tautly mounted in a grounded specimen holder.

6-18.4.2 Rubbing Wheel. The rubbing wheel shall have a diameter of 125 mm, ±2 mm (5 in., $\pm^1/_{16}$ in.). The standard wheel shall be constructed with a phenolic plastic back, a 25 mm (1 in.) thick foam cushion, and a felt polytetrafluoroethylene (PTFE) rubbing surface. Rubbing wheels shall be cleaned with a dry cloth after the completion of tests on a given material.

6-18.4.3 Data Gathering System. A digital oscilloscope with memory shall be used for gathering data.

The oscilloscope trigger shall be initiated with a 6-V battery connected to the oscilloscope trigger circuit through a microswitch on the sliding mechanism of the rubbing wheel.

When the rubbing wheel is moved away from the test specimen, thus ceasing charge generation, the microswitch shall initiate the oscilloscope trigger. The detector head shall sense the electrostatic field and the electrometer shall generate a dc voltage proportional to the electrostatic field sensed by the detector head. This voltage shall be fed into the oscilloscope input and shall be displayed on the oscilloscope Y axis versus time. The zero time shall be the time the microswitch circuit triggers the oscilloscope sweep that occurs at the cessation of sample rubbing.

The oscilloscope presentation shall also be permitted to be recorded on an x–y plotter directly connected to the oscilloscope.

The oscilloscope shall also be permitted to have a digital interface to send the data to a digital computer for further analysis and storage.

6-18.4.4 Static Eliminator. A static eliminator that is capable of removing a 25,000-V charge from a 200 mm square by 16 mm (8 in. square by $^5/_8$ in.) material specimen within 30 seconds shall be used. The static eliminator shall be placed in the test chamber or other testing area.

6-18.5 Procedure.

6-18.5.1 A clean rubbing wheel shall be placed in the test apparatus.

6-18.5.2 The triboelectric test apparatus shall be conditioned in a test environment of 23°C, ±3°C (75°F, ±5°F) and relative humidity of 45 percent, ±5 percent for a minimum of 24 hours.

6-18.5.3 The electrometer and oscilloscope shall be turned on and allowed to warm up for 30 minutes.

6-18.5.4 The test specimen shall be mounted in the sample holder.

6-18.5.5 The test operator shall verify or install the proper weights on the cord. The standard mass is 1.36 kg (3 lb).

6-18.5.6 The static eliminator shall be turned on for 30 seconds to remove any residual charge on the test specimen and rubbing wheel.

6-18.5.7 The rubbing wheel motor shall be turned on and the motor shall be adjusted to 200 rpm.

6-18.5.8 The oscilloscope shall be adjusted for the desired display needed.

6-18.5.9 The electrometer shall be zeroed.

6-18.5.10 The sample holder shall be raised and locked into position in front of the rubbing wheel.

6-18.5.11 The control lever shall be moved to initiate rubbing of the test specimen and shall continue rubbing for precisely 10 seconds. During the rubbing, the oscilloscope circuit shall be armed and the electrometer shall be ungrounded.

6-18.5.12 The rubbing wheel shall be retracted and the sample holder shall be permitted to drop in front of the detector head to initiate the measurement of the electrostatic field.

6-18.5.13 The voltage versus time shall be recorded at the peak voltage and at $^1/_2$, 1, 2, 3, 4, and 5 seconds. Alternatively, the voltages shall be recorded continuously using a data logger for at least 5 seconds.

6-18.5.14 The test shall be repeated with a fresh sample each time beginning with 6-18.5.2.

6-18.6 Report.

6-18.6.1 For each specimen, the peak charge generated, the corresponding charge after 5 seconds.

6-18.6.2 The time required for the charge to reach 10 percent or the maximum charge measured shall be recorded.

6-18.7 Interpretation. The average measured voltage at 5 seconds for each surface tested shall be used individually to determine pass/fail.

6-19 Puncture Resistance Test Two.

6-19.1 Application. This test method shall apply to footwear soles.

6-19.2 Sample Preparation. Samples for conditioning shall be footwear sole sections.

6-19.3 Specimens.

6-19.3.1 A minimum of three footwear soles shall be tested.

6-19.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-19.4 Procedure. Puncture resistance shall be performed in accordance with Section 3 of CSA Z195 M, *Standard for Protective Footwear, Occupational Health and Safety.*

6-19.5 Report. The force required to puncture the sole reinforcement device of each specimen shall be reported.

6-19.6 Interpretation. One or more footwear specimens failing this test shall constitute failing performance.

6-20 Abrasion Resistance Test.

6-20.1 Application. This test method shall apply to footwear soles.

6-20.2 Sample Preparation. Samples for conditioning shall be footwear soles.

6-20.3 Specimens.

6-20.3.1 A minimum of three footwear soles shall be tested.

6-20.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-20.4 Procedure. Abrasion resistance shall be performed in accordance with ASTM D 1630, *Standard Test Method for Rubber Property — Abrasion Resistance (NBS Abrader).*

6-20.5 Report. The abrasion resistance rating of each specimen shall be reported.

6-20.6 Interpretation. One or more footwear specimens failing this test shall constitute failing performance.

6-21 Impact and Compression Test.

6-21.1 Application. This test method shall apply to the toe section of the footwear.

6-21.2 Sample Preparation. Samples for conditioning shall be complete footwear toes.

6-21.3 Specimens.

6-21.3.1 A minimum of three footwear items shall be tested for both impact and compression.

6-21.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-21.4 Procedure. Footwear specimens shall be tested in accordance with Section 1.4 of ANSI Z41, *Standard for Safety-Toe Footwear.*

6-21.5 Report. The impact and compression forces for each specimen shall be reported.

6-21.6 Interpretation. One or more footwear specimens failing this test shall constitute failing performance.

6-22 Ladder Shank Bend Resistance Test.

6-22.1 Application. This test method shall apply to footwear ladder shanks.

6-22.2 Sample Preparation. Samples for conditioning shall be footwear ladder shanks.

6-22.3 Specimens.

6-22.3.1 A minimum of three footwear ladder shanks shall be tested.

6-22.3.2 Specimens shall be conditioned as specified in 6-1.2.

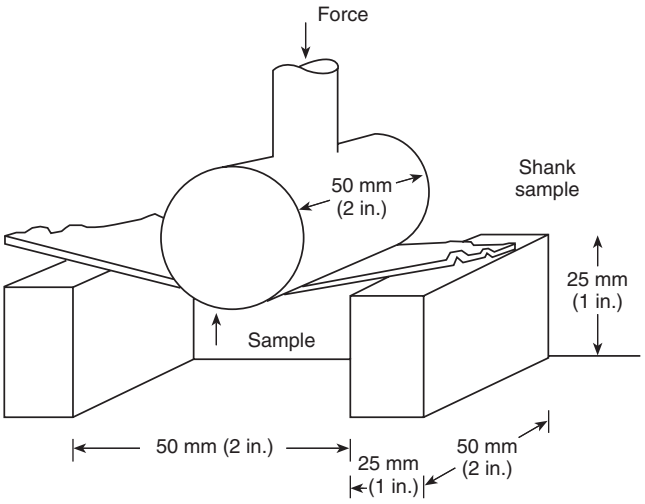
6-22.4 Apparatus.

6-22.4.1 The apparatus shall consist of a tensile testing machine, such as an Instron® or equivalent, that challenges a specimen with a simulated ladder rung.

6-22.4.2 A 32 mm diameter × 50 mm long ($1^1/_4$ in. diameter × 2 in. long) noncompressible probe shall be mounted on the movable arm.

6-22.4.3 The specimen support assembly shall consist of two 50 mm × 25 mm × 25 mm (2 in. × 1 in. × 1 in.) noncompressible blocks placed 50 mm (2 in.) apart as shown in Figure 6-22.4.3.

FIGURE 6-22.4.3 Ladder shank bend test set-up.



6-22.5 Procedure. The ladder shank shall be placed on mounting blocks as it would be oriented toward the ladder when affixed into the protective footwear and subjected to force on its center with the test probe operated at 50 mm/min (2 in./min).

6-22.6 Report.

6-22.6.1 Deflection at 182 kg (400 lb) shall be reported to the nearest 1 mm ($^1/_{32}$ in.).

6-22.6.2 The average deflection shall be calculated and reported to the nearest 1 mm ($^1/_{32}$ in.).

6-22.7 Interpretation. Pass/fail performance shall be determined using the average deflection for all specimens tested.

6-23 Slip Resistance Test.

6-23.1 Application. This test method shall apply to footwear soles.

6-23.2 Sample Preparation. Samples for conditioning shall be footwear.

6-23.3 Specimens.

6-23.3.1 A minimum of three footwear heels and ball of soles shall be tested.

6-23.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-23.4 Procedure. Slip resistance shall be performed in accordance with ASTM F 489, *Standard Test Method for Static Coefficient of Friction of Shoe Sole and Heel Materials as Measured by the James Machine* for a dry condition.

6-23.5 Report. The static coefficient of friction average of four readings obtained from each heel and each ball of sole shall be reported as the average of a total footwear sole.

6-23.6 Interpretation. One or more footwear specimens failing this test shall constitute failing performance.

6-24 Seam/Closure Breaking Strength Test.

6-24.1 Application.

6-24.1.1 This test shall be applied to suit seams and closure assembly used in the construction of the vapor-protective suit, including at least suit and suit-visor seams. If the suit consists of multiple separable layers, then the test shall be applied to the seams and closure assemblies of each separable layer.

6-24.1.2 Modifications to this test method for testing seams shall be as specified in 6-24.7.

6-24.1.3 Modifications to this test method for testing closure assemblies shall be as specified in 6-24.8.

6-24.2 Sample Preparation. Samples for conditioning shall be 1-m (1-yd) squares of material.

6-24.3 Specimens.

6-24.3.1 A minimum of five seam or closure assembly specimens representative of the suit shall be tested for each seam and closure assembly type.

6-24.3.2 A straight seam shall be permitted to be cut from the finished suit or shall be permitted to be prepared by joining two pieces of the suit material in a manner representing the actual seam construction in the finished vapor-protective ensemble.

6-24.3.3 Specimens shall be conditioned as specified in 6-1.2.

6-24.4 Procedure.

6-24.4.1 All seams and closure assemblies shall be tested in accordance with ASTM D 751, *Standard Methods of Testing Coated Fabric*. The test machine shall be operated at a rate of 305 mm/min (12 in./min).

6-24.5 Report.

6-24.5.1 The breaking strength for each seam or closure assembly specimen shall be reported. The average breaking strength for each seam or closure assembly type shall also be reported.

6-24.5.2 The type of seams and closure assemblies tested, that is, whether the specimens were cut from the finished suit or prepared from fabric samples, shall be reported.

6-24.6 Interpretation. The average seam breaking strength for each seam type shall be used to determine pass/fail performance.

6-24.7 Specific Procedures for Testing Seams. Samples for conditioning shall include 150 mm (6 in.) of material on either side of the seam.

6-24.8 Specific Procedures for Testing Closure Assemblies. Samples for conditioning shall include 150 mm (6 in.) of material on either side of the closure.

6-25 Closure Penetration Resistance Test.

6-25.1 Application. This test method shall apply to vapor-protective ensemble closure assemblies.

6-25.2 Sample Preparation. Samples for conditioning shall be complete vapor-protective ensembles.

6-25.3 Specimens.

6-25.3.1 A total of three different suit closure assembly specimens shall be tested. The suit closure assembly shall consist of the closure in combination with the seam attaching the closure to the suit.

6-25.3.2 Specimens shall be conditioned as specified in 6-1.7.

6-25.4 Procedure. Penetration resistance testing of suit closure assemblies shall be conducted in accordance with ASTM F 903, *Standard Test Method for Resistance of Protective Clothing Materials to Penetration by Liquids*, Procedure C using the following modifications:

(a) All tests shall be conducted at 25°C, ±3°C (77°F, ±5°F).

(b) The test cell shall be modified to accommodate the shape of the suit closure assembly without affecting other parts of the test procedure. The Plexiglas® shield shall be omitted from the test cell.

(c) Use of blotting paper at the end of the test shall be permitted to assist in the visual observation of liquid penetration. Visually observed chemical on the blotting paper shall constitute failure of this test.

(d) An observation to determine specimen penetration shall be made at the end of the chemical contact period.

6-25.5 Report. The report shall include the pass/fail results for each chemical tested and an identification of location where penetration occurs, if discernible.

6-25.6 Interpretation. Observed liquid penetration at the end of the test for any specimen shall constitute failure of this test.

6-26 Exhaust Valve Inward Leakage Test.

6-26.1 Application. This test method shall apply to vapor-protective suit exhaust valves.

6-26.2 Sample Preparation. Samples for conditioning shall be individual vapor-protective suit exhaust valves including mounting means.

6-26.3 Specimens.

6-26.3.1 A minimum of ten specimens shall be tested.

6-26.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-26.3.3 Specimens shall be tested not more than 5 minutes after removal from conditioning.

6-26.4 Apparatus.

6-26.4.1 The test fixture used to measure exhaust valve inward leakage shall have the following characteristics:

(1) The fixture shall allow mounting of an exhaust valve such that an airtight seal is achieved between the valve body and the fixture.

(2) The fixture shall provide for the application of suction from a vacuum pump capable of sustaining a −25 mm (−1 in.) water column gauge vacuum.

(3) The fixture shall include a pressure gauge or manometer capable of measuring pressures ranging from −25 mm to 76 mm, ±6 mm (−1 in. to 3 in., $\pm^1/_4$ in. water gauge) water column gauge.

(4) The fixture shall allow for the measurement of flow into the valve (valve exterior to valve interior sides) with a flow-measuring device capable of measuring flow rates from at least 0 ml/min to 100 ml/min, ±1 ml/min (0 $in.^3$/min to 6.1 $in.^3$/min, ±0.6 $in.^3$/min).

6-26.5 Procedure. The exhaust valve shall be mounted in the test fixture and a suction of −25 mm (−1 in.) water column gauge vacuum shall be applied to the side of the valve representing the suit interior for 30 seconds while the flow rate into the valve is measured.

6-26.6 Report. The inward leakage flow rate shall be reported for each specimen and the average inward leakage of all specimens shall be calculated.

6-26.7 Interpretation. The average inward leakage shall be used to determine pass/fail in accordance with this standard.

6-27 Overall Ensemble Flash Test.

6-27.1 Application. This test method shall apply to vapor-protective ensembles.

6-27.2 Sample Preparation.

6-27.2.1 Samples for conditioning shall be complete vapor-protective ensembles.

6-27.2.2 Samples shall include any additional protective clothing components and equipment that are necessary to provide full-body flash protection to the wearer, and shall be tested in conjunction with the vapor-protective suit.

6-27.3 Specimens.

6-27.3.1 A minimum of one specimen shall be tested.

6-27.3.2 Specimens shall be conditioned as specified in 6-1.2.

6-27.4 Apparatus.

6-27.4.1 A human form mannequin shall be used to support the protective suit during chemical flash fire testing. The mannequin shall be coated with a suitable flame-retardant coating.

6-27.4.2 A one-piece flame retardant coverall shall be placed over the mannequin.

6-27.4.3 The protective suit to be tested shall be placed on the mannequin, over the flame-resistant clothing, in accordance with the manufacturer's instructions.

6-27.4.4 A flash chamber shall be constructed as illustrated in Figure 6-27.4.4 and shall include the following:

(a) It shall have an internal width and depth of 2 m, ±100 mm ($6^1/_2$ ft, ±4 in.) and a height of 2.5 m, ±200 mm (8 ft, ±8 in.).

(b) It shall be constructed of 50 mm × 100 mm (2 in. × 4 in.) framing lumber or other suitable structural material. Fire wall, 20 mm ($^3/_4$ in.), or other suitable flame-resistant paneling, shall be used on the opposite two walls of the chamber. A piece of 13-mm ($^1/_2$-in.) heat-tempered safety glass shall be used on the remaining walls for multiple viewing points during testing. At least one of the glass walls shall be attached by a means that allows for easy removal of the mannequin. Both glass walls shall be configured to achieve gastight seals with the chamber.

(c) All fire wall seams shall be taped and the interior walls of the chamber coated with a suitable flame-retardant material.

(d) It shall have a port for filling the chamber with propane gas located as shown in Figure 6-27.4.4. The port shall allow isolation of the propane source through a valve. The port shall be leakfree with respect to the outside environment.

(e) It shall have two ports for electric ignitors located as showing in Figure 6-27.4.4. The port shall be leakfree with respect to the outside environment.

(f) It shall have a top that allows containment of propane gas within the chamber during filling and venting of flash pressure after ignition.

(g) A suitable stand that allows the mannequin to be positioned 305 mm, ±25 mm (1 ft, ±1 in.) above the chamber floor shall be constructed.

6-27.5 Procedure.

6-27.5.1 Each protective suit selected shall be tested for gastight integrity in accordance with ASTM F 1052, *Standard Test Method for Pressure Testing of Vapor-Protective Ensembles*.

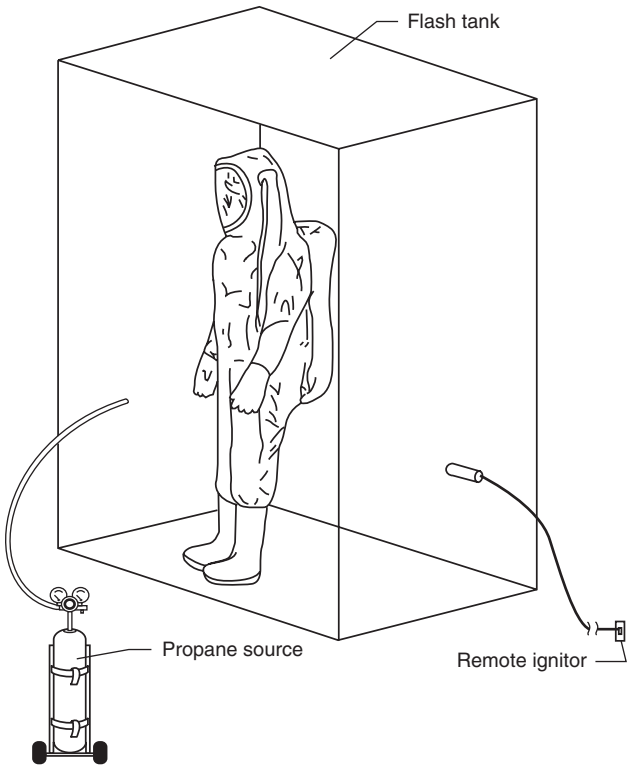
6-27.5.2 The suited mannequin shall be placed on the stand in the center of the flash chamber in an upright stationary position.

6-27.5.3 Propane gas, at 99 percent purity or better, shall be metered into the chamber at a delivery pressure of 172.3, ±13.8 kPa (25 psi, ±2 psi) and rate of 0.16 m^3/min, ±0.01 m^3/min ($5^1/_2$ ft^3/min, $\pm^1/_2$ ft^3/min). The concentration of propane within the chamber shall be sufficient to produce a visible chemical flash fire lasting 7 seconds, ±1 second. The concentration of the propane shall be permitted to be checked by a combustible gas meter or similar detector.

6-27.5.4 The flash chamber shall be viewed at both vantage points, front and back, throughout the test. Video documentation shall also be conducted from the front vantage point.

6-27.5.5 The chamber atmosphere shall be remotely ignited at 30 seconds, ±5 seconds after the chamber has been filled with propane gas.

FIGURE 6-27.4.4 Overall ensemble chemical flash chamber.



6-27.5.6 The suited mannequin shall not be removed until all surfaces have cooled to ambient temperature.

6-27.5.7 The protective suit shall be removed from the mannequin and examined visually for physical signs of damage from thermal exposure.

6-27.5.8 A gastight integrity test shall be performed on the suit in accordance with Section 6-2, Gastight Integrity Test, following the chemical flash fire exposure.

6-27.5.9 Following gastight integrity testing, the suit shall be donned by a test subject and evaluated for visual acuity.

6-27.5.9.1 The test subject shall have a minimum visual acuity of 20/20 in each eye, uncorrected or corrected with contact lenses, as determined in a visual acuity test or doctor's examination.

6-27.5.9.2 Visual acuity testing from within the suit shall be conducted using a standard 20-foot eye chart with a normal lighting range of 100–150 ft-candles at the chart and with the test subject positions at a distance of 6.1 m (20 ft) from the chart.

6-27.5.9.3 The test subject shall then read the standard eye chart through the lens of the SCBA facepiece and suit visor to determine his or her visual acuity.

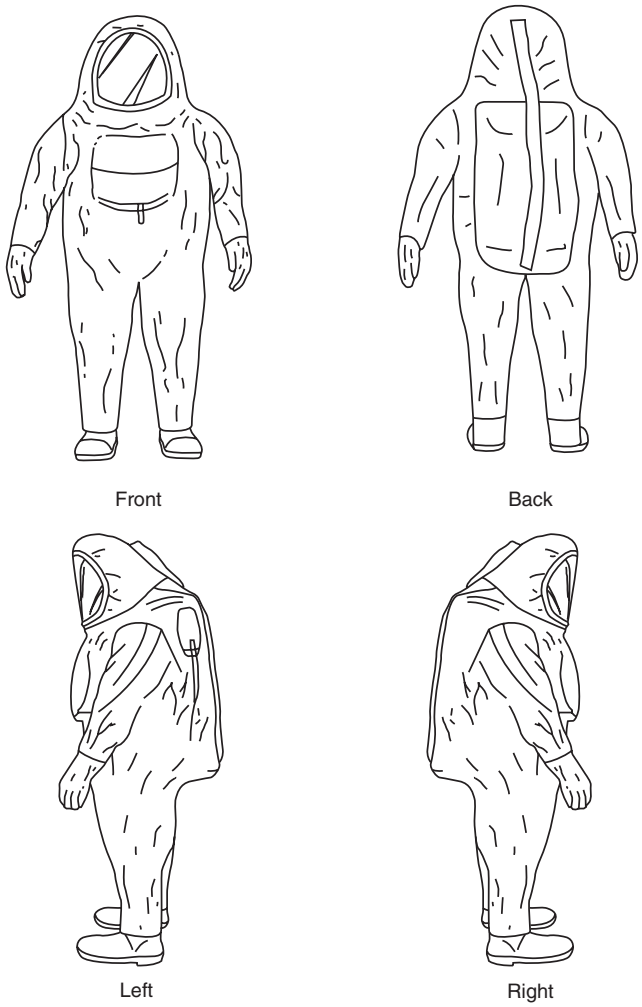
6-27.5.10 All testing shall be performed at a temperature of 24°C, ±11°C (75°F, ±20°F) and a relative humidity of 70 percent, ±25 percent. Tests shall not be conducted outdoors during precipitation.

6-27.6 Report.

6-27.6.1 The before and after gastight integrity test results, afterflame time, and visor clarity shall be reported for each test specimen.

6-27.6.2 An illustration of the protective suit, as shown in Figure 6-27.6.2, shall be prepared and the location of any damage shall be shown. Separate illustrations shall be prepared for over covers if tested with the protective suit. Damage shall include, but not be limited to, charring, blistering, evidence of material melting, delamination, or destruction of any suit components.

FIGURE 6-27.6.2 Suit diagram (for noting damage locations).



6-27.7 Interpretation.

6-27.7.1 Any specimen with an afterflame time greater than 2 seconds shall constitute failing performance.

6-27.7.2 If the ending pressure is less than 13 mm ($^1/_2$ in.), the specimen fails the test.

6-27.7.3 The visual acuity of the test subject inside the suit shall be used for determining pass/fail.

6-28 Thermal Protective Performance (TPP) Test.

6-28.1 Application. This test method shall apply to suit, glove, and footwear materials.

6-28.2 Sample Preparation.

6-28.2.1 Samples shall consist of all layers used in the construction of the suit, glove or footwear, excluding any areas with special reinforcements. Samples shall not include seams. Specimens shall not be stitched to hold individual layers together.

6-28.2.2 Samples for conditioning shall be of specimen size given in 6-28.2.1.

6-28.3 Specimens.

6-28.3.1 Thermal protective performance testing shall be conducted on three specimens.

6-28.3.2 Specimens shall measure 150 mm × 150 mm, ±5 mm (6 in. × 6 in. ±$^1/_4$ in.) and shall consist of all layers representative of the clothing item to be tested.

6-28.3.3 Specimens shall be conditioned as specified in 6-1.2.

6-28.4 Apparatus.

6-28.4.1 The test apparatus shall consist of a specimen holder assembly, specimen holder assembly support, thermal flux source, protective shutter, sensor assembly, and recorder. The apparatus shall also have a gas supply, gas rotameter, burners, and sensor.

6-28.4.1.1 The specimen holder assembly shall consist of upper and lower mounting plates. Specimen holder maintaining plates shall be 152.4 mm × 152.4 mm, ±1.6 mm, × 6.4 mm, ±0.8 mm (6 in. × 6 in., ±0.063 in. × 0.25 in., ±0.313 in.). The lower specimen mounting plate shall have centered a 101.6 mm × 101.6 mm, ±1.6 mm (4 in. × 4 in., ±0.063 in.) hole. The upper specimen mounting plate shall have centered a 133.4 mm × 133.4 mm, ±1.6 mm (5.25 in. × 5.25 in., ±0.063 in.) hole. The lower specimen mounting plate shall have a 25.4 mm, ±1.6 mm high, × 3.2 mm, ±0.8 mm (1.0 in., ±0.063 in. high, × 0.13 in., ±0.0315 in.) thick steel post welded to each corner 6.4 mm, ±1.6 mm (0.25 in., ±0.063 in.) from each side and perpendicular to the plane of the plate or some other method for aligning the specimen shall be provided. The upper sample mounting plate shall have a corresponding hole in each corner so that the upper specimen mounting plate fits over the lower specimen mounting plate. Specifications for the specimen holder assembly shall be as shown in Figure 6-28.4.1.1.

6-28.4.1.2 The specimen holder assembly support shall consist of a steel frame that rigidly holds and positions in a reproducible manner the specimen holder assembly and specimen relative to the thermal flux.

6-28.4.1.3 The thermal flux source shall consist of a convective thermal flux source and a radiant thermal flux source. The convective thermal flux source shall consist of two Meker or Fisher burners affixed beneath the specimen holder assembly opening and subtended at a nominal 45 degree angle from vertical so that the flames converge at a point immediately beneath the specimen. The radiant thermal flux source shall consist of nine quartz T-150 infrared tubes affixed beneath and centered between the burners as shown in Figure 6-28.4.1.3.

FIGURE 6-28.4.1.1 Lower specimen mounting plate.

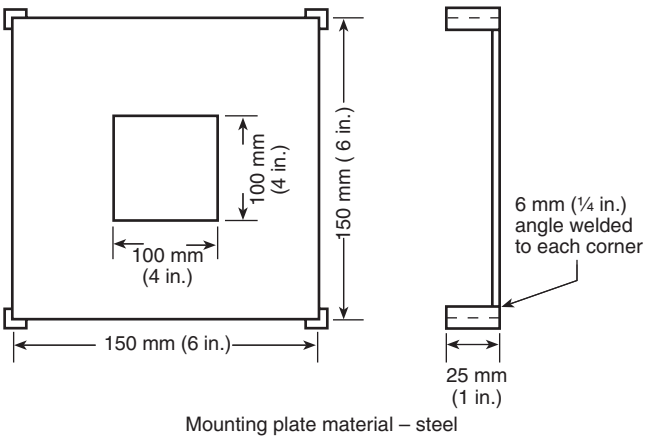
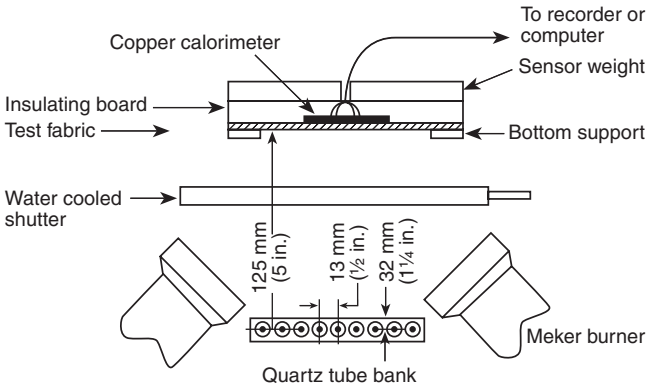


FIGURE 6-28.4.1.3 Specifications for TPP tester thermal flux source.



6-28.4.1.4 A protective shutter shall be placed between the thermal flux source and the specimen. The protective shutter shall be capable of completely dissipating thermal load from thermal flux source of the time periods before and after specimen exposure.

6-28.4.1.5 The sensor assembly shall be fitted into the opening in the top plate of the specimen holder and shall be in contact with the surface of the thermal barrier normally facing the wearer, as detailed in Figure 6-28.4.1.10. Sensor assembly shall consist of 133.4 mm × 133.4 mm × 12.7 mm (5.25 in. × 5.25 in. × 0.5 in.) heat-resistant block that fits without binding into the hole of the upper specimen mounting plate and shall be uniformly weighted such that complete sensor assembly, including copper calorimeter, weighs 1000 grams, ±10 grams (2.2 lb, ±0.022 lb).

6-28.4.1.6 The recorder shall be any strip chart recorder with full-scale deflection of at least 150°C (300°F) or 10 mV and sufficient sensitivity and scale divisions to read exposure time to ±0.1 second. Alternatively, an equivalent automated data acquisition system meeting or exceeding the sensitivity and accuracy requirements of the strip chart recorder shall be permitted to be used instead of a strip chart recorder.

6-28.4.1.7 The gas supply shall be propane, methane, or natural gas with appropriate reducer and valving arrangements to control the gas supply pressure at 8 psig, ±0.1 psig and capable

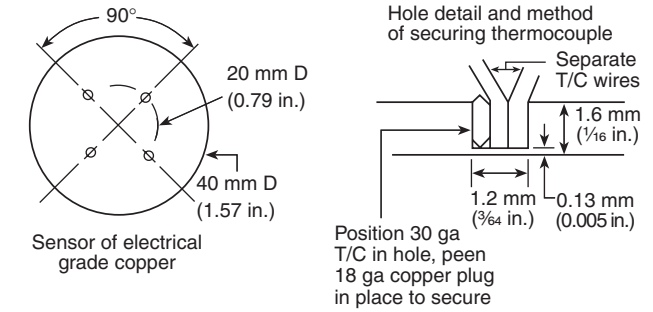
of providing flow equivalent to 2 L/min (0.07 ft^3/min) air at standard conditions.

6-28.4.1.8 The gas rotameter shall be any gas rotameter with range to give flow equivalent to 2 L/min (0.07 ft^3/min) air at standard conditions.

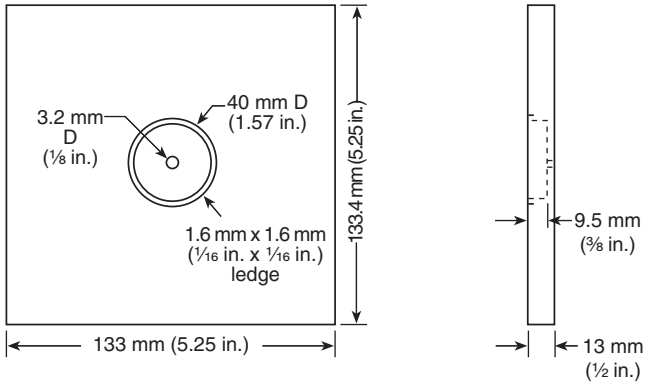
6-28.4.1.9 The burners shall be Meker or Fisher burners with 38 mm, ±2 mm (1.5 in., ±0.1 in.) diameter top and with orifice size of 1.2 mm (0.05 in.).

6-28.4.1.10 The sensor shall be a copper calorimeter mounted in an insulating block. The calorimeter shall conform to the specifications provided in Figure 6-28.4.1.10. The sensor shall be coated with a flat black paint.

FIGURE 6-28.4.1.10 Sensor assembly.



Details of calorimeter construction



Sensor support of soft insulation board

Connect 4 T/C in parallel, silver solder connections. Bring common lead out of center hole of support. Secure sensor into support with three or four sewing pins cut to 9.5 mm (3/8 in.) long.

6-28.4.2 A radiometer shall be used in the calibration of the test apparatus.

6-28.4.2.1 The radiometer shall be a Gardon-type radiation transducer with a diameter of 25.4 mm (1 in.).

6-28.4.2.2 The heat flux operating range shall be from 0 kW/m^2 to 60 kW/m^2 (0 cal/cm^2/s to 1.4 cal/cm^2/s or 0 BTU/ft^2/s to 5 BTU/ft^2/s).

6-28.4.2.3 The radiometer shall be water cooled and the cooling water temperature shall be above the ambient dew point temperature.

6-28.5 Procedure.

6-28.5.1 General Procedures.

6-28.5.1.1 All testing and calibration shall be performed in a hood or ventilated area to carry away combustion products, smoke, or fumes. If air currents disturb the flame, the apparatus shall be shielded. Procedures for testing and calibration shall be performed using the same hood and ventilation conditions.

6-28.5.1.2 Care shall be exercised in handling the burner with open flame. Adequate separation shall be maintained between flame and combustible materials. Since the specimen holder and sensor assembly become heated during prolonged testing, protective gloves shall be used when handling these hot objects. Since some test specimens become hazardous when exposed to direct flame, care shall be used when the specimen ignites or releases combustible gases. If specimens ignite, the gas supply at the cylinder shall be shut off and the flame shall be allowed to burn the gas.

6-28.5.2 Calibration Procedure.

6-28.5.2.1 Specimens shall be exposed to a thermal flux of 83 kW/m^2, ±4 kW/m^2 (2.0 cal/cm^2/s, ±0.1 cal/cm^2/s) as measured with the copper calorimeter. The copper calorimeter shall be the only heat sensor used in setting the total 83 kW/m^2 (2 cal/cm^2s) exposure condition. The total heat flux shall be calculated directly and only from the voltage output of the thermocouples, using the measured temperature rise of the testing copper calorimeter, the area and mass of the calorimeter, and the heat capacity of copper to calibrate the heat flux. Other heat sensing devices shall not be used to reference or adjust the total heat flux read by the copper calorimeter.

6-28.5.2.2 The total heat flux and the 50 percent/50 percent ±5 percent radiant/convective balance of the energy sources shall be set in accordance with the procedures in 6-28.5.2.3 through 6-28.5.2.6. The level of the radiant heat flux shall be determined using a radiometer and the level of the total heat flux shall be determined by using a calibration copper calorimeter designated and used only to set the total exposure level.

6-28.5.2.3 When an initial setting of 50 kW/m^2, ±4 kW/m^2 (0.3 cal/cm^2/s, ±0.1 cal/cm^2/s) has been made to the array of new quartz lamps, the operating voltage shall be recorded and permanently retained for test purposes. During all future calibration procedures, the voltage setting of the quartz lamps shall be compared to the current voltage setting of the new quartz lamps, and if the voltage increase is 5 V or greater from the initial setting, the lamps shall be replaced.

6-28.5.2.4 The two Meker or Fisher burners shall be initially adjusted so that the flames converge upon each other just below the center of the radiometer. The color of the flame shall primarily be blue.

6-28.5.2.5 The radiant thermal flux source of nine quartz infrared tubes alone shall be set to an incoming radiant heat flux of 12 kW/m^2, ±4 kW/m^2 (0.3 cal/cm^2/s, ±0.1 cal/cm^2/s) using a commercial radiometer meeting the specifications of 6-28.4.2. The radiometer window shall be positioned at the geometric center of the sample holder and at the same plane as a test specimen. The radiometer shall be mounted in a holder of the same overall size, shape, and material as the one used for the copper calorimeter to ensure similar heat and flame patterns across the faces of the radiometer and calorim-

eters. The radiant quartz tubes shall be turned on and "run" for a minimum of 2 minutes prior to measuring the radiant heat flux.

6-28.5.2.6 The total heat flux shall be set at 83 kW/m^2, ±4 kW/m^2 (2.0 cal/cm^2/s, ±0.1 cal/cm^2/s) using the calibration copper calorimeter, defined in 6-28.4.1.10, by adjusting only the gas supply to the Meker or Fisher burners. Without a mounted specimen, the calibration copper calorimeter shall be placed on top of the specimen holder with the blackened copper calorimeter facing down and then exposed directly to the flame of the burner. The response of the calorimeter shall be recorded for at least 10 seconds. The lowest temperature point on the curve where the response is linear shall be chosen, and the increase in sensor temperature for 10 seconds of heating shall also be determined. The initial reading from the 10-second reading shall be subtracted to obtain the increase. The response shall be 148°C, ±3.7°C (267°F, ±6.7°F) equivalent to 7.86, ±0.20 mV for an iron–constantan thermocouple for an exposure heat flux of 83 kW/m^2, ±2 kW/m^2 (2.0 cal/cm^2/s, ±0.05 cal/cm^2/s).

6-28.5.3 Test Procedure.

6-28.5.3.1 After the total thermal heat flux has been set at 83 kW/m^2, ±4 kW/m^2(2.0 cal/cm^2/s, ±0.1 cal/cm^2/s) using the calibration procedure in 6-28.5.2.4 through 6-28.5.2.6, the testing copper calorimeter shall be used to measure the total heat flux. Prior to testing, the testing copper calorimeter shall be used to measure the total heat flux by placing the calorimeter face down and then exposing it directly to the total heat source. The response of the calorimeter shall be recorded for at least 10 seconds. The lowest temperature point on the curve where the response is linear shall be chosen, and the increase in sensor temperature for 10 seconds of heating shall be determined. The initial reading from the 10-second reading shall be subtracted to obtain the increase. The response shall be 148°C, ±3.7°C (267°F, ±6.7°F) equivalent to 7.86 mV, ±0.20 mV for an iron–constantan thermocouple for an exposure heat flux of 83 kW/m^2, ±2 kW/m^2 (2.0 cal/cm^2/s, ±0.05 cal/cm^2/s).

6-28.5.3.2 If the measurement from the testing copper calorimeter is within +4/–0 kW/m^2 (+0.1/–0 cal/cm^2/s) then testing shall be done. If the measurement from the testing copper calorimeter does not agree within +4 kW/m^2 (+0.1 cal/cm^2/s) of the measurement of the calibration calorimeter, the testing copper calorimeter shall be repaired, reconditioned, or replaced to achieve agreement.

6-28.5.3.3 Specimens shall be mounted by placing the surface of the material to be used as the outside of the garment face down on the mounting plate. The subsequent layers shall be placed on top in the order used in the garment, with the surface to be worn toward the skin facing up. With the protective shutter engaged, the specimens shall be placed on the specimen holder.

6-28.5.3.4 The testing copper calorimeter shall be placed directly on the specimen in contact with the surface to be worn toward the skin.

6-28.5.3.5 The protective shutter shall be retracted and chart paper movement on the recorder shall be started using a chart speed consistent with the preparation of the overlay described in 6-28.5.4.1. The start time of the exposure shall be indicated. The exposure shall be continued for 30 seconds. The protective shutter shall be engaged (closed), the recorder shall be stopped, the calorimeter shall be removed and cooled, and then the specimen holder and exposed specimen shall be removed.

6-28.5.3.6 After each exposure, the calorimeter shall be cooled to 33°C, ±1°C (91°F, ±2°F) before the next heat flux determination. The sensor shall be cooled after exposure with a jet of air or by contact with a cold surface.

6-28.5.3.7 The sensor face shall be wiped immediately after each run, while hot, to remove any decomposition products that condense and could be a source of error. Where a deposit collects and appears to be thicker than a thin layer of paint, or is irregular, the sensor surface shall be reconditioned. The cooled sensor shall be carefully cleaned with acetone or petroleum solvent in an area where there is no ignition source.

6-28.5.3.7.1* Where copper is showing on the testing copper calorimeter, the surface shall be completely repainted with a thin layer of flat black spray paint. At least one calibration run shall be performed comparing the testing copper calorimeter with the calibration copper calorimeter. Where the testing calorimeter is in error by more than +4/–0 kW/m^2 (+0.1/–0 cal/cm^2/s), all electrical connections and points where thermocouples are secured to the testing calorimeter shall be checked. Two more calibration runs shall be conducted by comparing the testing copper calorimeter with the calibration grade copper calorimeter. The average error shall be calculated. If the average error of the testing calorimeter is more than +4 kW/m^2 (+0.1 cal/cm^2/s), then the testing calorimeter shall be repaired and recalibrated or the testing calorimeter shall be replaced.

6-28.5.4 Preparation of Human Tissue Burn Tolerance Overlay.

6-28.5.4.1 Tolerance Overlay. The thermal end point shall be determined with a plot of energy versus the time to cause a second-degree burn in human tissue as shown in Table 6-28.5.4.1. The calorimeter equivalent from Table 6-28.5.4.1 that corresponds to the recorder scale shall be plotted on recorder chart paper. Columns 6, 7, or 8 (ΔT°F, ΔT°C, or ΔmV) shall be plotted on the vertical axis and the corresponding time (column 1) shall be plotted on the horizontal axis. Chart units based on the recorder full-scale deflection and the chart speed for a graph directly comparable to the recorder sensor trace shall be used. If pen deflection is from left to right and paper movement down, the plot shall be from right to left with origin at lower right. If recorder trace differs, the graph shall be adjusted accordingly. An exact transparent duplicate shall be made for the overlay. The overlay shall be compared with the original to ensure change in the overlay size.

6-28.5.4.2 Computer Processing of the Data. The information provided in Table 6-28.5.4.1 shall be permitted to be used as the criteria of performance in the software of a computer program. In this case, the sensor response shall be compared with the thermal response, either pain sensation or second-degree burn in human tissue to determine the thermal end points. The product of the time to a second-degree burn in human tissue and the exposure energy heat flux shall be the TPP rating.

Table 6-28.5.4.1 Human Tissue[a] Tolerance to Second-Degree Burn

Exposure Time (s)	Heat Flux		Total Heat		Calorimeter[b] Equivalent		
	cal/cm²s	kW/m²	cal/cm²	kW/m²	ΔT°F	ΔT°C	ΔmV
1	1.2	50	1.20	50	16.0	8.9	0.46
2	0.73	31	1.46	61	19.5	10.8	0.57
3	0.55	23	1.65	69	22.0	12.2	0.63
4	0.45	19	1.80	75	24.0	13.3	0.69
5	0.38	16	1.90	80	25.3	14.1	0.72
6	0.34	14	2.04	85	27.2	15.1	0.78
7	0.30	13	2.10	88	28.0	15.5	0.80
8	0.274	11.5	2.19	92	29.2	16.2	0.83
9	0.252	10.6	2.27	95	30.2	16.8	0.86
10	0.233	9.8	2.33	98	31.1	17.3	0.89
11	0.219	9.2	2.41	101	32.1	17.8	0.92
12	0.205	8.6	2.46	103	32.8	18.2	0.94
13	0.194	8.1	2.52	106	33.6	18.7	0.97
14	0.184	7.7	2.58	108	34.3	19.1	0.99
15	0.177	7.4	2.66	111	35.4	19.7	1.02
16	0.168	7.0	2.69	113	35.8	19.8	1.03
17	0.160	6.7	2.72	114	36.3	20.2	1.04
18	0.154	6.4	2.77	116	37.0	20.6	1.06
19	0.148	6.2	2.81	118	37.5	20.8	1.08
20	0.143	6.0	2.86	120	38.1	21.2	1.10
25	0.122	5.1	3.05	128	40.7	22.6	1.17
30	0.107	4.5	3.21	134	42.8	23.8	1.23

[a]Stoll, A.M., and Chianta, M.A. "Method and Rating System for Evaluation of Thermal Protection," *Aerospace Medicine*, Vol. 40, 1968, pp. 1232–1238.
[b]Iron–constantan thermocouple.

6-28.5.5 Determination of Test Results.

6-28.5.5.1 The time to the second-degree burn shall be graphically determined from the recorder chart of the sensor response and criterion overlay prepared in 6-28.5.4.1. The overlay shall be positioned on the recorder chart, matching the zero of the overlay with the exposure start time resulting from heat transfer. The horizontal axis (time) shall be placed in line with the initial trace of the pen, keeping the overlay square with the recorder chart. The time to the second-degree burn shall be read to the nearest 0.1 second from the overlay chart at the point when the sensor response curve and the tissue tolerance curve cross. If the sensor response curve and the tissue tolerance curves do not cross, "> 30" shall be recorded as the test result.

6-28.5.5.1.1 If a computer software program is used, the sensor response shall be compared with the data describing the human tissue heat tolerance to determine like values. The time from the start of the exposure to the time when these values are the same shall be taken at the exposure time.

6-28.5.5.2 The TPP rating shall be calculated as the product of exposure energy heat flux and time to burn:

TPP rating = $F \times T$

where:

F = exposure heat flux (cal/cm^2/s)
T = time to burn(s)

6-28.6 Report.

6-28.6.1 The individual test TPP rating of each specimen shall be reported.

6-28.6.2 The average TPP rating shall be calculated and reported.

6-28.6.3 Where a TPP rating is greater than 60, then the TPP rating shall be reported as "> 60."

6-28.7 Interpretation.

6-28.7.1 Pass or fail determinations shall be based on the average reported TPP rating of all specimens tested.

6-28.7.2 If an individual result from any test set varies more than ±8 percent from the average result, the results from the test set shall be discarded and another set of specimens shall be tested.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix B.

7-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P. O. Box 9101, Quincy, MA 02269-9101.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, 1997 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, 1997 edition.

NFPA 1992, *Standard on Liquid Splash-Protective Clothing for Hazardous Materials Emergencies*, 2000 edition.

7-1.2 Other Publications.

7-1.2.1 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI Z34.1, *Standard for Third-Party Certification Programs for Products, Processes, and Services*, 1993.

ANSI Z41, *Standard for Safety-Toe Footwear*, 1983.

ANSI Z89.1, *Standard for Industrial Head Protection*, 1997.

7-1.2.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 747, *Standard Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam*, 1993.

ASTM D 751, *Standard Methods of Testing Coated Fabrics*, 1995.

ASTM D 1630, *Standard Test Method for Rubber Property–Abrasion Resistance (NBS Abrader)*, 1994.

ASTM D 2136, *Standard Test Method for Coated Fabrics–Low Temperature Bend Test*, 1994.

ASTM D 2582, *Standard Test Method for Puncture Propagation Tear Resistance of Plastic Film and Thin Sheeting*, 1993.

ASTM D 4157, *Standard Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)*, 1992.

ASTM F 392, *Standard Test Method for Flex Durability of Flexible Barrier Materials*, 1993.

ASTM F 489, *Standard Test Method for Static Coefficient of Friction of Shoe Sole and Heel Materials as Measured by the James Machine*, 1996.

ASTM F 739, *Standard Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids and Gases*, 1996.

ASTM F 903, *Standard Test Method for Resistance of Protective Clothing Materials to Penetration by Liquids*, 1996.

ASTM F 1001, *Standard Guide for Chemicals to Evaluate Protective Clothing Materials*, 1993.

ASTM F 1052, *Standard Test Method for Pressure Testing of Vapor-Protective Ensembles*, 1997.

ASTM F 1154, *Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical Protective Suit Ensembles*, 1996.

ASTM F 1301, *Standard Practice for Labeling Chemical Protective Clothing*, 1996.

ASTM F 1342, *Standard Test Method for Resistance of Protective Clothing Materials to Puncture*, 1996.

ASTM F 1358, *Standard Test Method for Resistance of Protective Clothing Materials to Flame Impingement,* 1995.

ASTM F 1359, *Standard Test Method for Measuring the Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Using a Shower Spray While on a Mannequin*, 1997.

ASTM F 1790, *Standard Test Methods for Measuring Cut Resistance of Materials Used in Protective Clothing*, 1997.

7-1.2.3 CSA Publication. Canadian Standards Association, 178 Rexdale Boulevard, Toronto, Canada M9W 1R3.

CSA Standard Z195 M, *Standard for Protective Footwear, Occupational Health and Safety,* 1992.

7-1.2.4 FIA Publication. Footwear Industries of America, 1420 K Street NW, Suite 600, Washington, DC 20005.

FIA Standard 1209, *Whole Shoe Flex*, 1984.

7-1.2.5 GSA Publication. General Services Administration, Specifications Activity, Printed Materials Supply Division, Building 197, Naval Weapons Plant, Washington, DC 20407.

Federal Test Method Standard 191A, *Textile Test Methods*, 1978.

7-1.2.6 ISO Publications. International Standards Organization, 1 rue de Varembé, Case Potale 56, CH-1211 Geneve 20, Switzerland.

ISO Guide 25, *General Requirements for the Competence of Calibration and Testing Laboratories*, 1990.

ISO 9001, *Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation, and Servicing*, 1994.

7-1.2.7 U.S. Army Publication. U.S. Army Chemical/Biological Defense Command, Aberdeen Proving Ground, MD 21010.

CRDC-SP-84010, *Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents,* June 1984.

7-1.2.8 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Title 29, *Code of Federal Regulations*, Part 1910.132, "Personal Protective Equipment," 1994.