

## Chapter 10 – Personal Protective Equipment

### 1. General

- a. Using personal protective equipment (PPE) is mandatory when occupational safety and health hazards cannot be eliminated or reduced through engineering controls or administrative procedures. This chapter contains guidance on selection, effective use and care of PPE that industrial hygienists may recommend for worker protection. This includes: (1) eye/face protection, including goggles, safety glasses, face shields and respirator lenses; and (2) chemical protective clothing (CPC), which includes gloves, aprons, coveralls, pants, jackets and boots. Appendix A provides in-depth guidance on protective glove related issues, including glove testing, glove selection and discussions on how human skin and polymer glove materials function as protective barriers against toxic chemicals. Guidance specific to protective ensembles worn by chemical, biological, radiological and nuclear (CBRN) first responders can be found in Reference 10-2. Appendix 10-B lists additional informational resources on PPE and dermal exposure. Hearing protection and respiratory protection are covered in Chapters 5 and 9 of this manual, respectively.
- b. Reference 10-1 and Chapter 20 of Reference 10-2 address policy for proper use of PPE. Per Chapter 20 of Reference 10-2, the Commanding Officer/Officer-in-Charge is responsible for ensuring that PPE is available, maintained and properly used by employees. Personnel must be trained in the selection, use, inspection and care of required equipment. Industrial hygienists should determine the need for PPE and provide recommendations regarding its selection during routine industrial hygiene surveys and upon request from customer commands.

### 2. PPE Selection and Use

- a. Use PPE when:
  - (1) Other control measures are not adequate. PPE should never be used as a substitute for engineering or administrative controls. PPE is always considered the last line of defense.
  - (2) The nature of hazard or degree of exposure cannot be determined, such as during emergency response (spills, etc.) or confined space entry.
  - (3) Occupational Exposure Limits (OELs) are exceeded.
- b. PPE is selected based on the nature of the hazard, route(s) of entry for the stressors and the degree of protection that a particular piece of equipment affords under varying conditions.
- c. If there are selection options available, additional considerations may include user acceptability and ease of using the PPE.
- d. PPE selection tools are detailed in the reference sections of this document; ensure the PPE selection is properly documented on PPE Hazard Assessment forms per 29 CFR 1910.132(d)(2) Reference 10A-3 and/or DON equivalent.



### 3. Eye/Face Protection

- a. Reference 10-3 provides requirements for design, construction, testing and use of eye and face protection. The Occupational Safety and Health Administration (OSHA) will adopt ANSI Z87.1-2010 through the [Final Rule - Updating OSHA Standards Based on National Consensus Standards, Personal Protective Equipment](#), which incorporates the latest three versions of national consensus PPE standards into law when OSHA determines that new consensus standards provide equal or greater protection. According to Reference 10-4, OSHA must still undergo rule-making process to incorporate new consensus standards into OSHA PPE standards and use of a new consensus standard prior to this rule making is a *de minimis* violation, which OSHA will not enforce. Although ANSI Z87.1-2010 is currently incorporated into 29 CFR 1910.133 (1910.133(b)(1)(i), Eye and Face Protection, the current standard is ANSI/ISEA Z87.1-2015.
- b. Eye protection is rated as either “impact” or “non-impact” and marked Z87+ or Z87, respectively. Use only impact protection whenever eye protection is required. Table 10-1 summarizes the ANSI Z87.1 eye protection markings.

**Table 10-1**

Summary Of ANSI Z87.1 Eye Protection Markings		
Type of Z87.1 Marking	Category	Marking
Impact (Meets Z87.1 high mass impact, high velocity impact and penetration tests)	Impact rated lens	Z87+
	Impact rated prescription lens	Z87-2+
Non-impact (Meets all Z87.1 requirements, except impact requirements)	Non-impact rated lens	Z87
	Non-impact rated prescription lens	Z87-2
Lens Type	Clear	None
	Welding	“W” plus shade # (Shades range from 1.3 – 14. Higher shade numbers are darker lenses.)
	UV Filter	“U” plus scale # (Scale ranges from 2 – 6. Higher numbers provide higher protection.)
	Visible Light Filter	“L” plus scale # (Scale ranges from 1.3 – 10. Higher numbers provide higher protection)



Summary Of ANSI Z87.1 Eye Protection Markings		
	Infrared (IR) Filter	"R" plus scale # (Scale ranges from 1.3 – 10. Higher numbers provide higher protection)
	Variable Tint	"V"
	Special Purpose	"S" (for lenses with less than 85% visible light transmission)
Chemical Splash and Dust Protection	Splash/Droplet	"D3"
	Dust	"D4"
	Fine Dust	"D5"

- c. Types of eye and face protection are described below:
- (1) Safety spectacles, including safety glasses, shield eyes from foreign body impact and/or radiation hazards. Prescription safety lenses are available. When using safety spectacles in identified eye hazard areas, side shields are required as provided by spectacle manufacturer to meet ANSI Z87.1.
  - (2) Flexible goggles give frontal and side protection. Goggles are designed to fit snugly but not necessarily provide a facial seal. The ventilation in the side protection area of frames opens straight through the goggle and will allow passage of liquids.
  - (3) Chemical splash goggles with covered ventilation openings protect eyes against sprays and chemical splashes.
  - (4) Goggles with no ventilation are most protective against dusts, mists, liquid splashes and vapors.
  - (5) Depending on the operation, face shields/helmets may be required in addition to safety glasses/goggles.
  - (6) Face shields protect the whole face from foreign debris and liquid splashes. However, liquid may pass around the edges of the face shield and still contact the wearer's face. Therefore, face shields must be worn with safety glasses or goggles.
  - (7) Welding helmets protect the eyes and face against arc rays, weld sparks and splatters. Welding goggles protect eyes only. In some instances, ultraviolet radiation has been reflected off workroom surfaces behind the worker and into the helmet from the rear. Welding helmets are available with lenses that instantaneously darken when an arc is struck. New PPE technology includes welding helmet-respirator combination units for use in long duration welding applications.
  - (8) Full face respirators may be required for eye and face protection even when contaminant concentrations are below 10 times the OELs. Although ANSI Z87.1-2010 markings apply to respirator lenses, the National Institute for Occupational Safety and Health (NIOSH) has not incorporated this requirement into all their pertinent respirator certification standards. If work processes require full face respirators and impact



protection, check with the respirator manufacturer to ensure respirator lenses comply with ANSI Z87.1+ impact testing requirements.

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

- a. CPC is a subset of PPE and includes all items of protective clothing whose main purpose is to provide skin protection against chemical, physical and/or biological hazards. CPC includes gloves, aprons, coveralls, jackets, pants and boots.
- b. Many stressors pose "invisible" hazards and offer no warning properties. Unfortunately, no single combination of protective equipment and clothing can protect against all hazards. Therefore, CPC should be used with other protective methods, such as engineering controls, to limit exposure.
- c. Using CPC can itself create hazards to the wearer, such as heat stress, physical and psychological stress, impaired vision and restricted mobility and communication. In general, the greater the level of CPC, the greater the associated risks. For any given situation, CPC should be selected that provides an adequate level of protection. Over-protection may cause its own hazardous situation and should be avoided.
- d. CPC must be worn whenever there are potential hazards arising from direct exposure. Some examples include: emergency response; equipment leaks or failures; chemical treatment processes, such as chemical baths; hazardous waste site cleanup and disposal; operations producing particulate hazards, including asbestos removal; and pesticide application.

#### 5. CPC Classification

CPC can be classified by:

- a. Design. Categorizing CPC by design is a means of describing what areas of the body the clothing item is intended to protect. This includes gloves, boots, coveralls, aprons and full body suits. References 10-5 and 10-6 have more detailed information.
- b. Performance. CPC may be classified by its ability to provide protection. This may be further divided into particulate protection, liquid or splash protection, vapor protection and/ or protection against heat/cold. Combinations of the physical and chemical attributes of the stressor(s) must be considered.
- c. Service life. This is a user decision depending on the cost and risks associated with clothing decontamination and reuse. CPC may be labeled as reusable (multi-use) or disposable (one-time use). Disposable clothing is generally lightweight and inexpensive. Reusable clothing is often more rugged, but also more costly.
- d. Extensive contamination of any garment may render it disposable. The basis of this classification depends on the cost involved in purchasing, maintaining and reusing CPC versus the alternative of disposal following exposure.



- e. The key assumption in this determination is that the garment will provide an effective barrier during and after exposure and can be effectively decontaminated.

## 6. Worksite Characterization

As required by Reference 10-1, the importance of characterizing the workplace or process before recommending appropriate PPE cannot be over-emphasized. This can be done as a plan review before the first piece of equipment is installed, as a process change or when there is a change in the use of hazardous materials. It may even come after worker complaints. References 10-7 and 10-8 provide further information on worksite characterization.

- a. Physical conditions of the worksite. Chemical exposures can happen indoors or outdoors. The environment may be hot, cold or moderate. The exposure site may present physical hazards. Chemical handling activities may involve entering confined spaces, heavy lifting, climbing a ladder or crawling on the ground. The choice of ensemble components must allow for adequate mobility and dexterity.
- b. Chemical hazard. Chemicals can be toxic, corrosive, flammable, reactive, cause oxygen deficiency or any combination of these. Consider the following: What is the concentration of the chemical in use? Is the concentration immediately dangerous to life or health (IDLH)<sup>1</sup>? What are the consequences of skin exposure? Are there known significant toxic exposures, chronic hazards or reported fatalities by skin absorption? Is the chemical an allergic sensitizer?
- c. Physical condition of the hazard:
  - (1) Solids or particulates. Porous CPC minimizes heat stress, but must also be able to block particulates.
  - (2) Liquids and/or vapors. CPC material must be non-porous for protection against liquids. Liquid splash protective garments also provide particulate protection. Vapor protective suits provide liquid splash and particulate protection.
- d. Exposure duration. The protective qualities of ensemble components may be limited to certain exposure levels (i.e., material chemical resistance). Assume the worst-case exposure and the maximum time that CPC will be worn so that safety margins can be applied to increase the protection available to the worker.

## 7. The CPC Ensemble

- a. A variety of clothing and equipment must be available to workers to handle a broad range of chemical exposures. Further, having several sizes of CPC will help eliminate dangers from clothing that is too loose (possible trip hazard; loss of dexterity) or too tight (loss of motion range from binding; tears in clothing). The approach in selecting CPC must encompass an "ensemble" of clothing and equipment items that are easily integrated to

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<sup>1</sup> Per ANSI Z88.2, IDLH is any atmosphere that poses an immediate hazard to life or poses immediate irreversible debilitating effects on health.



provide both an appropriate level of protection and still allow one to carry out activities involving direct exposure.

- b. Factors that affect the use of ensemble components include:
  - (1) The way in which each item fits the integration of other ensemble components. Some ensemble components may be incompatible because of how they are worn. For example, some self-contained breathing apparatuses (SCBAs) may not fit in a particular chemical protective suit or may not allow acceptable mobility.
  - (2) The ease of interfacing ensemble components without sacrificing required performance (e.g., a poorly fitting over-glove greatly reduces wearer dexterity).
  - (3) Limiting the number of PPE items to reduce donning time and complexity.
  - (4) Ensemble design or configuration alone is not sufficient to ensure adequate protection. The performance of the selected clothing or equipment must also be known.
- c. Protection level. The type of PPE used and the overall level of protection should be reevaluated periodically as the amount of information about the chemical situation or process increases, and when workers are required to do different tasks. Personnel should upgrade or downgrade their level of protection only with the concurrence with the safety officer, industrial hygienist or incident commander.

## 8. CPC Chemical Resistance

The ability of CPC to act as a chemical barrier is determined by the CPC material and the method of construction. Usually, each chemical interacts with a given plastic or elastomer differently so there is a unique situation for each chemical/CPC material pair. Ideally, the chosen material(s) must be based on:

- a. Permeation. Process by which a chemical moves through a material on a molecular basis.
  - (1) Permeation rate. Usually expressed in terms of amount of chemical, which passes through a given area per unit time (milligrams per square meter per minute). The total amount of chemical permeating a CPC material is dependent on the area exposed and the duration of exposure. For a given chemical/CPC material pair, the permeation rate decreases as the material thickness increases.
  - (2) Breakthrough time. The elapsed time from the initial contact of the chemical with the outside surface of the CPC material to the first detection of the chemical on the inside surface of the material. There may be situations where breakthrough times are longer in one chemical/CPC pair than another, yet the material with shorter breakthrough time is recommended because its permeation rate is very small when compared to the chemical/CPC material pair with the long breakthrough time. On the other hand, breakthrough time may be the most important criterion when the chemical is a carcinogen and no skin contact is desired. Most breakthrough time and permeation rate data has been determined by using the American Society for Testing and Materials (ASTM) F739 Standard (Reference 10-9).
- b. Degradation. Physical changes in a material as the result of a chemical/physical exposure



or use. The most common observation of material degradation is discoloration, swelling, and loss of physical strength or deterioration.

- c. Penetration. The gross movement of a chemical through zippers, seams or imperfections in CPC material.
- d. Chemical mixtures. Mixtures of chemicals can be significantly more aggressive on materials than any single chemical alone. One chemical may pull another with it through the material. Another may change the CPC material structure and allow greater diffusion of other chemicals. Reference 10-10 reports protective clothing chemical resistance data, listing over 10,500 chemical permeation tests on CPC exposed to 860 chemicals and mixtures of chemicals. It also contains over 3,000 chemical degradation tests.

## 9. CPC Physical Resistance

CPC garments offer a wide range of physical qualities in terms of strength, resistance to physical hazards and operation in extreme environmental conditions. Assess a garment's physical properties by asking:

- a. Will the garment resist tears, punctures, cuts and abrasions?
- b. Will the garment withstand repeated use after contamination and decontamination?
- c. Is the garment flexible enough to allow users to perform needed tasks?
- d. Will the material maintain its protective integrity and flexibility under hot and cold temperature extremes?
- e. Is the garment flame resistant or self-extinguishing if necessary?
- f. Are garment seams constructed so they provide the same physical integrity as the garment material?

## 10. CPC Selection

- a. CPC selection is a complex task and must be performed by personnel with appropriate training and experience. Clothing should be selected by evaluating its performance characteristics against the requirements and limitations imposed by the application. Some guiding principles for selecting CPC follow:
  - (1) Chemicals from the same family (alcohols, primary amines, alkanes, aldehydes, etc.) will tend to permeate a given CPC material at similar rates with similar breakthrough times.
  - (2) Permeation rate is inversely proportional to molecular weight within the same family.
  - (3) Attached groups (which increase the molecular size) tend to slow permeation relative to the simple molecule.
  - (4) Polar chemicals tend to permeate polar material more rapidly than non-polar chemicals and vice versa. For example, water permeates polyvinyl alcohol very quickly, but permeates rubber slowly.
  - (5) Consider effects of material thickness and effects of temperature extremes.



- b. Sources of selection information include:
- (1) Vendor data or recommendations. The best source of current information on material compatibility should be available from the manufacturer of the selected CPC. Many vendors supply charts that show actual test data or their recommendations for use with specific chemicals. However, use caution when interpreting this information, particularly if vendor data are not well documented. Material recommendations must be based on data obtained from tests performed in accordance with methods in Reference 10-9. Simple ratings of "poor," "good," or "excellent" do not quantitate the material's performance against various chemicals.
  - (2) Reference 10-8 provides chemical resistance data and recommendations for 19 CPC materials tested against over 800 chemicals. Color coding indicates resistance to chemical breakthrough for reported service life. For example, a green code indicates permeation testing that resulted in breakthrough between 4 and 8 hours and a green code with >8 indicates greater than 8-hour resistance to chemical breakthrough.
  - (3) Appendix 10-B lists internet sites that offer free manufacturers' software with chemical breakthrough times and permeation rates for CPC selection guidance.
  - (4) NIOSH provides PPE recommendations for hazardous chemicals on their web site entitled [Recommendations for Protective Clothing, A Companion to the NIOSH Pocket Guide to Chemical Hazards.](#)

## 11. Wearing CPC

- a. Establish routine procedures for donning and doffing various ensemble configurations. Practice periodically.
- b. Plan for providing donning and doffing assistance if ensembles are cumbersome or if solo efforts increase the possibility of ensemble damage.
- c. Once equipment is donned, evaluate its fit. If the clothing is too small, it will restrict movement, increasing the likelihood of tearing the material and accelerating wearer fatigue. Clothing that is too large increases the possibility of snagging the material and may hamper the wearer's dexterity and coordination.
- d. Doffing procedures should focus on preventing contaminant migration from the work site and ensuring that contaminants do not transfer to the wearer's body, to other personnel or to the environment. When necessary, doffing should be done after decontamination or in a manner to reduce contamination to the wearer.

## 12. Decontamination

- a. Decontamination removes or neutralizes contaminants that have accumulated on CPC, personnel and equipment. Proper decontamination:
  - (1) Protects users from hazardous substances that may contaminate and eventually permeate the CPC, respirators, tools, vehicles or other equipment used at or near the hazard area.
  - (2) Protects the community and site personnel by minimizing contaminant transfer into





clean areas.

- b. Things to consider during decontamination procedures:
  - (1) Is the CPC adversely affected by the decontamination? The physical or chemical resistance may be affected by heat or chemicals used to clean the CPC.
  - (2) Is the decontamination process effective? There is some indication that volatile, small molecule chemicals may be successfully removed from the CPC with the use of heat. No standard method is available to determine whether a product is decontaminated.
  - (3) Can the decontamination process cause exposure? Any chemicals used in the process must be evaluated to ensure they do not result in unacceptable exposures, either during the decontamination process or when the CPC is reused.
  - (4) Reference 10-11 provides guidelines for decontaminating chemical protective clothing.

### 13. PPE/CPC Inspection

- a. The PPE user must take all necessary steps to ensure that the protective ensemble will perform as expected. Emergencies are not the time to discover problems. Following a standard program for inspecting protective equipment and realizing its limitations are the best ways to avoid exposure during PPE use.
- b. Reference 10-5 provides guidelines for inspecting CPC. Appendix A of Reference 10-7 lists procedures for inspecting fully encapsulating suits. Additional inspection information may be available from the PPE manufacturer. The OSHA [eTool](#), Eye and Face Protection, provides requirements and guidance on eye and face protection maintenance. An effective PPE inspection program features:
  - (1) Equipment inspection and operational testing as received from the manufacturer or distributor;
  - (2) Equipment inspection as it is selected for a particular chemical operation;
  - (3) Equipment inspection after use or training;
  - (4) Periodically inspect stored equipment; and
  - (5) Inspection when questions arise concerning the selected equipment, or when problems with similar equipment are discovered.

### 14. Storage

All PPE must be stored properly to prevent damage or malfunction from exposure to dust, moisture, sunlight, damaging chemicals, extreme temperatures and impact. Some guidelines for storage include:

- a. Potentially contaminated clothing or equipment should be stored separately from street clothing and unused PPE.
- b. Potentially contaminated PPE should be stored in a well-ventilated area with good air flow around each item.
- c. Different types of CPC materials should be stored separately to prevent issuing the wrong material by mistake (i.e., many glove materials are the same color and cannot be identified



by appearance alone).

- d. To help avoid PPE failure from improper storage, fold or hang clothing according to manufacturer instructions.

## 15. Heat Stress

- a. Wearing full body PPE puts the wearer at considerable risk for heat stress. This can result in health effects ranging from transient heat fatigue to serious illness or death.
- b. Heat stress is caused by several interacting factors, including environmental conditions, type of protective ensemble worn, work activity required and physical condition of the wearer.
- c. When selecting protective clothing and equipment, each item's benefit should be carefully evaluated for its potential for increasing the risk of heat stress. For example, choose a lighter, less insulated suit if it can be worn without sacrificing protection. For more information on heat stress, consult References 10-12, 10-13 and 10-14.

## 16. Training

- a. Training is required by Reference 10-1 and must be provided to each employee who is required to wear PPE. Training should include at least the following:
  - (1) When to wear PPE;
  - (2) What PPE to wear;
  - (3) How to don, doff, adjust and wear PPE;
  - (4) What are the capabilities and limitations of the PPE;
  - (5) How to properly maintain PPE; and
  - (6) When and how to dispose of PPE.
- b. Employees must demonstrate knowledge of the training specified above and the ability to use PPE properly before being allowed to perform work requiring PPE.
- c. Training is required annually or whenever any of the following situations occur:
  - (1) Workplace operations change such that previous PPE or training is obsolete.
  - (2) Employees demonstrate that they do not understand the training they received.
- d. Written training records must include the employees' name, organization, job title, date(s) of training, course title, instructor's name and description of lesson plan. Paragraph 0605 of Reference 10-2 requires maintaining training records for five years.

## 17. References

- 10-1 Code of Federal Regulations, Title 29, Part 1910, Subpart I, Sections 132-138. Personal Protective Equipment. [29 CFR 1910.132 Personal Protective Equipment](#)
- 10-2 OPNAVINST 5100.23 Series. [OPNAVINST 5100](#)
- 10-3 American National Standards Institute (ANSI) Z87.1-2010, American National



Standard Practice for Occupational and Educational Eye and Face Protection.

<http://www.ansi.org/>

- 10-4 HONCON OSHA Mr. J. Steelnack/ NAVMCPUBHLTHCEN Mr. D. Spelce of 19 Jul 11
- 10-5 Occupational Safety and Health Administration Technical Manual, Section VII, Chapter 1, Chemical Protective Clothing. OSHA Instruction TED 1-0.15A. Washington, D.C.: U.S. Department of Labor. 2008. [OSHA Technical Manual, Section VII, Chapter 1, Chemical Protective Clothing](#)
- 10-6 Anna, D. H., ed.: Chemical Protective Clothing, 2nd ed. Fairfax, VA: AIHA Press. 2003
- 10-7 Code of Federal Regulations, Title 29, Part 1910.120. Hazardous Waste Operations and Emergency Response. [29 CFR 1910.120 Hazardous Waste Operations and Emergency Response](#)
- 10-8 Forsberg, K. and Mansdorf, S. Z. Quick Selection Guide to Chemical Protective Clothing, 6th ed. Cincinnati, Ohio: ACGIH®, 2014.
- 10-9 American Society for Testing and Materials (ASTM): Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact (ASTM F739-07). Philadelphia: ASTM, 2007.
- 10-10 Forsberg, K. and Keith, L. H. Chemical Protective Clothing: Performance Index, 2nd ed. Cincinnati, Ohio: ACGIH®, 1999.
- 10-11 American Industrial Hygiene Association (AIHA). Guideline for the Decontamination of Chemical Protective Clothing and Equipment (AIHA Guideline 6 - 2005), Fairfax, VA: AIHA, 2005.
- 10-12 OSHA. Occupational Safety and Health Administration Technical Manual, Section III, Chapter 4, Heat Stress. OSHA Instruction TED 01-00-015. Washington, D.C.: U.S. Department of Labor. 1999/2017. [OSHA Technical Manual, Section III, Chapter 4, Heat Stress](#)
- 10-13 Prevention and Treatment of Heat and Cold Stress Injuries NEHC-TM-OEM 6260.6A June 2007. [Navy Prevention and Treatment of Heat and Cold Stress Injuries](#)
- 10-14 NAVMED P-5010, Chapter 3, Prevention Of Heat And Cold Stress Injuries, 2009 (Ashore, Afloat, and Ground Forces) [Navy Prevention of Heat and Cold Stress Injuries](#)



## Appendix 10-A – Special Considerations for Glove Selection

### 1. Introduction

- a. This appendix provides guidance for selecting chemical resistant gloves. Appendix 10-B lists additional resources on this topic. As with all PPE, selecting chemical protective gloves is a complex task and should be performed by personnel with training and experience in this process.
- b. Training should include information on how human skin and polymer glove materials function as protective barriers against toxic chemicals. The information provided in this appendix on the skin's interaction with workplace chemicals and the properties of chemically resistant gloves is largely based on the information provided in Reference 10A-1.

### 2. Policy

- a. According to Reference 10A-2, the OSHA requires employers to select and provide appropriate hand protection when employees' hands are exposed to occupational hazards, including exposure to harmful substances absorbed through the skin. OSHA clearly states that protective equipment must be used in conjunction with sound workplace practices and proper engineering controls, such as substituting less hazardous chemicals.
- b. OSHA requires conducting workplace hazard assessments to ensure that protective equipment is properly selected for protection against specific workplace hazards. Chapter 20 of Reference 10A-3 requires a PPE program that includes a written hazard assessment, proper protective equipment selection, fitting and use procedures, maintenance (e.g., cleaning, disinfection, inspection and storage) and training, including documentation.

### 3. Skin Interaction with Workplace Chemicals

- a. The skin is the largest organ of the human body. It accounts for more than 10% of the body's mass and represents a potentially significant exposure pathway for many chemicals because of the large surface area. Skin functions as a two way barrier, preventing toxic substance absorption from the environment and preventing excessive water and electrolyte loss from the body. Skin contains three anatomically distinct regions: the epidermis, the dermis and the hypodermis. The skin's protective function lies solely in the epidermis. The dermis contains a rich blood supply and merges into the innermost layers of the epidermis. The body absorbs toxic substances into the blood stream at the dermal-epidermal interface. The hypodermis is between the dermis and underlying tissues and organs. It fastens the skin to the underlying surface, supplies the skin with blood vessels and nerves, provides thermal insulation and absorbs shocks from



impacts to the skin.

- b. Skin Absorption. Toxic substances absorb across skin in a two-step process. First, substances diffuse through the epidermis, which is the rate determining step. Then, the diffused material is carried from the dermis into the blood stream, which carries toxic materials throughout the body. Removal of toxic material from the dermis by the blood is up to 500 times faster than diffusion of the material through the epidermis.
- c. Occupational Contact Dermatitis. The [National Institute for Occupational Safety and Health](#) (NIOSH) has estimated that workplace skin diseases account for 15% – 20% of all reported occupational diseases in the United States, with estimated total annual costs (including lost workdays and lost productivity) up to \$1 billion. Skin exposures to chemicals can cause a wide array of injuries and illness, including contact dermatitis, immune-mediated responses and irreversible damage to the skin. Dermatitis refers to a skin abnormality induced by chemical contact. Chemicals in contact with the skin cause adverse health effects through both allergic and irritant contact dermatitis.
  - (1) Allergic contact dermatitis. An immunologic response of sensitized individuals in contact with an allergen. [Occupational sensitization to latex rubber](#) is an allergic reaction. Other workplace substances that cause allergic contact dermatitis include nickel, formaldehyde, chromates and epoxy resins.
  - (2) Irritant contact dermatitis. Accounts for the majority of occupational dermatitis. Acute reaction from a single exposure to a toxic compound results in reddening of the skin with a burning or stinging sensation. Multiple exposures can cause fissures in the skin. Chronic dermatitis results in greater redness and fissuring of the epidermis, sometimes resulting in a thickening and hardening of the skin, causing it to appear leathery.
- d. Skin Notation. [NIOSH](#), [OSHA](#) and other occupational exposure limits use the "skin" designation for chemicals that can be absorbed through the skin and contribute to systemic toxicity. However, some organizations also use this notation for non-systemic effects, such as skin irritation and corrosive properties, resulting in confusion. Reference 10A-4 discusses the NIOSH strategy for [assigning new skin notations](#) that distinguish between systemic, direct (e.g., skin irritation or corrosivity) and sensitizing effects of skin exposures to chemicals. A summary of these skin notations is provided in Table 10A-1. The new NIOSH skin notation system permits assigning several skin notations for a chemical when multiple skin hazards exist. For example, if health data indicates that a chemical causes systemic toxicity when absorbed by the skin and is also corrosive, the notation assigned to the chemical would be SK: SYS-DIR (COR).
  - (1) NIOSH plans to include the new skin notations in future NIOSH publications, including the [NIOSH Pocket Guide to Chemical Hazards](#). NIOSH also plans to develop a support document called a Skin Notation Profile for each chemical evaluated. The Skin Notation Profile will provide information substantiating the skin notation, including a summary of all relevant data used to determine the hazards associated with skin exposures.



**Table 10A-1**

Summary of NIOSH Multiple Skin Notations	
SYS	Indicates the potential for a chemical to contribute substantially to systemic toxicity through dermal absorption.
(FATAL)	A sub-notation of SYS, indicates that a chemical is highly or extremely toxic, and may be potentially lethal or life-threatening following skin exposures.
DIR	Indicates non-immune mediated direct effect(s) of a chemical on the skin at or near the point of contact, including corrosion, primary irritation, bleaching (blanching), staining and reduction/disruption of the skin barrier integrity.
(IRR)	A sub-notation of DIR indicates that a chemical is a skin irritant.
(COR)	A sub-notation of DIR indicates that a chemical is a corrosive.
SEN	Indicates that skin exposure to a chemical may cause or contribute to the onset of allergic contact dermatitis or other immune-mediated responses, such as airway hyper reactivity (asthma).
SK	Indicates that the reviewed data identified no health hazard associated with skin exposure and did not support assignment of the SYS, DIR or SEN notation.
ID(SK)	Indicates that insufficient data were available at time of evaluation to determine the hazards associated with dermal contact to a candidate chemical substance.
ND	Indicates that a chemical has not been evaluated by the improved skin notation strategy, and the health hazards associated with skin exposure are unknown.

#### 4. Polymeric Glove Materials

A basic understanding of the polymers used to make protective gloves will assist in the glove selection process. Appendix 10-B provides several sources of information on polymer chemistry. Protective gloves are made from many different types of polymer materials, and no two products are identical. For example, the quality of nitrile gloves made by different manufacturers may differ significantly because of differences in polymer blends, material thickness and manufacturing methods. Slight changes in the manufacturing process can change the protective properties considerably.

#### 5. Basic Types of Glove Materials

No single glove material will protect against all possible chemicals. Table 10A-2 lists general advantages and disadvantages of some of the more common glove materials. This table is compiled from the cited references and from the resources listed in Appendix 10-B. Since



Table 10A-2 provides general guidance, consult glove manufacturers and other sources to ensure proper selection. For instance, butyl gloves are listed as protecting against hydroxyl compounds, but they are not protective against all hydroxyl compounds. Also, note that test data from one brand of glove does not necessarily mean that other glove brands of similar material type and thickness will perform the same.

**Table 10A-2**

<b>Glove Material Comparison Chart</b>			
<b>Glove Material</b>	<b>Advantages</b>	<b>Disadvantages</b>	<b>Protects Against</b>
Natural latex rubber	Low cost, good physical properties, dexterity, excellent abrasion & tear resistance.	Poor protection against organic solvents, amides, ketones, isocyanates, aldehydes, methylene chloride, oils, greases, brake fluid or fuels like kerosene & gasoline. Gloves are derived from latex, which can cause allergic contact dermatitis. Poor flame resistance.	Aqueous solutions of acids & bases, Sevin® (carbaryl), organic & inorganic salts & solutions, mercury, ethylene glycol & glycerol. Good for food handling.
Polyvinyl chloride (PVC)	Medium cost, very good physical properties, medium chemical resistance.	Plasticizers can be stripped. Poor protection against aldehydes, ketones, isocyanates, hydrocarbons (aliphatic, alicyclic, & aromatic), halogen compounds, heterocyclic compounds, & nitro compounds.	Acids & bases, carbaryl, salts, aqueous solutions, hydrazine, ethylene glycol, glycerol, tricresyl phosphate, polychlorinated biphenyls, mercury, oils, & fats.
Neoprene (Poly-chloroprene)	Medium cost, medium chemical resistance. Excellent protection from physical hazards such as cuts & abrasions. Flexible over a wide temperature range.	Poor protection against isocyanates, hydrocarbons (aliphatic, alicyclic, & aromatic), halogen compounds, & ketones.	Acids, bases, carbaryl, alcohols, mercury, polychlorinated biphenyls, hydrazine, chlorine gas, oils, greases, petrochemicals, & some aldehydes.



**Glove Material Comparison Chart**

<b>Glove Material</b>	<b>Advantages</b>	<b>Disadvantages</b>	<b>Protects Against</b>
Nitrile	Low cost, excellent physical properties & dexterity.	Poor protection against methylene chloride, trichloroethylene, aromatic hydrocarbons, ketones, & acetates.	Oils, greases, hydraulic oil, motor oil, weak acids & bases, hydrazine, carbaryl, aliphatic & alicyclic hydrocarbons, fuels, pesticides, & mercury.
Butyl	Synthetic rubber with good resistance to a wide variety of chemicals. Highly resistant to gases.	Expensive. Poor protection against aliphatic & aromatic hydrocarbons (including gasoline), & chlorinated solvents.	Glycol ethers, aniline, ketones, some esters, acids, bases, acetates, alcohols, acetone, some amines, hydrazine, hydroxyl compounds, isocyanates, tricresyl phosphate, mercury, peroxides, polychlorinated biphenyls, nitro compounds, chlorine gas, & aldehydes.
Polyvinyl alcohol (PVA)	Durable. Resists a very broad range of organic compounds. Flexible over a wide temperature range.	PVA is water soluble - do not use in water or aqueous solutions. Poor protection against alcohols.	Aliphatic & aromatic hydrocarbons, methylene chloride, isocyanates, perchloroethylene, trichloroethylene, some ketones (not acetone or methyl ethyl ketone), tricresyl phosphate, xylene, & some esters.
Fluoro-elastomer (Viton)™	Specialty glove. Highly resistant to gases.	Expensive. Poor physical properties - minimal resistance to cuts & abrasions. Poor protection against most ketones.	Acids, bases, chlorinated hydrocarbons, aromatic & aliphatic hydrocarbons, hydroxyl compounds, glycol ethers, some esters, tricresyl phosphate, trichloroethylene, aniline, perchloroethylene, mercury, styrene, toluene, alcohols, polychlorinated biphenyls, & some amines.





## 6. Service Life Definitions

The service life of gloves and any other CPC is dependent on the time it takes for workplace chemicals to break through the glove material, the permeation rate after breakthrough occurs and chemical degradation of the glove material. Definitions of important terms for glove selection and other CPC are provided below.

- a. ASTM F739 Method. Most breakthrough time and permeation rate data has been determined using the American Society for Testing and Materials (ASTM) F739 Standard, Reference 10A-5. Per the Standard, glove material is placed in a test cell in continuous contact with the test substance on one side while its vapor is collected on the other side as it desorbs from the material. The [NIOSH Permeation Calculator](#), listed in the Resource Section, calculates the permeation parameters listed in ASTM F739 and displays all relevant information to assist in selection.
- b. Breakthrough time. According to Reference 10A-6, breakthrough time, measured in minutes, is the time it takes for a substance to travel through the glove material. Using the ASTM F739 method, breakthrough is measured from the time that the test substance begins contact with the glove material until the substance is first detected on the other side of the glove sample.
- c. Permeation. The process by which molecules of a substance migrate through a material by diffusion. Glove permeation rate is the speed at which the substance migrates through the glove material after breakthrough occurs. It is expressed in milligrams per square meter per minute. Permeation can occur without any visible signs on the protective material.
- d. Penetration. Penetration occurs when bulk liquid passes through openings in the polymer material. Defects such as pinholes can allow substances to penetrate through the glove, regardless of the degree of chemical resistance provided by the material.
- e. Degradation. Polymer material disintegration occurs because of interactions between the challenge substance and the polymer, plasticizers or other additives in the polymer. During degradation, the polymer's physical properties change (e.g., stiffen, swell, change weight or dissolve). Once degradation occurs, the challenge substance more readily permeates the material.

## 7. Polymer Material Permeation Process

No polymer is indefinitely resistant to chemical permeation, although it could take days or weeks for some solvents to pass through some polymers. For example, many ketones will permeate Viton in a matter of minutes, but isopropyl alcohol permeation requires days. Further, no single polymer material will protect against all chemicals. In mixtures, one component may have a faster permeation rate than the other components. The component with the faster permeation rate can change the internal polymer structure, thus allowing components, which would not normally permeate the polymer to diffuse more quickly through the altered polymer structure. Per Reference 10A-1, solvents permeate polymer



materials in a three-step process:

- a. Solution Step. Solvent-polymer solubility is an important factor in the solution step because “like dissolves like.” A solvent is soluble in a polymer if it exhibits the same types of secondary bonds (e.g., polar bonds and hydrogen bonds) as those holding the polymer chains together. Solubility is a complex issue, and Appendix 10-B contains several good references for further reading.
- b. Diffusion Step. In the second step of the permeation process, the solvent diffuses through the polymer. Chemical flow across polymer material is dependent on the solvent concentration, the thickness of the material and the free volume within the polymer. Solvent molecules diffuse through the spaces between polymer chains. Small molecules will move more easily through these spaces than larger molecules with similar secondary chemical attractions.
- c. Evaporation Step. During diffusion, solvent molecules move randomly within the polymer chains, even back toward the side of the polymer exposed to the solvent. In time, a concentration gradient forms and diffusion proceeds from high concentration to low concentration. This concentration gradient forms because the solvent evaporates from the unexposed surface of the polymer. As the solvent reaches the unexposed interior surface, it leaves the material and is either: carried away in the air during glove testing; or comes in contact with the skin when worn in the workplace. The higher the substance’s vapor pressure, the more rapidly it will desorb from the glove material.

## 8. General Considerations for Selection

Reference 10A-7 lists important considerations for selecting gloves (many of which also apply to any chemical protective clothing), such as;

- a. Glove selection should involve shop supervisors and the employees who will wear the gloves. This helps ensure that the gloves fit properly, are comfortable and employees can perform their tasks while wearing the gloves.
- b. Chemical resistance and physical resistance to cuts, tears and punctures are important factors in glove protection. In addition, the amount of dexterity necessary to accomplish a task must be considered. Thicker polymer material will increase breakthrough time (in general, doubling the thickness will quadruple the breakthrough time), but may decrease tactility and dexterity. Gloves without a textile substrate provide greater dexterity and touch sensitivity. Very thin gloves offer poor chemical resistance and mechanical strength.
  - (1) No one polymer material will protect against all chemicals. A glove that performs well against one chemical may not be protective against another chemical or a mixture of chemicals.
  - (2) Eventually, every chemical will permeate protective clothing. Permeation can occur without visible signs. Once absorbed, a chemical continues to permeate the polymer material.



- (3) Do not rely on glove color to identify their composition. Most protective clothing is available in different forms and colors. Permeability of the same type of glove material can vary greatly between different manufacturers.
- c. Ensure you are using the most current technical reference when conducting glove selection documentation. For instance, the American National Standards Institute (ANSI) cut resistance scale ANSI/ISEA 105 was expanded in 2016; glove selection documentation prior to 2016 might reference the old cut resistance ratings. Use the current standard, referenced below or a current glove selection tool and properly document the PPE selection on the PPE Hazard Assessment form per 29 CFR 1910.132(d)(2) Reference 10A-3 and/or DON equivalent.
  - d. Consider the depth at which the arm will be immersed when selecting glove length and allow for protection against chemical splash. Gloves are tested and rated at room temperature unless specifically noted. Glove use in high temperature applications usually increases the permeation rate. Carefully consider how high temperature environments may affect permeation rates.
  - e. Glove use may also cause hand perspiration inside the gloves and intern increase the absorption rate of certain chemicals (such as xylene); carefully consider perspiration when selecting the appropriate gloves.
  - f. Using multiple layers of gloves can increase thickness and incorporate properties of the different glove materials.

## 9. General Considerations for Use

Reference 10A-7 lists important considerations for glove use (many of which also apply to any CPC), such as:

- a. Training is required before using protective gloves.
- b. Inspect glove integrity before and after each use, including:
  - (1) Checking for cuts, tears and punctures. Check for holes in gloves by using air to inflate them.
  - (2) Checking for discoloration or stiffness, which may be signs of chemical degradation from previous use.
- c. Store and maintain protective gloves according to manufacturer's instructions.
- d. Ensure the shelf life has not expired.
- e. Do not reuse contaminated gloves unless certain that they have been thoroughly decontaminated. Reference 10A-8 provides decontamination guidelines.

## 10. References

10A-1 Anna, D. H., ed.: Chemical Protective Clothing, 2nd edition. Fairfax, VA: AIHA Press.



2003. pp.1-110.

- 10A-2 Occupational Safety and Health Administration (OSHA): 29 CFR Part 1910.138 Hand Protection: Revised as of January 1, 2007. Federal Register 59(16362):449–453. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, April 6, 1994. [29 CFR 1910.138 Hand Protection](#)
- 10A-3 Code of Federal Regulations, Title 29, Part 1910.132 Personal Protective Equipment. 1974/2008. [29 CFR 1910.132 Personal Protective Equipment](#)
- 10A-4 OPNAVINST 5100.23 Series. [OPNAVINST 5100 Series](#)
- 10A-5 National Institute for Occupational Safety and Health (NIOSH): Current Intelligence Bulletin (CIB) 61: A Strategy for Assigning New NIOSH Skin Notations, NIOSH Publication No. 2009–147: Cincinnati, Ohio: NIOSH, 2009. <http://www.cdc.gov/niosh/docs/2009-147/>
- 10A-6 American Society for Testing and Materials (ASTM): Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact (ASTM F739-07). Philadelphia: ASTM, 2007.
- 10A-7 Forsberg, K., Van Den Borre, A, Henry III, N., and Zeigler, J. Quick Selection Guide to Chemical Protective Clothing, 5th ed. Cincinnati, OH: ACGIH®, 2007.
- 10A-8 American Industrial Hygiene Association (AIHA). Guideline for the Decontamination of Chemical Protective Clothing and Equipment (AIHA Guideline 6 - 2005), Fairfax, VA: AIHA, 2005.



## APPENDIX 10-B

**Table 10B-1**

PPE Resources Not all available resources are included on this table. This is not an endorsement of particular websites and does not imply endorsement by the Department of Defense, the Navy or the Navy and Marine Corps Public Health Center, nor does it mean that these resources' content has been validated.	
Resource Description	Resource/Comments
Chemical Protective Clothing Selection	<p>Forsberg, K. and Keith, L. H. Chemical Protective Clothing: Performance Index, 2<sup>nd</sup> ed. Cincinnati, Ohio: ACGIH®, 1999</p> <p>Reports protective clothing chemical resistance data, listing over 10,500 chemical permeation tests on CPC exposed to 860 chemicals and mixtures of chemicals. It also contains over 3,000 chemical degradation tests. A “Chemical Permeation Index Number” is provided to assist individuals who are not familiar with the concepts of breakthrough times, permeation rates and degradation. Zero (0) is the best selection of protective clothing for the specific chemical or chemical mixture and 5 represents the worst selection.</p>
Resources on Glove Polymeric Materials	<p><a href="#">Michigan State University, Polymer Introduction</a></p> <p>Provides an in-depth discussion of polymer chemistry.</p> <p><a href="#">University of Southern Mississippi, Department of Polymer Science, Properties of Polymers</a></p> <p>Provides an in-depth discussion of polymer chemistry.</p> <p><a href="https://www.grainger.com/content/qt-safety-material-chemical-compatibility-resources-212">https://www.grainger.com/content/qt-safety-material-chemical-compatibility-resources-212</a></p>
Glove, Clothing and Material Chemical Compatibility Resources	<p><a href="https://www.grainger.com/content/qt-safety-material-chemical-compatibility-resources-212">https://www.grainger.com/content/qt-safety-material-chemical-compatibility-resources-212</a></p>

Internet Sources of Glove Selection and General PPE Guidance	<a href="http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf">http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf</a>
	<a href="#">Permeation/Degradation Resistance Guide for Ansell Chemical Resistant Gloves, 8<sup>th</sup> Edition</a>
	<a href="#">Recommendations for Chemical Protective Clothing: A Companion to the NIOSH Pocket Guide to Chemical Hazards</a>
	<a href="#">North Industrial Glove Selection Guide</a>
	<a href="#">ChemRest Guide to Chemical Resistant Best Gloves</a>
	<a href="#">Kimberly-Clark Gloves Chemical Compatibility Chart</a>
	<a href="#">Kimberly-Clark Product Selector, A Personal Selection Guide for Safety Products</a>
	<a href="#">MAPA Spontex, Inc. Glove Selection Guide</a>
	<a href="#">Argonne National Laboratory Glove Selection Guide</a>
	<a href="#">Cole-Parmer Safety Glove Chemical Compatibility Database</a>
	<a href="#">DuPont™ SafeSPEC™ 2.0</a>
	<a href="#">Permeation Guide for DuPont™ Tychem® Protective Fabrics</a>
	<a href="#">Guardian Chemical Protective Gloves</a>
	<a href="#">OSHA Personal Protective Equipment</a>
	<a href="#">ONGUARD Industrial Footwear Permeation and Degradation Charts</a>
	<a href="#">DuPont SafeSPEC™ 2.0</a>
<p><a href="#">National Institute for Occupational Safety and Health (NIOSH): Indexed Dermal Bibliography (1995-2007), NIOSH Publication No. 2009-153: Cincinnati, Ohio: NIOSH, 2009.</a></p> <p>Includes 229 references on occupational skin exposures to chemicals, including health effects surveillance, exposure characterization, hazard identification, risk assessment, risk control/management and personal protective equipment.</p>	



<p>Internet Sources of Glove Selection and General PPE Guidance (continued)</p>	<p><a href="#">National Institute for Occupational Safety and Health (NIOSH): Preventing Allergic Reactions to Natural Rubber Latex in the Workplace. NIOSH Publication No. 97-135: Cincinnati, Ohio: NIOSH, 1997.</a></p> <p>Discusses prevention of allergic reactions to latex rubber in the workplace.</p>
<p>Resources on Dermal Exposure</p>	<p>ACGIH®: TLVs and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, Ohio: ACGIH, 2012.</p> <p>Lists compounds regarded as skin hazards</p>
	<p><a href="#">National Institute for Occupational Safety and Health (NIOSH): NIOSH Pocket Guide to Chemical Hazards, NIOSH Publication No. 2005-149</a></p> <p>Lists compounds regarded as skin hazards.</p>
	<p><a href="#">NIOSH Skin Permeation Calculator</a></p> <p>Estimates the log of the octanol-water <math>K_{ow}</math> partition coefficient, which indicates a chemical's solubility in a nonpolar phase versus a polar phase. The most skin penetrating chemicals have a log <math>K_{ow}</math> between 1 and 3.</p>
	<p><a href="#">NIOSH Finite Dose Skin Permeation Calculator</a></p> <p>Estimates fluxes, skin concentrations and amounts absorbed from any size dose applied to partially or fully hydrated skin corresponding to typical occupational exposure scenarios.</p>
	<p><a href="#">NIOSH Safety and Health Topic Website: Skin Exposure &amp; Effects</a></p> <p>Provides an overview of occupational skin exposure.</p>
	<p>OSHA 29CFR 1910.1000, <a href="#">Table Z-1</a></p> <p>Lists compounds regarded as skin hazards.</p>



Resources on Dermal Exposure (continued)	<a href="#">NIOSH Dermal Exposure Research Program within the National Occupational Research Agenda</a> NIOSH endeavor to develop improved policy and guidelines for recognizing and controlling occupational dermal hazards.
	<a href="#">NIOSHTIC-2 search results on Skin Exposures and Effects</a> Searchable bibliographic database of skin exposures and effects.
Resources on Eye Protection	<a href="#">OSHA Fact Sheet - Eye Protection against Radiant Energy during Welding and Cutting in Shipyard Employment</a>
	<a href="#">OSHA Shipbreaking Eye and Face Protection</a>
	<a href="#">OSHA Eye and Face Protection E-Tool</a>
	<a href="#">3M ANSI Z87.1-2015 Standard Update for Non-Prescription Eye and Face Protective Devices</a>
	<a href="#">CDC Workplace Safety &amp; Health Topics – Eye Safety</a>

