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# A Technical Overview on Protective Clothing against Chemical Hazards

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## Abstract

Protection against harmful chemical materials is compulsory in many aspects of everyday life. Proper and adequate protective clothing is desirable during household chores and in industrial, agricultural, and medical work, during military operations; and in response to incidents of terrorism. Different types of materials and garment designs are used in these clothing items, and protection levels vary considerably. Selections must be made as to which items of protective clothing to select for a given situation or environment. Variables to be considered include weight, comfort, level of protection, and the duration of protection required. In addition, the nature of the challenges to be encountered is also of significant concern. Due to the huge number of variables involved, numerous levels and types of chemical protective clothing systems has been technologically developed.

## 1. Introduction

Protective clothing is now a major part of textiles classified as technical or industrial textiles. Protective clothing refers to garments and other fabric-related items intended to protect the wearer from harsh environmental effects that may result in injuries or death [1]. Today, the hazards that we are exposed to are often so specialized that no single type of clothing will be adequate for protection. Extensive research is being done to develop protective clothing for various regular and specialized civilian and military occupations [1-3]. Providing protection for the common population has also been taken seriously considering the anticipated disaster due to terrorism or biochemical attacks [3-4].

Fortunately, most of us are not involved in handling dangerous and toxic chemicals, since no amount of protection can provide complete isolation from the hazards of chemicals. In recent years, the chemical industry has been facing an ever-increasing degree of regulation to avoid workers being exposed to chemical hazards [2]. Chemical protective clothing (CPC) should be considered the last line of defense in any chemical-handling operation and every effort should be made to use less hazardous chemicals where possible, or to develop and implement engineering controls that minimize or eliminate human contact with chemical hazards [1,5]. Protective clothing cannot be made generic for all chemical applications, since chemicals vary in most cases and a particular CPC can protect only against a limited number of specific chemicals [6]. Important considerations in designing chemical protective clothing are the amount of chemical permeation, breakthrough time for penetration, liquid repellency, and physical properties of the CPC in specific chemical conditions [5,7-11]. Based on the specific requirements and type of clothing, CPC is classified in different ways. Chemical protective clothing can be categorized as encapsulating or non- encapsulating based on the style of wearing the clothing [1]. The encapsulating system covers the whole body and includes respiratory protection equipment and is generally used where high chemical protection is required. The non-encapsulating clothing is assembled from separate components and the respiratory system is not a part of the CPC. The Environmental Protection Agency (EPA) in the United States classifies protective clothing based on the level of protection from highest to normal protection. CPC is rated for four levels of protection, levels A, B, C and D from highest protection to normal protection [1, 5]. European standards for CPC are based on the 'type' of clothing based on testing of the whole garment and are classified as types 1 to 7, related to the type of exposure of the CPC such as gas-tight, spray-tight, liquid-tight, etc. [5]. Traditionally, used disposable clothing also offers resistance to a wide range of chemicals and some disposable clothing can be repaired using adhesive patches and reused before being disposed [1,5]. Chemicals that are in liquid form are more often used than solid chemicals. Therefore, chemical protective clothing should be repellent or impermeable to liquids. Developing pesticide-resistant clothing has received considerable attention from researchers since exposure of skin to pesticide is a major health hazard to farmers [12]. Clothing currently used for pesticide protection does not give adequate protection, especially to the hands and thighs, even if farmers use tractor-mounted boom sprayers with a closed cabin and wear protective clothing with gloves and rubber boots [13, 14]. Other important functions of chemical protective clothing are to protect from chemicals present in the air such as toxic and noxious gases or fumes from automobiles, dust and microorganisms present in the air. Safety masks containing activated carbon particles which can absorb the dust present in the atmosphere are commonly used against air pollution.

## 2. Chemical Hazards

The chemical hazard is the most complex and varied of all the hazards. It is estimated [15] that more than 100,000 chemical products with very different toxicological properties are in use throughout the world. Chemical hazards are experienced in most industries, examples range from protection against particle contamination in a clean room, for electronic component manufacture, to protection against chemical warfare agents. There are various ways of defining hazardous chemicals. The level of risk is one method; the amount of chemical, exposure time, toxicity are all factors that need to be taken into account. Another common method is by classification into particles, liquids and gases. This is useful for research and development of protective textiles because each chemical phase will behave differently and so require different strategies for protection. There are four possible interactions between a chemical and a chemical protective textile: [16] Firstly, Chemical degradation, which is a breakdown of the textile structure. Secondly, Chemical penetration, which is the chemical flow through the textile structure by wicking or pressure effects in air permeable structures, or through imperfections or seams and closures in impermeable structures. Thirdly, Chemical permeation, which is the molecular flow of chemicals through the material of the structure. Fourthly, the chemical may not interact but evaporate and the vapor will either go into the atmosphere or enter the garment. Any combination of the four possibilities could occur. Most research has been reported on permeation. There is a vast amount of chemical permeation data from manufacturers and published papers, for example around a third of the papers in the *Performance of Protective Clothing* book of papers [17] are on permeation data. Fibre, fabric type, fabric finishes, coatings and lamination are factors that can have a major influence on the level of protection. The chemical degradation of a material is determined by the reaction of the fibres, coating and lamination material to the chemical, which is determined by their chemical nature. For example, sulphuric acid at room temperature will attack cotton fabric, producing holes while nylon fabric is resistant. Chemical penetration is determined by the pore size and wickability of the material, which is determined by fibre linear density, yarn structure, fabric structure, fabric coating types and material surface energy. Examples of toxic chemical particles are carbon black, asbestos, dye powders, coal dust, beryllium particles and antineoplastic drugs. Lung damage can occur when particles around 1 m are inhaled [18]. Particles that are in the size range 0.001 m to 100 m are considered an aerosol and when liquid droplets reach micron dimensions, their behavior becomes similar to solid particles of the same size. If the particles are smaller than the textile structure pore size then other factors including Brownian diffusion and electrostatic capture will determine penetration [19-20]

## 3. Different Types of Protective Materials

There are basically four different types of Chemical Protective Materials [21] Figure 1 illustrates the differences in their protective capabilities.

### 3.1. Air-Permeable Materials

Permeable fabrics usually consist of a woven shell fabric, a layer of sorptive material such as activated carbon impregnated foam or a carbon-loaded non-woven felt, and a liner fabric. Since the woven shell fabric is not only permeable to air, liquids, and aerosols, but also vapors, a sorptive material is required to adsorb toxic chemical vapors. Liquids can easily penetrate permeable materials at low hydrostatic pressures; therefore, functional finishes such as Quarpel and other fluoro-polymer coatings are usually applied to the outer-shell fabric to provide liquid repellency. Additionally, a liquid and/or an aerosol-proof overgarment such as non-perforated Tyvek protective clothing must be used in addition to permeable clothing in a contaminated environment to provide liquid and aerosol protection. Many users like to use permeable clothing because convective flow of air is possible through the clothing and open closures. This evaporative action cools the body. Examples of air-permeable protective clothing that contain activated carbon include the

US, British, and Canadian current CP clothing.

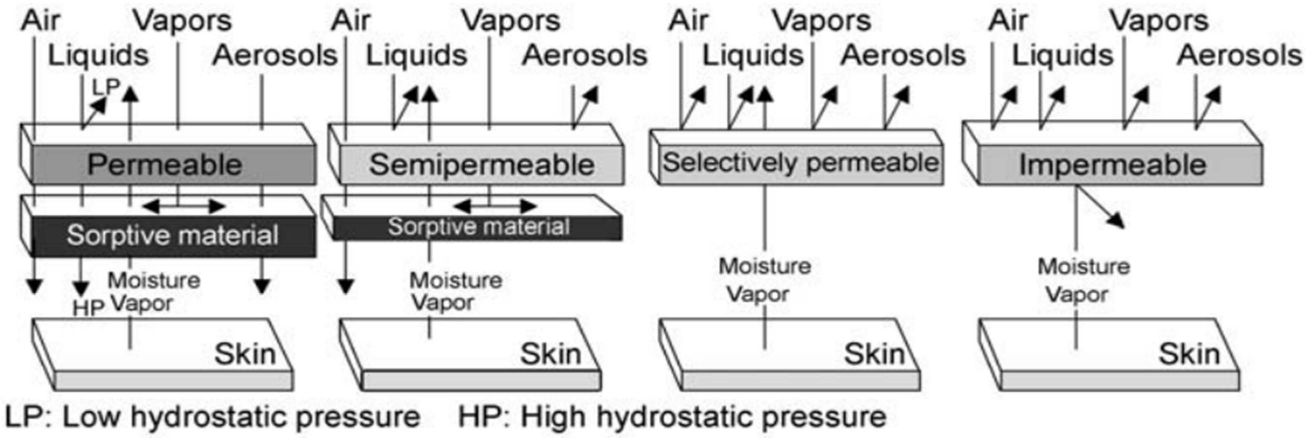


***Figure 1.*** *Different types of protective materials.*

### 3.2. Semipermeable Materials

There are two different types of semipermeable membranes: porous and solution–diffusion membranes [22-23].Porous membranes include macroporous, microporous, and ultraporous membrane structures. A macroporous membrane allows a convective flow of air, aerosols, vapors, etc., through their large pores. No separation occurs. A microporous membrane follows Knudsen diffusion through pores with diameters less than the mean free path of the gas molecules allowing lighter molecules to preferentially diffuse through its pores. An ultraporous membrane has also been referred to as a molecular sieving membrane where large molecules are excluded from the pores by virtue of their size. A solution-diffusion membrane has also been called a nonporous or a monolithic membrane. This membrane follows Fickian permeation through the nonporous membrane where gas dissolves into the membrane, diffuses across it, and desorbs on the other side based on concentration gradient, time, and membrane thickness. Examples of some semipermeable materials include W.L. Gore & Associates, Inc.'s Gore-Tex® [24], polytetrafluoroethylene (PTFE) micro-porous membrane, Mitsubishi's Diaplex™, [25] polyurethane nonporous membrane, and Akzo's Sympatex™, [26] copolyester ether nonporous membrane.

### 3.3. Impermeable Materials

Impermeable materials such as butyl, halogenated butyl rubber, neoprene, and other elastomers have been commonly used over the years to provide chemical agent protection [27]. These types of materials, while providing excellent barriers to penetration of chemical agents in liquid, vapor, and aerosol forms, impede the transmission of moisture vapor (sweat) from the body to the environment. Prolonged use of impermeable materials in protective clothing in the warm/hot climates of tropical areas, significantly increases the danger of heat stress. Likewise, hypothermia will likely occur if impermeable materials are used in the colder climates. Based on these limitations, a microclimate cooling/heating system is an integral part of the impermeable protective clothing system to compensate for its inability to allow moisture permeation. ITAP, STEPO, and other OSHA approved Level A suits are examples of impermeable clothing systems. They have been effectively used for protection from chemical warfare agents and TICs, but they are costly, heavy, bulky, and incur heat stress very quickly without an expensive and/or heavy microclimate cooling system after donning.

### 3.4. Selectively Permeable Materials (SPMs)

An SPM is an extremely thin, lightweight, and flexible protective barrier material to chemical agents but without the requirement for a thick, heavy, and bulky sorptive material such as the activated carbon material layer being used in current CP protective systems that are discussed above. It allows elective permeation of moisture vapor from the body to escape through the protective clothing layers so that the body of a soldier is continuously evaporatively cooled during missions while being protected from the passage of common vesicant chemical agents in liquid, vapor, and aerosol forms [28]. SPMs have the combined properties of impermeable and semipermeable materials. The protection mechanism of selectively permeable fabrics relies on a selective solution/diffusion process, whereas carbon-based fabrics rely on the adsorption process of activated carbon materials, which has limited aerosol protection, and activated carbon based clothing provides insufficient cooling due to its inherent bulk/insulative properties.

SPMs represent the US Army's pioneering advanced technology [29]. Figure 2 shows its material concept. SPMs have been widely used throughout.

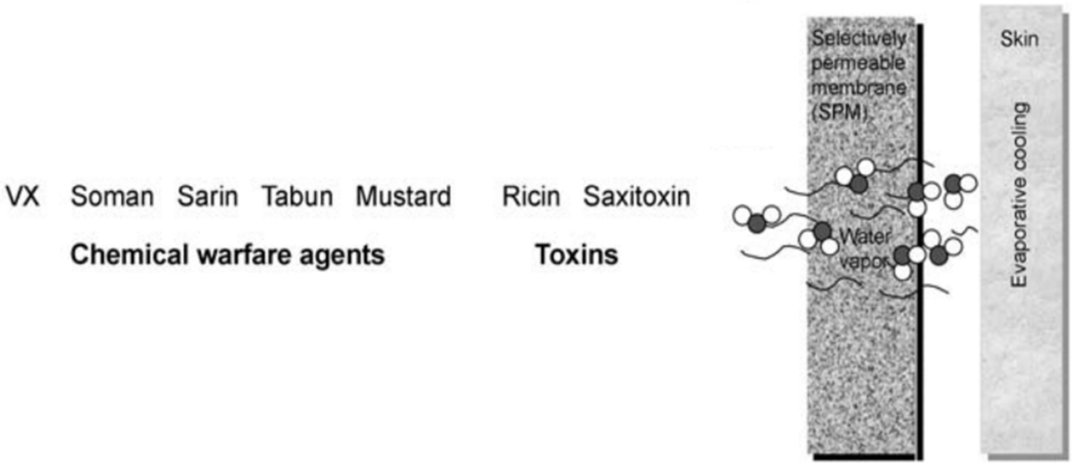


***Figure 2.*** *SPM material concept.*

the chemical industry in gas separation, water purification, and in medical/metabolic waste filtration [30]There have been many different material technologies co-developed by industry and the US Army Natick Soldier Center (NSC). SPMs consist of multi-layer composite polymer systems produced using various different base polymers such as cellulose, polytetrafluoroethylene (PTFE), polyallylamine, polyvinyl alcohol, among other gas or liquid molecular separation membranes. W.L. Gore & Associates, Inc., Texplorer GmbH, Dupont, and Innovative Chemical and Environmental Technologies (ICET), Inc. are among the leading companies that have been pursuing SPM developments with NSC.

## 4. Components of Chemical Protective Clothing (CPC)

Primary garment material consists of a "substrate" that provides strength for the garment. This material generally does not contribute to the chemical resistance qualities of the overall suit. This substrate provides for resistance against tears, rips, and punctures. Examples of substrates include Tyvek, Nomex, fiberglass, and woven polymer. A film is applied to the substrate in multiple layers to provide the chemical resistance. This film may be of differing kinds of materials, depending on the chemicals they are designed to protect against [31]

Seam construction is a very important component of CPC because this is one of the locations most vulnerable to leaks and tears. Various types of seams may found on CPC, including folded/lap sealed (by heat), glued, stitched, sewn, or combinations of the above. Stitched or sewn seams should be avoided for vapor-protective and liquid-splash suits because they are prone to leaking and can weaken the material. Seams must be constructed so they do not leak. [31]

On suits that have visors, the visor is considered separate component. Visors are usually made of a material other than that used for the primary garment. Popular options include polyvinyl chloride (PVC), clear polycarbonate, semi-flexible Lexan, clear Teflon, and glass. In most cases, visors are permanently attached to the suit by glue or heat welding. Some suits have visors that can be removed and replaced. In either case, the visor attachment must prevent leakage. [31]

Gloves are an important component of CPC. Gloves must be chemical-resistant and durable since work in the exclusion zone may require direct hand contact with the hazardous material (e.g., plugging and patching operations). Gloves may either be permanently attached to the suit or be a separate component. They must not leak and must be of equal or superior quality material as the primary garment. [31]

The boot is probably the part of the suit most likely to come in contact with hazardous materials. Responders may have to walk through the material to perform a task or may accidentally walk through the material. Boots may either be permanently attached to the suit or be separate. They may also be designed as a bootie that fits into a rugged outer chemical resistant boot. According to the NFPA standards, boots must meet and pass the same test criteria as the primary suit material. Over boots may also be worn to extend the life of outer boots. The overboots are inexpensive and can be reused a few times. [31]

Suit closure assemblies are the component that allows the wearer to enter (don) and exit (doff) the suit. Typically they incorporate a zipper or an interlocking seam. [31]

## 5. Levels of Chemical Protective Clothing

The OSHA Hazwoper regulation divides personal protective equipment ensembles into four levels (A, B, C, and D) based on the degree of protection afforded [32]. OSHA levels of CPC should not be confused with NFPA standards (1991, 1992, and 1993) for CPC [33-34]. The NFPA standards refer to design standards of a protective garment. Levels refer to a full ensemble of protective equipment (i.e. protective garment, boots, gloves, and SCBA). For example, a liquid splash-protective suit ensemble when used with SCBA would provide Level B protection. The same suit used with an air-purifying respirator would be Level C protection. Various combinations of personal protective equipment other that hose described for Levels A, B, C, and D may be used to provide the proper level of protection [31].

### 5.1. Level A Ensemble

Fully encapsulating suit with self-contained breathing apparatus. Level A should be worn when the highest level of respiratory, skin, and eye protection is required.

### 5.2. Level B Ensemble

Suits can be either fully encapsulating or offer only partial protection. They can be worn with or without a Self-Contained Breathing Apparatus. Splash protection suits are categorized as Level B suits

### 5.3. Level C Ensemble

Suits are merely overall that provide an adequate measure of protection against moderate splashes and run-of-the-mill dirt. They aren't worn with a Self-Contained Breathing Apparatus but can be worn with a gas mask or respirator should the need arise.

### 5.4. Level D Ensemble

Suits are not specialized suits as such. Ordinary industry-specific protective gear, such as boiler suits and face masks, falls under this category.

## 6. Selection of Chemical Protective Clothing

There are several factors to consider when selecting CPC. Determine the predicted type, measured concentration, and toxicity of a chemical substance in the ambient atmosphere. Evaluate the resistance of CPC material to permeation (the movement of a chemical through a material on a molecular level), degradation (physical changes in a material from chemical exposure, use, or other conditions), and penetration (movement of a chemical through a zipper, closure, or imperfection in the suit). Evaluate the potential for exposure to substances through inhalation or skin contact [31].

### 6.1. Level A Selection Criteria

Level A protection provides the greatest level of skin, respiratory, and eye protection and should be used when: The hazardous substance has been identified and requires the highest level of protection for skin, eyes and the respiratory system based on either the measured (or potential for) high concentration of atmospheric vapors, gases, or particulates; or the site operations and work functions involve 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 skin. Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible; or Operations are being conducted in confined, poorly ventilated areas, and the absence of conditions requiring Level A have not yet been determined.

### 6.2. Level B Selection Criteria

Level B protection provides the highest level of respiratory protection but a lesser level of skin protection and should be used when the type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection; and/or The atmosphere contains less than 19.5 percent oxygen; or The presence of incompletely identified vapors or gases is indicated by a 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 skin.

### 6.3. Level C Selection Criteria

Level C protection is for use when the concentration(s) and type(s) of airborne substance(s) are known and the criteria for using air purifying respirators are met. It should be used when the atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin; the types of air contaminants have been identified, concentrations measured, and an air-purifying respirator is available that can remove the contaminants; and all criteria for the use of air-purifying respirators are met.

### 6.4. Level D Selection Criteria

Level D protection is a work uniform affording minimal protection. It's used for nuisance contamination only. It should be used when the atmosphere contains no known hazard; and work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals.

## 7. Clothing System Designs

The use of excellent protective materials, effective closures, and ergonomic survival equipment for an individual soldier will be meaningless and unproductive without proper garment designs. Therefore, in designing materials, a designer should be familiar with garment design and fabrication. Material designers should understand that garments are designed differently based on the characteristics of the protective materials, different applications, and environment to protect and to maximize the time that a user can operate while wearing the protective garment. There are different garment designs with one piece garments, two-piece garments, over-garments, under-garments, multilayer garments, and last but not least important, closures and interfaces [35].

### 7.1. Coverall or One-Piece Garments

A one-piece garment eliminates agent penetration through the opening between jacket and trouser/pants. It allows for quick donning and doffing. Another advantage is that it has simplified seaming and sewing in joining fabric pieces during garment fabrication. However, there is no option to open jacket and/or pants for quick release of heat stress/body chill, or exchange of torn/defective jacket or pants. The whole garment must be replaced when it becomes defective and loses its protection.

### 7.2. Two-Piece Garments

A two-piece garment needs a closure system to seal the opening between jacket and pants. It also requires more seam sealing, sewing, and stitching in joining fabric pieces during garment fabrication. However, it allows donning and doffing for quick release of heat stress/body chill, and exchange of torn/ defective jacket or pants. This also allows greater flexibility in sizing users with different dimensions.

### 7.3. Undergarments

Undergarments include underwear and other liner fabrics. They provide protection from the inside and must be worn before the mission. Protection materials/ fabric is concealed. They are best used in situations where concealment of protective clothing are required such as in special security operations.

### 7.4. Multilayered Garments

Multilayered garments seem to be most popular since they can be oriented toward specific mission(s) in different environments. Clothing layers with specific functions can be donned and doffed for various protection levels (e.g., environmental, chemical, thermal insulation, and/or ballistic protection, etc.). They also provide the option for quick release of heat stress or to alleviate hypothermia, or to exchange torn/defective jacket or pants. However, the users must be conscious of heat stress as more layers are added in order to prevent heat stress injuries. When using multilayer garments, a microclimate cooling system may be necessary. Users must be educated in the protective capabilities of all available layers for maximum protection and environmental adaptability. It will also be time consuming for donning and doffing of clothing and compatibility between different layers may be an issue since they may not have been developed synergistically.

### 7.5. Closure System, Components, and Systems

Closure interfaces between hood and gas mask, jacket and gloves, jacket and trousers, and trousers and boots are very important in chemical protective garment. Closure systems are very important because protection is a function of fabric, closure/interfaces, activity level, and the motions of the user. To assess these systems, the U.S. Army has developed a test called Man-In-Simulant-Test, commonly referred to as the MIST test. Figure 3 confirmed that closure systems are necessary for all chemical protective fabric systems to improve protection. Natick has begun to develop a closure system for use with a selectively permeable fabric system. However, there remain technical barriers to overcome. Current work at NSC addresses concerns for closure system weight, add-on cost to current CP uniforms, and time factor for donning and doffing optimized closures vs. soldiers' comfort and performance. Soldiers' comfort perception of being encapsulated is being studied. Redesign of current gas mask(s) and uniform(s) may be needed and therefore are being addressed by the U.S. Army Edgewood Chemical and Biological Command (ECBC) and the NSC respectively.

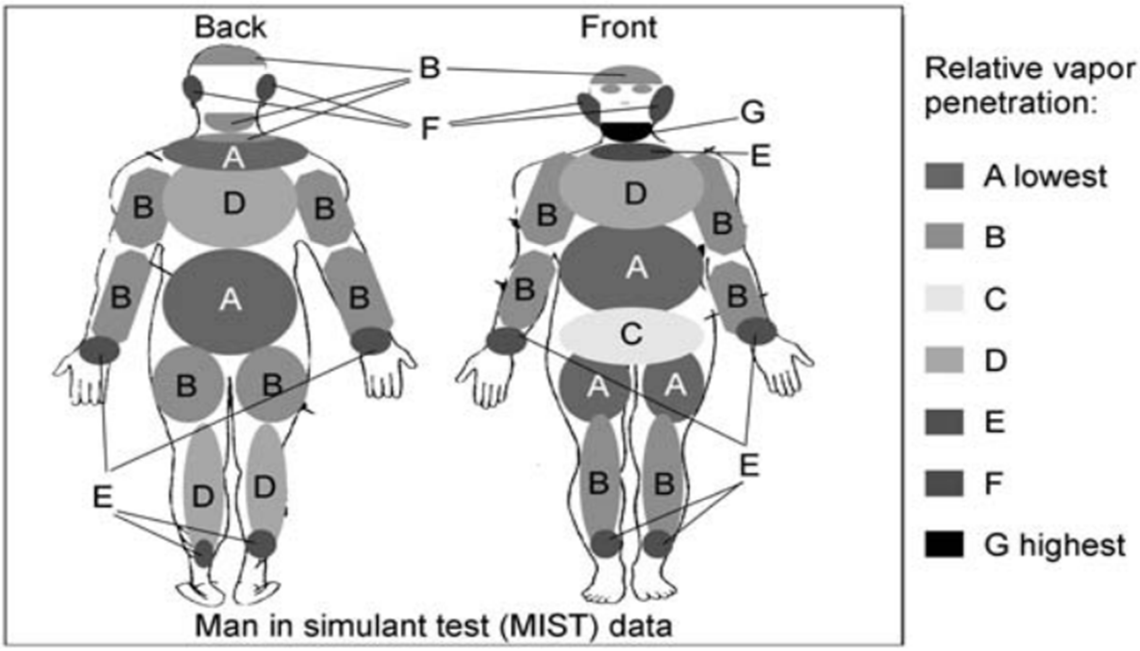


***Figure 3.*** *Vapor penetration resistance of a candidate ensemble.*

# 8. Physiological and Psychological Effects of Wearing Chemical Protective Clothing

In addition to coping with the thermal burden and heat strain associated with chemical protective ensembles, individuals must also manage a number of physiological and psychological effects brought on by wearing the ensembles. The material or garment design are not the only components of the ensemble that affect the physical and mental state of the individual; the over boots, gloves, glove liners, respirators, and head coverings all contribute additional strain on the end-user [36]. All protective equipment regardless of design, even something as simple as latex gloves, hinders an individual's ability to perform certain tasks compared with their performance without the equipment. This mechanical burden usually results in a decrease in performance and an increase in the amount of time spent on the task [37].

Physiological effects of wearing CPC ensembles are manifested in a number of different ways. Individuals generally have an increase in oxygen consumption and may experience headaches, nausea, hunger, discomfort. Users may also have a reduction in the range of body movement and flexibility as well as impaired dexterity and tactility because of thick gloves [38]. The piece of equipment that is responsible for the majority of physiological and psychological issues related to CPCensembles is the gas mask or respirator (Bensel, 1997). Simply wearing a respirator can increase the resistance to breathing by as much as four fold, which can make individuals feel anxiety and claustrophobia. Respirators also decrease and distort the field of vision, specifically peripheral vision, and make it very difficult to remain hydrated [38]. Many individuals that are required to wear CPC ensembles and respirators for long periods of time exhibit a decrease in cognitive performance and have many negative psychological responses. These responses can include hyperventilation, claustrophobia, compulsive practices, obsessive actions, depression, and even loneliness. Most of the time these responses are brought on from the fear or anxiety associated with chemical warfare and a lack of confidence in the protective equipment [38]. Many of the psychological issues can be managed by thorough training with the equipment, instruction on the hazards, and practicing stress management techniques [37].

# 9. Standards for Chemical Protective Clothing

## 9.1. ASTM Standards [39-59]

- F739-12 Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact
- F903-10 Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids
- F1001-12 Standard Guide for Selection of Chemicals to Evaluate Protective Clothing Materials
- F1052-09 Standard Test Method for Pressure Testing Vapor Protective Ensembles
- F1154-11 Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Durability of Protective Ensembles and Ensemble Components
- F1186-03(2013) Standard Classification System for Chemicals According to Functional Groups
- F1194-99(2010) Standard Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing
- F1296-15 Standard Guide for Evaluating Chemical Protective Clothing
- F1301-90(2011)e1 Standard Practice for Labeling Chemical Protective Clothing
- F1359/F1359M-13 Standard Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin
- F1383-12 Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Intermittent Contact
- F1407-12 Standard Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation–Permeation Cup Method
- F1461-12 Standard Practice for Chemical Protective Clothing Program
- F2053-00(2011) Standard Guide for Documenting the Results of Airborne Particle Penetration Testing of Protective Clothing Materials
- F2061-12 Standard Practice for Chemical Protective Clothing: Wearing, Care, and Maintenance Instructions
- F2130-11 Standard Test Method for Measuring Repellency, Retention, and Penetration of Liquid Pesticide Formulation Through Protective Clothing Materials
- F2588-12 Standard Test Method for Man-In-Simulant Test (MIST) for Protective Ensembles
- F2669-12 Standard Performance Specification for Protective Clothing Worn by Operators Applying Pesticides
- F2704-10 Standard Specification for Air-Fed Protective Ensembles
- F2815-14 Standard Practice for Chemical Permeation through Protective Clothing Materials: Testing Data Analysis by Use of a Computer Program
- F2962-13 Standard Practice for Conformity Assessment of Protective Clothing Worn by Operators Applying Pesticides

## 9.2. NFPA Standards

NFPA (National Fire Protection Association) is a worldwide leader in providing ire, electrical, and life safety to the public since 1896. It has established performance standards for chemical protective clothing for use in support areas, for splash protection, and for "Level A" related spill cleanup work. These standards are as follows

- NFPA 1991 Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies
- NFPA 1992 Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies
- NFPA 1994 Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents
- NFPA 1999 Standard on Protective Clothing for Emergency Medical Operations

### 9.3. ISO Standards [60-65]

- ISO 6529 Protective clothing—Protection against chemicals—Determination of resistance of protective clothing materials to permeation by liquids and gases
- ISO 6530 Protective clothing - Protection against liquid chemicals -- Test method for resistance of materials to penetration by liquids
- ISO 13994 Clothing for protection against liquid chemicals—Determination of the resistance of protective clothing materials to penetration by liquids under pressure
- ISO 13995 Protective clothing—Mechanical properties—Test method for the determination of the resistance to puncture and dynamic tearing of materials
- ISO 16602, Protective Clothing for Protection against Chemicals—Classification, labeling, and performance Requirements utilizes a 6 tier system similar to that found in the CEN standards. While there is subtle difference between the ISO and CEN requirement, garments will generally, but not always, meet the requirements of a given level in strategies.
- ISO 17491 Protective clothing—Protection against gaseous and liquid chemicals—Determination of resistance of protective clothing to penetration by liquids and gases

## 10. Conclusion

Depending upon the work environment, the level and target areas of exposure vary. The available protective clothing items available also differ. From protective hoods, shoes, and sleeves that protect where brush exposure may occur, to white lab coats and pants for laboratory work, and full body suits where exposure to any part of the body can be hazardous, the line of available chemical protective clothing is quite significant. No matter the model, when exposure occurs, all one needs to do is disposing of the protective garment. Any worker whose job involves exposure to harmful chemicals should have the opportunity to protect their health with disposable protective clothing. Industries that make the well-being of their employees a top concern should provide chemical protective clothing and white lab coats to ensure the safety of employees who work with potentially hazardous chemicals. From lab coats to disposable full body suits, disposable protective clothing is a cost effective way to protect the valuable employees.

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