Risk-Based Selection of Chemical-Protective Clothing

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INTRODUCTION

Hazardous material emergencies can occur anywhere, involve any number of substances, and result in a diverse set of environmental and operational conditions. In these situations, when action is needed to save lives and protect property, personal protective equipment (PPE) is the only viable protection for responders who may come into contact with hazardous substances.

> In 1983, a rail car was leaking anhydrous dimethylamine in Benicia, California, and the local hazmat team responded. During this event, a team member noticed the visor lens of his totally encapsulated suit began to crack. The team quickly exited the vapor cloud, but not before the visor had broken open and the team member was exposed. Fortunately, the self-contained breathing apparatus prevented respiratory injury, but the team member developed severe dermatitis as a result of the clothing failure. A subsequent National Transportation Safety Board (NTSB) report determined that, although the manufacturer recommended its suits for the chemical involved, the visor was susceptible to degradation and permeation by the chemical. Information on the visor was not addressed or provided by the manufacturer. As consequence, NTSB recommended the development of national consensus standards to address all parts and relevant performance properties of ensembles used in emergency response.

ROLE OF STANDARDS

Standards and regulations are often developed in response to a specific problem. The incident described above, and other similar incidents that have occurred over the years, helped create the protective equipment standards that exist today. This result illustrates that, in fact, these standards are based on the hard lessons of the real world where people can be hurt, or worse.

Before NFPA standards, first responders chose from a selection of protective clothing products used by the military as chemical warfare suits. These products lacked broad compatibility and performance against the multitude of chemicals and conditions being encountered by emergency responders in a vast range of industry and transportation accidents. Product testing was limited and manufacturer claims varied considerably, presenting a very confusing picture to the emergency responder community.

Today, emergency services end users and protective clothing manufacturers depend on the standards developed by NFPA to help define the appropriate PPE for hazardous materials and other related emergency incidents. These standards have become the benchmarks for establishing protective clothing and equipment minimum design and performance requirements. Thus, when a first responder or other operator dons a certified ensemble, NFPA standards provide assurance that the ensemble and its component parts have been designed and tested to meet a specific hazardous environment. Specific benefits of NFPA standards include:

- Uniform product testing and evaluation.
- Criteria based on specific end user needs.
- Minimum requirements for clothing design, performance, documentation, and labeling.
- Required third-party certification for both initial product qualification and continued review of manufacturer compliance and quality.

To take advantage of the benefits associated with the NFPA standards, some understanding is needed on the different performance characteristics and features that form the basis of the standards. In addition, the history of how standards have evolved to establish the protection levels that exist today is fundamental for being able to select the correct ensemble based on risks associated with a given response environment and other circumstances.

HISTORY OF CHEMICAL-PROTECTIVE CLOTHING STANDARDS

In order to provide protection to the entire body, chemical-protective ensembles must be part of an overall ensemble of PPE. As defined by the U.S. Environmental Protection Agency (EPA) and in the Occupational Safety and Health Administration (OSHA) regulations for hazardous waste site remediation and emergency response (OSHA Title 29 CFR 1910.120)[1], four different levels of protection are established based on different ensembles. These ensembles, further described in *Table 1*, consist of chemical-protective clothing (CPC), a respirator, gloves and boots, hard hats, communications equipment, cooling devices, and various types of undergarments.

First responders generally use Level A- and Level B-protective ensembles. Level A ensembles provide the highest level of protection and consist of a totally encapsulating suit, a self-contained breathing apparatus (SCBA) or combination SCBA and supplied-air respirator, chemically resistant gloves and footwear, and a communications system. Level A ensembles are for use in situations where the highest level of respiratory, skin, and eye protection are needed. Level B ensembles employ the same respiratory protection, but pertain to situations where hazards to the skin and eyes are not as significant as those encountered in Level A situations. Consequently, for Level B ensembles, one- or multi-piece chemical splash suits replace the totally encapsulating suits used in Level A ensembles. Though used to a much lesser extent in the emergency response community, Level C ensembles use the identical clothing

TABLE 1 *EPA Levels of Protection*

Level	Equipment	Protection Provided	Should Be Used When	Limiting Criteria
A	**Recommended:** • Pressure-demand, full facepiece SCBA or pressure-demand, supplied-air respirator with escape SCBA • Fully encapsulating chemical-resistant suit • Inner chemical-resistant gloves • Chemical-resistant safety boots/shoes • Two-way radio communications **Optional:** • Cooling unit • Coveralls • Long cotton underwear • Hard hat • Disposable gloves and boot covers	The highest available level of respiratory, skin, and eye protection	The chemical substance has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on either: • measured (or potential for) high concentration of atmospheric vapors, gases, or particulates, or • site operations and work functions involving a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the intact skin Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection is determined	Fully encapsulating suit material must be compatible with the substances involved
B	**Recommended:** • Pressure-demand, full facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA • Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit) • Inner and outer chemical-resistant gloves • Chemical-resistant safety boots/shoes • Hard hat • Two-way radio communications **Optional:** • Coveralls • Disposable boot covers • Face shield • Long cotton underwear	The same level of respiratory protection but less skin protection than Level A It is the minimum level recommended for initial site entries until the hazards have been further identified	The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection but less skin protection. This involves atmospheres: • with IDLH concentrations of specific substances that do not represent a severe skin hazard, or • that do not meet the criteria for use of air-purifying respirators Atmosphere contains less than 19.5% oxygen Presence of incompletely identified vapors or gases is indicated by direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the intact skin	Use only when the vapor or gases present are not suspected of containing high concentrations of chemicals that are harmful to skin or capable of being absorbed through the intact skin Use only when it is highly unlikely that the work being done will generate either high concentrations of vapors, gases, or particulates or splashes of material that will affect exposed skin

systems found in Level B ensembles, but replace SCBA or combination SCBA/supplied-air respirators with air-purifying respirators for situations where lower levels of respiratory hazards are perceived.

Although the EPA levels of protection describe what the ensemble should look like, little guidance is offered for how the ensemble should perform. It is vital that the ensemble elements work together to provide the intended level of protection, which means that ensemble items should fit together (provide good interfaces) and offer consistent performance for the wearer's entire body. Unfortunately, duct tape is often used in an attempt to correct ill-fitting suits and poorly designed interfaces. It can also pose a flammability hazard for those ensembles required to be flame resistant. Chemical-protective suits should be considered as a system,

TABLE 1 *(Continued)*

Level	Equipment	Protection Provided	Should Be Used When	Limiting Criteria
C	**Recommended:** • Full facepiece, air purifying, canister-equipped respirator • Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit) • Inner and outer chemical-resistant gloves • Chemical-resistant safety boots/shoes • Hard hat • Two-way radio communications **Optional:** • Coveralls • Disposable boot covers • Face shield • Escape mask • Long cotton underwear	The same level of skin protection as Level B but a lower level of respiratory protection	The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any exposed skin The types of air contaminants have been identified, concentrations have been measured, and a canister is available that can remove the contaminant All criteria for the use of air-purifying respirators are met	Atmospheric concentration of chemicals must not exceed IDLH levels The atmosphere must contain at least 19.5% oxygen
D	**Recommended:** • Coveralls • Safety boots/shoes • Safety glasses or chemical splash goggles • Hard hat **Optional:** • Gloves • Escape mask • Face shield	No respiratory protection Minimal skin protection	The atmosphere contains no known hazard Work functions preclude splashes, immersion, or the potential for unexpected inhalation of, or contact with, hazardous levels of any chemicals	This level should not be worn in the hot and warm zones The atmosphere must contain at least 19.5% oxygen

NOTES: SCBA: Self-contained breathing apparatus. IDLH: Immediately dangerous to life and health.

consisting of the base material, seams, closures, and the overall suit design. Often, attention is paid only to the base material, neglecting other parts of the suit that have a significant impact on the suit's effectiveness.

In 1990, three new NFPA standards were approved — NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents*[2], NFPA 1992, *Standard on Liquid Splash–Protective Ensembles and Clothing for Hazardous Materials Emergencies*[3], and NFPA 1993, *Standard on Support Function Protective Clothing for Hazardous Chemical Operations*[4]. These three standards established minimum requirements for chemical-protective suits and supplemented the EPA Level A and Level B designations with performance-based specifications. Since 1990, these standards have been periodically revised to keep pace with end user and manufacturer feedback, advances in materials, and modern evaluation methods, including incorporating the requirements from NFPA 1993 into NFPA 1992.

NFPA 1991 and NFPA 1992 have profoundly affected the products offered by the industry. Prior to their introduction, there were no manufacturers who provided suits that demonstrated protection against a broad range of chemicals and addressed performance for all parts of the ensemble — suit, visor, gloves, footwear, and seams. The idea of suits having some form of limited flame resistance in combination with material chemical resistance was thought to be unattainable. Once implemented, these standards prompted manufacturers to develop new material technologies and product designs, establishing fully qualified ensembles that improved the level and consistency of protection for first responders.

Before September 11, 2001, NFPA was just completing work on a standard for chemical and biological agent terrorism response, NFPA 1994, *Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents*[5], which set criteria for three different classes of protective ensembles that:

- Were responsive to hazards and responses associated with the intentional release of chemical warfare agents (CWAs), toxic industrial chemicals (TICs), and biological agents.
- Addressed a wider range of first responders, including special operations teams, law enforcement, emergency medical, first receivers, and others who were expected to require protection during such events.
- Subsequent revisions to NFPA 1994 addressed biological and radiological particulates; incorporated new methods of evaluation; and improved the understanding of ensemble selection by aligning the ensemble use with respirator use and the chemical/biological/radiological/nuclear (CBRN) criteria developed for respiratory protection.

In 2018, the NFPA 1994 standard's scope and title were modified to show inclusion of operational response to hazardous materials and CBRN terrorism incidents. Additional significant changes in the last series of revisions for these standards have included the following:

- Updating chemical batteries to provide a broader and more pertinent list of chemicals for each of the ensemble types. For example, the chemical battery used in NFPA 1992 now is more relevant to less volatile liquid chemical splash exposures. Additional changes have been made to the chemical lists in NFPA 1991 and NFPA 1994.
- Providing more options in the specification of ensembles such as flash fire escape protection for most standards, a liquefied gas protection option for NFPA 1991, ruggedized categories of performance for most classes of ensembles in NFPA 1994, and a stealth option for NFPA 1994 ensembles when used for law enforcement purposes.

Each of the three NFPA hazardous materials standards addresses entire ensembles to include the suit or garment, visor or faceshield (if present), gloves, and footwear. While respiratory equipment is a necessary part of the responder's protection, all respiratory-protective equipment must be certified to the respect National Institute for Occupational Safety and Health (NIOSH) regulations but these requirements are not specifically covered in the NFPA standards with the exception of SCBA, which further must either meet the NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services*[6] or NFPA 1986, *Standard on Respiratory Protection Equipment for Tactical and Technical Operations*[7] standards, in addition to the NIOSH certification criteria.

A related standard for first responders and other emergency personnel is NFPA 1999, *Standard on Protective Clothing and Ensembles for Emergency Medical Operations*[8]. This standard was originally developed to define protective clothing for persons providing emergency medical care against exposure to liquid-borne pathogens during emergency medical operations in response to the OSHA Final Rule (29 CFR Part 1910.1030)[1]. The first edition of the standard was introduced in 1992, with successive editions made in the following years to incorporate improved requirements and broaden the scope of the standard. For example, the standard now extends to both first responders engaged in emergency medical operations as well as first receivers. Several categories of protective clothing are covered by the standard, including single- and multiple-use garments, examination gloves, cleaning gloves, work gloves, and various eye and face protection devices such as goggles, faceshields, medical face masks, footwear, footwear covers, and helmets.

A significant amendment was made to the standard in April 2015 to provide a comprehensive revision that entailed creating new product categories of single-use and multiple-use ensembles in response to first responder needs for protection against Ebola Virus Disease. The 2018 edition of NFPA 1999 established the design, performance, certification, and labeling requirements for complete ensembles by specifying combinations of clothing items. The new ensembles are intended to protect individuals against highly infectious diseases that can be transmitted by both liquid and aerosol contact.

ORGANIZATION AND CONTENT OF NFPA STANDARDS

Each NFPA standard consists of a series of requirements that:

- Describes the product covered by the standard and the protection intended by the ensemble.
- Details procedures for independent certification of the product.
- Requires product labeling and user information.
- Contains specific criteria for design of the ensemble.
- Specifies minimum performance levels for the ensemble, its materials, and components evaluated using standardized tests.

A key distinction that the standards provided was the association of vapor protection with EPA Level A totally encapsulating chemical-protective suits and liquid-splash protection with EPA Level B (and Level C) chemical splash suits, with specific tests for demonstrating vapor and liquid protection for whole suits and suit materials. *Table 2* demonstrates the associations

TABLE 2 *Comparison of NFPA Standards and OSHA/EPA Levels for Respiratory Protection*

					Expected Dermal Protection from Suit(s)[5]			
NFPA Standard[1]	**Minimum OSHA/EPA Level**	**Respirator[2]**	**NFPA Barrier Method(s)[3]**	**Type of Challenge[4]**	**Chemical Vapor**	**Chemical Liquid**	**Particulate**	**Liquid-borne viruses**
1991 (2016)	A	SCBA	Permeation resistance	24 toxic industrial chemicals, 2 CWAs	X	X	X	X
1994 Class 1 (2018)	A	SCBA	Permeation resistance	10 toxic industrial chemicals, 2 CWAs	X	X	X	X
1994 Class 2 or 2R (2018)	B	SCBA	Permeation resistance; viral penetration resistance	5 toxic industrial chemicals, 2 CWAs; bacteriophage	X	X	X	X
1992 (2018)	B	SCBA	Penetration resistance	10 toxic industrial chemicals		X		
1994 Class 3 or 3R (2018)	C	CBRN APR or CBRN PAPR	Permeation resistance; viral penetration resistance	5 toxic industrial chemicals, 2 CWAs; bacteriophage	X	X	X	X
1994 Class 4 or 4R (2018)	C	CBRN APR or CBRN PAPR	Viral penetration resistance	Bacteriophage			X	X
1999 Single-Use or Multiple-Use (2018)	C	APR with P100 filter or PAPR with HEPA filter	Viral penetration resistance	Bacteriophage				X

[1] Refers to current edition of NFPA standard that defines complete ensemble (suit or garment, gloves, footwear, and respirator). NFPA 1991 also includes options for liquefied protection and flash fire protection. NFPA 1992 includes option for flash fire protection and addresses both encapsulating and non-encapsulating ensembles. In NFPA 1994, there are four classes of ensembles ranging from Class 1 (highest level of protection) to Class 4 (lowest level of protection). Type R or ruggedized protection is defined for Class 2, 3, and 4 for additional physical protection and durability over baseline ensembles. NFPA 1999 defines two types of ensembles for single use and multiple use (higher level of physical protection and durability).

[2] SCBA: Self-contained breathing apparatus; APR: Air-purifying respirator; PAPR: Powered air-purifying respirator; all SCBA are certified to at least NFPA 1981 for open-circuit SCBA with mandatory CBRN protection. SCBA specified for NFPA 1992 and NFPA 1994 Class 2 or 2R may alternatively be certified to NFPA 1986 (tactical and technical operations SCBA with CBRN protection). Where specified, APR or PAPR are certified as providing CBRN protection; NFPA 1999 does not require CBRN protection and only addresses particulate protection.

[3] Permeation resistance measures molecular transfer of chemical through materials and seams over 1-hr period; depending on standard, different chemical challenge concentrations are applied. NFPA 1991 specifies 100 g/m^2 for liquid challenges and 100% for gas challenges; NFPA 1994, Class 1 specifies 20 g/m^2 for liquid challenges and 1% for gas challenges; NFPA 1994 Class 2 or 2R specifies 10 g/m^2 for liquid challenges and 350 ppm for gas challenges; NFPA 1994 Class 3 or 3R specifies 10 g/m^2 liquid challenge with air flowing and 40 ppm for gas challenges; Penetration resistance testing determines if bulk liquid chemical passes through in 1-hr period, where part of exposure is at 13.8 kPa (2 psi) pressure; Viral penetration resistance determines if bacteriophage (a virus surrogate for Hepatitis virus and HIV) suspended in a liquid passes through material over a 1-hr period where part of the exposure is at 13.8 kPa (2 psi) as determined using a microbiological assay procedure.

[4] Different challenge substances are used for the different standards to represent a broad range of chemical exposures and properties. Where chemical warfare agents (CWAs) are indicated, distilled mustard (HD) and Soman (GD) are evaluated. NFPA 1991 involves the 21 liquid and gaseous chemicals specified in ASTM F1001, less acetonitrile, plus acrolein (liquid), acrylonitrile (liquid), and dimethyl sulfate (liquid); NFPA 1994, Class 1 specifies testing against 10 toxic industrial chemicals that include acrolein (vapor), acrylonitrile (vapor), ammonia (gas), chlorine (gas),

diethylamine (vapor), dimethyl sulfate (liquid), ethyl acetate (vapor), sulfuric acid (liquid), tetrachloroethylene (liquid), and toluene (liquid). NFPA 1992 entails only liquids that include butyl acetate, dimethyl formamide, Fuel H (synthetic gasoline), isopropyl alcohol (91%), methyl isobutyl ketone, nitrobenzene, sodium hydroxide (50%), sodium hypochlorite (10%), sulfuric acid (93%), and tetrachloroethylene (95%). Chemicals for NFPA 1994 Class 2, 2R, 3, and 3R include acrolein (vapor), acrylonitrile (vapor), ammonia (gas), chlorine (gas), and dimethyl sulfate (liquid).

[5] In addition to material and seam testing for barrier performance, ensembles compliant to NFPA standards are evaluated for their integrity to different types of exposures. NFPA 1991 and NFPA 1994 Class 1, 2, 2R, 3, and 3R ensembles are evaluated for man-in-simulant testing (MIST) to determine protection for vapor exposures where different levels of performance are specified for each standard and class. Liquid chemical protection is demonstrated by passing performance using a full ensemble liquid integrity test where the exposure time is varied with the particular standard or class. With the exception of NFPA 1994 Class 4 or 4R, particulate protection is demonstrated through ensembles passing both vapor (MIST) and liquid integrity tests. For NFPA 1994 Class 4 or 4R ensembles, an inward particulate leakage test is conducted. Protection from liquid-borne viruses (and other microorganisms) is demonstrated by the combination of material/seam viral penetration resistance and liquid integrity testing with the exception that NFPA 1994 Class 4 or 4R ensembles are only evaluated for material viral penetration resistance.

between the NFPA protection standards and the EPA levels of protection.

NFPA 1991 and NFPA 1992 each specify one type of ensemble with different variants. NFPA 1994 covers multiple classes of ensembles — Class 1 through Class 4, with Classes 2, 3, and 4 having ruggedized options as well. NFPA 1999 defines two different types of ensembles — single-use and multiple-use — in addition to several individual categories of protective clothing (garments, gloves, eye/facewear, and footwear). The primary elements of each standard are briefly described in the following subsections.

NFPA 1991

The standard specifies the requirements for vapor-protective ensembles intended to offer the highest level of chemical protection, which provide performance consistent with EPA Level A. NFPA 1991 ensembles are used with self-contained breathing apparatus (SCBA) or SCBA/supplied air respirator (SAR) respiratory protection in immediately dangerous to life and health (IDLH) environments. Features of these products include:

- Fully encapsulated suits that cover both the wearer and the respirator.
- Generally have a built-in face shield or visor, attached gloves, and sock-like extensions of the suit.
- Single- and multi-layer material approaches are applied.
- Multiple gloves are used to meet hand protection requirements.
- Suits generally use outer boots combined with the sock-like extensions of the suit (booties) where splash flaps cover the top of the outer boots.
- Covers or flaps are required for certain components such as exhaust valves and closures.
- Provided in at least four sizes.

In terms of key performance attributes, NFPA 1991 ensembles:

- Provide gas-tight integrity (will hold pressure).
- Resist inward leakage of hazardous vapors.
- Demonstrate long-term integrity against liquid (spray) penetration.
- Incorporate materials and seams that resist permeation of a broad range of liquid and gaseous chemicals, including TICs and CWAs with levels at 100% concentration over 1-hour period.
- Meet minimum standards for strength, durability, and functionality.
- Offer limited material flame resistance.
- Can comply with optional criteria defining additional protection against chemical flash fires for escape purposes and/or ability to withstand contact with liquefied gases.

Representative ensembles are pictured in *Exhibit 1.*

EXHIBIT 1 *Example of an NFPA 1991 Compliant Ensemble. (Courtesy of Ansell)*

NFPA 1992

This standard specifies the requirements for liquid splash–protective ensembles; these are not intended for protection from gases or vapors. The standard covers full ensembles and separate garments, gloves, and footwear. NFPA 1992 ensemble performance is consistent with EPA Level B. These ensembles are used with SCBA or SCBA/SAR respiratory protection in IDLH environments. Specific features of NFPA 1992 ensembles include:

- May be one- or multiple-piece garments.
- Some products include attached gloves and footwear.
- Garments may or may not be encapsulating.
- If not encapsulating, interfaces are required for the respirator, gloves, and footwear.
- Multiple gloves may be used to meet hand protection requirements.
- Suits generally use socks combined with outer boots.
- Typically garments are of a single layer construction.
- Garments must be provided in at least four sizes while gloves have to be provided in five sizes.
- Garments may be breathable. Manufacturers making this claim are required to provide data in support of specific claim.

In terms of key performance attributes, NFPA 1992 ensembles:

- Demonstrate integrity against liquid (spray) penetration.
- Are constructed of materials that resist liquid penetration against low volatility liquids, or liquids with high vapor pressures that do not produce hazardous vapors over 1-hour period.
- Meet minimum standards for strength, durability, and functionality (levels lower than NFPA 1991).
- Can be certified to meet optional criteria defining additional protection against chemical flash fires for escape purposes.
- Allow garments, gloves, and footwear to be separately certified.

Representative ensembles are pictured in *Exhibit 2*.

NFPA 1994 Class 1

The Class 1 requirements of NFPA 1994 are a new category of NFPA 1994 that defines ensembles that protect against chemical warfare agents, toxic industrial chemicals, biological agents (bloodborne pathogens), and particulates. These ensembles are intended for IDLH environments requiring SCBA and provide protection against vapors, liquid droplets, and aerosols where potential skin contact is expected to be at moderate to high levels. Specific expected features of these ensembles include:

- One-piece or multiple-piece garments, which may or may not cover respiratory-protective equipment.
- If not encapsulating, the ensemble is required to have an interface with SCBA, gloves, and footwear.

EXHIBIT 2 *Example of an NFPA 1992 Compliant Ensemble. (Courtesy of Saint Gobain Performance Plastics and DuPont Protection Technologies.)*

- Multiple gloves may be used to meet hand protection requirements.
- Garments generally may use socks combined with outer boots.
- Garments typically have a single-layer construction.
- Ensembles must be provided in at least four sizes.

In terms of key performance attributes, NFPA 1994 Class 1 ensembles:

- Demonstrate integrity against vapors and aerosols, and prevent inward leakage of liquid spray (less than NFPA 1991).
- Are constructed of materials and seams that resist permeation by selected chemical warfare agents and toxic industrial chemicals, and also prevent penetration of bloodborne pathogens (tests at realistic concentrations).
- Meet minimum standards for strength, durability, and functionality.
- Must be constructed of materials that provide limited flame resistance.
- Are intended for single exposure, although some products may be worn more than once.
- Can be constructed using optional criteria that define additional protection against chemical flash fires for escape purposes and having stealth characteristics.

NFPA 1994 Class 2

The Class 2 requirements of NFPA 1994 define ensembles that protect against chemical warfare agents, toxic industrial chemicals, biological agents (bloodborne pathogens), and particulates. These ensembles are intended for IDLH environments requiring SCBA and provide protection against vapors, liquid droplets, and aerosols where potential skin contact is expected to be limited. Specific features of NFPA 1994 Class 2 ensembles include:

- One-piece or multiple-piece garments, which may or may not cover respiratory-protective equipment.
- Garments require interface with SCBA (if not encapsulated), gloves, and footwear.
- Multiple gloves may be used to meet hand protection requirements.
- Garments generally use integrated socks combined with outer boots.
- Typically garment materials are of a single-layer construction.
- Ensembles must be provided in at least four sizes.

In terms of key performance attributes, NFPA 1994 Class 2 ensembles:

- Demonstrate integrity against vapors and aerosols, and prevent inward leakage of liquid spray.
- Incorporate materials and seams to resist permeation by selected chemical warfare agents and toxic industrial chemicals, as well as prevent penetration of bloodborne pathogens.
- Meet minimum standards for strength, durability, and functionality.
- Have materials that are not evaluated for limited flame resistance.
- Are intended for single exposure; some products may be worn more than once.
- Can be certified to optional criteria that define additional protection against chemical flash fires for escape purposes and having stealth characteristics.
- May also be certified as ruggedized type with greater durability.

Representative ensembles are pictured in *Exhibit 3.*

a) b)

EXHIBIT 3 *Two Examples of NFPA 1994 Class 2 Compliant Ensembles. [Courtesy of a) Blauer Manufacturing Company, and b) LION First Responder PPE, Inc.]*

NFPA 1994 Class 3

The Class 3 requirements of NFPA 1994 define ensembles that protect against chemical warfare agents, toxic industrial chemicals, biological agents (bloodborne pathogens), and particulates. These ensembles are intended for incidents classified below IDLH conditions and where air-purifying respirators (APRs) or powered air-purifying respirators (PAPRs) are permitted. They are designed for lower levels of protection against vapors, liquid droplets, and aerosols, at lower levels of exposure where direct skin contact is not likely. Specific features of NFPA 1994 Class 3 ensembles include:

- One-piece or multiple-piece garments.
- Ensembles require interface with APR or PAPR, gloves, and footwear.
- Multiple gloves may be used to meet hand protection requirements.
- Garments generally use integrated socks combined with outer boots.
- Garments are typically of single-layer construction.
- Ensembles must be provided in at least four sizes.

In terms of key performance attributes, NFPA 1994 Class 3 ensembles:

- Demonstrate integrity against vapors and aerosols (lower than Class 2 ensembles).
- Prevent inward leakage of liquid spray (shorter liquid exposure durations than Class 2 ensembles).
- Are constructed of materials and seams that resist permeation by selected chemical warfare agents and toxic industrial chemicals (evaluated at lower concentrations and less severe conditions than Class 2).
- Are constructed of materials and seams that prevent penetration of bloodborne pathogens.
- Meet minimum standards for strength, durability, and functionality (lower requirements than Class 2).
- Use materials that have minimum level of breathability.
- Use materials that are not evaluated for limited flame resistance.
- Are intended for single exposure; some products may be worn more than once.
- Can be certified to optional criteria that define additional protection against chemical flash fires for escape purposes and having stealth characteristics.
- May also be certified as ruggedized type with greater durability.

Representative ensembles are pictured in *Exhibit 4.*

EXHIBIT 4 *Examples of NFPA 1994 Class 3 Compliant Ensembles. [Courtesy of a) Blauer Manufacturing Company, and b) LION First Responder PPE, Inc.]*

NFPA 1994 Class 4

The Class 4 requirements of NFPA 1994 define ensembles that protect against biological agents (bloodborne pathogens) and particulates. These ensembles are intended for protection against biological aerosols or radiological-contaminated particulates below IDLH levels where APRs or PAPRs would be suitable; no protection offered against chemical warfare agents or toxic industrial chemicals. An example application is "white powder" (anthrax or fentanyl) response or biological exposure events (e.g., potential victims of Ebola Virus Disease). Specific features of NFPA 1994 Class 4 ensembles include:

- One-piece or multiple-piece garments.
- Garments require interface with APR or PAPR, gloves, and footwear.
- Multiple gloves may be used to meet hand protection requirements.
- Garments generally use booties (or integrated socks) combined with outer boots.
- Garment materials are typically of single-layer construction.
- Ensembles must be provided in at least four sizes.

In terms of key performance attributes, NFPA 1994 Class 4 ensembles:

- Demonstrate integrity against particulate penetration.
- Are constructed of materials and seams that prevent penetration of bloodborne pathogens.
- Meet minimum standards for strength, durability, and functionality.
- Use garments that have minimum level of breathability (more breathable than Class 3).
- Are constructed of materials that are not evaluated for limited flame resistance.
- Are intended for single exposure; some products may be worn more than once.
- Can be certified to optional criteria that define additional protection against chemical flash fires for escape purposes and having stealth characteristics.
- May also be certified as ruggedized type with greater durability.

A representative ensemble is shown in *Exhibit 5*.

EXHIBIT 5 *Example of NFPA 1994 Class 4 Compliant Ensemble. (Courtesy of Blauer Manufacturing Company.)*

NFPA 1999

NFPA 1999 specifies the requirements for single-use and multiple-use medical-protective ensembles for protecting against liquid-borne or airborne highly infectious diseases. Single-use ensembles are intended for one-time use. Multiple-use ensembles are intended for repeated use with reuse predicated on their adequate cleaning and decontamination before reuse. These ensembles have the following characteristics:

- Both ensemble types provide full body coverage with no exposed skin.
- Single-use ensembles include single-use coveralls or two-piece garments, two pairs of examination gloves, multiple-use footwear or single-use footwear covers, and different combinations of eye/face protection devices (e.g., goggles, faceshields, and N95 filtering facepieces).
- Multiple-use ensembles include multiple-use coveralls or two-piece garments, cleaning or work gloves worn over examination gloves, multiple-use footwear, and either a full-face APR with P100 filters, or

tight or loose-fitting PAPR having a high efficiency ("HE") particulate protection level.

In terms of key performance attributes, NFPA 1999 ensembles:

- Prevent inward leakage of liquid spray (multiple-use ensembles are tested for a longer duration exposure).
- Are constructed of materials and seams that prevent penetration of bloodborne pathogens (multiple-use ensembles are evaluated after repeated laundering).
- Have garments that meet minimum standards for strength, durability, and functionality (multiple-use garments are evaluated under more severe conditions with higher criteria).
- Meet individual criteria established for ensemble elements, including gloves, footwear, and eye/face protection devices.
- Separate items of clothing can be certified to NFPA 1999, including single-use garments, multiple-use garments, examination gloves, cleaning gloves, work gloves, footwear, medical receiver footwear (without physical protection), footwear covers, helmets, and PAPR.

A representative ensemble is shown in *Exhibit 6.*

EXHIBIT 6 *Example of NFPA 1999 Compliant Ensemble. (Courtesy of International Personnel Protection, Inc.)*

RELEVANCE OF PERFORMANCE TESTING

An essential component of the NFPA PPE standards is the operational relevance of the testing that is applied to the different ensembles. In developing the NFPA standards, specific test methods and validated criteria for establishing acceptable performance can be summarized by five basic questions.

Question 1: Do NFPA ensembles prevent the penetration of specific chemicals and other substances into the ensemble that may be encountered during emergency operations?

Overall ensemble integrity tests correspond to expected types of exposure stated in each standard and address the most likely pathway for wearer exposure to hazardous substances — ensemble interfaces, seams, and closures.

- Man-in-Simulant Tests (MIST) are used to demonstrate integrity of the ensemble against the penetration of gases and vapors and are applied to NFPA 1991 and NFPA 1994 Class 1, 2, and 3 ensembles. MIST entails human test subjects wearing the ensemble in a controlled chamber where they are exposed to a hazardous chemical simulant (salicylate) while performing a range of exercises. Small, specially designed adsorbent dosimeters are positioned on the test subject's body to collect any penetrating vapor and are analyzed to show the relative protection factor in each area of the body where the dosimeters are located. Quantitative protection factor results are provided for the individual body areas and the overall system.
- Suit inflation testing is performed as a supplemental assessment of gas/vapor integrity for NFPA 1991 ensembles. This test involves inflating the ensemble to a specific pressure and determining the pressure drop after a given period of time to provide an indication of air leakage from the ensemble. In order for the test be performed, the exhaust valves must be blocked.
- Overall liquid integrity testing is applied to all ensembles in each standard with the exception of NFPA 1994 Class 4 ensembles. In this testing, the ensemble is placed on a manikin that is already dressed in a liquid absorptive garment. The ensemble is exposed to surfactant treated water from nozzles positioned around the ensemble at a controlled liquid flow rate. *Exhibit 7* shows an ensemble being evaluated for overall liquid integrity. Over the course of the test, the ensemble is rotated so that all portions of the ensemble are exposed to liquid spray. Different test durations are specified depending on the intended level of liquid integrity. Following the liquid spray exposure and careful removal of the test ensemble, the inner liquid absorptive garment is inspected for liquid marking as evidence of liquid penetration. Test results are reported as pass or fail.
- Inward particle leakage testing is performed on NFPA 1994 Class 4 ensembles where a human subject wears a solid black garment underneath their ensemble and performs a number of exercises in a chamber with fluorescently tagged silica particles.

EXHIBIT 7 *Ensemble Being Evaluated for Overall Liquid Integrity. (Courtesy of International Personnel Protection, Inc.)*

The particles are driven by an airflow during the test subject exposure. Following the exposure and the careful removal of the test ensemble, the test subject is photographed under UV light to show any evidence of particle penetration. Results are reported as pass or fail.

Question 2: Do the materials used in the construction of NFPA ensembles adequately resist permeation and penetration of hazardous substances under relevant exposure conditions?

Resistance of barrier materials and seams is the most extensive requirement of each standard. Each ensemble element, including the suit (or garment), visor, gloves, footwear, and primary seams of the ensemble, are tested; closures are also tested for penetration resistance in NFPA 1991.

- Permeation resistance testing is used for vapor, gases, or highly toxic chemicals, and is applied in NFPA 1991 and NFPA 1994 for Class 1, 2, and 3 ensembles. It is also used in the evaluation of cleaning gloves under NFPA 1999 against selected disinfection chemicals. Permeation resistance testing involves measuring the amount of chemical that passes through a material in a specified test period (1 hour). Permeation resistance testing is carried out in a special test cell where ensemble material specimens divide the test cell into two chambers — the challenge side where the exterior side of the material faces the test chemical, and the collection side on the interior side of the material for collection of permeating chemical. Depending on the NFPA standard, exposure conditions are different in terms of the chemical concentration, temperature, humidity, and airflow over the tested material. The test provides the cumulative permeation (dose of chemical passing through given area of material) for the entire chemical exposure period and at 15-minute intervals.
- Liquid penetration resistance is primarily used when ensembles are expected to protect against short-term chemical contact by liquid splashes. It is principally applied in NFPA 1992 for liquid splash–protective ensembles. It is also used in NFPA 1991 for evaluating the barrier properties of the closure. In penetration resistance testing, ensemble material specimens are placed in a test cell where the ensemble material specimen covers an open cavity while the exterior side of the specimen is visible. Test chemical is placed in the test cell cavity and the exterior side of the material is observed for liquid penetration. During a portion of the 1-hour test, pressure is applied to the liquid. Test results are reported as pass or fail depending on the observation of test chemical coming through the material during the 1-hour exposure period. An example of a failing test is shown in *Exhibit 8.*

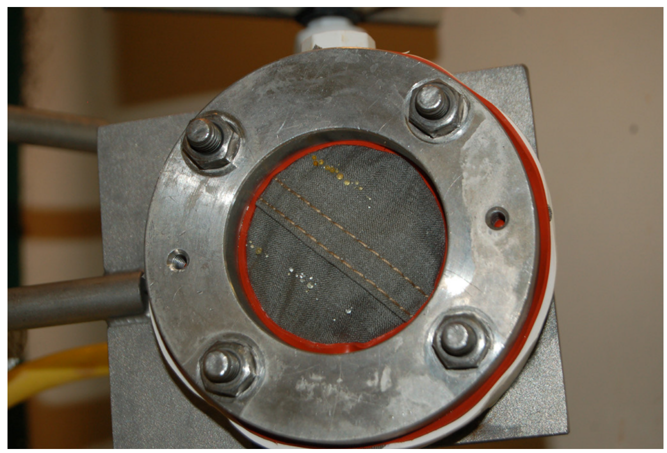

EXHIBIT 8 *Liquid Penetrating Material Samples During Liquid Penetration Resistance Test. (Courtesy of International Personnel Protection, Inc.)*

- Viral penetration resistance testing is used on all NFPA 1994 and NFPA 1999 ensembles. A similar test cell is used as in liquid penetration resistance testing but the test chemical is replaced with a special liquid challenge solution that contains a surrogate virus. At the conclusion of the test, the viewing surface of the ensemble material specimen is rinsed with a clean solution and assayed for the presence of penetrating virus. If any viruses are detected in the assay solution, the specimen fails the test.

Because it is impossible to test with every possible chemical, specific chemicals have been chosen to represent a range of chemical exposure concerns. *Table 3* illustrates the range of chemicals used in the evaluation of ensemble materials that are part of each standard. It includes chemicals that are both skin toxic

TABLE 3 *Standard Chemical Batteries for Evaluating Protective Ensemble Materials*

Chemical	State	Skin Toxic?	NFPA 1991	NFPA 1991 Liquefied Gases	NFPA 1992	NFPA 1994 Class 1	NFPA 1994 Class 2 and 3
Acetone	Liquid	No	◆				
Acetonitrile	Liquid	Yes	◆				
Acrolein	Liquid*	Yes	◆			◆	◆
Acrylonitrile	Liquid *	Yes	◆			◆	◆
Ammonia	Gas	No	◆	◆		◆	◆
1,3-Butadiene	Gas	No	◆				
Butyl Acetate	Liquid	No			◆		
Carbon Disulfide	Liquid	Yes	◆				
Chlorine	Gas	No	◆	◆		◆	◆
Dichloromethane	Liquid	No	◆				
Diethylamine	Liquid*	Yes	◆			◆	
Dimethylformamide	Liquid	Yes	◆		◆		
Dimethyl sulfate	Liquid	Yes	◆			◆	◆
Ethyl Acetate	Liquid*	No	◆			◆	
Ethylene Oxide	Gas	No	◆	◆			
Fuel H†	Liquid	No			◆		
Hexane	Liquid	Yes	◆				
Hydrogen Chloride	Gas	No	◆				
Isopropyl Alcohol (91%)	Liquid	No			◆		
Methanol	Liquid	Yes	◆				
Methyl Chloride	Gas	Yes	◆				
Methyl Isobutyl Ketone	Liquid	No			◆		
Mustard (distilled)	Liquid	Yes	◆			◆	◆
Nitrobenzene	Liquid	Yes	◆				
Sodium Hydroxide (50%)	Liquid	No	◆		◆		
Sodium Hypochlorite (10%)	Liquid	No			◆		
Soman	Liquid	Yes	◆			◆	◆
Sulfuric Acid (93.1%)	Liquid	No	◆		◆	◆	
Tetrachloroethylene	Liquid	Yes	◆		◆	◆	
Tetrahydrofuran	Liquid	No	◆				
Toluene	Liquid	No	◆			◆	

* Tested as vapor for NFPA 1994 permeation testing applications

† 42.5% Toluene, 42.5% Isooctane, 15% Ethanol

and those that are predictive for a range of chemicals that can affect protective ensemble materials. Some chemicals were selected to represent different classes of chemicals. Different batteries are used in each NFPA standard depending on the intended application of the ensemble.

Question 3: Does the ensemble have the durability and physical properties necessary for the expected use?

The required testing criteria in the standards provide confidence that the protective capabilities will be maintained over time. Ensemble materials are subjected to repeated flexing and abrasion to simulate use prior to barrier testing. Different materials used in the construction of the ensemble are evaluated for relevant physical properties where specific criteria have been set for the respective NFPA standards based on acceptable levels of strength and physical hazard resistance.

- Suit/garment and visor materials are evaluated for burst strength, puncture/tear or impact resistance, and cold temperature stiffness.
- Glove materials are tested for cut resistance (see *Exhibit 9*), puncture resistance, and cold temperature stiffness.

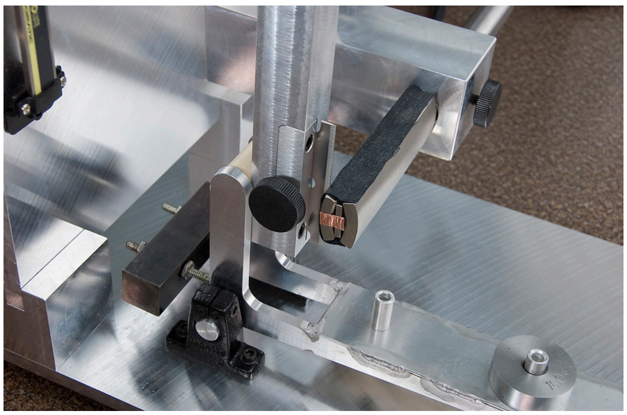

EXHIBIT 9 *Ensemble Glove Material Being Evaluated for Cut Resistance. (Courtesy of International Personnel Protection, Inc.)*

- Footwear is tested for cut resistance, puncture resistance, abrasion resistance, impact/compression resistance, and slip resistance.
- Specialized materials such as those used in interfaces are also evaluated for specific physical properties.

In NFPA 1994, a ruggedized type of each ensemble is specified for Class 2, 3, and 4 ensembles as a variant intended for more physically demanding environments and to allow potential ensemble reuse (considering the ensemble is safe to reuse). The ruggedized type for these ensembles specifies more rigorous physical property requirements for garment and glove materials, and further evaluates garment barrier performance following five wash and dry cycles combined with an increased number of flexing and abrasion cycles.

Question 4: Will ensemble materials contribute to wearer injury in the event of accidental short-term exposure to severe hazards such as flame, flash fire, or liquefied gases?

During an emergency response, accidental flame contact may occur. To ensure ensembles do not readily ignite and continue to burn, test methods are applied to:

- Assess the ease of ignition and the propensity for continued burning of ensemble materials when exposed to a flame (NFPA 1991 and NFPA 1994 Class 1 only). Flame resistance testing involves exposing a folded edge of the ensemble material directly in a burn or flame for a 3-second period and measuring the subsequent continued time the specimen burns (afterflame time). See *Exhibit 10*. Acceptable materials cannot have an afterflame time of more than 2 seconds and are further not permitted to melt and drip when exposed under these conditions.

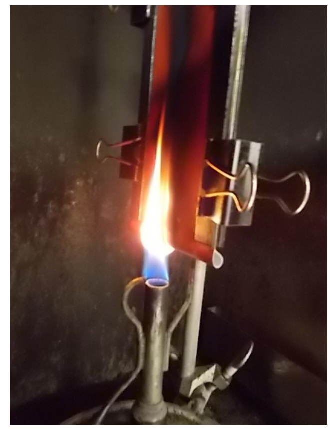

EXHIBIT 10 *Exposure of Ensemble Material in Flame Resistance Test. (Courtesy of International Personnel Protection, Inc.)*

- Apply additional criteria for those ensembles that claim protection against chemical flash fires for escape purposes (NFPA 1991, 1992, and 1994 only). For flash fire testing, a longer flame exposure time is used (12 seconds) and the material cannot show damage over more than 100 mm. In addition, ensemble materials are evaluated for their insulation properties and the overall ensemble is subjected to a simulated flash fire where it is expected to show no continued afterflame and maintain its integrity for permitting the wearer to escape from the flash fire event.
- Ensemble materials used in NFPA 1999 ensembles must demonstrate limited flammability by assessing the rate of flame spread on the material specimen.
- Offer a separate option for protection against liquefied gases — ammonia, chlorine, and ethylene oxide (NFPA 1991 only). Demonstration of protection from liquefied gases is determined by specific permeation resistance testing against selected chemicals and liquefied states in combination with assessments on the physical damage created by the liquefied gas exposure.

Question 5: Will the ensemble limit user functionality and their ability to complete required missions and response activity?

Protection requirements do not come at the expense of ensemble functionality. Each NFPA standard addresses functionality by testing ensembles with their elements to ensure that responders can readily complete mission-based tasks. Functional aspects tested include visor clarity and field of vision, accommodation of hard hats, glove impact on dexterity and hand function, and footwear levels of slip resistance (traction) on smooth surfaces. Ensembles are assessed for overall function by having test subjects wear the ensembles and perform various exercises to determine the range of motion and ability to carry out mission-specific tasks such as moving a 55-gallon drum with a hand truck (*Exhibit 11*); lifting weighted boxes and putting them onto and taking them off of a table; coiling and uncoiling a length of hose; using a wrench and a screwdriver to install/remove a bolt and screw; and climbing a ladder.

Some NFPA standards including NFPA 1994 Class 3 and Class 4 ensembles, as well as the ensembles specified in NFPA 1999, require the garment material to be breathablew by the application of total heat loss, evaporative resistance, or moisture vapor transmission rate test. These requirements are intended to promote improved comfort to the wearer while balancing the barrier characteristics of the ensemble.

Table 4 shows the types of requirements that are applied in the various NFPA standards.

EXHIBIT 11 *Ensemble Being Evaluated for Overall Function by Test Subject Moving 55-Gallon Drum. (Courtesy of Intertek Testing Services.)*

VALUE OF APPLYING NFPA STANDARDS FOR PPE

NFPA standards are developed through a voluntary consensus process accredited by the American National Standards Institute. The process ensures the balanced participation of users, enforcers, consumers, manufacturers, special experts, and labor, research, and testing organizations. No single interest category may constitute more than one-third of the committee voting membership. Standards are developed in an open and transparent way, with specific stages for public input and comment.

TABLE 4 *Matrix of Performance Properties Applied in NFPA Standards*

Performance Areas	**NFPA 1991 (2016)**	**NFPA 1992 (2018)**	**NFPA 1994 Class 1 (2018)**	**NFPA 1994 Class 2 (2018)**	**NFPA 1994 Class 3 (2018)**	**NFPA 1994 Class 4 (2018)**	**NFPA 1999 Multiple Use (2018)**	**NFPA 1999 Single Use (2018)**
Ensemble Integrity Tests								
Inflation (gas-tight integrity)	◆							
Overall airflow	◆		◇					
Man-in-simulant-test (MIST)	Very High		High	Moderate	Low			
Liquid-tight integrity	Long	Moderate	Moderate	Moderate	Short		Short	Very Short
Particulate inward leakage						◇		
Material Barrier Tests								
Permeation resistance								
- Standard industrial chemicals	◆ Very High		◆ High					
- Toxic industrial chemicals	◆ Very High		◆ High	◆ Moderate	◆ Low			
- Chemical warfare agents	◆ Very High		◆ High	◆ Moderate	◆ Low			
Liquid penetration resistance	Closure	◆						
Viral penetration resistance				◇	◇	◇	◇	◇

TABLE 4 (Continued)

Performance Areas	NFPA 1991 (2016)	NFPA 1992 (2018)	NFPA 1994 Class 1 (2018)	NFPA 1994 Class 2 (2018)	NFPA 1994 Class 3 (2018)	NFPA 1994 Class 4 (2018)	NFPA 1999 Multiple Use (2018)	NFPA 1999 Single Use (2018)
Durability/Physical Properties								
Garment burst/puncture-tear resistance	High	Low	High	Moderate	Low	Low	Moderate	Very Low
Garment/visor/glove seam strength	High	Low	High	Low	Low	Low	Moderate	Very Low
Visor impact resistance	◆	◆	◆	◆	◆	◆	◇	
Glove cut/puncture resistance	High	Low	High	Moderate	Low	Low	Moderate	Low
Footwear upper cut/puncture resistance	High	Low	High	Moderate	Low	Low	Moderate	Moderate
Footwear sole abrasion/puncture	◆	◆	◆	◆	◆	◆	◇	◇
Footwear toe impact/compression resistance	◆	◆	◆	◆	◆	◆	◇	◇
Cold temperature performance	◆	◆	◆	◆	◆	◆		
Abrasion/flexing barrier durability	Very High	Moderate	High	Moderate	Moderate	Moderate	Moderate	
Exhaust valve mounting strength	◆		◇					
External fitting pull out strength	◆		◇					
Other Hazards								
Limited flame resistance	◆		◇					
Flash fire performance	◇	◇	◇	◇	◇	◇		
Material flammability							◇	
Liquefied gas protection	◇							
Functionality Tests								
Ensemble effect on wearer mobility	◆	◆	◆	◆	◆	◆	◇	◇
Exhaust valve one-way flow	◆		◇					
Garment total heat loss		◇		◇	◆Moderate	◆ High	◆ High	
Garment evaporative resistance		◇		◇	◆ High	◆ High	◆ High	
Moisture vapor transmission								◇
Visor clarity	◆	◆	◆	◆	◆	◆	◇	
Ensemble field of vision	◆	◆	◆	◆	◆	◆	◇	
Timed removal of hands from gloves	◆							
Glove-hand dexterity	Low	Moderate	Low	Moderate	Moderate	Moderate	Moderate	High
Footwear traction	◆	◆	◆	◆	◆	◆	◇	◇

◆Requirement applied within standard

◇ Optional requirement for standard; that there is no mandatory requirement for certification to the standard, but the manufacturer may choose to provide this performance for certifying their ensemble. If the manufacturer chooses to provide this additional performance, the optional requirements become mandatory.

Very high, high/low, high/moderate/low, long/moderate/short, or very short provide a comparison of the criteria applied in that standard relative to the other NFPA chemical-protective ensemble standards. Note that low does not mean that the ensemble provides low levels of performance.

NFPA standards are minimum performance specifications. For example, minimum sizing requirements are specified in each standard. Manufacturers can and do exceed the established criteria. End user organizations can specify higher limits or set additional criteria to meet their intended protection applications. Manufacturers provide a technical data package that consists of detailed descriptions of all ensemble parts and components, and includes the performance data that demonstrates compliance of the ensemble with the respective standard. The NFPA product certification process requires that:

- All ensembles must meet all criteria in the standard in order to be considered compliant. No partial certifications are allowed.
- Each standard includes an independent, third-party certification, minimum manufacturer quality assurance (including manufacturer ISO 9001 quality standard registration), and annual recertification.
- Certifying organizations use unannounced visits to audit manufacturer products for compliance with the applicable standard. Follow-up testing is conducted to ensure products remain compliant.
- The criteria for third-party certification in all three standards exceed industry practices applied in other PPE specifications and standards used in the chemical protection industry, including requirements for a recall or safety alerts, if necessary.

The NFPA standards are by no means all inclusive; they are not a substitute for user education and appropriate training as covered in NFPA 472. Many response organizations consider these standards to be overly rigorous and as producing expensive products. Nevertheless, the NFPA standards do provide a baseline performance that has spurred the development of chemical-protective garments for improved wearer protection. When used in conjunction with user experience, the process for selecting a chemical-protective suit can become much easier.

RISK-BASED APPROACH FOR SELECTING PPE

The selection of PPE must be based on first completing a risk assessment. Two types of risk assessments will aid in selecting PPE for purchase or for use — those performed on the general, expected situations that response teams encounter and assessments that are performed for a specific hazard. In each case, the risk assessment should consist of the following steps:

- Identifying the hazards present or likely to be present
- Estimating the likelihood of exposure
- Understanding the consequences of exposure
- Determining the risk

General Risk Assessment

A simple model for conducting a risk assessment is shown in *Table 5*. In this model, the likelihood of exposure and the consequences of exposure are estimated for each expected hazard. Risk is determined by multiplying the exposure likelihood by the exposure consequences. In this way, risks associated with specific hazards can be determined and ranked to ascertain protection and clothing performance needs.

The hazards alone need not be the determining factor for choosing PPE; rather the potential for exposure should govern selection of CPC. For example, the risk is different when dealing with 1 gal (3.8 L) of toluene versus dealing with a tank car full of the same chemical. Under-protection should be avoided to prevent exposure, but over-protection can be just as dangerous. Over-protection can lead to injury through heat stress and hinder the wearer from safely performing the needed tasks. Contingencies must be planned for, but a sense of realism should prevail when it comes to suit selection. The following factors should be collectively considered when selecting CPC:

- Overall ensemble integrity
- Material chemical resistance
- Material strength and physical hazard resistance
- Ensemble functional properties
- Overall suit design
- Service life
- Cost

Earlier sections of this chapter indicated how specific ensemble performance properties related to overall integrity, material chemical resistance, and material strength and physical hazard resistance, and ensemble functional properties.

Design Features

How the ensemble is designed affects wearer function, fit, and comfort. These features are difficult to measure and are most often subjective of all evaluations, but are still an important part of the selection process. The best way to evaluate suit design is through trial wearing or field testing of prospective ensembles. These trials need to include tasks that replicate the same types of movements and stresses that would be placed on suits during actual use. Through this type of evaluation, end users can determine how the suit impacts their ability to perform work. The following are examples of relevant design features:

- Location and length of the closure (affects ease of putting on and taking off suit)
- Position, size, and type of the visor (affects user ability to see outside the suit)
- The bulk of the suit materials, in terms of the number of layers and the relative stiffness (affects user movement, ability to perform tasks)

TABLE 5 *Risk Assessment Areas for Selection of CPC*

	Body Area Affected					
Hazard Area	**Full Body**	**Respiratory System**	**Head Area**	**Torso**	**Arms/Hands**	**Legs/Feet**
Chemical vapor inhalation		■				
Chemical vapor skin absorption	■					
Chemical liquid skin contact	■					
Chemical ingestion			■			
Falling objects			■		■	■
Flying debris	■		■	■	■	■
Sharp objects	■		■	■	■	■
Rough surfaces	■		■	■	■	■
Slippery surfaces					■	■
Extreme cold	■	■	■	■	■	■
High heat	■	■	■	■	■	■
Flame exposure	■		■	■	■	■
Chemical flash fire	■		■	■	■	■
Static discharge	■		■	■	■	■
Electrical shock	■		■		■	■
Poor visibility	■					
Falling from height	■					
Falling into water	■	■				
Cold stress	■	■	■	■	■	■
Heat stress	■	■	■	■	■	■
Mobility restriction	■		■	■	■	■
Dexterity restriction					■	
Vision restriction						
Hearing restriction						

Note: Shaded boxes indicate where the hazard applies to a specific body area.

- The type of glove system (the number of gloves that must be used and the relative bulk and stiffness)
- The type of footwear system (combination of all footwear articles needed for foot protection)
- Interfaces between the suits and gloves and footwear (affects system integrity)
- The volume inside the suit hood area for accommodating the wearing of a respirator facepiece, head protection, and other equipment
- The overall volume inside the suit for those suits where the respirator is worn inside
- Available suit, glove, and footwear sizes (for accommodating different sized individual responders)
- Accommodation of different types of other response equipment, including respirators, cooling systems, and helmets

These features dramatically affect user function. In particular, glove systems have been found to decrease dexterity and cause hand function problems. Gloves are a problem for hazardous materials responders for some types of ensembles. Currently, many responders use double or triple gloving techniques to compensate for a limited size range and material selection shortcomings. However, using this multiglove technique is not without its tradeoffs, including limited dexterity (e.g., difficulty using gas detector button controls). Some responders carry a small pencil stub or other disposable tool taped to their suit sleeves to help press small meter buttons with accuracy. Sizing is important because manufacturers offer these suits in a number of different sizes and first responders often have to wear other equipment, which affect the ensemble's fit and function. Accommodating particularly large or small people can be difficult with a limited number of sizes. Ill-fitting clothing is particularly apparent for persons not being able to clearly see out of suits having visors or creating restrictions in the ability to move. Many hazardous materials response teams make up for the poor ergonomic design of an ensemble by applying generous amounts of duct tape or its chemical-resistant equivalent, binding clothing areas to keep interfaces in place and improve the profile of the clothing. Yet, an ensemble does not have to fit poorly if it is properly sized and evaluated by each individual wearer.

Service Life

In general, most users perceive inexpensive, lightweight plastic-based products as less durable and disposable, and relatively more expensive, heavy, rubber-based products as reusable. The service life of a product is actually based on its life cycle cost, durability, and ease of decontamination. Life cycle cost includes all costs associated with the use of the product including the initial purchase, maintenance, decontamination, storage, and disposal costs. There are also costs for putting clothing back into use and ensuring that it is safe. While purchase costs may be the principal cost for product use, disposal costs are taking on greater significance.

Determining how well the suit maintains its original condition for providing protection to the wearer best assesses durability. This factor can be evaluated by measuring product chemical resistance for representative products following simulated use (information generally not provided in manufacturer literature). If the clothing loses its chemical resistance from abrasion, repeated flexing, or other forms of wear, this suggests suits might not maintain their barrier performance during use. The ruggedness of the CPC is also a factor for how durable the suit might be.

Ease of decontamination is also important. If the product cannot be easily decontaminated, it becomes disposable regardless of the initial purchase cost. Products that are reused must be decontaminated to an acceptable level, knowing that it is safe to wear the suit without exposing the user to residual levels of chemical contaminants. Making this assessment is not a straightforward process because it requires a detailed knowledge of the interaction of the chemicals with the clothing materials for understanding whether a particular decontamination technique will reliably remove residual chemical. For some chemicals, this may not be a large issue because the combination of a relatively good chemical resistance in CPC materials and the volatility of many chemicals may mean that the chemical is removed by surface cleaning with the remainder evaporating. However, there are many chemicals that can be persistent and that are not easily removed through conventional decontamination techniques. Furthermore, the ability to assess the effectiveness of the decontamination process might be hampered by an inability to measure residual chemical in the clothing and to realize the significance of any measured levels of that chemical.

Cost

The issue of cost cannot be dismissed. In an ideal world, the "best" suit in the marketplace would be purchased. But the fact is that organization resources for multiple forms of protective ensembles are limited. While some organizations have been able to set up programs to recoup PPE costs from those responsible for the incident, this form of chemical-protective suit reimbursement cannot always be relied on. Response organizations want the optimum number and types of protective ensembles in their inventory to minimize selection decisions and obtain the best protection for their team members. Therefore, issues of product service life are also important to the cost as is the recognition that any protective ensemble use can render it disposable.

Specific Selection Approach

The selection process follows the hazard and risk information and an understanding of the NFPA standards and product features through a series of decisions to determine which type of ensemble provides the needed minimum protection.

International Personnel Protection, Inc. developed a risk-based selection tool to assist emergency response personnel in the proper selection of PPE based on the available NFPA standards. The decision logic used in the tool is provided in Appendix A.

REFERENCES

1. Title 29, Code of Federal Regulations, OSHA Parts 1910.120 and 1910.1030, U.S. Government Printing Office, Washington, DC.
2. NFPA 1991, *Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents*, National Fire Protection Association, 2016.
3. NFPA 1992, *Standard on Liquid Splash–Protective Ensembles and Clothing for Hazardous Materials Emergencies*, National Fire Protection Association, 2018.
4. NFPA 1993, *Standard on Support Function Protective Clothing for Hazardous Chemical Operations*, National Fire Protection Association, 1994.
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6. NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services*, National Fire Protection Association, 2013.
7. NFPA 1986, *Standard on Respiratory Protection Equipment for Tactical and Technical Operations,* National Fire Protection Association, 2017.
8. NFPA 1999, *Standard on Protective Clothing and Ensembles for Emergency Medical Operations*, National Fire Protection Association, 2018.

APPENDIX A

SELECTION OF HAZARDOUS MATERIALS AND CBRN PROTECTIVE ENSEMBLES

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INTRODUCTION

The selection of PPE for a specific response or operational mission should account for the specific hazard levels as well as an understanding for the specific types of available protective ensembles that can provide appropriate levels of protection.

- The selection of the appropriate hazardous materials or CBRN PPE is dependent on a thorough hazard and risk assessment that identifies the specific exposure threats and conditions at the response or operations scene.
- The selection process follows with the hazard and risk information through a series of decisions to determine which type of ensemble provides the needed minimum protection.
- These decisions are set as part of the logical approach where depending on the answers provided, a certain pathway is taken that ultimately ends in a recommended protective ensemble that meets a specific NFPA standard.

PRIMARY ASSUMPTIONS

For selection of appropriate chemical, biological, or CBRN PPE, several assumptions must be made to make the selection process more manageable. These assumptions include:

- The selection process is limited to chemical- or biological-protective clothing for emergency response or other operators and technicians involved in hazardous materials or CBRN operations.
- Individuals involved in the selection process have training in hazardous materials operations at an appropriate level for the selection of PPE.
- Individuals involved in the selection also have knowledge of the different types of chemical- or biological-protective clothing used as part of ensembles.
- At least some forms of clothing and equipment that meet the NFPA standards are available for use.

KEY INFORMATION NEEDED

In order to make specific selection decisions, the following information is needed:

- Type of hazards present in the response area.
- Expected form of exposure to the type of hazard.
- Expected severity of the hazards (or potential consequences of exposure).
- Portions of the body that are likely to come in contact with the hazard.
- Type of response environment and presence of other hazards (heat, cold, physical, etc.).
- Length of the work to be performed while wearing PPE.

GENERAL APPROACH FOR SELECTION DECISIONS

Information gained primarily from the hazard assessment is used to answer a series of questions that result in specific decisions. Depending on the type of answer given, other questions are asked and those answers also lead to different paths that ultimately will lead to a specific type of recommended PPE. This process is known as a decision logic and begins with asking the most significant questions first so that better performing PPE will be selected first in order to ensure appropriate levels of protection to operators and technicians.

There are many different possible choices of PPE that can be selected. In several cases, more than one form of PPE may be recommended. However, one possible outcome from the decision logic is not to enter the situation because adequate protection cannot be guaranteed.

There are many other conditions and circumstances that can also affect the choice of PPE that must also be taken into account. This document attempts to identify the most important factors that go into PPE selection.

STEP 1: PERFORM HAZARD AND RISK ASSESSMENT

PPE selection starts with a detailed hazard and risk assessment which also involves a characterization of the site where the PPE will be used. The hazard assessment is intended to identify all primary hazards that can create potential harm to the responding operators or technicians.

Hazard and risk assessments also take into consideration the likelihood of exposure to a specific hazard as well as the consequences of exposure to that same hazard. The combination of both of these factors establish the potential risk. For example, a low risk may exist for a hazard that is infrequently encountered and produces only moderate effects. Conversely, exposure to a highly hazardous substance that can produce immediate acute effects would be charged as a high risk.

Hazards can be characterized in a number of different ways. For this document, hazards are identified as specific to the substance, the working environment, and the type of work being performed.

Chemical/Biological/Radiological Hazards

The principal hazards during hazardous materials or CBRN responses include those hazards posed by the specific substances present in the response environment. Chemical substances are of varying toxicity and harmful effects where exposure may occur in a variety of forms:

- As a gas or vapor
- As a liquid or aerosol
- As a solid

Biological substances may be presented as either liquids or aerosols, although some forms of solid biotoxins or spores also can exist.

Radiological substances may be by electromagnetic radiation or as contaminated gases, liquids, or solids.

Risk increases with increasing volume and concentration, or strength, of the substance or hazard combined with the length of time where exposure may occur.

Environmental Hazards

The environment where responders must work can equally affect the hazards present. Different environmental factors include the following:

- The overall size of the space (confined spaces represent special hazards because the overall environment limits the dilution or release of the substance, as well as creating other hazards such as slips and falls and limited ease of escape).
- The ambient temperature will affect how quickly volatile substances may evaporate. High temperatures can also lead to heat stress while colder environments can also create hypothermic conditions.
- The physical environment can also lead to hazards at affect response activity and can compromise the barrier materials or integrity of the ensemble. Some aspects of the physical environment may allow for substances to accumulate in certain areas, creating higher risk.

Work/Task Hazards

The type of work can also contribute to hazards at the response scene. Wearing PPE for extended periods of time while undertaking moderate to hard work can create heat stress. In addition, the types of activities required may place strains on the individual operator or technician that lead to mistakes or possible injuries.

Work required on elevated platforms can lead to falls or objects dropped on others below.

STEP 2: DETERMINE KNOWN THREATS

After information is obtained from the hazard and risk assessment, the very first decision is whether the hazards are known. If the hazards are unknown then a separate decision has to be made whether entry into the site is actually needed.

- If there is no significant consequence for not responding, then no entry should be made.
- Even if there is potential loss of life or significant loss of property, any decision to enter a response area where the hazards are not completely characterized brings significant risk, and should be avoided until more information is obtained to ensure the safety of the first responders.
- When entry into the site is determined as necessary, then the highest level of protection in the form of an NFPA 1991 certified ensemble with both flash fire escape and liquefied gas protection should be chosen.

STEP 3: DETERMINE FLASH FIRE THREATS

The next key decision is to determine if there is a potential flash fire or explosive situation involved for the particular response or operation.

This decision is best supported by having portable monitoring equipment to measure the lower explosive limit (LEL). If monitoring equipment or circumstances indicate a LEL that is 10% or greater, then the environment should be considered a flash fire or explosive risk. It is possible that certain chemicals and the conditions of their storage for release will automatically make this determination evident.

As part of this decision, it is necessary to determine whether there is also a toxic threat posed by the substances present at the response scene.

- If toxic threats **DO NOT** exist and there is no threat of an explosion, wear appropriate flame-resistant–protective clothing (compliant to either NFPA 1971 or 2112).
- If toxic threats **DO** exist, then choose an NFPA 1991 ensemble that also meets the optional flash fire escape requirements.

STEP 4: DETERMINE CBRN THREATS

If there is the potential for exposure to a CBRN agent, then a series of different determinations are needed to present the correct path for choosing appropriate PPE.

The first determination as part of this decision process is to identify whether the agent is chemical, biological, or radiological/nuclear:

- If the agent is radiological/nuclear in nature and limited to contaminated particles that are of relatively low radiation levels, then choose an NFPA 1994 Class 4 or 4R ensemble.
- If the agent is chemical in nature, then follow Step 5 or 6 to make decisions for vapor/gas or liquid threats.
- If the agent is biological nature, then follow Step 7 to make decisions for biological threats.

STEP 5: DETERMINE GAS/VAPOR CHEMICAL THREATS

If the hazard/risk assessment identifies chemical agents or substances where exposure can occur either as a gas or vapor, then the following specific decision logic takes one of four paths, depending on the chemical gas or vapor concentration:

- The first path is for environments that present an immediately dangerous to life and health (IDLH) concentration or conditions that warrant the wearing of self-contained breathing apparatus (SCBA). IDLH conditions also include environments that involve potentially flammable vapor, liquefied gases, and oxygen deficiencies. This path is based on gas/vapor concentrations that are over 10,000 ppm or 1%.
- The second path is also IDLH, but exists for substances at lower concentrations (gas/vapor concentrations that are over 350 ppm but equal to or below 10,000 ppm).
- The third path is also IDLH, but exists for substances at even lower concentrations (gas/vapor concentrations that are over 40 ppm but equal to or below 350 ppm).
- The fourth path is for environments that are not determined to be IDLH and where either air-purifying respirators (APR) or powered air purifying respirators (PAPR) are considered acceptable. For this path, gas/vapor concentrations are at 40 ppm or below.

IDLH, Higher Concentrations

The following choices are made along the IDLH pathway:

- If the substance is a liquefied gas and is flammable, then choose an NFPA 1991 ensemble with the optional liquefied gas protection AND flash fire protection.
- If the substance is a liquefied gas but is not flammable, then choose an NFPA 1991 ensemble with the optional liquefied gas protection.
- If the gas or vapor is not skin toxic, then choose structural firefighting clothing or other flash fire–protective clothing that conforms to NFPA 1971 or NFPA 2112, respectively.
- If the substance is flammable vapor at a concentration over 10,000 ppm or 1%, then choose either an NFPA 1991 ensemble that also meets the optional flash fire protection requirements.
- If the substance is vapor at a concentration over 10,000 ppm or 1% that is not flammable, then choose an NFPA 1991 ensemble.
- If the substance is flammable vapor at a concentration over 350 ppm but at or less than 10,000 ppm or 1%, then choose either an NFPA 1994 Class 1 ensemble that also meets the optional flash fire protection requirements.
- If the substance is vapor at a concentration over 350 ppm but at or less than 10,000 ppm or 1% that is not flammable, then choose an NFPA 1994 Class 1 ensemble.

IDLH, Lower Concentrations

Some circumstances exist where the principal threat is a gas or vapor but the concentration is deemed to be relatively low. In these cases, apply the following choices:

- If the substance is flammable vapor at a concentration over 40 ppm but at or less than 350 ppm, then choose an NFPA 1994 Class 2 or 2R ensemble that also meets the optional flash fire protection.
- If the substance is vapor at a concentration over 40 ppm but at or less than 350 ppm that is not flammable, then choose an NFPA 1994 Class 2 ensemble.
- If heavy work is expected or the ensemble may be reused, then choose an NFPA 1994 Class 2R "ruggedized" ensemble.

Non-IDLH

Where relatively low vapor and/or liquid exposures are expected, such as may occur during decontamination, then a lower level of protective ensemble may be used. Where it is acceptable to wear either APR or PAPR, apply the following choices:

- If the substance is below IDLH conditions and flame hazard exists, then choose an NFPA 1994 Class 3 or 3R ensemble that also meets the optional flash fire protection.
- If the substance is below IDLH conditions and there is no flame hazard, then choose an NFPA 1994 Class 3 or 3R ensemble.
- If the above conditions exist and heavy work is expected or the ensemble may be reused, then choose an NFPA 1994 Class 3R "ruggedized" ensemble.

STEP 6: DETERMINE LIQUID/ PARTICULATE CHEMICAL THREATS

Some assessments will show that gas or vapor hazards do not exist and the principal hazards are from either liquid or particulate exposure. Liquid exposures may be at various levels depending on the volume, frequency, applied pressure and length of liquid contact. Severe liquid splash or exposure conditions would include high volumes of liquid, frequent splashes, liquid spraying under pressure, or an expected extended exposure to liquid. In contrast, liquid exposure may involve relatively low volumes or less likely, infrequent contact. In these situations, apply the following choices:

- If severe liquid splash or repeated/extended exposure liquid hazards exist, then choose an NFPA 1992 or NFPA 1994 Class 2 or 2R ensemble.
- If low volume or infrequent liquid exposure hazards exist, then choose an NFPA 1994 Class 3 or 3R "ruggedized" ensemble.
- If exposure is only expected to solid particles, then choose an NFPA 1994 Class 4 or Class 4R ensemble.
- If the above conditions exist and heavy work is expected or the ensemble may be reused, then choose Type R "ruggedized" ensembles.

STEP 7: DETERMINE BIOLOGICAL THREATS

Biological threat may include bloodborne pathogens in the form of infected blood, body fluids, or other liquids, various types of aerosols, or contaminated solid particles or spores. Where biological-only hazards are encountered, then apply the following choices:

- If the primary hazard is from airborne or aerosolized biological substances which are considered dangerous for skin contact, then choose an NFPA 1994 Class 4 or Class 4R ensemble.
- If the primary hazard is from airborne or aerosolized biological substances which are **NOT** transmissible through skin contact, then choose an appropriate respirator such as an air-purifying respirator (APR) with P100 filters or a powered air-purifying respirator (PAPR) with HEPA filter.
- If the primary hazard is from highly hazardous liquid-borne biological substances, then choose either an NFPA 1994 Class 4 or 4R or a single-use or multiple-use NFPA 1999 ensemble.
- If the primary hazard is from potentially infectious blood or body fluids then choose protective NFPA 1999 garments, gloves, footwear, and face/eyewear to protect those portions of the wearer's body where exposure is expected.
- If the above conditions exist and heavy work is expected or the ensemble may be reused, then choose NFPA 1994 Type R "ruggedized" or NFPA 1999 multiple-use ensembles.

OTHER CONSIDERATIONS FOR PPE SELECTION

The preceding steps in the decision logic cover general selection of PPE for hazardous materials and CBRN incidents. The results of the branched decision making are one or more ensembles certified to a given NFPA standard or class within that standard. In many cases, an organization may not have all of the different types of ensembles available. When this occurs, a higher performing ensemble can be selected. The following table provides a hierarchy of protection for each of the major categories of protection.

It is also important to recognize that chemical resistance data for those ensembles for protection against either chemical vapors or liquids can be an additional factor for the selection of an appropriate protective ensemble. The NFPA ensembles are tested to a limited number of chemicals and often there may be no data for the encountered chemical(s) for all of the relevant exposed materials used in the construction of the ensemble that include the garment or suit, hood, gloves, footwear, and seams joining these materials or items. Where possible, chemical resistance data for the respective ensemble should be consulted, but it is important that these data are applied to all portions of the ensemble that may be exposed to the exposure chemical(s).

Level	**Chemical Vapors**	**Chemical Liquids**	**Biological Liquids**	**Biological Aerosols**	**Radiological Particles**
Highest	NFPA 1991	NFPA 1991	NFPA 1991	NFPA 1991	NFPA 1991
↑	NFPA 1994 C1	NFPA 1994 C1	NFPA 1994 C1	NFPA 1994 C1	NFPA 1994 C1
	NFPA 1994 C2	NFPA 1994 C2	NFPA 1994 C2	NFPA 1994 C2	NFPA 1994 C2
	NFPA 1994 C3	NFPA 1992	NFPA 1992	NFPA 1992	NFPA 1992
		NFPA 1994 C3	NFPA 1999 MU	NFPA 1999 MU	NFPA 1999 MU
			NFPA 1994 C3	NFPA 1994 C3	NFPA 1994 C3
Lowest			NFPA 1999 SU	NFPA 1994 C4	NFPA 1994 C4

Several other factors can be considered which may or may not be part of the NFPA Standards. Certain incidents may cover unique hazards or needs. As part of the selection some other considerations include:

- Stealth
- Equipment compatibility
- Differences in design and conformity levels

Stealth

For some types of missions, particularly law enforcement, it may be important that the ensemble provide stealth characteristics so that the responder is not obvious. In these cases, it is important that the ensemble be of a dull dark color and not be reflective. It is also important that the ensemble not create excessive noise during movement. NFPA 1994 includes an optional category for the different classes of ensembles that can be specified if these types of ensemble characteristics are needed.

In addition, the tactical operation requirements of law enforcement will generally dictate ensembles that are form fitting and offer the greatest levels of mobility, functionality, tactility, and dexterity. For these reasons, encapsulating ensembles are generally not considered acceptable for tactical law enforcement or similar operations.

Equipment Compatibility

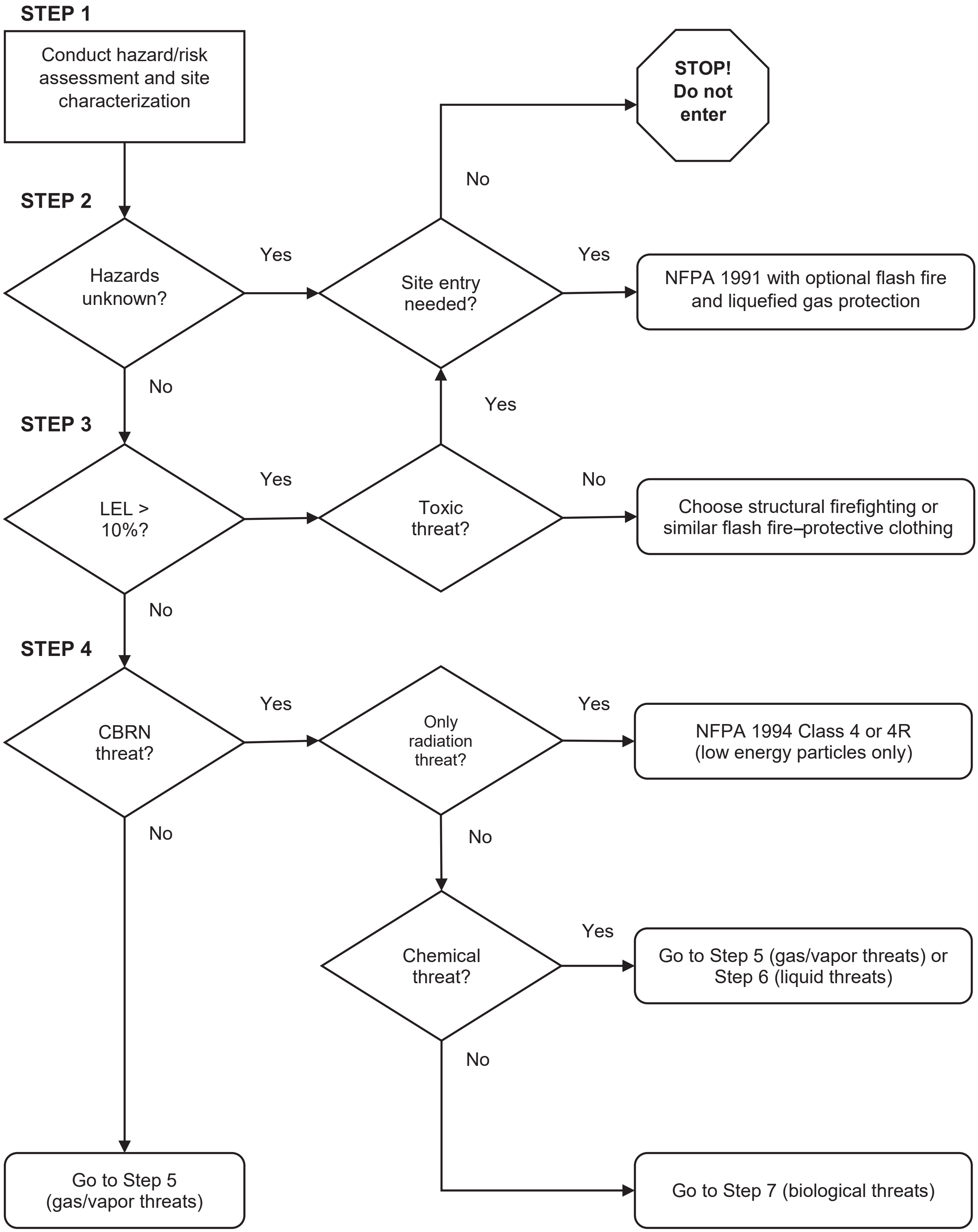
Ensembles consist of the garment or suit along with an attached or unattached hood, gloves, and footwear, as well as a respirator. Yet, depending on the mission, there may also be the requirement for other equipment to be worn by the operator or technician such as a cooling vest, body armor, helmet, communications equipment, or hydration system. The ability of the ensemble to accommodate these additional items is another consideration that must be weighed in selecting an ensemble.

Some equipment computability will also depend on the sizes of ensembles that are offered. While the NFPA Standards specify minimum sizes for the suit, gloves, and footwear, some products may be offered in a larger number of sizes or allow for features that permit adjustment of the ensemble such as side torso take up straps or internal harnesses.

Differences in Design and Conformity Levels

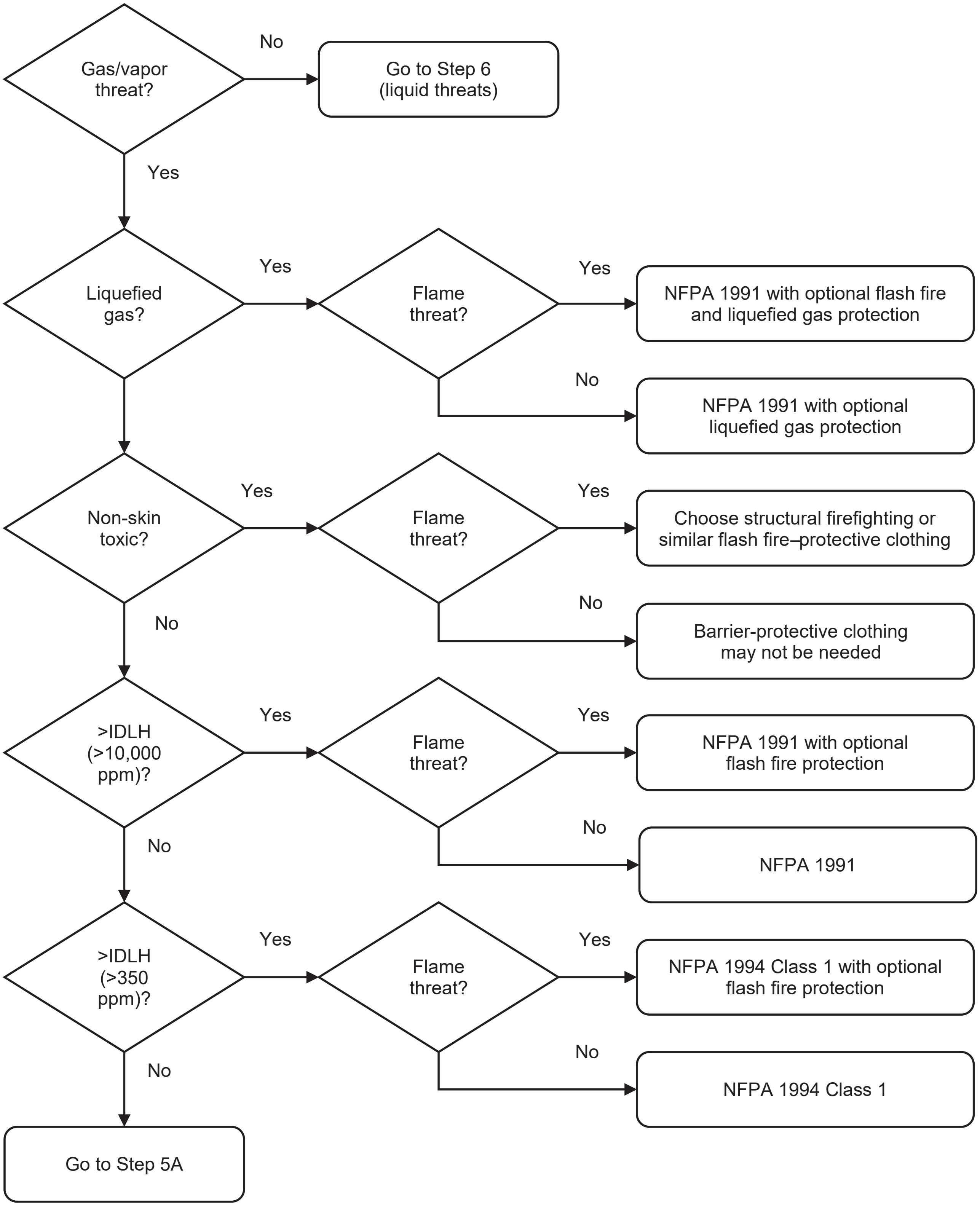
Lastly, not all ensembles that meet a given standard are alike. Each ensemble is required to meet the minimum design, performance, documentation, and labeling requirements of the specific NFPA Standards. Relatively few requirements exist for how the ensemble must be designed, which can lead to different features in the configuration of the ensemble. For example, whether the zipper is placed on the front or back of the ensemble and the type of interface that is used to join a glove to a suit or garment sleeve.

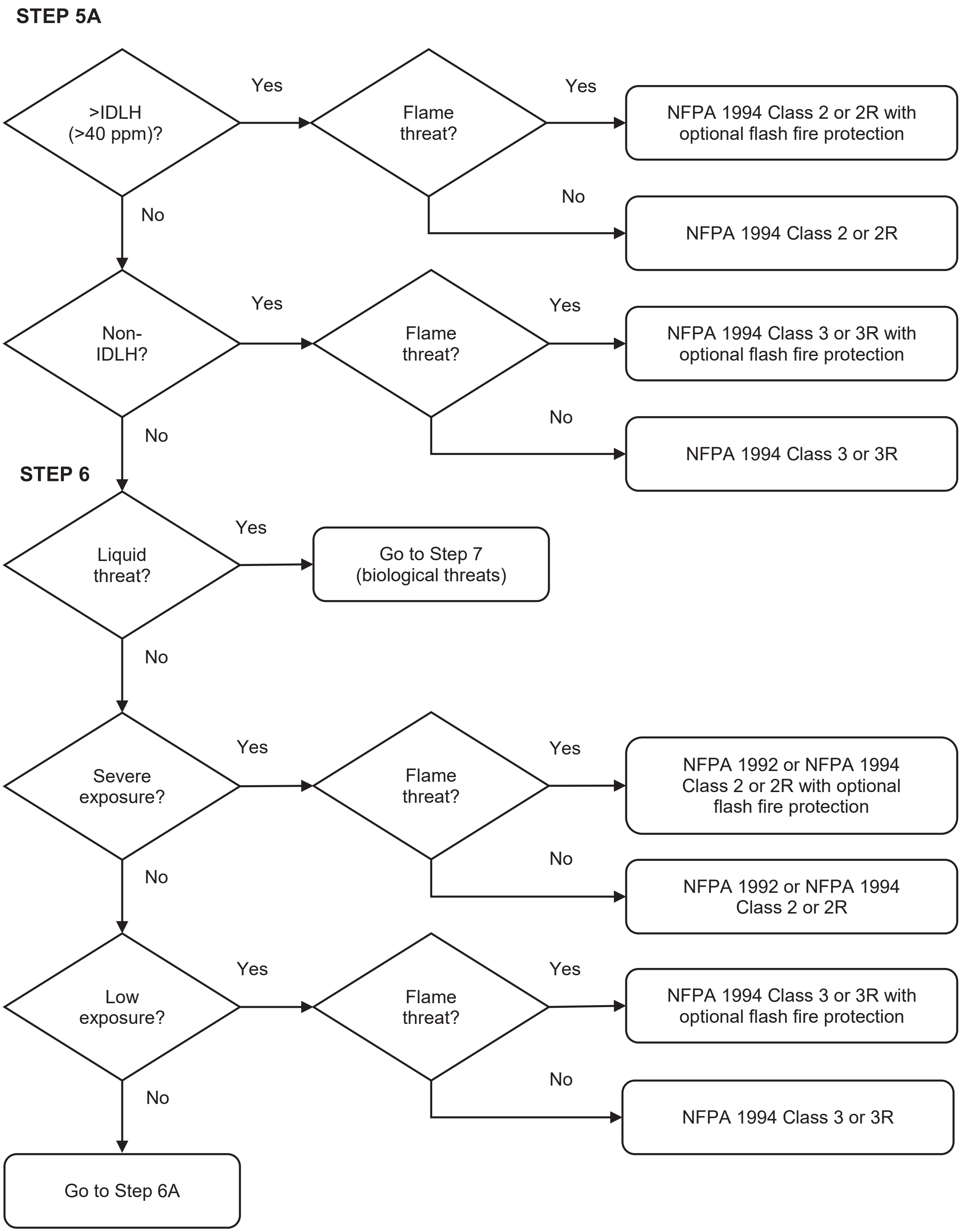
In addition, most products exceed the performance requirement of the respective NFPA Standard. These differences may mean additional chemicals for which the ensemble barrier materials have been tested, increased physical properties, or greater levels of integrity. Differences in products can be ascertained by examining the Technical Data Package that is provided with each ensemble.



STEP 1
Conduct hazard/risk assessment and site characterization
STEP 2
Hazards unknown?
Yes
No
Site entry needed?
No
STOP! Do not enter
Yes
NFPA 1991 with optional flash fire and liquefied gas protection
STEP 3
LEL > 10%?
Yes
No
Toxic threat?
Yes
No
Choose structural firefighting or similar flash fire–protective clothing
STEP 4
CBRN threat?
Yes
No
Only radiation threat?
Yes
NFPA 1994 Class 4 or 4R (low energy particles only)
No
Chemical threat?
Yes
Go to Step 5 (gas/vapor threats) or Step 6 (liquid threats)
No
Go to Step 7 (biological threats)
Go to Step 5 (gas/vapor threats)

STEP 5


Gas/vapor threat?
No
Go to Step 6 (liquid threats)
Yes
Liquefied gas?
Yes
Flame threat?
Yes
NFPA 1991 with optional flash fire and liquefied gas protection
No
NFPA 1991 with optional liquefied gas protection
Non-skin toxic?
Yes
Flame threat?
Yes
Choose structural firefighting or similar flash fire–protective clothing
No
Barrier-protective clothing may not be needed
No
>IDLH (>10,000 ppm)?
Yes
Flame threat?
Yes
NFPA 1991 with optional flash fire protection
No
NFPA 1991
No
>IDLH (>350 ppm)?
Yes
Flame threat?
Yes
NFPA 1994 Class 1 with optional flash fire protection
No
NFPA 1994 Class 1
No
Go to Step 5A


STEP 5A
>IDLH (>40 ppm)?
Yes
Flame threat?
Yes
NFPA 1994 Class 2 or 2R with optional flash fire protection
No
NFPA 1994 Class 2 or 2R
No
Non-IDLH?
Yes
Flame threat?
Yes
NFPA 1994 Class 3 or 3R with optional flash fire protection
No
NFPA 1994 Class 3 or 3R
No
STEP 6
Liquid threat?
Yes
Go to Step 7 (biological threats)
No
Severe exposure?
Yes
Flame threat?
Yes
NFPA 1992 or NFPA 1994 Class 2 or 2R with optional flash fire protection
No
NFPA 1992 or NFPA 1994 Class 2 or 2R
No
Low exposure?
Yes
Flame threat?
Yes
NFPA 1994 Class 3 or 3R with optional flash fire protection
No
NFPA 1994 Class 3 or 3R
No
Go to Step 6A

STEP 6A

STEP 7