CHAPTER 8

PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT

INTRODUCTION

Personal protective clothing (PPC) and equipment (PPE) are selected only after all managerial (sometimes called "administrative") efforts and potential engineering controls have been scrutinized toward the objective of minimizing risk. Managerial efforts include alternative procedures and protocols used in incident response as well as those used to conduct normal off-site activities, such as cleaning and maintenance. Engineering controls include alternative uses of barriers, space and area-ventilation (e.g., vehicular ventilation systems for ambulances; spatial isolation of hazards (e.g., biohazard disposal area, on-site decontamination area, hazardous runoff collection system) to confine hazardous materials and/or conditions within areas under management control. PPC and PPE must be viewed as the last available means of controlling responder risk and, therefore, the most sensitive to the consequence of failure. In short, any failure of PPC and/or PPE exposes the responder to immediate life-threatening risk.

While protective clothing and equipment are specifically intended to protect the responder against risks otherwise uncontrolled by managerial procedures and engineering controls, PPC and PPE also present additional risks of their own, including impaired vision, mobility, and communication, as well as physical and psychological stress of the user. The objective must therefore be to achieve an effective and assured balance between the risks attendant to the incident and the risks inherent in the use of PPC and PPE, while avoiding both over- and under-protection.

SELECTION OF PPC AND PPE

A wide range of factors must be considered in the selection of PPC and PPE, ranging from general criteria of durability and comfort to highly specific criteria for assessing the capacity of materials to withstand chemical and physical agents and conditions. Examples of basic categories of factors to be considered include:

- Design features (e.g., sizes and other options, easing of donning, accommodation to use of diverse garment add-ons as well as ancillary equipment, restriction of mobility, visibility in dark, color, weight, comfort for wearer, ease of cleaning and decontamination, ease of field evaluation of functional integrity)
- Chemical resistance (e.g., permeation of chemical through material; discoloration, loss of physical strength, and other degradation due to chemical interaction; penetration of liquids, gases, vapors and mists through zippers, seams, closures, seals or material imperfections)
- Physical quality (e.g., resistance to wear, tear, puncture, and abrasion; pliability and flexibility under variable environmental conditions; susceptibility to shrinkage; integrity under extremes of temperature; flame resistance; breathability; resistance to decontamination procedures and solutions; resistance to physical shock and vibration; resistance to static electrical charge and electric current)
- Vendor-related factors (e.g., ready availability of replacement parts, cost, special servicing requirements, available customization)
- Other factors (e.g., proven effectiveness, use by other similar emergency services, user complaints, professional certification of meeting appropriate engineering standards, documented failures, state-of-the-art technology, maintenance requirements, service life)

No selection of PPC or PPE should be made without full documentation of (a) design and engineering specifications provided by manufacturers, (b) relevant standards, specifications and guidelines, including those promulgated by governmental agencies (e.g., OSHA; NIOSH; EPA; U.S. Fire Administration) and professional organizations (e.g., National Fire Prevention Association [NFPA], American Conference of Governmental Industrial Hygienists [ACGIH], American Society for Testing and Materials [ASTM], and (c) available methods and procedures for conducting visual inspections and field assessments (Table 8.1) of critical parameters of PPC and PPE performance. Much of this information is today readily available via the internet, especially through internet links and networks accessible through governmental agencies, including:

TABLE 8.1 Recommended Chemicals for Field Evaluation of the Performance of Protective Clothing (Adapted from U.S. Department of Labor, OSHA. OSHA Technical Manual. OSHA Electronic Reference Library)

Note	— Chemical —	— Class —
U.S. EPA has developed a portable test kit that allows field qualification of protective clothing materials within one hour using these chemicals.	Acetone	Ketone
	Acetonitrile	Nitrile
	Ammonia	Strong base gas
	1,3-Butadiene	Olefin gas
	Carbon disulfide	Sulfur-containing organic
	Chlorine	Inorganic gas
	Dichloromethane	Chlorinated hydrocarbon
	Dietheylamine	Amine
	Dimethyl formamide	Amide
	Ethyl acetate	Ester
	Ethylene oxide	Oxygen heterocyclic gas
	Hexane	Aliphatic hydrocarbon
Use of this kit may overcome the absence of specific data and provide additional criteria for selection of appropriate clothing.	Hydrogen chloride	Acid gas
	Methanol	Alcohol
	Methyl chloride	Chlorinated hydrocarbon gas
	Nitrobenzene	Nitrogen-containing organic
	Sodium hydroxide	Inorganic base
	Sulfuric acid	Inorganic acid
	Tetrachloroethylene	Chlorinated hydrocarbon
	Tetrahydrofuran	Oxygen heterocyclic
	Toluene	Aromatic hydrocarbon

- CDC (Centers for Disease Control)
  http://www.cdc.gov/cdc.html
- EPA (Environmental Protection Agency)
  http://www.epa.gov/ncepihom/index.html
- U.S.FA (U.S. Fire Administration)
  http://ww.usfa.fema.gov/pubs
- FEMA (Federal Emergency Management Administration)
  http://www.nrt.org/nrt/home.nsf
- NCID (National Center for Infectious Diseases)
  http://www.cdc.gov/ncidod/ncid.htm
- NIOSH (National Institute of Occupational Safety and Health)
  http://ftp.cdc.gov/niosh/homepage.html
- NRT (National Response Team)
  http://www.nrt.org/nrt/home.nsf
- OSHA (Occupational Safety and Health Administration)
  http://www.osha.gov/

PROTECTIVE CLOTHING AND ENSEMBLES

Protective clothing for emergency responders is inclusive of individual items (e.g., bib overalls, helmet, bunker coat) as well as ensembles, which are collections of items that are integrated to meet the needs of a specific condition (e.g., approach suit, fragmentation suit) or constellation of risks (e.g., hazardous chemicals). Each item or ensemble should be considered to offer certain types of protection as well as to impose specific limitations.

Some ensembles are recommended on the basis of *generic types of protection required,* such as splashes of hazardous chemicals, chemical vapors, and hazardous dusts (Table 8.2). Other ensembles are recommended on the basis of *level of protection required under certain emergency conditions,* such as degree of protection required for skin, eyes, and respiratory system when working with hazardous chemicals (Table 8.3). Still other ensembles are defined essentially by the *type of emergency-related mission* undertaken, such as search and rescue missions under a wide range of environmental factors.

For example, urban search and rescue missions are classified as involving three distinct sets of conditions: (a) technical rescue, (b) swift water rescue, and (c) contaminated water diving. Technical rescues are typically land-based rescues where the principal hazards are physical, such as encountered in the collapse of structures; the protective turnout clothing usually worn for firefighting is too bulky or heavy for responders who must extricate victims from collapsed debris. Protective clothing and ensembles used in such circumstances (Table 8.4) must be flame resistant, but also lighter and permissive of greater physical flexibility than that accorded by typical fire fighting gear. Principal criteria used for selecting PPC and PPE for technical rescue include:

- Protection from physical hazards (abrasion, tears, cuts, and punctures)
- High degree of visibility (including light and dark conditions)
- Thermal and physical comfort, fit, and mobility
- Protection from airborne particulates
- Limited flame and heat protection
- Limited chemical flash fire protection
- Limited electrical exposure protection
- Minimal chemical protection
- Minimal protection from biological fluids

Swift water rescue primarily involves the risk of drowning not only through the press of water but also through entanglement, as well as hypothermia. Appropriate criteria for selecting PPC and PPE for swift water rescue (Table 8.5) include:

TABLE 8.2 Types of Protective Clothing for Full-Body Protection(Adapted from U.S. Department of Labor, OSHA. OSHA Technical Manual. OSHA Electronic Reference Library)

Description	Type of Protection	User Considerations
Fully Encapsulating Suit		
One-piece garment; boots and gloves may be integral, attached and replaceable, or separate	Protects against splashes, dust, gases and vapors	Does not allow body heat to escape; may contribute to heat stress in wearer, particularly if worn in conjunction with a closed-circuit SCBA; a cooling garment may be needed; impairs worker mobility, vision, and communication
Nonencapsulating Suit		
Jacket, hood, pants or bib overalls, and one-piece coveralls	Protects against splashes, dust, and other materials, but not against gases and vapors; does not protect parts of head or neck	Do not use where gas-tight or pervasive splashing protection is required; may contribute to heat stress in wearer; tape-seal connections between pant cuffs and boots and between gloves and sleeves
Aprons, Leggings, and Sleeve Protectors		
Fully sleeved and gloved apron; separate coverings for arms and legs; commonly worn over nonencapsulating suit	Provides additional splash protection of chest, forearms, and legs	Whenever possible, should be used over a nonencapsulating suit to minimize potential heat stress; useful for sampling, labeling, and analysis operations; should be used only when there is a low probability of total body contact with contaminants
Firefighters' Protective Clothing		
Gloves, helmet, running or bunker coat, running or bunker pants	Protects against heat, hot water, and some particles; does not protect against gases and vapors, or chemical permeation or degradation. NFPA Standard No. 1971 specifies that a garment consists of an outer shell, an inner liner and a vapor barrier with a minimum water penetration of 25 lbs/in^2 to prevent passage of hot water	Decontamination is difficult; should not be worn in areas where protection against gases, vapors, chemical splashes or permeation is required

continues

- Flotation (buoyancy)
- Insulation from cold water exposure
- Protection from physical hazard (abrasion, tears, cuts, and punctures)
- High degree of visibility (in light and dark)
- Physical and thermal comfort, fit, and mobility
- Limited chemical protection
- Limited protection from biological fluids

TABLE 8.2—*continued*

Description	Type of Protection	User Considerations
Proximity Garment (Approach Suit)		
One- or two-piece overgarment with boot covers, gloves and hood of aluminized nylon or cotton fabric; normally worn over other protective clothing, firefighters' bunker gear, or flame-retardent coveralls	Protects against splashes, dust, gases, and vapors	Does not allow body heat to escape; may contribute to heat stress in wearer, particularly if worn in conjunction with a closed-circuit SCBA; a cooling garmet may be needed; impairs worker mobility, vision, and communication
Blast and Fragmentation Suit		
Blast and fragmentation vests and clothing, bomb blankets, and bomb carriers	Provides some protection against very small detonations; bomb blankets and baskets can help redirect a blast	Does not provide for hearing protection
Radiation-Contamination Protective Suit		
Various types of protective clothing designed to prevent contamination of the body by radioactive particles	Protects against alpha and beta particles; does not protect against gamma radiation	Designed to prevent skin contamination; if radiation is detected on site, consult an experienced radiation expert and evacuate personnel until the radiation hazard has been evaluated
Flame/Fire Retardant Coveralls		
Normally worn as an undergarment	Provides protection from flash fires	Adds bulk and may exacerbate heat stress problems and impair mobility

While diving in contaminated water involves some of the same hazards as those encountered in swift water rescue, primary attention must be given to protecting personnel from exposure to biological and chemical contaminants. Criteria used for selecting PPC and PPE for contaminated water rescue (Table 8.6) include:

- Integrity of breathing air supply
- Integrity of overall system to water penetration
- Insulation from cold water exposure
- Protection from physical hazards (abrasion, tears, cuts, and punctures)
- Physical and thermal comfort, fit, and mobility
- Protection from chemicals and biological fluids

Having made a preliminary selection of PPC and PPE on the basis of expected hazards, level of protection required, and/or type of response mission, it becomes absolutely vital to ensure that vendor specifications conform to appropriate technical standards(Table 8.7), including governmentally enforceable standards and professionally recommended standards. These

TABLE 8.3 Types of Protective Ensembles (Adapted from NIOSH, USCG, and EPA, 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities)

Level of Protection and Equipment	Overview of Protection	Conditions for Use and Limitations
A **Recommended:** • Pressure-demand, full-facepiece SCBA or pressure-demand supplied air respirator with escape SCBA • Fully encapsulating, chemical resistant suit • Inner chemical-resistant gloves • Chemical resistant safety boots/shoes • Two-way radio **Optional:** • Cooling unit • Coveralls • Long cotton underwear • Hard hat • Disposable gloves and boot covers	The highest available level of respiratory, skin, and eye protection	• The chemical substance has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on either: 1. Measured (or potential for) high concentration of atmospheric vapors, gases, or particulates, or 2. Site operations and work functions involving a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the intact skin. • Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible. • Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection is determined. • Fully encapsulating suit materials must be compatible with the substances involved.
B **Recommended:** • Pressure-demand, full facepiece SCBA or pressure-demand supplied air respirator with escape SCBA • Chemical-resistant clothing • Inner and outer chemical-resistant gloves • Chemical resistant safety boots/shoes • Hard Hat • Two-way Radio **Optional:** • Coveralls • Disposable boot covers • Face shield • Long cotton underwear	The same level of respiratory protection but less skin protection than Level A. This is the minimum level recommended for initial site entries until the hazards have been further identified.	• The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection. This involves atmospheres -- with IDLH concentrations of specific substances that do not represent a severe skin hazard, or -- that do not meet the criteria for use of air-purifying respirators. • Atmosphere contains less than 19.5 % oxygen. • Presence of incompletely identified vapors or gases is indicated by direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through intact skin. • Use only when highly unlikely that the work will generate either high concentrations of vapors, gases, or particulates or splashes of material will affect exposed skin.

continues

TABLE 8.3—*continued*

Level of Protection and Equipment	Overview of Protection	Conditions for Use and Limitations
C **Recommended:** • Full-facepiece, air purifying, canister equipped respirator • Chemical resistant clothing • Inner and outer chemical resistant gloves • Chemical resistant safety boots/shoes • Hard hat • Two-way radio **Optional:** • Coveralls • Disposable boot covers • Face shield • Escape mask • Long cotton underwear	The same level of skin protection as Level B, but a lower level of respiratory protection	• Atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any exposed skin. • The types of air contaminants have been identified, concentrations measured, and a canister is available that can remove the contaminant. • All criteria for the use of air-purifying respirators are met. • Atmospheric concentration of chemicals must not exceed IDLH levels. • The atmosphere must contain at least 19.5 % oxygen.
D **Recommended:** • Coveralls • Safety boots/shoes • Safety glasses or chemical splash goggles • Hard hat **Optional:** • Gloves • Escape mask • Face shield	No respiratory protection; minimal skin protection	• The atmosphere contains no known hazard. • Work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals. • This level should not be worn in the Exclusion Zone. • The atmosphere must contain at least 19.5 % oxygen.

TABLE 8.4 Technical Rescue Ensemble (Adapted from U.S. Fire Administration, 1993: Protective Clothing and Equipment Needs of Emergency Responders for Urban Search and Rescue Missions [FA-136])

Protective Garment
Should cover the wearer's upper and lower torso, legs, and arms; may be one piece coveralls or two piece coat and trousers; two piece garments should have sufficient overlap for mid-torso protection
Materials should resist tearing, snagging, and abrasion due to physical environment
Should be reinforced at elbows and knees; seam and closure strength should be equal to strength of material
Should provide high visibility in the dark
Material should be breathable and comfortable to wear for extended periods of time
Materials should resist ignition when contacted by flame
When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's skin. In hot environments, materials should not shrink
Should maintain measured size when repeatedly cleaned
Materials should resist static charge accumulation
Supplemental liners should be provided which prevent chemical penetration of common fire scene chemicals and biologically contaminated liquids
Protective Hood
Should cover the wearer's head and neck with the exception of those areas of the face which may be covered by a SCBA or air purifying respirator
Material should be breathable and comfortable to wear for extended periods of time
Material should resist ignition when contacted by flame. When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's skin. In hot environments, material should not shrink
Should maintain measured size when repeatedly cleaned
Material should resist static charge accumulation
Protective Gloves
Should cover the wearer's hands to one inch above the wrist and include a wristlet which prevents entry of foreign objects into the glove
Materials should resist tearing, cutting, punctures, or abrasion due to the physical environment
Materials should be breathable and comfortable to wear for extended periods of time
Should offer adequate dexterity and grip to handle tools and machinery
Materials should resist ignition when contacted by flame. When exposed to convective and radiant heat, should prevent transmission of heat that could burn the wearer's skin. In hot environments, materials should not shrink
Materials should insulate wearer from electrical currents
Supplemental gloves should be provided which prevent chemical penetration of common fire scene chemicals and biologically contaminated fluids

continues

TABLE 8.4—*continued*

Protective Boots

Should cover wearer's foot from the bottom of the foot to a point eight inches above the foot bottom

Should not have any exposed metal parts. Should include a ladder shank and non-metallic toe protective cap

Upper materials should resist abrasion, cutting, or puncture due to the physical environment. Soles should resist abrasion and puncture

Materials should resist ignition when contacted by flame. When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's skin. In hot environments, materials should not shrink

Should maintain water-tight integrity following repeated flexing

Should insulate the wearer from electrical currents

Materials should prevent chemical penetration of common fire scene chemicals and biologically contaminated fluids

Protective Helmet

Should cover the top of the wearer's head. Should resist impact on top and sides from falling objects

Straps should keep helmet in place when impacted

When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's skin. In hot environments, materials should not shrink

Goggles

Should prevent impact of foreign objects to the eyes. Should keep particulates from reaching eyes

Materials should resist ignition when contacted by flame. When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's eyes. In hot environments, materials should not shrink

Air Purifying Respirator

Should be NIOSH certified. Should keep fine particulates from entering wearer's respiratory system

Ear Protectors

Should meet ANSI requirements for ear and hearing protection

TABLE 8.5 Swift water Rescue Ensemble (Adapted from U.S. Fire Administration, 1993: Protective Clothing and Equipment Needs of Emergency Responders for Urban Search and Rescue Missions [FA-136])

Personal Floatation Device
Should meet U.S. Coast Guard requirement for Type III or Type V
Should include hardware for attaching lifeline
Should be corrosion resistant and have sufficient strength to withstand swift water forces

Protective Dry Suit
Should cover wearer's upper and lower torso, arms and legs. Should be easily and quickly donned
Should prevent water penetration to parts of body covered (should include wrist, foot, and neck seals)
Materials should provide insulation from cold water exposure for at least one hour
Materials should resist tearing, snagging, and abrasion due to physical environment
Should be reinforced at elbows and knees. Seam and closure strength should be equal to strength of material
Should not shrink after cleaning or contact with warm water
Should provide high visibility in the dark
Materials should be breathable and comfortable to wear for extended periods of time
Materials should prevent penetration of diluted chemicals and biological contaminants
Materials should not retain contaminants following clean water rinsing

Protective Gloves
Should be 5-fingered design and cover wearer's hands to one inch above the wrist
Should be available in at least 3-sizes
Should limit water penetration to hands and provide insulation from cold water exposure for at least one hour
Materials should resist tearing, cutting, and punctures due to physical environment
Materials should be breathable and comfortable to wear for extended periods of time
Should offer adequate dexterity and grip to tie knots and operate a knife
Should not slip off wearer's hand if inner glove is worn
Retention straps should not become loosened by use. Metal parts should not corrode or rust
Materials should prevent penetration of diluted chemical and biological contaminants. Should not retain contaminants following clean water rinsing

continues

TABLE 8.5—*continued*

Personal Booties
Should cover wearer's feet to one inch above the ankle
Should limit water penetration to feet and provide insulation from cold water exposure for at least one hour
Materials should resist tearing, cutting, puncture, and abrasion due to physical environment
Soles should be slip-resistant and provide good traction under wet condition
Should accommodate swimming fins
Retention straps should not become loosened in use. Metal parts should not corrode or rust
Materials should prevent penetration of diluted chemicals and biological contaminants
Should not retain contaminants following clean water rinsing
Swimming Fins
Should allow wearer to walk normally
Helmet
Should cover top of wearer's head. Should resist impact on top and sides from floating or stationary objects
Should be ventilated to allow passage of water. Should not have brim or other surfaces suceptable to swift water forces
Metal parts should not corode or rust
Knife
Should be single edged. Should remain in sheath when inverted and shaken
Whistle
Should be non-metallic. Should not include a pall

standards are highly changeable due to changes in technology as well as actual field experience; it is therefore necessary to ensure the use of up-to-date standards, with full awareness of potential trends in both (a) materials-research and development, and (b) schedules of standard-setting processes (Table 8.8).

Heat Stress

A key consideration regarding all PPC is its contribution to the wearer's *heat stress*. Heat stress may be manifest in several distinct symptomatologies, including:

TABLE 8.6 Contaminated Water Diving Ensemble (Adapted from U.S. Fire Administration, 1993: Protective Clothing and Equipment Needs of Emergency Responders for Urban Search and Rescue Missions [FA-136])

Protective Dry Suit
Should cover wearer's upper and lower torso, arms, legs, and feet. Should be hooded or have attachable hood
Should prevent water penetration to parts of body covered (should include wrist, foot, and neck seals)
Materials should provide insulation from cold water exposure for at least one hour
Materials should be rugged and strong and resist tearing, snagging, and abrasion due to physical environment
Wrist, ankle, or neck seal materials should be adjustable for sizing
Wrist, ankle, or neck seal materials should resist cuts and punctures
Should be reinforced at elbows and knees. Seam and closure strength should be equal to material strength
Should provide high visibility in dark
Materials should prevent penetration of diluted chemicals and biological contaminants. Materials should not retain contaminants following clean water rinsing

Protective Gloves
Should mate directly to the dry suit
Materials should prevent penetration of diluted chemicals and biological contaminants
Materials should provide insulation from cold water exposure for at least one hour
Materials should resist cuts, punctures, and abrasion due to physical environment
Should offer adequate dexterity and grip to tie knots and operate a knife
Should not retain contaminants following clean water rinsing

Protective Booties
Should be a part of the drysuit (directly attached)
Materials should prevent penetration of diluted chemicals and biological contaminants
Materials should provide insulation from cold water exposure for at least one hour
Materials should resist tearing, cutting, punctures, and abrasion due to physical environment
Sole materials should resist puncture and wear due to abrasion. Soles should be slip resistant
Should not retain contaminants following clean water rinsing

Swimming Fins
Should be resistant to diluted chemicals

continues

TABLE 8.6—*continued*

Helmet
Should cover entire head and neck. Should mate directly to the dry suit with safety mechanism to avoid accidental removal
Should be neutrally buoyant in water
Should include non-return valve in breathing system. Should include emergency valve for connecting bail-out system
Should have double exhaust (for demand diving helmets)
Should have defogging mechanism. Should have shatter resistant face piece
Should have equalizing device (to equalize air pressure in ears)
Should include integrated communication system
Should not retain contaminants following clean water rinsing
Full Face Mask
Should enclose eyes, nose, and mouth. Should include integral second stage regulator
In surface-supplied mode, should be used with bail-out block
Should have equalizing device, automatic defogging mechanism, and earphone pockets
Should have low volume, large buckles and wide straps, and modular communications components
Should not retain contaminants following clean water rinsing
Dry Suit Underwear
Should provide insulating performance even when wet. Must not produce lint
Communication System
May be hard-wire or wireless system. Should be constructed of rugged materials
Should have mechanism to attach electronics housing to tank harness or buoyancy compensator
Exposed parts should be able to be decontaminated
Should include back-up systems (line pull signals)
Compressed Air Supply
Should be a low pressure (175 – 250 psi) compressor or series of high-pressure bottles
Should include emergency air supply for diver (bail-out system)

continues

TABLE 8.6—*continued*

Air Manifold Box

Should monitor air-pressure to diver. Should regulate high-pressure air to proper pressure for diver

Should provide connection for top-side emergency air supply

Pneumofathometer

Should usually be contained in the air manifold box. Should be accurate to 0.25% of the gauge's full scale

Umbilical

Should be at least 250 ft long. Air supply hose should have minimal length change when pressurized

Air supply hose should be at least 3/8 in. diameter

Air supply hose should have rated pressure at least 50% higher than maximum pressure required by regulator or maximum diving depth

Should resist kinking. Should include air-tight fittings and strong diving tether

Should have individual umbilical components (hose, communications wire) connected with plastic cable ties

Should include stainless steel ring to attach air supply hose to diver's harness

Weight Belt/Harness

Materials should be compatible with diluted chemicals. Materials should not retain contaminants following clean water rinsing

Should be plastic or rubber for easier decontamination. Should include minimum amount of weight possible

Should be able to be quickly ditched in emergency. Should not include ankle weights

Diving Tether

Should be attached to harness. Should include synthetic line compatible with diluted chemicals and strong enough to bear weight of diver

Should not retain contaminants following clean water rinsing

SCUBA System

Materials should be compatible with diluted chemicals. Should include bail-out block mounted on diver's harness

Should include bail-out air bottle with first stage regulations. Should not retain contaminants following clean water rinsing

Bail-Out System

Should include 5-minute air supply. Should include bail-out bottle, diver's harness, first-stage regulator, relief valve, submersible pressure gauge, quick disconnect whip/low pressure whip

Knife and Wire Cutter

Should be single edged and sheathed. Should not fall out of sheath when inverted

TABLE 8.7 Examples of Standards Related to Clothing Ensembles and Respirators (Based on Information Provided by U.S. Department of Labor, OSHA. OSHA Technical Manual. OSHA Electronic Reference Library)

Vapor-Protective Suit (NFPA Standard 1991)

- Provides "gas tight" integrity
- Intended for response situations where no chemical contact is permissible
- Equivalent to the clothing required for EPA Level A

Liquid Splash-Protective Suit (NFPA Standard 1992)

- Protection against liquid chemicals in the form of splashes, but not against continuous liquid contact or chemical vapors or gases
- Equivalent to the clothing required for EPA Level B
- It is important to note that, by wearing liquid splash-protective clothing, the wearer accepts exposure to chemical vapors or gases because this clothing does not offer gas-tight performance
- The use of duct tape to seal clothing interfaces does not provide the type of encapsulation necessary for protection against vapors or gases

Support Function Protective Garment (NFPA Standard 1993)

- Provide liquid splash protection but offer limited physical protection
- May comprise several separate protective clothing components (i.e., coveralls, hoods, gloves, and boots)
- Intended for use in non-emergency, nonflammable situations where chemical hazards have been completely characterized
- Examples of support functions include proximity to chemical processes, decontamination, hazardous waste clean-up, and training.
- Should not be used in chemical emergency response or in situations where chemical hazards remain uncharacterized

— Cautionary Note Regarding Respirators —

Protective clothing should completely cover both the wearer and his or her breathing apparatus. In general, respiratory protective equipment is not designed to resist chemical contamination. Level A protection (vapor-protective suits) require this configuration. Level B ensembles may be configured either with the SCBA on the outside or inside. However, it is strongly recommended that the wearer's respiratory equipment be worn inside the ensemble to prevent its failure and to reduce decontamination problems. Level C ensemble uses cartridge or canister type respirators that are generally worn outside the clothing.

TABLE 8.8 NFPA Standards Related to Protective Clothing and Equipment

— Standard —	— Title —
NFPA 1971*	Protective Clothing for Structural Fire Fighting (includes hoods)
NFPA 1972	Helmets for Structural Fire Fighting
NFPA 1973	Gloves for Structural Fire Fighting
NFPA 1974	Protective Footwear for Structural Fire Fighting
NFPA 1975	Station/Work Uniforms for Fire Fighting
NFPA 1976	Protective Clothing for Proximity Fire Fighting
NFPA 1977	Protective Clothing and Equipment for Wildlands Fire Fighting
NFPA 1981	Open –Circuit Self-Contained Breathing Apparatus for the Fire Service
NFPA 1982	Personal Alert Safety Systems (PASS) for Fire Fighters
NFPA 1983	Fire Service Life Safety Rope, Harnesses and Hardware
NFPA 1991	Vapor-Protective Suits for Hazardous Chemical Emergencies
NFPA 1992	Liquid Splash-Protective Suits for Hazardous Chemical Emergencies
NFPA 1993	Support Function Protective Clothing for Hazardous Chemical Operations
NFPA 1999	Protective Clothing for Emergency Medical Operations

* NFPA 1971 incorporates NFPA 1972, 1973 & 1974

NFPA reviews and, as necessary in light of new developments in clothing and material technology and testing protocols, revises its standards on a 5-year cycle.

Temperature (°F)	Relative Humidity 10%	20%	30%	40%	50%	60%	70%	80%	90%
104	98	104	110	120	132				
102	97	101	108	117	125				
100	95	99	105	110	120	132			
98	93	97	101	106	110	125			
96	91	95	98	104	108	120	128		
94	89	93	95	100	105	111	122		
92	87	90	92	96	100	106	115	122	
90	85	88	90	92	96	100	106	114	122
88	82	86	87	89	93	95	100	106	115
86	80	84	85	87	90	92	96	100	109
84	78	81	83	85	86	89	91	95	99
82	77	79	80	81	84	86	89	91	95
80	75	77	78	79	81	83	85	86	89
78	72	75	77	78	79	80	81	83	85
76	70	72	75	76	77	77	77	78	79
74	68	70	73	74	75	75	75	76	77

Note: Add 10°F when protective clothing worn;
add 10°F when in direct sunlight

80-90: Fatigue possible if exposure is prolonged and there is physical activity

90-105: Heat cramps and heat exhaustion if exposure is prolonged and there is physical activity

105-130: Heat cramps or exhaustion likely; heat stroke possible if exposure prolonged and there is physical activity

Above 130: Heat Stroke Imminent

FIGURE 8.1 Determination of heat stress based on ambient temperature and relative humidity.

• Heat cramps (caused by profuse sweating with inadequate replacement of electrolytes): muscle spasms and pain in hands, feet, and abdomen

• Heat exhaustion (severe effects of dehydration and stress on body organs due to cardiovascular insufficiency): pale, cool, moist skin; heavy sweating; dizziness; nausea and fainting spells

• Heat stroke (temperature regulation of body fails, with body temperature rising to critical levels, with increasing risk of death; immediate medical attention required): red, hot, dry skin; lack of or reduced perspiration; nausea; dizziness or confusion; strong, rapid pulse; coma

As shown in Fig. 8.1, an increase in relative humidity results in increased risk of heat stress at any ambient temperature. While heat stress can be a significant risk when working in encapsulating suits or other protective clothing, it is always a risk when undertaking any type of work in direct sunlight or under conditions of high temperature and relative humidity.

There are several strategies that can prove useful for lowering the risk of heat stress. The worker who is acclimatized to working under hot conditions has a lower heart rate and body temperature than a worker who is not acclimatized. Acclimatization can most often be accomplished over a 6-day period. During the first day, only 50% of the normal workload and exposure-time is allowed, with 10% more added each day. For a particularly fit individual, acclimatization can be accomplished in 2 or 3 days.

In an encapsulating suite, acclimated persons sweat more profusely than nonacclimated persons and are therefore more subject to the risk of dehydration. It is therefore necessary to provide for a drinking water program to ensure the proper replacement of water lost through sweating.

Additional approaches for reducing heat stress include the use of the lightest and coolest PPC and PPE possible, along with the use of light-colored clothing that absorbs less heat than dark-colored clothing. Artificially produced shade (e.g., tarp canopy, beach umbrella) can significantly contribute to reducing heat exposure. Finally, cooling vests (often called "ice vests") may be worn, though many workers dislike cold so close to the skin.

Cold Stress

In cold environments, a critical factor in the selection of PPC is cold stress, which includes hypothermia and the freezing of flesh. Hypothermia, a potentially catastrophic drop in body temperature with significantly reduced blood flow and rate of metabolism, is of particular concern during cold water diving operations. The freezing of flesh, with potential subsequent development of gangrene, is always a risk attendant to land operations in cold climates, especially when wind velocity acts to increase risk significantly (Fig. 8.2).

Decontamination

Wherever possible and subject to the important constraints of effectiveness and cost, PPC and PPE should be selected to maximize the use of non-reusable clothing and equipment in order to minimize the need for decontaminating reusable clothing and equipment—an activity that presents its own risk to personnel and to environmental resources. However, most PPC and PPE items are, in fact, reusable (as well as costly) and must therefore be selected with careful consideration given to means and methods for re-

Wind Speed (MPH)	Temperature (°F) 45	40	35	30	25	20	15	10	5	0	-5	-10	-15
5	43	37	32	27	22	16	11	6	0	-5	-10	-15	-21
10	34	28	22	16	10	3	-3	-9	-15	-22	-27	-34	-40
15	29	23	16	9	2	-5	-11	-18	-25	-31	-38	-45	-51
20	26	19	12	4	-3	-10	-17	-24	-31	-39	-46	-53	-60
25	23	16	8	1	-7	-15	-22	-29	-36	-44	-51	-59	-66
30	21	13	6	-2	-10	-18	-25	-33	-41	-49	-56	-64	-71
35	20	12	4	-4	-12	-20	-27	-35	-43	-52	-58	-67	-75
40	19	11	3	-5	-13	-21	-29	-37	-45	-53	-60	-69	-76
45	18	10	2	-6	-14	-22	-30	-38	-46	-54	-62	-70	-78

43 *to* **–22:** Little danger for properly clothed person
-24 *to* **–71:** Increasing danger; flesh may freeze
-75 *to* **–78:** Great danger; flesh may freeze in 30 seconds

FIGURE 8.2 Determination of cold stress based on ambient temperature and wind velocity.

moving and/or deactivating incident–related contaminants, including dirt and debris as well as chemical and biological agents (Table 8.9) so as to prevent any loss of integrity or functionality of the PPC and PPE.

Available decontamination methods should be assessed for their compatibility with PPC and PPE materials in a rigorous manner (Fig. 8.3). Appropriate decontamination procedures, cleaning and disinfecting solutions, and associated equipment and materials should then be incorporated into SOPs for both incident-related and normal operations (Fig. 8.4).

Inspection of PPC

In any response organization, written SOPs that give detailed instructions for periodic examination of protective clothing should be readily available and rigidly enforced. Different types and levels of inspections, as well as schedules, are most appropriately developed to cover the life-cycle of the clothing, including (a) receipt of the clothing from the manufacturer, (b) issuance of clothing to personnel, (c) preventive maintenance, prior to and following use (including use during training sessions), (d) receipt of personnel complaints or concerns, governmental or other alerts (e.g., manufacturers other response agencies) regarding field experience with similar clothing, and (e) upon replacement either in-kind or by substitution with other types, styles, or models.

TABLE 8.9 Decontamination Methods (Adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities)

Removal

- **Contaminant Removal**
  - Water rinse, using pressurized or gravity flow
  - Chemical leaching and extraction
  - Evaporation/vaporization
  - Pressurized air jets
  - Scrubbing/scraping (commonly done using brushes, scrapers, or sponges and water-compatible solvent cleaning solutions)
  - Steam jets
- **Removal of Contaminated surfaces**
  - Disposal of deeply permeated materials (e.g., clothing, floor mats, and seats)
  - Disposal of protective coverings, coatings

Inactivation

- **Chemical Detoxification**
  - Halogen stripping
  - Neutralization
  - Oxidation/reduction
  - Thermal degradation
- **Disinfection/Sterilization**
  - Chemical disinfection
  - Dry heat sterilization
  - Gas/vapor sterilization
  - Irradiation
  - Steam sterilization

Regardless of the type and schedule of formal inspections, all personnel must understand that it is their responsibility to perform visual checks of PPC prior to , during, and immediately following use, with particular attention given to the following:

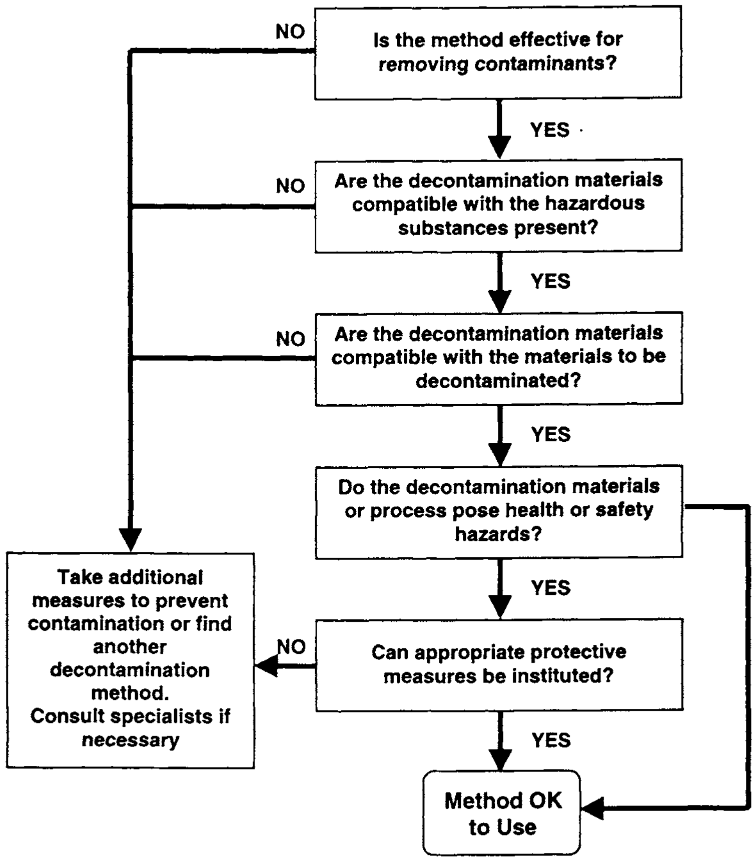

FIGURE 8.3 Assessment of decontamination methods (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

- Check coding device (e.g., color, alpha-numeric, name) to ensure that the clothing is properly identified for use in the intended task
- Visually inspect for imperfect seams, nonuniform coatings, tears, malfunctioning closures, improper seals
- Check for pinholes
- Check inside and out for any indications of chemical degradation, including discoloration, swelling, or stiffness
- Flex material and look for cracks, wear, abrasion, or any other sign of deterioration
- Pressurize gloves and hold under water to check for pinholes

Infection Control
Standard Operating Procedures ***SOP # IC6: Post-Response***

- Upon return to quarters, contaminated equipment will be revived and replaced with clean equipment. Supplies of PPE on response vehicles will be replenished.
- Contaminated equipment will be stored only in the decontamination area. Cleaning and decontamination will be performed as soon as practical.
- Disposable equipment and other biohazard waste generated during on-scene operations will be stored in the biohazard disposal area in appropriate leakproof containers. Sharps containers, when full, will be closed and placed in the biohazard disposal area.
- Gloves will be worn for all contact with contaminated equipment or materials. Other PPE will be used depending on splash or spill potential. Heavy-duty utility gloves will be used for cleaning, disinfection, or decontamination of equipment.
- Eating, drinking, smoking, handling contact lenses, or applying cosmetics or lip balm is prohibited during cleaning or decontamination procedures.
- Disinfection will be performed with a department-approved disinfectant or with a 1:100 solution of bleach in water. All disinfectants will be tuberculocidal and EPA approved and registered.
- Any damaged equipment will be cleaned and disinfected before being sent out for repair.
- The manufacturer's guidelines will be used for the cleaning and decontamination of all equipment. Unless otherwise specified:
    - ➢ Durable equipment (backboards, splints, MAST pants) will be washed with hot soapy water, rinsed with clean water, and disinfected with an approved disinfectant or 1:100 bleach solution. Equipment will be allowed to air dry.
    - ➢ Delicate equipment (radios, cardiac monitors, etc.) will be wiped clean of any debris using hot soapy water, wiped with clean water, then wiped with disinfectant or 1:100 bleach solution. Equipment will be allowed to air dry.
- Work surfaces will be decontaminated with an appropriate disinfectant after completion of procedures, and after spillage or contamination with blood or potentially infectious materials. Seats on response vehicles contaminated with body fluids from soiled PPE also will be disinfected upon return to station.
- Contaminated structural firefighting gear (turnout coats/bunker pants) will be cleaned according to manufacturer's recommendations found on attached labels. Normally, this will consist of a wash with hot soapy water followed by a rinse with clean water. Turnout gear will be air-dried. ***Chlorine bleach may impair the fire-retardant properties of structural firefighting gear and will not be used.***
- Contaminated boots will be brush-scrubbed with a hot solution of soapy water, rinsed with clean water, and allowed to air dry.
- Contaminated work clothes (jump suits, T-shirts, uniform pants) will be removed and exchanged for clean clothes. Personnel will shower if body fluids were in contact with skin under work clothes.
- Contaminated work clothes will be laundered at the station using hot water. ***Under no circumstances will contaminated work clothes be laundered at home.***
- Infectious wastes generated during cleaning and decontamination operations will be properly bagged and placed in the biohazard disposal area.

FIGURE 8.4 Example of SOP included in infection control program (adapted from U.S. Fire Administration, 1992: Guide to Developing and Managing an Emergency Service Infection Control Program [FA-112]).

- For fully encapsulating suits, check operation of pressure relief valves; inspect fitting of wrist, ankle, and neck seals; check faceshield for cracks and other anomalies

RESPIRATORY PROTECTION

Air Contaminants

Air contaminants include a variety of solid and liquid particles that range greatly in size, from relatively large-size liquid chemical mists (>100μm) to progressively smaller particles, like dusts (e.g., foundry dust and fly ash [1–1000μm]), fumes and vapors (e.g., metallurgical fumes and oil smoke [0.001–1.0 μm]; bacteria and fungal spores [0.1–1.0 μm]), and, finally, gases. The size of an inhaled particle is a key determinant of the depth to which that particle can penetrate into the respiratory tract. While the depth of penetration is also influenced by the shape of the particle and whether inhalation is primarily through the nose or the mouth, the majority of larger dusts and mists can become deposited along the nasopharyngeal portion of the respiratory tract (above the larynx and including nasal passages), with progressively smaller particles progressing to the upper esophagus, to the tracheobronchial branch of the respiratory tract, and, finally, even to the alveoli of the lung. Particles deposited in nasal passages and within the throat can also ultimately enter the stomach via passage along the esophagus—demonstrating that inhalation, as a route of entry, can be equivalent to that other route of entry, ingestion.

Given the range of potential deposition of inhaled particles within both the respiratory and gastrointestinal tract, various organs and tissues become exposed to the diverse health hazards associated with those particles, including such relatively mild acute afflictions as nasal irritation (e.g., certain chromium dusts), persistent sneezing (e.g., o-chlorobenzylidene malononitrile), and cough (e.g., chlorine), as well as life-threatening acute and chronic afflictions, such as pneumonia (e.g., manganese dusts in lower airways and alveoli), hemorrhage (e.g., boron vapors in alveoli), emphysema (e.g., aluminum abrasives in alveoli), and cancer (e.g., nickel dusts in nasal cavities and the lungs).

Upon being inhaled, various gases, vapors, and mists (e.g., halogenated hydrocarbons, methyl ethyl ketone, methyl methacrylate) can pass directly from the alveoli (or the gastrointestinal tract) into the blood and, depending upon their differential solubilities in body fluids and tissue (e.g., fat), affect other tissues (e.g., bone), organs (e.g., liver), and systems (e.g., central nervous system). Of course, many air contaminants begin to exert their effect immediately upon entry into the blood by triggering an immunological response. For example, many organic dusts, such as cork, malt, and cheese dust and even those (e.g., pollen) that collect in air conditioners, as well as inorganic dusts (e.g., tungsten carbide, platinum salts, toluene 2,4-diisocyanate, nickel metal), can cause allergenic reactions in hypersensitive persons that can quickly become life threatening. Differential solubilities of air contaminants in body fluids and tissues, as well as their potential as immunological antigens, clearly illustrate that many inhaled contaminants are not simply respiratory hazards, but are in fact hazards to many different organs and tissues.

Action Levels

An *action level* is typically a numerical limit (but it may also be a qualitative situation) that triggers a protective response. In some few cases, action levels may be established by regulation pertaining to specific chemicals, such as benzene or formaldehyde. In most instances, action levels are established by common practice. For example, evacuation from an area containing flammable vapors is most often required whenever ambient concentrations attain 10% of the lower explosive limit (LEL). The rationale for any action limit is that protection must begin well in advance of an actual life- or health-threatening situation.

In the absence of either an action level or even so much as a standard or guideline established by legal authority (which is by far the most common situation), a criterion for deciding whether or not the measured quality of an atmosphere requires the use of respiratory protection must be established. Sometimes, given the dearth of action levels and standards as compared with the seemingly limitless number of health and safety standards, the safety officer opts to require respiratory protection regardless of ambient concentrations. In normal operational situations (i.e., nonemergency), this practice should be strongly discouraged because the use of any protective clothing or devices always produces its own risk. Ideally, the objective should be to balance the risks that derive from the lack of specific protection with the risks that derive from wearing protective equipment. However, during an emergency, it is most often prudent to assume the worst case and prepare accordingly. This is usually done for any or all of several reasons:

- Immediate response action is required even in the absence of specific data and information on ambient air concentrations of chemical or biological contaminants, and/or
- Even in situations where ambient air concentrations of chemical contaminants are known, it is always possible that actual concentrations can vary significantly over the spaces to be penetrated by emergency response personnel, and/or
- In some situations (e.g., fire, explosion, release of biological pathogens, any other situation resulting in chemical by-products of combustion or chemical reactions), there is no practical alternative but to implement the highest level of respiratory protection.

Types of Respirators

Any reputable manufacturer or supplier of respirators today offers potential clients detailed documentation regarding the broad range of available respirators and the specific uses and limits of each type. In no circumstance should the safety officer purchase any respirator without carefully examining this documentation or consulting with manufacturers' or suppliers' technical staffs.

The basic types of respiratory protection devices (Fig. 8.5) may be briefly described as follows:

Air-Purifying Respirators

These respirators use filter and/or sorbent materials to remove contaminants from inhaled air. *They must not be used in atmospheres that may have either a deficiency (<19.5%) or an excess (>22.5%) of oxygen.*

1. Mechanical filter respirator: Removes particles from the air; consists of a simple mesh material that fits over the nose and mouth and is tied with straps of strings behind the neck; some styles include a flexible metal strip that can be easily bent across nose bridge to enforce a more secure seal between face and mask; a comfortable, low-profile, lightweight respirator (often called simply a "paper" or "dust mask") for limited use; low-cost protection against dust, mist, and fumes, but not effective for gases, vapors, or nonabsorbable contaminants; modification of the standard dust mask is the "toxic dust mask," having smaller mesh size; no cleaning, disinfection, or spare parts required; the usual limit for use is set at 10 times the permissible exposure limit (PEL).
2. Chemical cartridge respirator: Either a disposable half-face respirator in which the cartridge is integral to the facepiece or a nondisposable half- or full-face respirator with one or two screw-on chemical cartridges that are specific for particular contaminants; use limited by ambient concentration of contaminants; expended cartridges may be replaced; easy to use; needs little cleaning and few if any spare parts; protection against gas, vapor, dust, and mists; limit is usually set at 10 times the PEL (but may be different) and is indicated on the cartridge.
3. Gas mask: A full-face mask to which is attached a relatively long-lived canister containing sorbent materials that can remove toxic gases and particles; expended canisters may be replaced; offers a greater capacity for removing high ambient concentrations of contaminants than cartridge respirators; limits for ambient concentrations are specified on the canister.
4. Powered air-purifying respirator: A helmeted, hooded, or full-face mask containing one or more cartridges through which air is forced by an

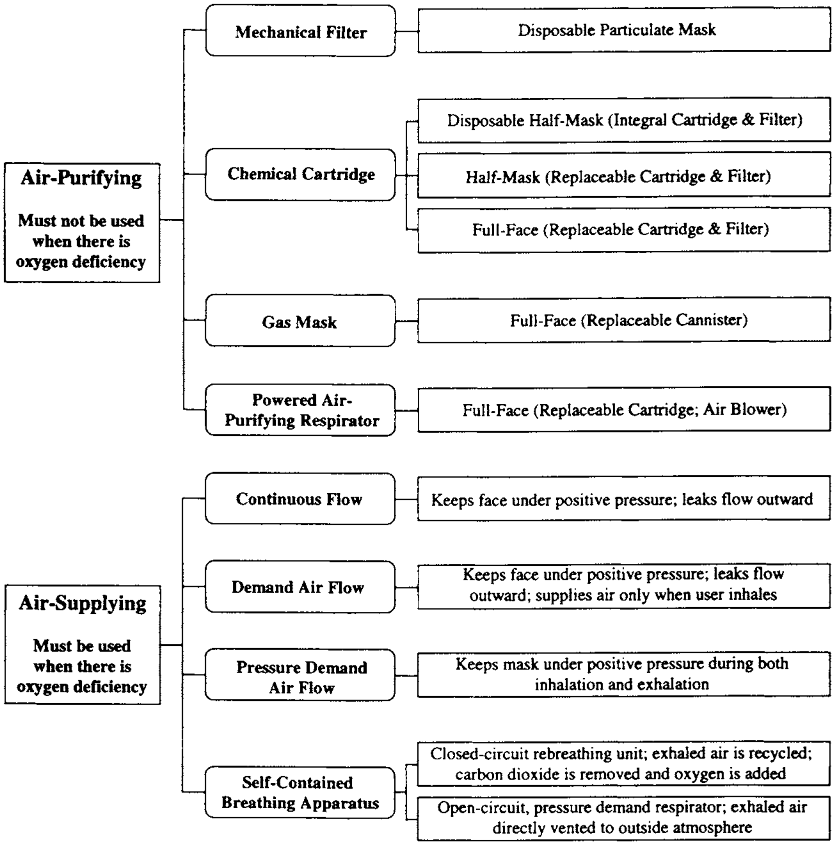

FIGURE 8.5 Typology of respirators (adapted from information provided by Jean Letendre). Each respirator has specific limitations and requirements that must be assessed in light of site-specific circumstances.

air blower; less exhausting for user than chemical cartridge or gas mask respirators; face- or belt-mounted blower that is battery powered; limits are usually set at 100 times the PEL (or as specified on the cartridge.

Air-Supplying Respirators

These respirators consist of a helmet, hood, and full- or half-face mask that is provided air though a compressor compressed air cylinder. *They are used in atmospheres that may have a deficiency or an excess of oxygen,* *or if the concentration of the contaminant vapors, gases, or particles may be immediately dangerous to life or beyond the capacity of an air-purifying cartridge or canister.*

1. Continuous flow respirator: The facepiece is kept at positive pressure; air flow is outward from the mask, preventing contaminants from entering the facepiece; supplies clean, breathable air from a source independent of the contaminated air; the flow of air remains constant.
2. Demand air flow respirator: Supplies air only when the user inhales; exhalations are ejected directly to the atmosphere; flow of air is regulated by pressure valve.
3. Pressure demand air flow respirator: Supplies air when the user inhales or exhales; exhalations are ejected directly to the atmosphere; flow of air is regulated by pressure valve.
4. Self-contained breather apparatus (SCBA): Provides an independent air supply that is not mixed with the outside atmosphere and which may be either recycled or exhaled directly into the outside atmosphere; offers greatest respiratory protection available. SCBA may be of several types, including open- and closed-circuit units (for multipurpose response operations) and so called "escape-only" SCBA, which can only be used for a period of 5 to 15 minutes for the purpose of escaping a hazardous atmosphere (Fig. 8.6).

In the United States, respirator types are subject to 42 CFR 84 regulations, which became effective in July 1995 (Fig. 8.7). These regulations provide for nine classes of filters (three levels of filter efficiency, each with three categories of resistance to degradation of filter efficiency) for *nonpowered particulate respirators.* The three levels of filter efficiency are 95, 99, and 99.97%; the three categories of resistance to degradation of filter efficiency are labeled N (*N*ot resistant to oil), R (*R*esistant to oil), and P (oil *P*roof). Notice of NIOSH certification of nonpowered particulate respirators (Fig. 8.8) is available through the electronic reference library of NIOSH (http://ftp.cdc.gov/niosh/homepage.html).

General Procedures

A written respiratory protection program is mandatory and must include specific procedures that govern the proper use, maintenance, and replacement of respirators. The following examples of general procedures that apply throughout American industry illustrate the range of issues that must be addressed and adapted to the specific needs and managerial practices of any emergency response organization.

Open-Circuit SCBA

Supplies clean air to the wearer from a cylinder; wearer exhales directly to the atmosphere

Advantages	Disadvantages
Operated in a positive-pressure mode, open-circuit SCBAs provide the highest respiratorv protection currently available. A warning alarm signals when only 20-25% of the air supply remains	Shorter operating time (30 to 60 minutes) and heavier weight (up to 35 lbs) than a closed-circuit SCBA. The 30 to 60-minute operating time may vary depending on the size of the air tank and the work rate of the individual

Closed-Circuit SCBA

Recycles exhaled gases by removing CO_2 with an alkaline scrubber and replenishing the consumed oxygen with oxygen from a liquid or gaseous source

Advantages	Disadvantages
Longer operating time (up to 4 hours), and lighter weight (21 to 30 lbs) than open-circuit apparatus. A warning alarm signals when only 20 to 25% of the oxygen supply remains. Oxygen supply is depleted before the CO_2 sorbent scrubber supply, thereby protecting the wearer from CO_2 breakthrough	At very cold temperature, scrubber efficiency may be reduced and CO_2 breakthrough may occur. Units retain heat normally exchanged in exhalation and generate heat in the CO_2 scrubbing operations, adding to danger of heat stress. Auxiliary cooling devices may be required. When worn outside an encapsulating suit, breathing bag may be permeated by chemicals, contaminating breathing apparatus and respirable air. Decontamination of breathing bag may be difficult

Note: Positive-pressure closed-circuit SCBAs offer substantially more protection than negative-pressure units, which are not recommended on hazardous waste sites.

Escape-Only SCBA

Supplies clean air from either an air cylinder or from an oxygen-generating chemical

Advantages	Disadvantages
Lightweight (10 pounds or less), low bulk, easy to carry. Available in pressure-demand and continuous-flow modes	Cannot be used for entry. Provides only 5 to 15 minutes of respiratory protection, depending on the model and wearer breathing rate

FIGURE 8.6 Advantages and disadvantages of different types of SCBA (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

1. Respirators will be selected on the basis of the specific hazards to which individual personnel may be exposed in normal, nonroutine, and emergency response situations. While the selection of respirators is finally the responsibility of the safety officer, the safety officer will coordinate with all supervisors having responsibility for personnel identified as in need of respiratory protection.

2. Only personnel authorized by the safety officer will utilize respiratory protection. Authorization consists of (a) selection by the safety officer or supervisor on the basis of potential exposure to dangerous atmosphere, (b) appropriate training of personnel in the proper use, maintenance, and

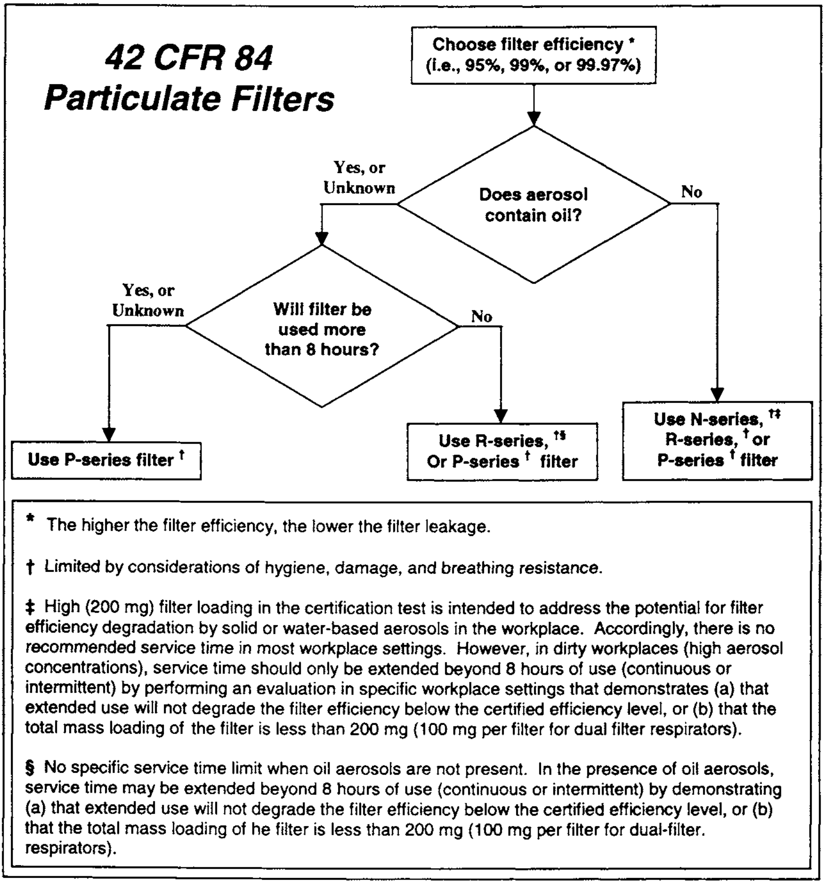

FIGURE 8.7 Flow chart for selecting 42 CFR 84 particulate filters (adapted from NIOSH, 1997: Particulate Respirator Selection and Use: Detailed Guidelines [NIOSH Electronic Library]).

limitations of the respirator(s) specified for their use, and (c) completion of medical evaluation and fit testing requirements.

3. All authorized personnel will be trained in the proper fitting of respirators and taught how to conduct fit testing. All supervisors of authorized personnel will be fully trained in all aspects regarding the proper use, maintenance, and fitting of respirators.

4. The safety officer will ensure that, whenever possible, training of personnel and supervisors will be conducted by the vendors of respiratory protection devices and will maintain all training records, including the date

Particulate Respirators Certified Under 42 CFR Part 84

***NOTICE:* Only Non-powered Particulate Respirators are listed here!**
Call 1-800-35-NIOSH for listings of other Certified Respirators

On July 10, 1995, a new NIOSH certification program for respirators went into effect. This regulation, 42 CFR Part 84, replaced the long standing regulation 30 CFR Part 11. (Commonly referred to as Part 84 and Part 11, respectively.) The new Part 84 covers all respirator types (self-contained breathing apparatus, air-line respirators, gas and vapor respirators, powered air-purifying respirators, etc.) but only the standards for non-powered, particulate respirators have changed from the provisions of the old Part 11.

The following is a list of ONLY non-powered (negative pressure) particulate respirators that have been tested and certified by NIOSH under provisions of the new Part 84. Many other respirator types, such as particulate filters in combination with gas and vapor cartridges, have been certified under provisions of Part 84 but are not included in this listing. Inquiries about other respirators may be made to 1-800-35-NIOSH. This list is updated periodically as additional non-powered, particulate respirators are certified. The current reference date is provided at the top of the listing.

Note: Multiple listings under the same certification number will be present when that same respirator is marketed by different suppliers under private labels.

Particulate Respirators Certified Under 42 CFR Part 84

Effective Date: July 31, 1997

Approval Number	Supplier/ Phone Number	Respirator Type/ Trade Name	Protection Level/ Series	Exhalation Valve
84A-0001	Better Breathing, Inc. 1-800-638-6275	Filtering Facepiece APR-3-N95-1	N95	Yes
84A-0002	Racal Health and Safety, Inc. 1-800-682-9500	Filtering Facepiece Delta N95	N95	Yes
84A-0003	Racal Health and Safety, Inc. 1-800-682-9500	Filtering Facepiece Delta N95	N95	No
84A-0004	Racal Health and Safety, Inc. 1-800-682-9500	Filtering Facepiece Delta N100	N100	Yes

http://ftp.cdc.gov/niosh *Continued ....*

FIGURE 8.8 Example of listing (partial) of particulate respirators certified under 42 CFR 84 (adapted from NIOSH, 1997: NIOSH Electronic Library).

of training, the names of persons attending the training, the specific subject matter addressed, and the name and affiliation of the trainer.

5. Wherever possible, respirators will be assigned to individual workers for their exclusive use; in such cases, the employee's name will be clearly marked o the respirator.

6. All nondisposable respirators must be cleaned and disinfected after each use and will be stored in a convenient, clean, sanitary, and clearly identified location. Written instruction for the proper cleaning, disinfection, storage, and maintenance of respirators will be included in standard operating procedures posted at each storage location.

7. Respirators will be inspected during cleaning or at least monthly. Worn or deteriorated parts will be replaced. Inspection will include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tubes, and canisters. Rubber or elastomer parts will be inspected for pliability and signs of deterioration. Inspection records will be maintained by supervisors at the respirator storage location.

8. Respirators must be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators placed at ready stations will be immediately accessible at all times and should be stored in dedicated and clearly marked compartments. Routinely used respirators, such as dusts masks, may be placed in plastic bags for storage. Respirators should not be stored in such places as lockers or tools boxes unless they are in carrying cases or cartons.

9. Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position.

10. All personnel who issue or use canister-type respirators will ensure that canisters purchased or used by them are properly labeled and color coded (in accordance with 29 CFR 1910.134, Table I-1) before they are placed in service and that labels and colors are properly maintained at all times thereafter.

11. The safety officer will ensure that normal (nonemergency) work areas and operations (e.g., postincident cleaning and disinfection of contaminated equipment and vehicles) requiring the use of respirators are monitored at least twice a year to ensure proper respiratory protection. The safety officer will maintain written records that document the date of monitoring, chemical monitored, measurement devices, concentrations, conversion factors, and mathematical transformations of data, as well as any actions undertaken as a result of the monitoring effort.

12. In the case of SCBA, air may be supplied to respirator from cylinders or air compressors only if in compliance with 29 CFR 1910.134(d).

13. In areas where the wearer of a respiratory protection device could, upon failure of that device, be overcome by a toxic chemical or

oxygen deficiency or superabundance, at least one additional person will be present. Communication will be maintained between both or all individuals present. Planning will be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to effect rescue.

14. Personnel using air line respirators in atmospheres immediately hazardous to life or health will be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres.

15. In no circumstances will any personnel using a respiratory protective device wear eye contact lenses in any atmosphere that may be chemically contaminated.

Cleaning and Disinfecting Respirators

Respirators should be cleaned and disinfected after each use. Cleaning should be accomplished by washing nonfilter components with detergent in warm water using a soft brush, followed by a thorough rinsing in clean water. If possible, detergents containing a biocide should used. In no circumstance should any organic solvent (e.g., acetone, benzene) be used, as such solvents will typically damage the rubber facepiece. Alternatively, following detergent washing, a disinfecting rinse can be used, such as :

- Hypochlorite disinfecting solution (2 tablespoons of chlorine bleach per gallon of water)
- Iodine disinfecting solution (1 teaspoon of tincture of iodine per gallon of water)

It should be understood that the efficacy of any chemical disinfectant depends upon the time of actual contact between the disinfecting chemical and the target microbe (bacterium, virus, fungus). To ensure contact between disinfectant and microbe, dirt and other substances that can physically interpose between disinfectant and microbe must be completely removed. Once dirt and other interfering substances are removed, allow at least a 2-minute immersion of respirator components in the disinfecting solution.

Inspection of Respirators

All respirators should be visually inspected (a) before and after each use, (b) during cleaning and disinfection, and (c) at least monthly (and preferably weekly). Written SOPs should identify signs and symptoms of needed maintenance and replacement, including the following (based on NIOSH recommendations):

1. Disposable Respirator

- holes in filter (replace respirator)
- poor elasticity or deterioration of straps (replace straps or respirator)
- deterioration or excessive deformation of metal nose clip (replace respirator)

2. Air-Purifying Respirator

- Rubber facepiece: excessive dirt (clean thoroughly); cracks, tear, or holes (replace facepiece); permanent distortion (replace facepiece); cracked, stretched, or loose fitting lenses (replace lenses or facepiece)
- Headstraps: breaks or tears (replace headstrap); loss of elasticity (replace headstrap); broken or malfunctioning buckles or attachments (replace items); excessive wearing of head harness (replace headstrap)
- Inhalation valve, exhalation valve: detergent residue, dust particles, or dirt on valve or valve seat (clean); cracks, tears, or distortion of valve material or valve seat (replace); missing or defective valve cover (replace valve cover)
- Filter element(s): improper filter and approval designation (replace); missing or worn gaskets (replace gaskets); worn threads (replace filter and/or facepiece); cracks or dents in filter housing (replace filter); deterioration of gas mask canister harness (replace harness); service life indicator (determine proper indicator from manufacturer)
- Corrugated breathing tube (gas mask): cracks or holes (replace tube); missing or loose hose clamps (replace clamps); broken or missing end connectors (replace connectors)

3. Air-Supplying Respirator

- Facepiece, headstraps, valves, and breathing tube (as for air-purifying respirators, above)
- Hood, helmet, blouse, or full suit (as applicable): rips and worn seams (repair or replace); headgear suspension (adjust properly for wearer); cracks or breaks in faceshield (replace faceshield); damaged or improper fit of protective screen (replace screen)

4. Air Supply System

- breathing air quality
- breaks or kinks in air supply hose and end fitting attachments (replace)

- tightness of connections (adjust; replace as necessary)
- proper setting of regulators and valves (see manufacturer's recommendations)
- correct operation of air-purifying elements and carbon monoxide or high-temperature alarms (see manufacturer's recommendations)

5. Self-Contained Breathing Apparatus (SCBA)

- See manufacturer's recommendations

Key Issues in Respirator Maintenance Program

On the basis of its analysis of the cause of deaths of firefighters, NIOSH has strongly emphasized (NIOSH Alert: September 1994; Publication No. 94-125) the critical importance of the various standards to be used *to establish a policy of providing and operating with the highest possible levels of safety and health for all firefighters,* including standards directly pertinent to respiratory protection:

1. NFPA 1404 specifies the *minimum requirements* for a fire service respiratory protection program,
2. NFPA 100 specifies (1) *the minimum requirements* for a fire department's occupational safety and health program, and (2) the safety procedures for members involved in rescue, fire suppression, and related activities,
3. NFPA 1561 defines the *essential elements* of an incident management system, and other relevant NFPA standards include NFPA 1971 (clothing), NFPA 1972 (helmets), NFPA 1973 (gloves), NFPA 1974 (footwear), NFPA 1981 (SCBA), and NFPA 1982 (PASS).

HEARING PROTECTORS

Work-related noise is inclusive of two basic categories of sound: (a) *impulsive sound,* which is sound that varies more than 40 dB per 0.5 sec, and (b) *nonimpulsive sound,* which includes so-called *continuous* and *intermittent* (i.e., varies less than 40 dB per 0.5 sec) sound. The standard action level for the general workplace is an 8-hour TWA of 85 dB.

There are four basic types of ear protectors, each having certain advantages and limitations, especially with regard to personal comfort level:

1. Enclosure: helmet type protection, typically providing attenuation of 35 dB at $f < 1000$ Hz and 50 dB at $f > 1000$ Hz; while highly effective

for attenuating sound conducted through air, not very effective for attenuating sound conducted through one or body; relatively bulky and uncomfortable for most work situations; generally used where both hearing and head protection are required

2. Aural insert (earplug): most commonly used type of protector in general industry; inserted into the ear to plug the ear canal; provides attenuation of up to 25 dB at $f < 1000$ Hz and 35 dB at $f > 1000$ Hz, with common attenuations of 5–15 dB and 15–25 dB, respectively; three different types commonly available:

A. Formable earplug: designed to be discarded after one-time use; made of expandable foams, glass fiber, wax-impregnated cotton, Swedish wool, or mineral-down; available in single size only; degree of attenuation depends on snugness of fit
B. Custom molded earplug: designed to fit an individual's ear; changes in ear canal and drying of the mold material can detract from effectiveness
C. Premolded earplug: made of soft silicone, rubber, or plastic; fits generic shapes of ear canals; various modifications for particular situations, including modifications for differential attenuations at different frequencies and for various combinations of continuous or impact noise; some models developed for specific occupational groups

3. Canal cap (semi- and supraaural): used to seal external opening of the ear canal (as opposed to plugging the ear canal); held in place by band or other head suspension device; range of attenuation comparable to that by earplug; ideal for intermittent use

4. Earmuff (circumaural device): domed cup covering the entire external ear; can provide up to 35 dB attenuation at $f < 1000$ Hz and 45 dB at f 1000 Hz, but often reaching only 10–12 dB; may be uncomfortable due to slight pressure applied to side of head

Any hearing protector presents special risk to the wearer during incident operations because of its interference with (a) vital communication among team members (e.g., voice command to evacuate or other sound signal), and (b) the wearer's awareness of developing ambient hazard (e.g., noise associated with impending structural collapse). No hearing protector should be worn by any emergency response personnel except when specific provision is made (e.g., integrated earmuff and radio receiver) to ensure that the wearer will not thereby be subject to undue risk.