Hazardous Materials: Managing the Incident

CHAPTER 8

Selecting Personal Protective Clothing and Equipment

Learning Objectives Overview

- Knowledge Objectives
- Skills Objectives

Introduction

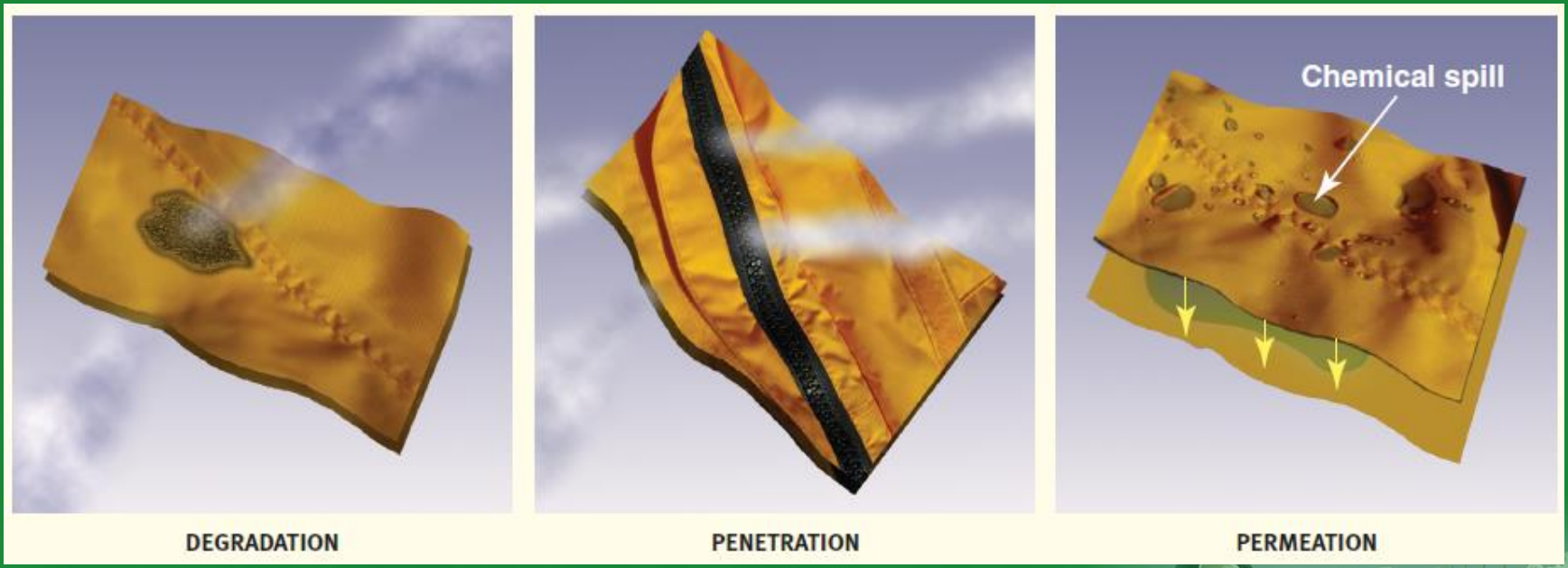
- Tactical objective must be determined before selection of personal protective clothing
- Responders must be trained in the application, limitations, and use of PPE.
- Engineering controls and the use of safe work practices and administrative controls also provide protection from hazardous materials.

Basic Principles (1 of 2)

- CPC evaluation concerns should focus upon the following:
  - Chemical resistance of the garment
  - Integrity of the entire protective clothing ensemble
  - The tasks to be performed

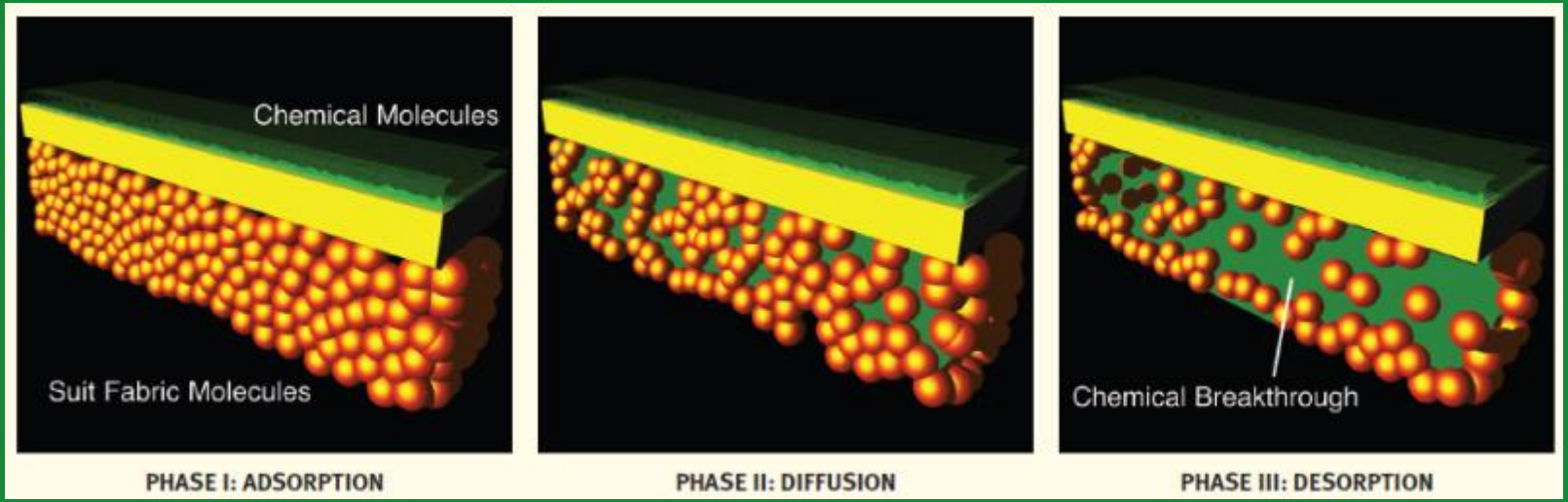
Courtesy of Jerry Grey

Basic Principles (2 of 2)



- Key terms in evaluating chemical barriers:
  - Degradation
  - Penetration
  - Permeation

Permeation Theory (1 of 2)



- The process of chemical permeation through an impervious barrier is a three-step process consisting of the following:
  - Adsorption of the chemical
  - Diffusion of the chemical
  - Desorption of the chemical

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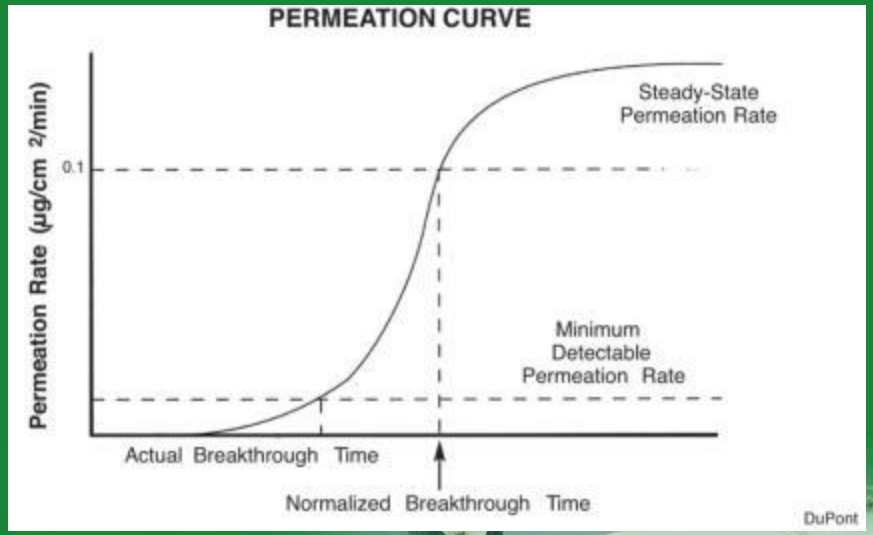
Permeation Theory (2 of 2)

- Chemical permeation rates are a function of many factors, including the following:
  - Temperature
  - Thickness
  - The unknown effects of chemical mixtures upon chemical resistance
  - Previous exposures



Protective Clothing Materials

- Parameters that should be considered when evaluating and choosing CPC:
  - Chemical resistance
  - Flammability
  - Strength and durability
  - Overall integrity
  - Flexibility
  - Temperature characteristics
  - Shelf life
  - Decontamination and disposal

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Categories of Chemical Protective Clothing

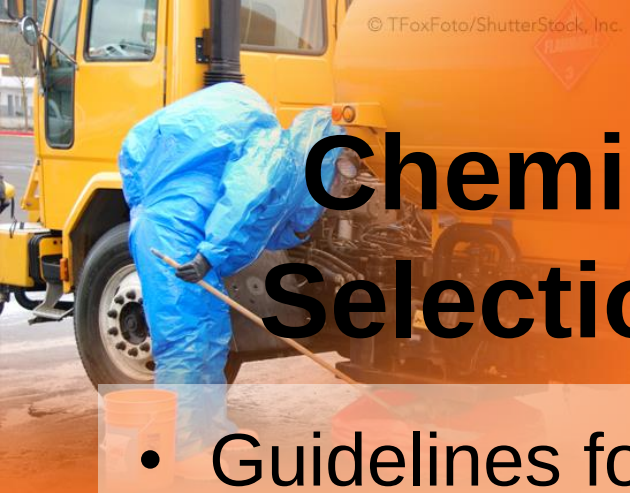
- Protective clothing materials can be classified by use into two broad categories:
  - Limited-use garments
  - Reusable garments

Chemical Barrier and Initial Selection Considerations (1 of 3)

- No single protective clothing material offers total chemical protection.
- Selection should be based on a hazard assessment of chemicals involved.
- User must rely on the manufacturer's representation.
- Evaluate all suit components and their construction materials.

Chemical Barrier and Initial Selection Considerations (2 of 3)

- Chemical resistance data is described in terms of either:
  - Chemical permeation/breakthrough times and rates
  - Cumulative permeation for a given test duration
  - Pass/fail chemical penetration testing results



Chemical Barrier and Initial Selection Considerations (3 of 3)

- Guidelines for evaluating chemical barrier recommendations:
  - Recommendations should come from documentation published by the vendor.
  - Determine the basis of chemical barrier recommendations.
  - Degradation recommendations based upon immersion testing data may be quite old.
  - Testing criteria and descriptions defining key words may not be documented.

Respiratory Protection

(1 of 3)

- The respiratory system is the most direct and critical exposure route.
- Inhalation is the most common exposure route and is often the most damaging.
- Material does not have to be a gas in order to be inhaled.

Respiratory Protection
(2 of 3)

- Respiratory protection selection factors:
  - What is the physical form of the contaminant (i.e., solid, liquid, or gas)?
  - Has the contaminant been identified?
  - Are concentrations known or unknown?
  - What is the purpose of response operations?

Respiratory Protection
(3 of 3)

- What will be the duration of response operations?
- What is the operating environment and operating conditions (e.g., indoors, outdoors, heat, cold, precipitation, etc.)?
- What type and level of skin protection will be required?

Air Purification Devices (1 of 4)

- Air purification devices are respirators that remove particulate matter, gases, or vapors from the ambient air before inhalation.

Air Purification Devices (2 of 4)

DuPont® Personal Protection

Courtesy of Chris Hawley

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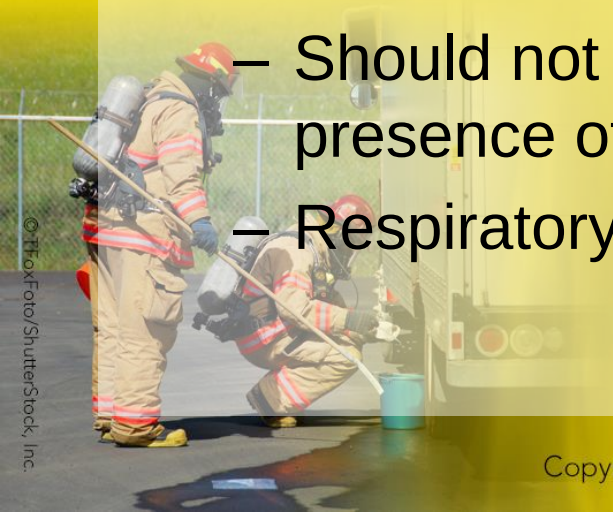
- Two basic types:
  - Air purification respirators (APRs)
  - Powered-air purification respirators (PAPRs)

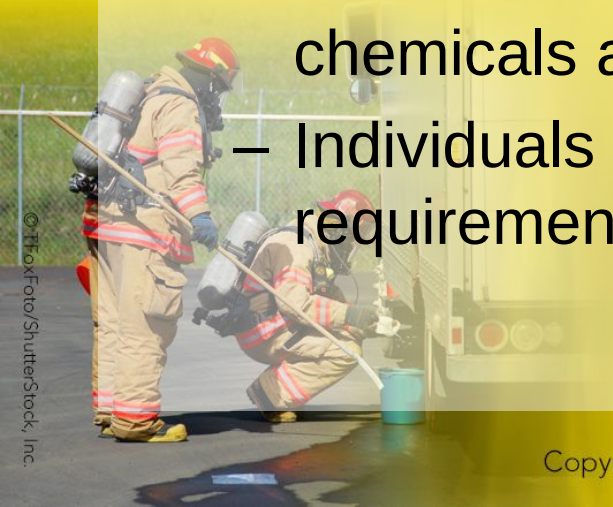
Air Purification Devices (3 of 4)

- Operational considerations when using APRs and PAPRs include the following:
  - Qualified personnel have first monitored the environment.
  - Cannot be used in IDLH environments or in oxygen-deficient atmospheres
  - Should not be used in the presence or potential presence of unidentified contaminants
  - Respiratory protection can be downgraded.



Air Purification Devices (4 of 4)

- Operational considerations when using APRs and PAPRs include the following:
  - May present logistical problems for storage and maintenance
  - Have a limited-protection duration
  - APRs and PAPRs only protect against specific chemicals and only to specific concentrations.
  - Individuals must meet the fit testing and medical requirements.

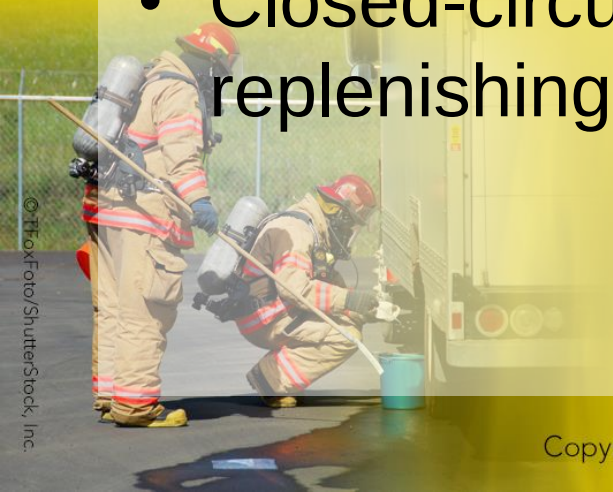


Atmosphere Supplying Devices

- There are two basic types:
  - Self-contained breathing apparatus (SCBA)
  - Supplied air respirator (SAR), which supplies air from a source away from the scene connected to the user by an airline hose
- Provide the highest available level of protection

Self-Contained Breathing Apparatus (1 of 3)

- There are two basic types of SCBA:
  - Open-circuit
  - Closed-circuit
- Open circuit SCBAs use a compressed air cylinder to supply fresh air.
- Closed-circuit SCBAs recycle exhaled air while replenishing the consumed oxygen.



Self-Contained Breathing Apparatus (2 of 3)

- CBRN-compliant SCBAs must meet the performance requirements of NFPA 1981 and NIOSH CBRN requirements.
- Advantages of using SCBA:
  - Readily available
  - Most responders are proficient in their use.
  - Provide the highest level of respiratory protection

Self-Contained Breathing Apparatus (3 of 3)

- Operational considerations when using SCBA:
  - Atmosphere-supplying units are required for initial response operations.
  - Duration of the operation is 30, 45, or 60 minutes.
  - Depending on the type of cylinder, certain chemicals may attack the outer shell of an air cylinder.

Supplied Air Respirators (1 of 3)

- SARs may be used when extended working times are required.

Supplied Air Respirators (2 of 3)

- Components of a SAR include:
  - Source of breathing air
  - Airline hose
  - Positive-pressure respirator
  - Emergency air supply, such as a small escape cylinder

Supplied Air Respirators (3 of 3)

- Operational considerations when using SARs include the following:
  - Atmosphere-supplying units are required for initial response operations.
  - NIOSH limits hose length to 300 feet.
  - IDLH or oxygen-deficient atmosphere requires a emergency air supply.
  - Airline hose may impair user mobility.
  - Airline hose is vulnerable to damage, chemical contamination, and degradation.

Levels of Protection

- There is no one type of PPE that satisfies our protection needs under all conditions.
- Three basic types of protective clothing:
  - Structural firefighting clothing
  - Chemical protective clothing
  - High-temperature protective clothing

Structural Firefighting Clothing (1 of 4)

- Normally not the first PPE choice for most hazmat response scenarios
- SFC includes:
  - Helmet
  - SCBA/PASS
  - Turnout coat and pants
  - Gloves and boots
  - Hood made of a fire-resistant material

Structural Firefighting Clothing (2 of 4)

- The ensemble should meet NFPA 1971 requirements.

Structural Firefighting Clothing (3 of 4)

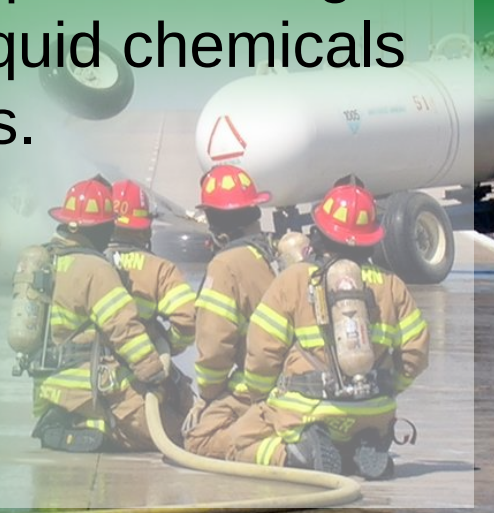
- SFC may be used when the following conditions are met:
  - Contact with splashes of extremely hazardous materials is unlikely.
  - Total atmospheric concentrations do not contain high levels of chemicals toxic to the skin.
- Exposed garments must have chemical contamination removed or lowered to a safe level.

Structural Firefighting Clothing (4 of 4)

- Body protection components
  - Manufacturers of Goretex™ recommend that their fabric not be worn in any type of chemical atmosphere.
  - SFC is not designed to offer chemical protection!
- Respiratory protection
  - SCBA is the minimum level of respiratory protection.

Liquid Chemical Splash Protective Clothing (1 of 3)

- May be used under the following conditions:
  - Vapors or gases present are not suspected of containing high concentrations of chemicals that are harmful to or can be absorbed by the skin.
  - Highly unlikely that the user will be exposed to high concentrations of vapors, gases, or liquid chemicals that will affect any exposed skin areas.



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Liquid Chemical Splash Protective Clothing (2 of 3)

- May be used under the following conditions:
  - Operations will not be conducted in a flammable atmosphere.
- Wearing a flame-resistant garment underneath flammable chemical protective outer garments does not provide protection against heat and flame exposure.

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Liquid Chemical Splash Protective Clothing (3 of 3)

LIMITED-USE ENCAPSULATING SUIT

DuPont

LIMITED-USE SINGLE-PIECE COVERALLS

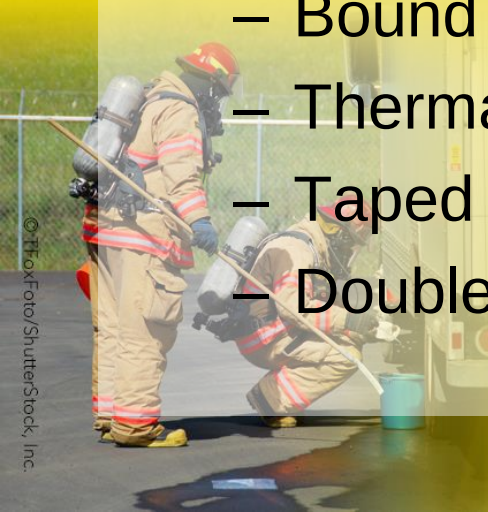
DuPont

MULTI-USE TWO-PIECE SPLASH SUIT

MULTI-USE SINGLE-PIECE SPLASH SUIT WITH HOOD

Skin and Body Protection (1 of 5)

- Several common types include the following:
  - Single-piece suits
  - Two-piece suits
- CPC seams may be:
  - Sewn
  - Bound
  - Thermally welded
  - Taped
  - Double taped

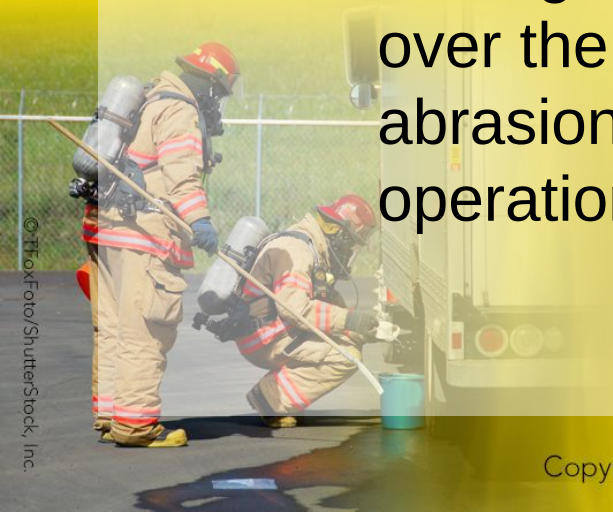


Skin and Body Protection (2 of 5)

- Head protection
  - Hard hat, helmet, or hood
  - Hard hat protection is recommended when using a hood or encapsulating suit.
  - Some manufacturers offer a respirator-fit hood.

Skin and Body Protection (3 of 5)

- Gloves
  - For maximum protection, over-gloving and double-gloving should be used.
    - Double-gloving involves the use of surgical gloves under a work glove.
    - Over-gloving is the wearing of a second glove over the work glove for additional chemical and abrasion protection during lifting and moving operations.

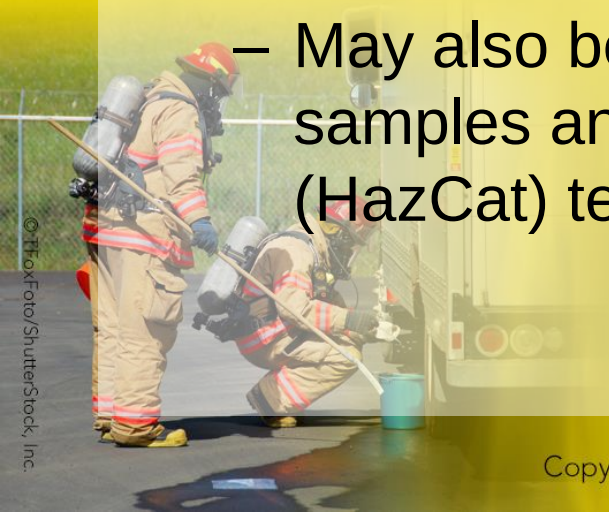


Skin and Body Protection (4 of 5)

- Footwear and shoe covers
  - May be chemical boots, separate shoe covers, or booties
  - Boots should provide both chemical and mechanical protection.
  - Some chemical protective suits have attached boots specifically designed for hazmat response operations.

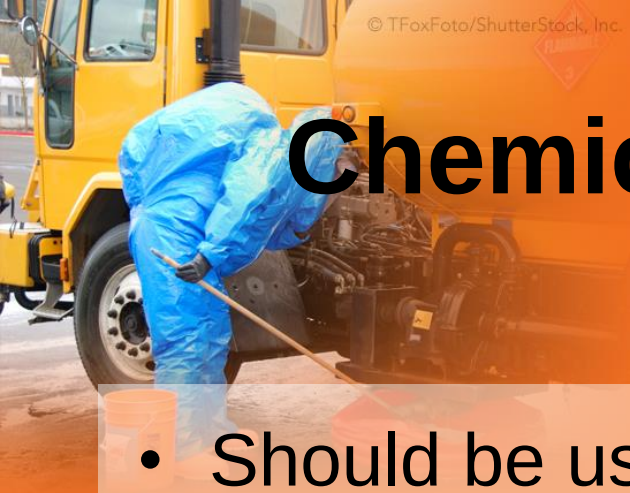
Skin and Body Protection (5 of 5)

- Aprons and body coverings
  - Designed for protection against spills and splashes that occur when physically handling chemicals and other hazardous materials
  - Primarily used for routine chemical handling operations
  - May also be worn by responders while handling samples and performing hazardous categorization (HazCat) tests



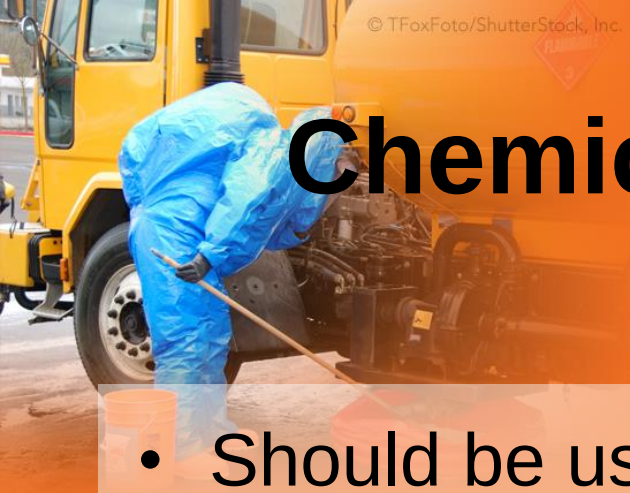
Chemical Vapor Protective Clothing (1 of 5)

- Chemical vapor protective clothing (i.e., EPA Level A clothing) provides full-body protection with vapor-tight integrity.
- Provides a gas-tight envelope around the wearer



Chemical Vapor Protective Clothing (2 of 5)

- Should be used when the following conditions exist:
  - Extremely hazardous substances are known or suspected to be present, and skin contact is possible.
  - There is potential contact with substances that harm or destroy skin.



Chemical Vapor Protective Clothing (3 of 5)

- Should be used when anticipated operations involve:
  - A potential for splash or exposure to vapors, gases, or particulates capable of being absorbed through the skin
  - Unknown or unidentified substances and the scenario dictates that vapor-tight skin protection is required

Chemical Vapor Protective Clothing (4 of 5)

- Skin and body protection
  - Manufactured in several configurations
  - Most common is where the SCBA is worn underneath the ensemble
  - Easily identified by its “humpback”
  - Expanded-back design incorporates an airline hose bulkhead connection onto the suit if a supplied air respirator will be used

Chemical Vapor Protective Clothing (5 of 5)

- Skin and body protection
  - Face piece serves as the primary barrier for respiratory protection against chemical permeation.
  - All components of the ensemble must provide an equivalent level of protection.
  - Visibility through faceshield will be critical.
  - A chemical vapor suit is only as strong as its weakest link.

Vapor Suit Attachments and Accessories (1 of 8)

- Gloves
  - Permanently attached or detachable
  - Permanently attached gloves offer integral, vapor-tight wrist protection
  - Detachable permits the user to select the glove material.
  - When detachable gloves are changed, the suit should undergo a pressure test.
  - Gloves must match the chemical resistance of the primary suit material.

Vapor Suit Attachments and Accessories (2 of 8)

- Boots
  - Can be either an integral part of the suit or a separate item
  - Most chemical vapor suits incorporate an integral sock boot or “bootie” design constructed of the same material as the suit.
  - Boots used for emergency response purposes should have both steel toe and shank protection.

Vapor Suit Attachments and Accessories (3 of 8)

- Suit fit and closure assemblies
  - Mobility is sacrificed whenever a chemical vapor suit is worn.
  - All chemical vapor suits are sealed by a closure assembly.
  - Emergencies may arise when the suit integrity is compromised or when the SCBA malfunctions.
  - Beware of the initial impulse to immediately get out of the suit.

Vapor Suit Attachments and Accessories (4 of 8)

- Overgarments
  - Overgarments may provide additional physical protection and thermal protection.
  - Can also have a negative impact upon:
    - Visibility (i.e., user may have to look through two or three faceshields or visors)
    - Mobility
    - Manual dexterity
  - Flash overgarments are not entry or proximity clothing.

Vapor Suit Attachments and Accessories (5 of 8)

- Undergarments
  - Personal clothing worn by hazmat responders can influence heat stress potential, as well as the ability of the user to effectively operate within a hostile environment.
  - Fire retardant coveralls worn underneath CPC that melts or burns offers little-to-no added protection.

Vapor Suit Attachments and Accessories (6 of 8)

- Cooling and ventilation
  - Both liquid chemical splash and vapor protective clothing retain body heat and moisture.
  - Heat stress becomes a concern even in moderate ambient temperatures.
  - Individuals should be in good health and physical condition.

Vapor Suit Attachments and Accessories (7 of 8)

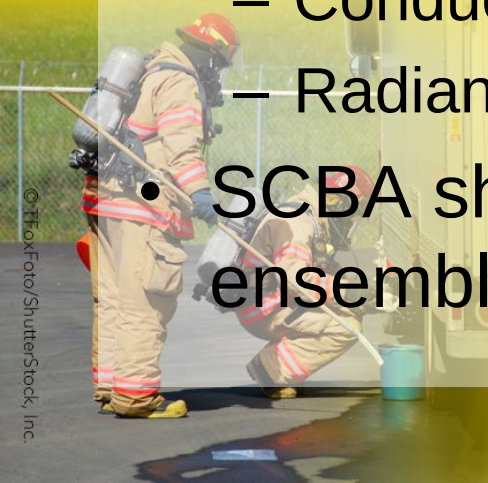
- Communications
  - Verbal, person-to-person communications are virtually impossible.
  - Radio communications are a necessity.
  - Other alternatives include:
    - Voice amplifiers
    - Hand signals
    - Large flash cards

Vapor Suit Attachments and Accessories (8 of 8)

- Communications
  - Communications systems include:
    - Radio headsets
    - Ear, mouth, and bone microphones
    - Voice amplifiers
  - Identification methods can include:
    - Different colored suits
    - Large numbers attached to the suit
    - Color-coded (or numbered) traffic vests
    - Reflective tape
    - Cyalume® lightsticks

High-Temperature Protective Clothing

- Hazmat responders may be required to operate in high-temperature environments.
- Aluminized fabric PPE may be necessary.
- Three forms thermal energy:
  - Ambient heat
  - Conductive heat
  - Radiant heat
- SCBA should always be considered part of the ensemble.



Types of High-Temperature Clothing (1 of 2)

- Two types of high-temperature protective clothing exist.
  - Proximity suits are designed for exposures of short duration and close proximity to flame and radiant heat.
  - Fire entry suits offer complete, effective protection for short-duration entry into a total flame environment.

Types of High-Temperature Clothing (2 of 2)

Courtesy of USAF

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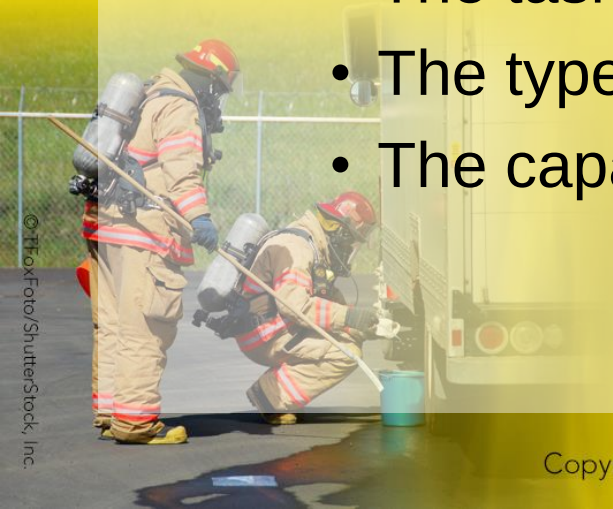
The two most common examples of high temperature protective clothing are proximity suits and fire entry suits.

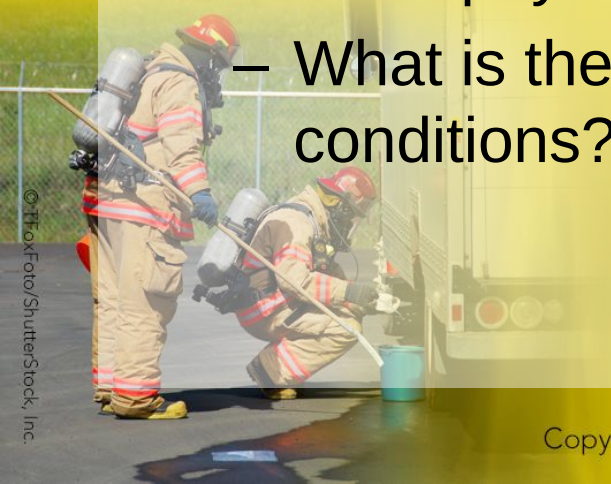
Tying the System Together

- Operational considerations
  - A systems perspective is used to select and use specialized PPE at a hazmat/WMD emergency.
  - Four key factors are evaluated:
    - The hostile environment
    - The tasks to be performed
    - The type of protective clothing required
    - The capabilities of the user/wearer



Hostile Environment

- Questions that must be considered:
  - What material(s) is/are involved?
  - What is the physical state of the substance?
  - What are the hazards of the substance?
  - What is the result of contact to the skin?
  - What physical hazards are present?
  - What is the ambient temperature and weather conditions?



Tasks to be Performed

- Given the tactical response objectives being implemented, what is the potential for exposure to the substances involved, including the level and duration of exposure?

Type of Protective Clothing Required

- Strategic goals and tactical response objectives will determine the level of protective clothing required.
- The decision must take into account the level of risk associated with the overall response.

Capabilities of the User/Wearer

(1 of 6)

- All responders have personal strengths and weaknesses.
- Unrealistic expectations of what CPC can and cannot do will significantly increase the level of risk.

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Capabilities of the User/Wearer
(2 of 6)

- All responders will be affected by two types of stressors:
  - Physical stressors
  - Psychological stressors

Capabilities of the User/Wearer

(3 of 6)

- Operational issues and safety procedures:
  - The selection, maintenance, and use of protective clothing must be an integral part of an overall PPE and safety program.
  - Chemical protection and thermal protection are mutually exclusive.
  - Decon should be established prior to entry operations into the hot zone.

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Capabilities of the User/Wearer

(4 of 6)

- Operational issues and safety procedures:
  - Always minimize direct contact with any chemicals.
  - Depending upon the ambient temperature and humidity, fogging may occur inside the face piece of a chemical vapor suit.
  - Ensure entry and backup crews have equivalent levels of protection.

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Capabilities of the User/Wearer

(5 of 6)

- Operational issues and safety procedures:
  - "Two-In/Two-out" may work in an open-air environment, but it won't your operating inside a structure.
  - Entry personnel must maintain their situational awareness at all times.
  - Communications is a critical element in entry operations.

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Capabilities of the User/Wearer
(6 of 6)

- Operational issues and safety procedures:
  - Conduct pre-entry briefing prior to entry.
  - Any plan to allow the same entry personnel to reenter requires approval.
  - Support personnel are always needed to assist entry and backup crews in donning and doffing protective clothing.

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Emergency Procedures (1 of 2)

- Organizations should develop procedures to address in-suite emergencies.
  - Loss of air supply
  - Loss of suit integrity
  - Loss of communications
  - Buddy down in the hot zone
  - Suit overpressurization
  - Reduced egress scenarios

Emergency Procedures (2 of 2)

Emergency procedures while wearing chemical vapor protective clothing

Donning, Doffing, and Support Considerations

- Time-consuming process
- Based on manufacturer's instructions
- Donning and doffing area should be adjacent to each other.
- A pre-entry safety briefing should be conducted prior to donning operations.

Donning and Doffing Chemical Protective Clothing

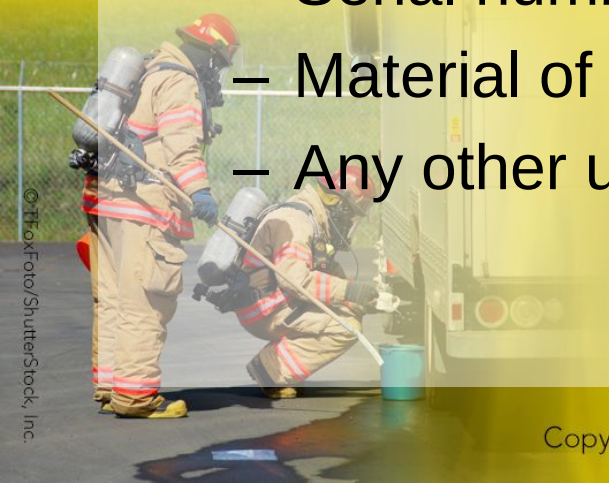
- Responders should review all donning and doffing procedures.
  - Level A
  - Level B
  - Level C
  - Level D

Training Considerations

- System must include organized and documented training.
- Both classroom and hands-on training is essential.
- System should require regular responder qualification on all suit types.
- Training suites should be used to minimize damage to front-line equipment.

Inspection and Maintenance Procedures (1 of 3)

- Preventive maintenance and documentation are integral elements of a PPE program.
- Documentation should indicate:
  - Date of purchase
  - Manufacturer and vendor
  - Serial number
  - Material of construction
  - Any other unique or specific information



Inspection and Maintenance Procedures (2 of 3)

- A logbook should be established.
- Inspection benchmarks
  - Upon receipt from the manufacturer or vendor
  - Periodic inspections after each use
  - Whenever questions arise regarding selected protective equipment or when problems with similar equipment arise

Inspection and Maintenance Procedures (3 of 3)

- Both chemical vapor and splash protective clothing should also undergo visual inspections for any signs of the following:
  - Degradation
  - Stress cracks
  - Other damage
- All protective clothing must be stored properly to prevent damage.

Summary (1 of 4)

- Personal protective clothing and equipment are critical to the success of an organization's hazardous materials response program.

Summary (2 of 4)

- An effective and comprehensive personal protective clothing program should address six fundamental elements:
  - Hazard identification
  - PPE selection and use
  - Medical monitoring
  - Training
  - Inspection
  - Maintenance

Summary (3 of 4)

- Chemicals may attack and pass through protective clothing materials via three methods:
  - Degradation
  - Penetration
  - Permeation
- CPC materials are classified as either limited-use (disposable) garments or reusable garments.

Summary (4 of 4)

- Remember that the longer the breakthrough time or the lower the cumulative permeation value, the better the level of protection.