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Personal Protection

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Personal Protection Equipment (PPE)

4.1 INTRODUCTION

Anyone handling hazardous waste must be adequately protected from potential exposure and injury hazards. The purpose of personal protective equipment (PPE) is to shield or isolate individuals from the chemical, physical, and biologic hazards that exist when working with hazardous waste. Careful selection and use of adequate PPE should protect the respiratory system, skin, eyes, face, hands, feet, head, body, and ears.

Use of PPE is required by Occupational Safety and Health Administration (OSHA) regulations in 29 CFR Part 1910 and reinforced by U.S. Environmental Protection Agency (EPA) regulations in 40 CFR Part 300. This unit is based on these regulations and NIOSH (National Institute for Occupational Safety and Health) publications.

No single combination of protective equipment and clothing is capable of protecting against all hazards. Thus PPE should be used in conjunction with other protective methods. The use of PPE can itself create significant worker hazards, such as heat stress, physical and psychological stress, and impaired vision, mobility, and communication. In general, greater levels of PPE protection can cause the associated risks to increase. For any given situation, equipment and clothing should be selected that provide an adequate level of protection. *Overprotection as well as underprotection can be hazardous and should be avoided.*

4.2 TYPES OF PROTECTION

There are three types of protection available: body defenses, personal hygiene, and PPE.

4.2.1 BODY DEFENSES

The body has various capabilities for protecting itself against harmful contamination. Some of the body's first-line defenses include skin that

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provides a physical barrier, mucous membranes that capture particles on their sticky surfaces, tears that flush contaminants out of the eyes, and coughing that removes large particles from the mouth and windpipe before they enter the lungs.

4.2.2 PERSONAL HYGIENE

Along with the body defenses, it is necessary to practice good personal hygiene to reduce the toxicological effects of any contamination. The longer most harmful substances are exposed to the human body, the greater the chance for contaminant-related effects. Good personal hygiene practices reduce the time the body is exposed. Some of the good personal hygiene habits expected from hazardous waste workers include:

- taking full body showers before leaving site at the end of the day;
- washing hands and face after leaving work areas;
- never smoking in work areas;
- never eating, drinking, or chewing gum or tobacco in work areas;
- smoking, eating, drinking, and chewing tobacco or gum only in designated break areas after following proper decontamination procedures;
- changing into clean work uniforms daily;
- never laundering work uniforms at home;
- never entering the clean area after working; always using the decontamination area first; and
- making good personal hygiene practices into good habits.

4.2.3 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Even with the healthiest body defenses and good personal hygiene habits, many hazardous substances require use of specialized safety and protective equipment. OSHA requires employers to provide personal safety and protective equipment for their employees. Table 1 describes the OSHA standards for using PPE.

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Table I OSHA Standards For Use of PPE

{PRIVATE }Type of Protection	Regulation
General	29 CFR Part 1910.132
	29 CFR Part 1910.1000
	29 CFR Part 1910.1001-1045
Eye and Face	29 CFR Part 1910.133(a)
Noise Exposure	29 CFR Part 1910.95
Respiratory	29 CFR Part 1910.134
Head	29 CFR Part 1910.135
Foot	29 CFR Part 1910.136
Electrical Protective	29 CFR Part 1910.137

According to the OSHA regulations, the following body areas require special protection:

- eyes and face;
- head;
- ears;
- skin;
- hands, arms, and feet; and
- respiratory system.

Tables 2 and 3 provide a summary of recommended personal protective equipment.

4.3 THE RESPIRATORY PROTECTION PROGRAM

The OSHA Respiratory Protection Standard 29 CFR 1910.134 requires employers to supply suitable respiratory protection equipment and establish a respiratory protection program. The respiratory protection program should include the following:

- standard operating procedures for selection and use of respirators;

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- proper selection of respirators on the basis of hazard;
- training of personnel in use and limitations;
- regular cleaning and maintenance;
- proper storage;
- routine monthly inspections and inspections before and after use;
- constant monitoring of work area for adverse conditions and worker stress;
- continual evaluation of respiratory compliance program after it is put into operation;
- determination of medical fitness of each potential user; and
- supply only approved equipment and only after proper fit-testing has been performed.

Respiratory protection equipment must be approved by the National Institute of Occupational Safety and Health (NIOSH): for equipment manufactured before March of 1972, it must be approved by the Mine Safety and Health Administration (MSHA).

4.4 SELECTION OF RESPIRATORY PROTECTION

Before a good respiratory protection program can be developed, the possible contaminants and exposure levels must be determined so that the proper respirator selection, medical surveillance, environmental monitoring, and training can be performed.

Since air-purifying respirators (APR) filter ambient air, the following conditions must be met so that an APR can be worn:

- atmospheric oxygen levels are above 19.5%;
- chemical substance is known;
- chemical substance must be able to be filtered, absorbed, or neutralized;
- chemical substance has an odor or other warning property;
- airborne concentration of chemical substance does not exceed .1% or 1000 ppm;
- airborne concentrations of chemical substance does not exceed the established IDLH (Immediately Dangerous to Life and Health); and
- no firefighting will be required.

Otherwise, an atmosphere-supplying respirator (ASR) such as a self-contained breathing apparatus (SCBA), or supplied-air respirator (SAR) must be used. A supplied-air respirator is also called an airline respirator.

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4.4.1 OXYGEN-DEFICIENT ATMOSPHERE

NIOSH defines an oxygen-deficient atmosphere as any atmosphere containing oxygen at a concentration below 19.5% at sea level. NIOSH certification of supplied airline or air-purifying respirators is limited to those respirators used in atmospheres containing at least 19.5% oxygen, except for those airline respirators equipped with auxiliary self-contained breathing apparatus (SCBA).

The minimum requirement of 19.5% oxygen at sea level provides an adequate amount of oxygen for most work assignments and includes a safety factor. The safety factor is needed because oxygen-deficient atmospheres offer little warning of the danger, and the continuous measurement of an oxygen-deficient atmosphere is difficult.

Breathing oxygen concentrations below 16% at sea level can decrease mental effectiveness, visual acuity, and muscular coordination. At oxygen concentrations below 10%, loss of consciousness may occur, and below 6% oxygen, death will result. Often only mild subjective changes are noted by individuals exposed to low concentrations of oxygen, and collapse can occur without warning.

Since oxygen-deficient atmospheres are life-threatening, only the most reliable respirators are recommended; the most reliable respirators are the self-contained breathing apparatus (SCBA) or the supplied-air respirators (SAR) with auxiliary self-contained units. Because a high protection factor is not necessary to ensure an adequate supply of oxygen even in an atmosphere containing no oxygen, any certified self-contained unit is adequate. All aspects of a respiratory protection program must be instituted for these recommendations to be valid.

4.4.2 IDENTIFIED AIR CONTAMINANT

To determine exposure limits, contaminant health effects, contaminant warning properties, and type of respirator, the air contaminant must be identified.

4.4.3 KNOWN AIR CONTAMINANT CONCENTRATION

After the air contaminant is identified, the concentration must be determined so that the Threshold Limit Values (TLV) or Permissible Exposure Limits (PEL) and the IDLH (immediately dangerous to life and health) limits can be compared, and the proper decision can be

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made regarding exposure.

4.4.4 EXPOSURE LIMITS

The majority of the OSHA PELs were adopted from the ACGIH TLVs published in 1968. The difficulty in changing PELs through promulgation of standards when new toxicologic information is identified has caused many standards to become outdated. The effectiveness of this decision logic is limited to the adequacy of the selected exposure limits in protecting the health of workers. Exposure limits based on a thorough evaluation of more recent or extensive data should be given priority.

For all chemicals that cause irritation or systemic effects but do not cause carcinogenic effects, it is currently believed that a threshold exposure concentration exists such that virtually all persons in the working population (with the possible exception of hypersensitive individuals) would experience no adverse health effects.

For many carcinogenic substances, most available data provide no evidence for the existence of a threshold exposure concentration below which the substance would be safe. As with noncarcinogenic substances, there appears to be a dose-response relationship for carcinogenic substances. If no threshold exists for a carcinogen, then there is no safe exposure concentration; however, lower exposures would be associated with lower risks.

For some carcinogens, NIOSH attempts to identify the lowest PEL on the basis of the quantitative detection limit for the method used to monitor exposures. For other carcinogens, NIOSH does not identify a precise exposure limit but recommends instead that the employer control worker exposures to the lowest feasible limit.

4.4.5 IDLH

An IDLH exposure condition is defined in this decision logic as one that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment. The purpose of establishing an IDLH exposure level is to ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment. The IDLH is considered a maximum level above which only a highly reliable breathing apparatus providing maximum worker protection is permitted. Any appropriate, approved respirator may be used to its maximum-use concentration, up to the IDLH concentration.

In establishing the IDLH concentration, two conditions must be

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ensured:

- The ability to escape without loss of life or immediate or delayed irreversible health effects. (Thirty minutes is considered the maximum time for escape to provide some margin of safety in calculating the IDLH.)
- The prevention of severe eye or respiratory irritation or other reactions that would hinder escape.

4.4.6 WARNING PROPERTIES

For the purpose of this decision logic, adequate warning properties include odor, taste, eye irritation, or respirator irritation. Adequate warning properties imply that the gas or vapor in question has a persistent odor or irritant effect at concentrations below the OSHA PEL or NIOSH REL. Recognition of an odor depends on a person's sensory ability to detect it. Since the range of odor recognition thresholds within a population is a very large, odor recognition should not be relied on as the only means for determining that a cartridge or canister is no longer effectively removing a contaminant from the air.

NIOSH recommends the employer ensure that each worker who is required to wear an air-purifying cartridge or canister respirator is capable of recognizing the odor of the substance of concern at a concentration at or below the applicable exposure limit. Such a determination will necessitate that an odor-screening test be conducted on each individual for each substance of concern in the particular workplace.

4.4.7 PROTECTION FACTORS

The level of protection that can be provided by a respirator is indicated by the respirator's protection factor. This number, which is determined experimentally by measuring facepiece seal and exhalation valve leakage, indicates the relative difference in concentrations of substances outside and inside the facepiece that can be maintained by the respirator. For example, the protection factor for full-facepiece air-purifying respirators is 50. This means, theoretically, that workers wearing these respirators should be protected in atmospheres containing chemicals at concentrations that are up to 50 times higher than the appropriate limits.

At sites where the identity and concentration of chemicals in air are

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known, a respirator should be selected with a protection factor that is sufficiently high to ensure that the wearer will not be exposed to the chemicals above the applicable limits. These limits include the ACGIH's TLVs, OSHA's PELs and the NIOSH Recommended Exposure Limits (RELs). These limits are designed to protect most workers who may be exposed to chemicals day after day throughout their working life. The OSHA PELs are legally enforceable exposure limits, and are the minimum limits of protection that must be met. Remember that the protection provided by a respirator can be compromised in several situations, most notably, (1) if a worker has a high breathing rate, (2) if the ambient temperature is high or low, and (3) if the worker has a poor facepiece-to-face seal. A similar reduction in protection may result from high or low ambient temperatures. For example, at high temperatures excessive sweat may cause a break in the face-to-facepiece seal. At very low temperatures, the exhalation valve and regulator may become ice-clogged to moisture in the breath and air.

Table IV
Table V

4.4.8 EMPLOYEE QUALIFICATIONS

At a minimum, you must have performed the following tasks to use the respiratory protection selected:

- received current medical monitoring, including pulmonary function tests;
- been fit-tested for respirator selected; and
- been trained on the care and use of the respirator selected.

4.4.9 SERVICE LIMIT CONCENTRATION

Not all canisters and cartridges are created equal. Each canister and cartridge is manufactured for a certain range and type of contamination. This range must be compatible with the exposure predicted at the site. Canisters and cartridges are manufactured for certain contaminant categories (e.g. pesticides, acids, asbestos) and are shelf life dated. Users need to insure the canister/cartridge they intend to use is for the appropriate category and that it is in date.

4.4.10 BREAKTHROUGH

When the respiratory protection selected becomes compromised and allows contamination to be inhaled, breakthrough occurs. Through careful selection of respiratory protection, breakthrough will be minimized, providing the user with a safer environment.

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4.5 RESPIRATOR USE UNDER LIMITING CONDITIONS

Following are special problems that may be encountered in the wearing and use of respiratory protective equipment:

4.5.1 FACIAL HAIR

Facial hair that lies along the sealing area of the respirator, such as beards, sideburns, moustaches, or even a few days growth of stubble, should not be permitted on employees who are required to wear respirators that rely on a tight facepiece fit to achieve maximum protection. Facial hair between the wearer's skin and the sealing surfaces of the respirator will prevent a good seal. A respirator that permits negative air pressure inside the facepiece during inhalation may allow leakage and, in the case of positive-pressure devices, will either reduce service time or waste breathing air. A worker should not enter a contaminated work area when conditions prevent a good seal of the respirator facepiece to the face.

4.5.2 EYEGLASSES

Ordinary eyeglasses should not be used with full-facepiece respirators. Eyeglasses with temple bars or straps that pass between the sealing surface of a full-facepiece and the worker's face will prevent a good seal, and should not be used. Special corrective lenses can be mounted inside a full-facepiece respirator and are available from all manufacturers of full-facepiece respirators. To ensure good vision, comfort, and proper sealing of the facepiece, these corrective lenses should be mounted by an individual designated by the manufacturer as qualified to install accessory items.

Eyeglasses or goggles may also interfere with half-masks. When interference occurs, a full-facepiece with special corrective lenses should be provided and worn.

4.5.3 CONTACT LENSES

Several factors restrict and/or prohibit the use of contact lenses while

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wearing any type of respiratory device. This is especially true of atmosphere-supplying respirators. With full-facepieces, incoming air directed toward the eye can cause discomfort from dirt, lint, or other debris lodging between the contact lens and the cornea.

4.5.4 FACIAL IRREGULARITIES

Facial irregularities, such as scars, deep skin creases, prominent cheekbones, severe acne, and the lack of teeth or dentures, can prevent a respirator from sealing properly.

4.5.5 COMMUNICATIONS

Talking while wearing a respirator equipped with a facepiece may break the seal of the facepiece. Communication is usually accomplished by prearranged hand signals. In some situations, special communication equipment can be obtained from the manufacturer of the respirator.

4.5.6 DANGEROUS ATMOSPHERES

Written procedures should be prepared for safe respirator use in IDLH atmospheres that may occur in normal operations or emergencies. Personnel should be familiar with these procedures and respirators. At least one standby person, equipped with proper rescue equipment including an SCBA, should be present in the nearest safe area for emergency rescue of those wearing respirators in an IDLH atmosphere. Communications (visual, voice, signal line, telephone, radio, or other suitable type) should be maintained among all persons present (those in the IDLH atmosphere and the standby person or persons). The respirator wearers should be equipped with safety harnesses and safety lines to permit their removal from the IDLH atmosphere if they are overcome.

Confined spaces are enclosures that are difficult to get out of, such as storage tanks, tank cars, boilers, sewers, tunnels, pipelines, pits, and tubs. The atmospheres in a confined space may be immediately dangerous to life or health because of toxic air contaminants or lack of oxygen. Before anyone enters a confined space, tests should be made to determine the presence and concentration of any flammable vapor or gas, or any toxic airborne particulate, vapor, or gas, and to determine the oxygen concentration.

4.5.7 LOW AND HIGH TEMPERATURES

Low temperatures may fog respirator lenses. Coating the inner surface of the lens with the anti-fogging compound normally available from the respirator manufacturer should prevent fogging down to 32° F, but severe fogging may occur below 0° F. Full facepieces with nose cups that direct the warm, moist exhaled air through the exhalation valve

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without its touching the lens, are available. They should provide satisfactory vision at as low as -30° F. At very low temperatures, exhalation valves may freeze due to moisture. Dry respirable air should be used with airline respirators and with the type of SCBA that has an air cylinder when they are used in very low temperatures.

A person working in high temperature air is under stress. Wearing a respirator causes additional stress which should be minimized by using a lightweight respirator with low breathing resistance. In atmospheres that are not immediately dangerous to life or health, the airline-type supplied-air respirator is recommended. Such a respirator used in low or high temperature atmospheres may be equipped with a vortex tube to either warm or cool the air supplied.

4.5.8 PHYSIOLOGICAL RESPONSE OF RESPIRATOR USE

Wearing any respirator, alone or in conjunction with other types of protective equipment, will impose some physiological stress on the wearer. The weight of the equipment, for example, increases the energy requirement for a given task. Selection of respiratory protective devices should be based on the breathing resistance, weight of the respirator, the type and amount of protection needed, as well as the individual's tolerance of the given device.

Use of respirators in conjunction with protective clothing can greatly affect the human response and endurance, especially in hot environments. Normally, in hot environments or during heavy work, the body relies a great deal on heat loss through the evaporation of sweat. With impermeable clothing, the heat loss by water evaporation is not possible. Additionally, the weight of the respirator (up to 35 pounds for an SCBA) adds to the metabolic rate of workers, increasing the amount of heat the body produces. The net effect is one of heat stress.

4.6 AIR-PURIFYING RESPIRATORS (APR)

4.6.1 PARTICULATE-FILTERING

Particulate-filtering respirators are used for protection against dusts, fumes, and/or mists. A dust is a solid, mechanically produced particle. A fume is a solid condensation particle, usually of a vaporized metal. A mist is a liquid condensation particle.

Presently, all particulate-filtering respirators use fibrous material (a

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filter) to remove the contaminant. As a particle is drawn onto or into the filter, it is trapped by the fibers. The probability that a single particle will be trapped depends on such factors as its size relative to the fiber size; its velocity; and, to some extent, the composition, shape, and electrical charge of both particle and fiber. With current filter media, any filter designed to be 100% efficient in removing particles would be unacceptably difficult to breathe through.

Particulate filters are of two types: absolute and non-absolute. Absolute filters use screening to remove particles from the air; that is, they exclude the particles which are larger than the pores. However, most respirator filters are non-absolute filters, which means they contain pores which are larger than the particles to be removed. They use combinations of interception capture, sedimentation capture, inertial impaction capture, diffusion capture, and electrostatic capture to remove the particles. The exact combination of filtration mechanisms that come into play depends upon the flow rate through the filter and the size of particle.

4.6.2 VAPORC AND GAS-REMOVING

The other major class of airborne contaminants consists of gases and vapors. Air-purifying respirators are available for protection against both specific gases and vapors, such as ammonia gas and mercury vapor, and classes of gases and vapors, such as acid gases and organic vapors. In contrast to filters, which are effective to some degree no matter what the particulate, the cartridges and canisters used for vapor and gas removal are designed for protection against specific contaminants.

VaporC and gas-removing respirators normally remove the contaminant by the interaction of the gas or vapor molecules with a granular, porous material, commonly called the sorbent. The general method by which the molecules are removed is called sorption. In addition to sorption, some respirators use catalysts that react with the contaminant to produce a less toxic gas or vapor.

Three removal mechanisms are used in vaporC and gas-removing respirators, adsorption, absorption, and catalysis.

4.6.2.1 Adsorption

Adsorption retains the contaminant molecule on the surface of the sorbent granule by physical attraction. The intensity of the attraction varies with the type of sorbent and contaminant. Adsorption by physical attraction holds the adsorbed molecules weakly. If chemical forces are involved, however, in the process called chemisorption, the bonds holding the molecules to the sorbent granules are much stronger

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and can be broken only with great difficulty.

4.6.2.2 Absorption

Absorbents may also be used to remove gases and vapors. Absorbents differ from adsorbents in that, although they are porous, they do not have as large a specific surface area. Absorption is also different because the gas or vapor molecules usually penetrate deeply into the molecular spaces throughout the sorbent and are held there chemically. Probably, absorption cannot occur without prior adsorption on the surface of the particles. Furthermore, adsorption occurs instantaneously, whereas absorption is slower. Most absorbents are used for protection against acid gases. They include mixtures of sodium or potassium hydroxide with lime and/or caustic silicates.

4.6.2.3 Catalysis

A catalyst is a substance that influences the rate of chemical reaction between other substances. A catalyst used in respirator cartridges and canisters is hopcalite, a mixture of porous granules of manganese and copper oxides that speeds the reaction between toxic carbon monoxide and oxygen to form carbon dioxide. As applied to respirators, the foregoing processes are essentially 100% efficient until the sorbent's capacity to adsorb gas and vapor or catalyze their reaction is exhausted. Then the contaminant will pass completely through the sorbent and into the facepiece.

4.6.3 COMBINATION PARTICULATE, VAPOR AND GAS-REMOVING

Cartridges and canisters are available to protect against both particulates and vapors and gases. These devices look much like the sorbent cartridge or sorbent canister alone. There are several methods of attaching a particulate filter to a typical cartridge. One includes the particulate filter inside the cartridge. Another is mounted to the outside of the cartridge using a snap-on cover. Other variations may be found, but the principle is the same. Where filters are used in combination with cartridges, the filter must always be located on the inlet side of the cartridge.

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4.6.4 APR OPERATIONS

4.6.4.1 Donning Procedures

1. QuarterC and Half-face Respirator

   ! Make sure that the respirator is assembled correctly and is equipped with the proper filter and/or cartridge for the work assignment to be performed.

   CAUTION: OSHA requirements state that a respirator must be inspected by the wearer before and after each use to ensure that it is in good working condition.

   ! Remove protective eyewear, and place respirator under the chin and over the nose. The narrow part of the facepiece should be located over the nose.

   ! Pull the crown strap over the head and adjust its placement until it is comfortable. The crown strap is adjustable in length for ease of fit.

   ! Using both hands, hook the lower headband straps together behind the neck.

   ! Adjust the upper headbands by pulling downward from the crown strap. Adjust the lower headbands by pulling sideways from the hook and loop. Do not adjust headbands and tension at the yoke. Continue adjusting headbands until a comfortable fit has been obtained.

   DO NOT over tighten the respirator to the face.

2. Full-face Respirator

   ! Make sure that the respirator is assembled correctly and is equipped with the proper filter and/or cartridge for the work assignment to be performed.

   CAUTION: OSHA requirements state that a respirator must be inspected by the wearer before and after each use to ensure that it is in good working condition.

   ! Pull all six head straps out to the end tabs.

   ! Clasp temple and side straps with each respective hand, as close to facepiece as possible, and stretch straps over the head, fitting mask against the chin first.

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- Pull side straps as tightly as necessary to obtain a snug fit. (At this stage, mask may still hang lower than desired.)

- Pull temple straps next, tight enough to ensure a snug fit.
- Pull top forehead straps last, completing air-tight seal. To avoid forehead kinks, pull these two straps toward each other.

4.6.4.2 Fit-Check Procedures

The seal of a respirator should be tested prior to entering a contaminated atmosphere by procedures recommended by the manufacturer or by the following fit checks:

1. **Irritant or Odorous Chemical Agent Test**CThe wearer is exposed to an irritant smoke, isoamyl acetate vapor, or other suitable test agent easily detectable by irritation, odor, or taste. An air-purifying respirator must be equipped with the appropriate air-purifying element. If the wearer is unable to detect penetration of the test agent, the respirator is probably tight enough.

2. **Positive Pressure Test**CThis test is similar to the negative-pressure test, and it has the same advantages and limitations. It is conducted by closing off the exhalation valve and exhaling gently into the facepiece. The fit is considered satisfactory if slight positive pressure can be built up inside the facepiece without any evidence of outward leakage. For some respirators, this method requires that the wearer remove the exhalation valve cover and then carefully replace it after the test, often a difficult task. Removing and replacing the exhalation valve cover often disturbs the respirator fit even more than does the negative pressure test. Therefore, this test should be used sparingly if it requires removing and replacing a valve cover. The test is easy for respirators whose valve cover has a single small port that can be closed by the palm or a finger. The wearer should perform this test just before entering any hazardous atmosphere.

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3. **Negative Pressure Test**CThe wearer can perform this test by himself in the field. The wearer should use this test just before entering any toxic atmosphere. It consists merely of closing off the inlet of the canister, cartridge(s), or filter(s) by covering with the palm(s) or replacing the seal(s), or of squeezing the breathing tube so that it does not pass air; inhaling gently so that the facepiece collapses slightly; and holding the breath for 10 seconds. If the facepiece remains slightly collapsed and no inward leakage is detected, the respirator is probably tight enough. This test, of course, can be used only on respirators with tight-fitting facepieces.

4.6.4.3 Respirator Fit-Testing

All users or potential users of negative-pressure type respiratory protection devices shall be fit-tested to ensure proper facepiece-to-face seal of the respirator. The fit test shall be accomplished by use of an approved test aerosol and using standard OSHA methods. Users will be tested with a selection of brands of masks and allowed to choose the most comfortable from those that fit satisfactorily.

4.6.4.4 APR Maintenance

The OSHA standards strongly emphasize the importance of an adequate maintenance program, but permit its tailoring to the type of plant, working conditions, and hazards involved. However, all programs are required to include an inspection for defects (including a leak check), cleaning and disinfecting, repair, and storage. A proper maintenance program ensures that the worker's respirator remains as effective as when it was new.

! **Inspection for Defects**CProbably the most important part of a respirator maintenance program is frequent inspection of the devices. If conscientiously performed, inspections will identify damaged or malfunctioning respirators before they can be used. The OSHA requirements outline two primary types of inspection, one while the respirator is in use and the other while it is being cleaned. In a small operation where workers maintain their own respirators, the two types of inspection become essentially one and the same. In a large organization with a central respirator maintenance facility, the inspections differ.

! **Frequency of Inspection**COSHA requires that "all respirators be inspected before and after each use," and that those not used routinely, such as emergency escape and rescue devices, "shall be inspected after each use and at least monthly ...." NIOSH, however, recommends that all

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stored SCBA be inspected weekly. In one case, the respirator is to be inspected both before and after each use, in the other case, only after use. However, it is highly unlikely that anyone needing a respirator in a hurry, as during an emergency, is going to inspect it. In fact, it could be dangerous to take time to do so.

! **Inspection Procedures**C Inspection procedures differ depending upon whether air-purifying or atmosphere-supplying devices are involved, and whether the inspection is to be conducted in the field during use, or during routine cleaning.

The OSHA standards require that respirator inspection includes a check of the tightness of the connections; a check of the facepiece, valves, connecting tube, and canister; and a check of the regulator and warning devices on SCBA for proper functioning.

! **Field Inspection of Air-Purifying Respirators**C Routinely used air-purifying respirators should be checked as follows before and after each use.

C Examine the facepiece for excessive dirt; cracks,cracks, tears, holes, or distortion from improper storage; inflexibility (stretch and massage to restore flexibility); cracked or badly scratched lenses in full-facepieces; incorrectly mounted full-facepiece lens or broken or missing mounting clips; and cracked or broken air-purifying element holder(s), badly worn threads, or missing gasket(s) (if required).

C Examine the head straps or head harness for breaks; loss of elasticity; broken or malfunctioning buckles and attachments; and excessively worn serrations on the head harness which might permit slippage (full-facepieces only).

C After removing its cover, examine the exhalation valve for foreign material, such as detergent residue, dust particles, or human hair under the valve seat; cracks, tears, or distortion in the valve material; improper insertion of the valve body in the facepiece; cracks,

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breaks, or chips in the valve body, particularly in the sealing surface; missing or defective valve cover; and improper installation of the valve in the valve body.

C Examine the air-purifying elements for incorrect cartridge, canister, or filter for the hazard; incorrect installation, loose connections, missing or worn gaskets, or cross-threading in holder; expired shelf-life date on cartridge or canister; cracks or dents in outside case of filter, cartridge, or canister; and evidence of prior use of sorbent cartridge or canister, indicated by absence of sealing material, tape, foil, etc., over inlet.

C If the device has a corrugated breathing tube,examine it for broken or missing end connectors, gaskets, or o-rings; missing or loose hose clamps; and deterioration, determined by stretching the tube and looking for cracks.

C Examine the harness of a frontC or back-mounted gas mask for damage or wear to the canister holder that may prevent its being held securely in place, and broken harness straps or fastenings.

! **Cleaning and Disinfecting**CThe OSHA requirements in 29 CFR 1910.134 are not specific about cleaning and disinfecting procedures. The regulations state that "routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to ensure that proper protection is provided" and that emergency use respirators "shall be cleaned and disinfected after each use."

4.7 ATMOSPHERE-SUPPLYING RESPIRATORS (ASR)

Atmosphere-supplying respirators do not purify the contaminated air but supply the wearer with "clean" air from some other source. The air may be either self-contained or air-supplied.

The two basic classes of ASR are Supplied Airline-Respirator (SAR) and Self-Contained Breathing Apparatus (SCBA). Self-contained (SCBA) respirators can be purchased as closed circuit or open circuit.

A closed-circuit breathing apparatus recycles the wearer's exhaled air. The carbon dioxide is chemically removed and fresh oxygen is introduced. This type of breathing apparatus is commonly referred to as a "rebreather."

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An open-circuit SCBA exhausts exhaled air directly into the environment. Air is supplied to the wearer by either a single-stage (conventional) or a two-stage (NASA) regulator. Single-stage regulators reduce the air pressure from the air cylinder only once before reaching the wearer. This type of SCBA is usually characterized by a low pressure tube hanging from the facepiece. Two-stage regulators have an initial reduction of cylinder air pressure immediately existing the air cylinder. A second regulator is then placed at the facepiece.

4.7.1 TYPES OF ASR REGULATORS

Positive-pressure respirators maintain a positive pressure in the facepiece during both inhalation and exhalation. The two main types of positive-pressure respirators are pressure-demand and continuous flow. In pressure-demand respirators, a pressure regulator and an exhalation valve on the mask maintain the mask's positive pressure except during high breathing rates. If a leak develops in a pressure-demand respirator, the regulator sends a continuous flow of clean air into the facepiece, preventing penetration by contaminated ambient air. Continuous-flow respirators (including some SARs and all powered air-purifying respirators (PAPRs) send a continuous stream of air into the facepiece at all times. With SARs, the continuous flow of air prevents infiltration by ambient air, but uses the air supply much more rapidly than with pressure-demand respirators. Powered air-purifying respirators (PAPRs) are operated in a positive-pressure continuous-flow mode utilizing filtered ambient air. (However, at maximal breathing rates, a negative pressure may be created in the facepiece of a PAPR.)

Negative-pressure respirators draw air into the facepiece via the negative pressure created by user inhalation. The main disadvantage of negative-pressure respirators is that if any leaks develop in the system (such as a crack in the hose or an ill-fitting mask or facepiece), the user draws contaminated air into the facepiece during inhalation.

4.7.2 PROPER USAGE OF ASR

4.7.2.1 SCBA

Key questions to ask when considering whether an SCBA is appropriate are:

- **Is the atmosphere IDLH or is it likely to become IDLH?**

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If yes, a positive-pressure SCBA should be used. A positive-pressure SAR with an escape SCBA can also be used.

- **Is the duration of air supply sufficient for accomplishing the necessary tasks?** If no, a larger cylinder should be used, a different respirator should be chosen, and/or the work plan should be modified.
- **Will the bulk and weight of the SCBA interfere with task performance or cause unnecessary stress?** If yes, use of an SAR may be more appropriate if conditions permit.
- **Will temperature effects compromise respirator effectiveness or cause added stress in the worker?** If yes, the work period should be shortened or the mission postponed until the temperature changes.

4.7.2.2 SAR

Key questions to ask when considering SAR use are:

- **Is the atmosphere IDLH or likely to become IDLH?** If yes, an SAR/SCBA combination or SCBA should be used.
- **Will the hose significantly impair worker mobility?** If yes, the work task should be modified or other respiratory protection should be used.
- **Is there a danger of the airline being damaged or obstructed (such as by heavy equipment, falling drums, rough terrain, or sharp objects) or permeated and/or degraded by chemicals (such as by pools of chemicals)?** If yes, either the hazard should be removed or another form of respiratory protection should be used.
- **If a compressor is the air source, is it possible for airborne contaminants to enter the air system? If yes, have the contaminants been identified and are efficient filters and/or sorbents available that are capable of removing those contaminants?** If no, either cylinders should be used as the air source or another form of respiratory protection should be used.
- **Can other workers and vehicles that might interfere with the airline be kept away from the area?** If no, another form of respiratory protection should be used.

4.7.3 ASR OPERATIONS

4.7.3.1 Fit-Check Procedures

Since most ASRs used around hazardous substances provide a positive pressure, it is very difficult to perform a negative-pressure

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check while connected to the air source. A negative-pressure check may be performed by covering the bottom of the inhalation tube with your hand while inhaling. The other fit checks may be perform like the APR fit-check procedures.

4.7.3.2 Operator Maintenance

Like the APR maintenance program, inspection for defects, cleaning and disinfecting, repair, and storage need to be included in the ASR maintenance program.

! **Field Inspection of Atmosphere-Supplying Respirators** C For a routinely used ASR, use the following procedures.

1. If the device has a tight-fitting facepiece, use the procedures outlined previously for APR, except those pertaining to the air-purifying elements.

2. If the device is a hood, helmet, blouse, or full suit, use the following procedures:

   C examine the hood, blouse, or full suit for rips and tears, seam integrity, or other defects;

   C examine the protective headgear, if required, for general condition, with emphasis on the suspension inside the headgear;

   C examine the protective faceshield, if any, for cracks, breaks, or impaired vision due to rebounding abrasive particles; and

   C make sure that the protective screen is intact and secured correctly over the faceshield of abrasive blasting hoods and blouses.

3. Examine the air-supply system for:

   C integrity and good condition of air supply lines and hoses, including attachments and end fittings; and

   C correct operation and condition of all regulators,

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valves, or other air-flow regulators.

On SCBA, determine that the high-pressure cylinder of compressed air is sufficiently charged for the intended use, preferably fully charged (mandatory for emergency devices). On closed-circuit SCBA, make sure that a fresh canister of CO_2 sorbent is installed before use, or in accordance with manufacturer's instructions. On open-circuit SCBA, recharge the cylinder if less than 80% of the useful service time remains. However, it is much preferred that an open-circuit SCBA be fully charged before use.

! **Cleaning and Disinfecting**CFollow the cleaning and disinfecting procedures for the APR, except during disassembly:

1. Remove the air tanks from the SCBA and send them to a charging station.
2. Check regulator for proper operation.

During cleaning and rinsing, remember to keep water temperatures between 120° and 140° F to ensure that the components are not damaged.

! **Reassembly**CThe facepiece of a SCBA can now be combined with the tested regulator and a full charged cylinder from the storage rack, and an operational check should be performed.

! **Maintenance**CMaintenance personnel should be thoroughly trained. They should be aware of their limitations and never try to replace components or make repairs and adjustments beyond the manufacturer's recommendations, unless they have been specially trained by the manufacturer. These restrictions apply primarily to maintenance of the more complicated devices, especially SCBA regulators.

An important aspect of any maintenance program is having enough spare parts on hand. Only continual surveillance of replacement rate will determine what parts in what quantities should be kept in stock. It is desirable to have some sort of record-keeping system to indicate spare parts usage and the inventory on hand.

4.8 PROTECTIVE CLOTHING AND ACCESSORIES

In this manual, personal protective clothing is considered to be any article offering skin and/or body protection. Each type of protective

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clothing has a specific purpose; many, but not all, are designed to protect against chemical exposure. It includes:

- fully-encapsulating suits;
- non-encapsulating suits;
- aprons, leggings, and sleeve protectors;
- gloves;
- firefighters' protective clothing;
- proximity, or approach, garments;
- blast and fragmentation suits;
- cooling garments; and
- radiation-protective suits.

Table 2

4.8.1 SELECTION OF CHEMICAL-PROTECTIVE CLOTHING (CPC)

Chemical-protective clothing (CPC) is available in a variety of materials that offer a range of protection against different chemicals. The most appropriate clothing material will depend on the chemicals present and the task to be accomplished. Ideally, the chosen material resists permeation, degradation, and penetration. Permeation is the process by which a chemical dissolves in and/or moves through a protective clothing material on a molecular level. Degradation is the loss of or change in the fabric's chemical resistance or physical properties due to exposure to chemicals, use, or ambient conditions (e.g., sunlight). Penetration is the movement of chemicals through zippers, stitched seams or imperfections (e.g., pinholes) in a protective clothing material.

Selection of chemical-protective clothing is a complex task and should be performed by personnel with training and experience. Under all conditions, clothing is selected by evaluating the performance characteristics of the clothing against the requirements and limitations of the siteC and task-specific conditions. If possible, representative garments should be inspected before purchase and their use and performance discussed with someone who has experience with the clothing under consideration. In all cases, the employer is responsible for ensuring that the personal protective clothing (and all PPE) necessary to protect employees from injury or illness that may result from exposure to hazards at the work site is adequate and of safe design and construction for the work to be performed (see OSHA standard 29 CFR Part 1910.132-1910.137).

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4.8.1.1 Permeation and Degradation

The selection of chemical-protective clothing depends greatly upon the type and physical state of the contaminants. This information is determined during site characterization. Once the chemicals have been identified, available information sources should be consulted to identify materials that are resistant to permeation and degradation by the known chemicals. The American Conference of Governmental Industrial Hygienists publishes *Guidelines for the Selection of Chemical-Protective Clothing*, which provides a matrix of clothing material recommendations for approximately 300 chemicals based on an evaluation of permeation and degradation data from independent tests, vendor literature, and raw material suppliers. Charts indicating the resistance of various clothing materials to permeation and degradation are also available from manufacturers and other sources. It is important to note, however, that no material protects against all chemicals and combinations of chemicals, and that no currently available material is an effective barrier to any prolonged chemical exposure.

In reviewing vendor literature, it is important to be aware that the data provided are of limited value. For example, the quality of vendor test methods is inconsistent; vendors often rely on the raw material manufacturers for data rather than conducting their own tests; and the data may not be updated. In addition, vendor data cannot address the wide variety of uses and challenges to which CPC may be subjected. Most vendors strongly emphasize this point in the descriptive text that accompanies their data.

Another factor to bear in mind when selecting CPC is that the rate of permeation is a function of several factors, including clothing material type and thickness, manufacturing method, the concentration(s) of the hazardous substance(s), temperature, pressure, humidity, the solubility of the chemical in the clothing material, and the diffusion coefficient of the permeating chemical in the clothing material. Thus permeation rates and breakthrough time (the time from initial exposure until hazardous material is detectable on the inside of the CPC) may vary depending on these conditions.

Most hazardous wastes are mixtures, for which specific data with which to make a good CPC selection are not available. Due to a lack of testing, only limited permeation data for multicomponent liquids are currently available.

Mixtures of chemicals can be significantly more aggressive towards CPC materials than can any single component alone. Even small amounts of a rapidly permeating chemical may provide a pathway that accelerates the permeation of other chemicals. Formal research is

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being conducted on these effects. NIOSH is currently developing methods for evaluating CPC materials against mixtures of chemicals and unknowns in the field. For hazardous waste site operations, CPC should be selected that offers the widest range of protection against the chemicals expected on site. Vendors are now providing CPC materialCcomposed of two or even three different materials laminated togetherCthat is capable of providing the best features of each material.

4.8.1.2 Heat Transfer Characteristics

The heat transfer characteristics of CPC may be an important factor in selection. Since most chemical-protective clothing is virtually impermeable to moisture, evaporative cooling is limited. The "clo" value (thermal insulation value) of chemical-protective clothing is a measure of the capacity of CPC to dissipate heat loss through means other than evaporation. The larger the clo value, the greater the insulating properties of the garment and, consequently, the lower the heat transfer. Given other equivalent protective properties, clothing with the lowest clo value should be selected in hot environments or for high work rates. Unfortunately, clo values for clothing are rarely available at present.

4.8.1.3 Other Considerations

In addition to permeation, degradation, penetration, and heat transfer, several other factors must be considered during clothing selection. These affect not only chemical resistance, but also the worker's ability to perform the required task. The following checklist summarizes these considerations.

- Durability

  - Does the material have sufficient strength to withstand the physical stress of the task(s) at hand? Will the material resist tears, punctures, and abrasions?
    Will the material withstand repeated use after contamination/decontamination?

- Flexibility

  - Will the CPC interfere with the workers' ability to perform their assigned tasks (this is particularly

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important to consider for gloves)?

! Temperature Effects

C Will the material maintain its protective integrity and flexibility under hot and cold extremes?

! Ease of Decontamination

C Are decontamination procedures available on site? Will the material pose any decontamination problems? Should disposable clothing be used?

! Compatibility with Other Equipment

C Does the clothing preclude the use of another, necessary piece of protective equipment (e.g., suits that preclude hardhat use in hardhat area)?

! Duration of Use

C Can the required task be accomplished before contaminant breakthrough occurs, or degradation of the CPC becomes significant?

4.8.1.4 Special Conditions

Fire, explosion, heat, and radiation are considered special conditions that require special-protective equipment. Unique problems are associated with radiation and it is beyond the scope of this manual to discuss them properly. A qualified health physicist should be consulted if a radiation hazard exists. When using special-protective equipment, it is important to also provide protection against chemicals, since the specialized equipment may provide little or no protection against chemicals which may also be present.

4.8.2 SELECTION OF ENSEMBLES

The individual components of clothing and equipment must be assembled into a full protective ensemble that both protects the worker from the site-specific hazards and minimizes the hazards and drawbacks of the PPE ensemble itself.

Personnel who work with hazardous waste or respond to emergencies involving hazardous materials and substances must wear protective clothing. Full-face respiratory protection provides the lungs, eyes, and gastrointestinal tract with a level of protection against airborne toxins.

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Chemical protective clothing protects the skin from direct contact with skin-destructive and skin-absorbable materials and substances.

Protective equipment has been divided into four (4) categories according to the degree of protection afforded against contact with known or anticipated toxic materials or substances.

Level A should be worn when the highest level of respiratory, skin, and eye protection is required or needed.

Level B should be worn when the highest level of respiratory protection is needed but a lesser level of skin protection is required.

Level C should be worn when the criteria for using air-purifying respiratory protection is met.

Level D should be worn only as a work uniform and not on any site with respiratory or skin hazard.

When activities are conducted where atmospheric contamination is known or suspected to exist, PPE must be worn. PPE is designed to prevent or reduce skin and eye contact with and inhalation or ingestion of the chemical substance.

Personal protective equipment is divided into four categories based on the degree of protection afforded.

I. Level ACTo be selected when the greatest level of skin, respiratory, and eye protection is required. The following constitute Level A equipment: it may be used as appropriate.

    1. Positive pressure, full face-piece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA, approved by the National Institute for Occupational Safety and Health (NIOSH).
    2. Totally-encapsulating chemical-protective suit.
    3. Coveralls.[1]
    4. Long underwear.[1]
    5. Gloves, outer, chemical-resistant.
    6. Gloves, inner, chemical-resistant.
    7. Boots, chemical-resistant, steel toe and shank.
    8. Hard hat (under suit).[1]
    9. Disposable protective suit, gloves and boots (depending on suit

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construction, may be worn over totally-encapsulating suit).

II. Level BCThe highest level of respiratory protection is necessary but a lesser level of skin protection is needed. The following constitute Level B equipment; it may be used as appropriate.

1. Positive pressure, full-facepiece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA (NIOSH approved).
2. Hooded chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; one or two-piece chemical-splash suit; disposable chemical-resistant overalls).
3. Coveralls.[1]
4. Gloves, outer, chemical-resistant.
5. Gloves, inner, chemical-resistant.
6. Boots, outer, chemical-resistant, steel toe and shank.
7. Boot-covers, outer, chemical-resistant (disposable.)[1]
8. Hard hat.[1]
9. Face shield.[1]

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[1] Optional, as applicable

III. Level CCThe concentration(s) and type(s) of airborne substance(s) is known and the criteria for using air purifying respirators are met. The following constitute Level C equipment; it may be used as appropriate.

1. Full-face or half-mask, air purifying respirators (NIOSH approved).
2. Hooded chemical-resistant clothing (overalls; two-piece chemical-splash suit; disposable chemical-resistant overalls).
3. Coveralls.[1]
4. Gloves, outer, chemical-resistant.
5. Gloves, inner, chemical-resistant.
6. Boots, outer, chemical-resistant, steel toe and shank.[1]
7. Boot-covers, outer, chemical-resistant (disposable.)[1]
8. Hard hat.[1]
9. Escape mask.[1]
10. Face shield.[1]

IV. Level DCA work uniform affording minimal protection, used for nuisance contamination only. The following constitute Level D equipment; it may be used as appropriate.

1. Coveralls.

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2. Gloves.[1]
3. Boots/shoes, chemical-resistant, steel toe and shank.
4. Boots, outer, chemical-resistant (disposable.)[1]
5. Safety glasses or chemical splash goggles[*].
6. Hard hat.[1]
7. Escape mask.[1]
8. Face shield.[1]

The types of hazards for which Levels A, B, C, and D protection are appropriate are described below:

I. Level ACLevel A protection should be used when:

1. The hazardous substance has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on either the measured (or potential for) high concentration of atmospheric vapors, gases, or particulates; or the site operations and work functions involve a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the skin;
2. Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible; or
3. Operations are being conducted in confined, poorly ventilated areas, and the absence of conditions requiring Level A have not yet been determined.

II. Level BCLevel B protection should be used when:

1. The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection;
2. The atmosphere contains less than 19.5 percent oxygen; or
3. The presence of incompletely identified vapors or gases is indicated by a direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the skin.

NOTE: This involves atmospheres with IDLH concentrations of specific substances that present severe inhalation hazards and that do not represent a severe skin hazard; or that do not meet the criteria for use

of air-purifying respirators.

III. Level CCLevel C protection should be used when:

1. The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin;
2. The types of air contaminants have been identified, concentrations measured, and an air-purifying respirator is available that can remove the contaminants; and
3. All criteria for the use of air-purifying respirators are met.

IV. Level DCLevel D protection should be used when:

1. The atmosphere contains no known hazard; and
2. Work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals.

NOTE: As stated before, combinations of personal protective equipment other than those described for Levels A, B, C, and D protection may be more appropriate and may be used to provide the proper level of protection.

These lists can be used as a starting point for ensemble creation; however, each ensemble must be tailored to the specific situation in order to provide the most appropriate level of protection. For example, if work is being conducted at a highly contaminated site or if the potential for contamination is high, it may be advisable to wear a disposable covering, such as Tyvek coveralls or PVC splash suits, over the protective ensemble. It may be necessary to slit the back of these disposable suits to fit around the bulge of an encapsulating suit and SCBA.

The type of equipment used and the overall level of protection should be reevaluated periodically as the amount of information about the site increases, and as workers are required to perform different tasks. Personnel should be able to upgrade or downgrade their level of protection with concurrence of the Site Safety Officer and approval of the Field Team Leader.

Reasons to upgrade:

- known or suspected presence of dermal hazards;
- occurrence or likely occurrence of gas or vapor emission;
- change in work task that will increase contact or potential contact with hazardous materials; and

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- request of the individual performing the task.

Reasons to downgrade:

- new information indicating that the situation is less hazardous than was originally thought;
- change in site conditions that decreases the hazard; and
- change in work task that will reduce contact with hazardous materials.

4.8.3 PPE MAINTENANCE

The technical depth of maintenance procedures varies. Manufacturers frequently restrict the sale of certain PPE parts to individuals or groups who are specially trained, equipped, and "authorized" by the manufacturer to purchase them. Explicit procedures should be adopted to ensure that the appropriate level of maintenance is performed only by individuals having this specialized training and equipment. The following classification scheme is often used to divide maintenance into three levels:

- Level 1: User or wearer maintenance, requiring a few common tools or no tools at all.
- Level 2: Shop maintenance that can be performed by the employer's maintenance shop.
- Level 3: Specialized maintenance that can be performed only by the factory or an authorized repair person.

4.8.4 INSPECTION

An effective PPE inspection program will probably feature five different inspections:

1. inspection and operational testing of equipment received from the factory or distributor;
2. inspection of equipment as it is issued to workers;
3. inspection after use or training and prior to maintenance;
4. periodic inspection of stored equipment; and
5. periodic inspection when a question arises about the appropriateness of the selected equipment, or when problems with similar equipment arise.

Each inspection will cover somewhat different areas in varying degrees

of depth. Detailed inspection procedures, where appropriate, are usually available from the manufacturer. The inspection checklists provided in Table 4 may also help.

Table 6 Sample PPE Inspection Checklists

! **Clothing**

CBefore use

[ ] Determine that the clothing material is correct for the specified task.

[ ] Visually inspect for:
imperfect seams,
non-uniform coatings,
tears, and
malfunctioning closures.

[ ] Hold up to light and check for pinholes.

[ ] Flex product:
observe for cracks, and
observe for other signs of shelf deterioration.

[ ] If the product has been used previously, inspect inside and out for signs of chemical attack:
discoloration,
swelling, and
stiffness.

Table 6 Sample PPE Inspection Checklists (continued)

CDuring the work task, periodically

[ ] Inspect for evidence of chemical attack such as discoloration, swelling, stiffening, and softening. Keep in mind, however, that chemical permeation can occur without any visible effects. Check for:
closure failure,
tears,
punctures, and
seam discontinuities.

! **Gloves**

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CBefore use

[ ] Pressurize glove to check for pinholes. Either blow into glove, then roll gauntlet toward fingers, or inflate glove and hold under water. In either case, no air should escape.

! **Fully-encapsulating suits**

CBefore use

[ ] Check the operation of pressure relief valves.

[ ] Inspect the fitting for wrists, ankles, and neck.

[ ] Check faceshield, if so equipped, for:
cracks,
crazing, and
fogginess.

! **Respirators**

CSelf-Contained Breathing Apparatus (SCBA)

[ ] Inspect SCBAs:
before and after each use,
at least monthly when in storage, and
every time they are cleaned.

[ ] Check all connections for tightness.

[ ] Check material conditions for: signs of pliability,
signs of deterioration, and
signs of distortion.

[ ] Check for proper setting and operation of regulators and valves (according to manufacturer's recommendations).

[ ] Check operation of alarm(s).

[ ] Check faceshields and lenses for:
cracks,

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crazing, and
fogginess.

CSupplied-air respirators (SAR)

[ ] Inspect SARs:
daily when in use,
at least monthly when in storage, and
every time they are cleaned.

[ ] Inspect air lines prior to each use for cracks, kinks, cuts, frays and weak areas.

[ ] Check for proper setting and operation of regulators and valves (according to manufacturer's recommendations).

[ ] Check all connections for tightness.

[ ] Check material conditions for:
signs of pliability,
signs of deterioration, and
signs of distortion.

[ ] Check faceshields and lenses for:
cracks,
crazing, and
fogginess.

Table 6 Sample PPE Inspection Checklists (continued)

CAir-purifying respirators

[ ] Inspect air-purifying respirators before each use to be sure they have been adequately cleaned, and:
after each use,
during cleaning, and
monthly if stored for emergency use.

[ ] Check material conditions for:
signs of pliability,
signs of deterioration, and
signs of distortion.

[ ] Examine cartridges or canisters to ensure that:
they are the proper type for the intended use,
the expiration date has not passed, and
they have not been opened or used

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previously.

[ ] Check faceshields and lenses for:
cracks,
crazing, and
fogginess.

4.8.4.1 Donning an Ensemble

A routine should be established and practiced periodically for donning a fully-encapsulating suit/SCBA ensemble. Assistance should be provided for donning and doffing since these operations are difficult to perform alone, and solo efforts may increase the possibility of suit damage.

Table 9 lists sample procedures for donning a fully-encapsulating suit/SCBA ensemble. These procedures should be modified depending on the particular type of suit and/or when extra gloves and/or boots are used. These procedures assume that the wearer has previous training in SCBA use and decontamination procedures.

Once the equipment has been donned, its fit should be evaluated. If the clothing is too small, it will restrict movement, thereby increasing the likelihood of tearing the suit material and accelerating worker fatigue. If the clothing is too large, the possibility of snagging the material is increased, and the dexterity and coordination of the worker may be compromised. In either case, the worker should be recalled and provided with better-fitting clothing.

Table 7 Sample Donning Procedures

1. Inspect the clothing and respiratory equipment before donning (see Inspection procedures).

2. Adjust hard hat or headpiece if worn, to fit user's head.

3. Open back closure used to change air tank (if suit has one) before donning suit.

4. Standing or sitting, step into the legs of the suit; ensure proper placement of the feet within the suit; then gather the suit around the waist.

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5. Put on chemical-restraint safety boots over the feet of the suit. Tape the leg cuff over the tops of the boots. If additional chemical-resistant boots are required, put these on now. Some one-piece suits have heavy-soled protective feet. With these suits, wear short, chemical-resistant safety boots inside the suit.

6. Put on air tanks and harness assembly of the SCBA. Don the facepiece and adjust it to be secure, but comfortable. Do not connect the breathing hose. Open valve on air tank.

7. Perform negative and positive respirator facepiece seal test procedures.

   - To conduct a negative-pressure test, close the inlet part with the palm of the hand or squeeze the breathing tube so it does not pass air, and gently inhale for about 10 seconds. Any inward rushing of air indicates a poor fit. Note that a leaking facepiece may be drawn tightly to the face to form a good seal, giving a false indication of adequate fit.

Table 7 Sample Donning Procedures (continued)

   - To conduct a positive-pressure test, gently exhale while covering the exhalation valve to ensure that a positive pressure can be built up. Failure to build a positive pressure indicates a poor fit.

8. Depending on type of suit:

   - Put on long-sleeved inner gloves (similar to surgical gloves).

   - Secure gloves to sleeves, for suits with detachable gloves (if not done prior to entering the suit).

   - Additional overgloves, worn over attached suit gloves, may be donned later.

9. Put sleeves of suit over arms as assistant pulls suit up and over the SCBA. Have assistant adjust suit around SCBA and shoulders to ensure unrestricted motion.

10. Put on hard hat, if needed.

11. Raise hood over head carefully to avoid disrupting face seal of SCBA mask. Adjust hood to give satisfactory comfort.

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12. Begin to secure the suit by closing all fasteners on openings until there is only adequate room to connect the breathing hose. Secure all belts and/or adjustable leg, head, and waistbands.

13. Connect the breathing hose while opening the main valve.

14. Have assistant first ensure that wearer is breathing properly, then make final closure of the suit.

15. Have assistant check all closures.

16. Have assistant observe the wearer for a period of time to ensure that the wearer is comfortable, psychologically stable, and that the equipment is functioning properly.

4.8.4.2 Doffing an Ensemble

Exact procedures for removing fully-encapsulating suit/SCBA ensembles must be established and followed to prevent contaminant migration from the work area and contaminant transfer to the wearer's body, the doffing assistant, and others.

Sample doffing procedures are provided in Table 6. Doffing procedures should be performed only after decontamination of the suited worker. They require a suitably attired assistant. Throughout the procedures, both worker and assistant should avoid any direct contact with the outside surface of the suit.

Table 8 Sample Doffing Procedures

If sufficient air supply is available to allow appropriate decontamination before removal:

1. Remove any extraneous or disposable clothing, boot covers, outer gloves, and tape.

2. Have assistant loosen and remove the wearer's safety shoes or boots.

3. Have assistant open the suit completely and lift the hood over the head of the wearer and rest it on top of the SCBA tank.

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4. Remove arms, one at a time, from suit. Once arms are free, have assistant lift the suit up and away from the SCBA backpackCavoiding any contact between the outside surface of the suit and the wearer's bodyCand lay the suit out flat behind the wearer. Leave internal gloves on, if any.

5. Sitting, if possible, remove both legs from the suit.

6. Follow procedure for doffing SCBA.

7. After suit is removed, remove internal gloves by rolling them off the hand, inside out.

8. Remove internal clothing and thoroughly cleanse the body.

Table 8 Sample Doffing Procedures (continued)

If the low-pressure warning alarm has sounded, signifying that approximately 5 minutes of air remain:

1. Remove disposable clothing.

2. Quickly scrub and hose off, especially around the entrance/exit zipper.

3. Open the zipper enough to allow access to the regulator and breathing hose.

4. Immediately attach an appropriate canister to the breathing hose (the type and fittings should be predetermined).

Note: Although this provides some protection against any contamination still present, it voids the certification of the unit.

5. Follow Steps 1 through 8 of the regular doffing procedure above. Take extra care to avoid contaminating the assistant and wearer.

4.8.5 IN-USE MONITORING OF PERSONAL PROTECTIVE EQUIPMENT

The wearer must understand all aspects of the clothing operation and its limitations; this is especially important for fully-encapsulating ensembles where misuse could potentially result in suffocation.

During equipment use, workers should be encouraged to report any perceived problems or difficulties to their supervisor(s). These

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malfunctions include, but are not limited to:

- degradation of the protective ensemble;
- perception of odors;
- skin irritation;
- unusual residues on PPE;
- discomfort;
- resistance to breathing;
- fatigue due to respirator use;
- interference with vision or communication;
- restriction of movement; and
- personal responses such as rapid pulse, nausea, and chest pain.

If a supplied-air respirator is being used, all hazards that might endanger the integrity of the air line should be removed from the working area prior to use. During use, air lines should be kept as short as possible, and other workers and vehicles should be excluded from the area.

4.8.6 CLOTHING REUSE

Chemicals that have begun to permeate clothing during use may not be removed during decontamination and may continue to diffuse through the material toward the inside surface, presenting the hazard of direct skin contact to the next person who uses the clothing.

Where such potential hazards may develop, clothing should be checked inside and out for discoloration or other evidence of contamination. This is particularly important for fully encapsulating suits, which are generally subject to reuse due to their cost. Note, however, that negative (i.e., no chemical found) test results do not necessarily prove that some absorbed chemical has not reached the suit's interior.

At present, little documentation exists about clothing reuse. Reuse decisions must consider the known factors of permeation rates as well as the toxicity of the contaminants(s). In fact, unless extreme care is taken to ensure that clothing is properly decontaminated and that the decontamination does not degrade the material, it is not advisable to reuse chemical protective clothing that has been contaminated with toxic chemicals.

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4.8.7 STORAGE

Clothing and respirators must be stored properly to prevent damage or malfunction due to exposure to dust, moisture, sunlight, damaging chemicals, extreme temperatures, and impact. Procedures must be specified for both pre-issuance warehousing and, more importantly, post-issuance (in-use) storage. Many equipment failures can be directly attributed to improper storage.

4.8.7.1 Clothing

Potentially contaminated clothing should be stored in an area separate from street clothing.

Potentially contaminated clothing should be stored in a well-ventilated area, with good air flow around each item, if possible.

Different types and materials of clothing and gloves should be stored separately to prevent issuing the wrong type or material by mistake.

Protective clothing should be folded or hung in accordance with manufacturers' recommendations.

4.8.7.2 Respirators

SCBAs, supplied-air respirators, and air-purifying respirators should be dismantled, washed, and disinfected after each use.

SCBAs should be stored in storage chests supplied by the manufacturer. Air-purifying respirators should be stored individually in their original cartons or carrying cases, or in heat-sealed or resealable plastic bags.

4.8.8 TRAINING

Training in PPE use is recommended and, for respirators, required by federal regulation in the OSHA standards in 29 CFR Part 1910 Subparts I and Z. This training:

- allows the user to become familiar with the equipment in a nonhazardous situation;
- instills confidence of the user in his/her equipment;
- makes the user aware of the limitations and capabilities of the equipment;
- increases the efficiency of operations performed by workers wearing PPE;
- may increase the protective efficiency of PPE use; and
- reduces the expense of PPE maintenance.

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Training should be completed prior to actual PPE use in a hazardous environment and should be repeated at least annually. At a minimum, the training portion of the PPE program should delineate the user's responsibilities and explain the following, utilizing both classroom and field training when necessary:

- OSHA requirements as delineated in 29 CFR Part 1910 Subparts I and Z;
- the proper use and maintenance of the selected PPE, including capabilities and limitations;
- the nature of the hazards and the consequences of not using the PPE;
- the human factors influencing PPE performance;
- instruction in inspecting, donning, checking, fitting, and using PPE;
- individualized respirator fit testing to ensure proper fit;
- use of PPE in normal air for a long familiarity period and, finally, wearing PPE in a test atmosphere to evaluate its effectiveness;
- the user's responsibility (if any) for decontamination, cleaning, maintenance, and repair of PPE;
- emergency procedures and self-rescue in the event of PPE failure;
- the buddy system; and
- the Site Safety Plan and the individual's responsibilities and duties in an emergency.

The discomfort and inconvenience of wearing PPE can create a resistance to the conscientious use of PPE. One essential aspect of training is to make the user aware of the need for PPE and to instill motivation for the proper use and maintenance of PPE.

4.9 HEAT/COLD STRESS MANAGEMENT

Heat stress and cold injury are major hazards, especially for workers wearing protective clothing. The same protective materials that shield your body from chemical exposure also limit the dissipation of body heat and moisture. Heat stress can cause impaired abilities, fatigue, cramps, exhaustion, heat stroke, and even death. Careful training and frequent monitoring of personnel who wear protective clothing, appropriate scheduling of work and rest periods, and frequent replacement of fluids can protect against this hazard. Frostbite, hypothermia, and an impaired ability to work are dangers at low

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temperatures and when the wind-chill factor is low.

4.9.1 OCCUPATIONAL HEAT STRESS

The four primary factors of occupational heat stress are:

- environmental temperature;
- radiant heat;
- humidity; and
- workload.

Wearing PPE puts a hazardous waste worker at considerable risk of developing heat stress. This can cause health effects ranging from transient heat fatigue to serious illness or death. Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, and individual characteristics. Heat stress is the most common (and potentially serious) illness at hazardous waste sites. Regular monitoring and other preventive precautions are critical to protect workers from heat stress.

Individuals vary in their susceptibility to heat stress. Factors that may predispose someone to heat stress include:

- lack of physical fitness;
- lack of acclimatization;
- age;
- dehydration;
- obesity;
- alcohol and drug use;
- infection;
- sunburn;
- diarrhea; and
- chronic disease.

Reduced work tolerance and increased risk of excessive heat stress are directly influenced by the amount and type of PPE worn. PPE adds weight and bulk, severely reduces you body's access to normal heat exchange mechanisms (evaporation, convection, and radiation), and increases your energy expenditure. Therefore, when selecting PPE, carefully evaluate each item's benefit relative to its potential for increasing the risk of heat stress.

4.9.2 HEAT-RELATED ILLNESS AND TREATMENT

When you wear PPE in a hot environment and do heavy work, your body's response to this excessive heat load can easily be recognized. Heat stress may cause several harmful health effects: heat fatigue,

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heat cramps, heat exhaustion, and heat stroke.

The following lists provide characteristic signs and symptoms of heat stress. These lists also include the correct first aid to administer under these conditions.

4.9.2.1 Heat Fatigue

Heat fatigue is a common effect of prolonged heat exposure that produces discomfort and psychological strain. Heat fatigue can cause you to lose coordination and alertness, and you may also develop a heat rash. Heat fatigue and rash may result from continuous exposure to heat or humid air.

! Symptoms:
  Crash;
  Cedema; and
  Cfatigue.

! First aid:
  Cmove to a cooler place and rest.

4.9.2.2 Heat Cramps

Heat cramps are painful muscle spasms caused by excessive perspiration through which you lose large amounts of water and salts. Heat cramps are caused by heavy sweating with inadequate fluid and salt replacement.

! Symptoms:
  Cmuscle spasms; and
  Cpain in the hands, feet, and abdomen.

! First aid:
  Cmove to cool place, in resting position;
  Cdrink cool saline water (1 teaspoon salt per 8 ounces water);
  Cdo not use hotpacks; and
  Cdo not massage the cramping area.

4.9.2.3 Heat Exhaustion

Heat exhaustion is caused by the excessive loss of fluid and/or salt

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through perspiration. The symptoms of heat exhaustion include extreme weakness, nausea, or headache.

Heat exhaustion occurs from increased stress on various body organs and from inadequate blood circulation due to cardiovascular insufficiency or dehydration.

! Symptoms:
Cpale, cool, moist skin;
Cheavy sweating;
Cdizziness;
Cnausea; and
Cfainting.

! First aid:
Clay down in a cool place;
Cloosen clothing; and
Cif conscious, drink saline water (1 teaspoon salt per 8 ounces water).

4.9.2.4 Heat Stroke

Heat stroke is the most serious effect of heat stress and can occur with little or no warning. It occurs when your body's heat regulatory process fails under stress, and your sweating stops. It can be fatal if you do not receive immediate treatment. Heat stroke is the most serious form of heat stress. Temperature regulation fails, and the body temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur. Competent medical help must be obtained.

! Symptoms:
Cred, hot, usually dry skin;
Clack of or reduced perspiration;
Cnausea;
Cdizziness and confusion;
Cstrong, rapid pulse; and
Ccoma.

! First aid:
Ccool immediately;
Cremove clothing, cover with wet sheet;
Cplace in air-conditioned area or cool with fan;
Ctransport to medical facility immediately;
Cadminister oxygen, if possible; and
Cdo not apply rubbing alcohol (some may be absorbed through the skin).

4.9.3 MONITORING HEAT STRESS

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Because the incidence of heat stress depends on a variety of factors, all workers, even those not wearing PPE, should be monitored.

- Workers who wear permeable clothing (standard cotton or synthetic work clothing), must follow recommendations for monitoring requirements and suggested work/rest schedules in the current American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values for Heat Stress. If the actual clothing worn differs from the ACGIH standard ensemble in insulation value and/or wind and vapor permeability, change the monitoring requirements and work rest schedules accordingly.

- The ACGIH standard does not apply to workers who wear semipermeable or impermeable encapsulating ensembles. These workers should be monitored when the temperature in their work area is above 70° F.

To monitor workers for heat stress, you must measure:

- **Heart Rate**. Count the radial pulse for 30 seconds at the beginning of the rest period. If the heart rate exceeds 110 beats per minute, shorten the following work cycle by one-third, and keep the rest period the same. If the heart rate still exceeds 110 beats per minute at the beginning of the next rest period, shorten the next work cycle by an additional one third. For example, if heart rate is excessive at the end of a one-hour cycle, change the next work cycle to 40 minutes (2/3 of 60 minutes); if the heart rate is still excessive at the next rest period, change the next work cycle to 27 minutes (2/3 of 40 minutes).

- **Oral temperature**. Use a clinical thermometer (3 minutes under the tongue) or a similar device to measure the oral temperature at the end of the work cycle (before drinking).

  - If oral temperature exceeds 99.6^{o} F, shorten the next work cycle by one third without changing the rest period.

  - If oral temperature still exceeds 99.6^{o} F, shorten the next work cycle by one third.

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C Do not permit a worker to wear a semipermeable or impermeable garment when his/her temperature exceeds 100.6° F.

! **Body water loss, if possible**. Measure worker's weight on a scale accurate to "0.25 lb at the beginning and end of each work day to see if enough fluids are being taken to prevent dehydration. Weights should be taken while the employee is nude or at least wearing similar clothing. The body water loss should not exceed 1.5 percent total body weight in a work day.

Initially, the frequency of physiological monitoring depends on the air temperature adjusted for solar radiation and the level of physical work. The length of the work cycle will be governed by the frequency of the required physiological monitoring.

4.9.4 PREVENTION OF HEAT STRESS

Proper training and prevention measures will help avert serious illness and loss of work productivity. Preventing heat stress is particularly important because after someone suffers from heat stroke or heat exhaustion, that person may be predisposed to additional heat injuries. To avoid heat stress, in workers, management should take the following steps.

! **Adjust work schedules**. Modify work/rest schedules according to monitoring results. Mandate work slowdowns as needed.

! **Rotate personnel**. Alternate job functions to minimize excessive stress or overexertion at one task. Add additional personnel to work teams. Perform work during cooler hours of the day if possible, or at night if adequate lighting can be provided.

! **Provide shelter**. Use air conditioning, if possible, or shaded areas to protect personnel during rest periods.

! **Maintain workers' body fluids** at normal levels. This is necessary to ensure that the cardiovascular system functions adequately. Daily fluid intake must approximately equal the amount of water lost in sweat, that is, 8 fluid ounces (0.23 liters) of water must be ingested for every 8 ounces of perspiration lost. The normal thirst mechanism is not sensitive enough to ensure that enough water will be drunk to replace perspiration lost.

When heavy sweating occurs, encourage the worker to drink

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more. The following strategies may be useful.

CMaintain drinking water temperature at 50° to 60° F (10° to 15.6^o C).

CProvide small, disposable cups that hold about 4 ounces.

CHave workers drink 16 ounces of fluid before beginning work.

CUrge workers to drink a cup or two every 15 to 20 minutes, or at each break. A total of 1 to 1.6 gallons of fluid per day is recommended, but more may be necessary to maintain body weight.

CWeigh workers before and after work to determine if fluid replacement is adequate.

! Encourage workers to **maintain** an **optimal level of physical fitness.**

CWhere indicated, acclimatize workers to site work conditions: temperature, protective clothing, and workload.

CUrge workers to maintain normal weight levels.

! **Provide cooling devices** to aid natural body heat exchange during prolonged work or severe heat exposure. Cooling devices include:

Cfield showers or hose-down areas to reduce body temperature and/or to cool off protective clothing. Cooling jackets, vests, or suits to cool inside the suits; and

Cfans for spot cooling, and air conditioning of an enclosed space for indoor workers.

4.9.4.1 <u>Use of Ice Vest</u>

An ice vest is an insulated vest with a number of small pockets into which sealed packets of ice are inserted. It is used to remove excess heat generated by worker activity, the equipment, or the environment. These jackets may pose ice storage or recharge problems.

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When using an ice vest, use the following procedures.

- Carry the ice vest to the job site in an insulated container to prevent melting of the ice packets.
- Wear an undergarment under the ice vest; never allow the ice vest to make direct contact with to skin.
- Wear the ice vest loosely until you are ready to enter the hot environment.
- Just before entering the hot environment, make sure the ice vest is closed tightly beneath your protective garments.
- When removing the ice vest, remember to check for, and discard, any broken or leaking ice packets.
- The ice vest and its liquid packets should be returned to a freezer for about 24 hours before reuse.

4.9.5 APPROPRIATE HEALTH PRACTICES

It's important to drink an adequate amount of liquids each day. Many of the harmful effects of heat stress result from fluid and salt loss caused by sweating. As much as 8 to 24 pints of body fluid could be lost each day while working in a hot environment. If that much water is not replaced, dehydration (water depletion) occurs.
Dehydration is a serious health problem. Death from dehydration can occur if 18 to 20 pints of fluid are lost from the body without replacement. Dehydration may not always occur rapidly. Whether the water depletion occurs rapidly in a single day, or progressively over many days, the end result is the same. You can avoid the dangers of dehydration by drinking enough water each day to equal the water lost by sweating. It is best to drink small amounts of water frequently during the day. Weighing yourself before and after work is one way to monitor your water loss.

To prevent salt depletion, you can increase your use of salt on food. However, if you have heart problems, or are on a "low sodium" diet, consult your physician before following this recommendation.

Consumption of alcoholic beverages can greatly enhance dehydration. Do not drink alcoholic beverages during off hours if you anticipate working in a hot environment.

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4.9.6 COLD STRESS AND INJURY

Cold stress injury (hypothermia and frostbite) may result from exposure to a cold environment without proper protection. High winds with severe cold lower the apparent temperature by increasing the wind chill factor and may increase the risk of frostbite and hypothermia. The wind chill factor is a measure of the cooling effect of the wind velocity and cold temperatures. Please refer to the wind chill chart in Appendix A. Snow blindness may also occur in cold environments; it is caused by bright sunlight reflecting from snow.

4.9.6.1 Hypothermia

Hypothermia is the general cooling of the body; it is a very serious and often fatal condition. Normal human body temperature is 98.6^{o} F or 37° C. A person shows signs of hypothermia when their core body temperature falls below 95° F (35° C). Below 86° F (36° C), the brain functions may cease and the person is in grave danger. Some people, especially children, have survived a body temperature of 65° F (18.3^{o} C), but usually with irreversible brain damage and loss of fingers or toes. Hypothermia may develop as a result of exposure to an above-freezing temperature on or off the job. Dehydration from lack of water may contribute to the effects of hypothermia. Drink as much water as possible and melt snow to drink, but don't eat snow because this will lower your body temperature further. Exhaustion, hunger, drunkenness, drug use, and high altitudes may also contribute to frostbite and hypothermia. Symptoms of hypothermia may include:

- lack of coordination;
- shivering (may be absent);
- semi-consciousness progressing to coma;
- slow, irregular pulse;
- body temperature below 95° F (35° C); and
- cardiac arrest.

4.9.6.2 Frostbite

Frostbite occurs when body tissues freeze. **Frostnip** occurs when ice crystals begin to form in the skin. Frostbite first appears in the exposed areas of the face, ears, nose, fingers, hands, feet, and toes. Water expands as ice crystals form, and this may rupture the tissues. Frostbite can also be caused by skin contact with leaking compressed

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gas or cryogenic liquids. Frostbite victims may also develop hypothermia.

The early onset of superficial frostbite may be painless, so you can be unaware that damage is occurring. Early warnings are:

- dull aches in the extremities;
- redness of the skin; and
- loss of flexibility in the extremities.

Advanced deep frostbite is painless and results in cold, gray, or mottled blue-white skin. The skin and muscles will also be hard and inflexible.

4.9.6.3 Snow Blindness

Snow blindness can result from the bright reflection of the sun on the snow resulting in eye fatigue, severe pain, and sometimes permanent blindness.

4.9.7 PREVENTION

To prevent hypothermia and frostbite when going out in the cold:

- always wear layers of clothing and take extra layers to put on in case you are trapped outdoors;
- wear hat, gloves and coat. A hat prevents loss of heat from the scalp;
- change any wet clothing immediately;
- eat high-carbohydrate food to provide energy to keep you warm;
- stay active and keep moving. Try not to sleep unless you are warm in a sleeping bag;
- check medications with a doctor. Barbiturates, such as nembutal and seconal; and phenothiazines, such as compatine, triavil, and thorzine, can induce hypothermia;
- use protective equipment to conserve your body heat;
- don't drink alcoholic beverages. Drink water, melted snow, or hot beverages to prevent dehydration;
- always work or travel with a buddy, not alone; and
- to prevent snow blindness, wear appropriate dark glasses with side shields.

4.9.8 TREATING COLD-RELATED INJURIES

Cold-related injuries such as hypothermia and frostbite should be treated as soon as possible.

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4.9.8.1 Hypothermia

Never assume that a hypothermic person is dead until after you have warmed the person up. To treat a patient with hypothermia:

- ensure that the patient can breathe comfortably; for accident victims, immobilize the spine;
- begin basic life support procedures if necessary;
- remove wet clothing and keep the body dry;
- rewarm the patient with blankets and warm packs; and
- place the patient next to another person with normal body heat, or place the patient between two persons in a sleeping bag.

4.9.8.2 Frostbite

You must rewarm all affected areas rapidly by applying warm water; the water temperature should be 104°-106° F (40°-41.1^{o} C). Do not place the affected extremity over a fire or on a hot radiator. Excessive heat can cause even greater tissue damage. When frostbite and severe hypothermia coexist, delay rapid rewarming of extremities until the patient's core body temperature nears a normal 98.6^{o} F (37° C).

As rewarming occurs, the tissue should turn pink and become painful; this is a positive sign that the tissue is returning to a normal condition. The patient may complain of burning, prickling, or numbness.

- Pad and splint the frostbitten area to protect the tissue from further injury.
- If blisters develop, do not disturb or break them.
- Do not remove clothes frozen to the affected area until after the area is thawed.
- Do not let the patient smoke, since nicotine causes constriction of the small blood vessels in the extremities.
- Do not apply ointments.
- Do not rub the frostbitten area with snow or ice; this will only add to the injury.
- Do not attempt rapid thawing if there is any chance of refreezing.
- Do not let the patient drink alcoholic beverages.

4.9.9 WHAT TO DO WHEN TRAPPED OUTDOORS

Don't panicCsit down, have a drink, stay calm, and think.

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Maintain your body temperature by adding layers of clothing and eating heat-producing foods (carbohydrates). Find or build a shelter that will protect you from the rain and wind. Drink warm or hot liquids.

- **Build a fire** to dry clothing, heat water, signal rescuers and help maintain your morale. Be cautious of enclosed areas and CO (carbon monoxide) accumulation.
- **Prevent dehydration**Cdrink water (3-4 quarts per day). Do not eat snow, melt it first.
- **Prevent hypothermia**Cwatch out for cool or cold, wet, windy conditions that cause massive heat loss.
- **Do not travel**Cstay put and wait for rescue forces to find you.
- **Signal**Cuse a signal mirror, whistle, or flares to attract attention to yourself.
- **Do not give up hope**Crescuers will find you.

4.10 EFFECTS OF NOISE EXPOSURE

About one in every ten Americans suffers from some degree of hearing loss caused by instant loud noises or long-term exposure to high noise levels. The most destructive form of hearing loss is nerve damage. It occurs when the sensitive, tiny hair cells in the inner ear are damaged and cease to function, causing permanent loss of hearing. Since these hair cells can never be repaired or replaced, you need to prevent this type of ear damage.

Early hearing loss is frequently not noticed. In the beginning stages, high pitched squeaks and sounds like birds chirping cannot be heard. In time, hearing loss spreads to the range of speech sounds where words in normal conversation become difficult to understand. Even though a person can still hear some sounds, others may be unclear or distorted. Distortion occurs especially when there are background noises or many people talking.

Excessive noise can quicken the pulse, increase the heart rate, increase blood pressure, and narrow blood vessels. Over a long period of time, added burden is placed on the heart.

Excessive noise may also put stress on other parts of the body by causing the abnormal secretion of hormones and tensing of muscles. Workers exposed to noise sometimes complain of nervousness, sleeplessness, and fatigue. Excessive noise exposure also can reduce job performance and may cause high rates of absenteeism. The extent of damage depends on:

- the loudness or intensity measured in decibels;
- pitch or frequency (some high-pitched sounds may be more damaging than low-pitched ones); and

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! the length of time of exposure.

OSHA regulation 29 CFR 1910.95 (the hearing conservation amendment) limits a worker's noise exposure to 95 decibels, A-weighted (dBA) for an 8-hour exposure. Time limits are shorter for higher noise levels (Table 10). A decibel is the unit used in sound level measurements. An A-weighted scale is used on the measuring instrument so that the instrument responds to the different sound frequencies in the same way as the human ear.

IITable 9 Limits for Human Exposure to Noise

{PRIVATE }	**Sound level**	**Exposure Limits**
	dBA	hours per day
	80 *	32.0
	83 *	21.0
	85	16.0
	87	12.0
	90	8.0
	92	6.0
	94	4.0
	97	3.0
	100	2.0
	102	1.5
	105	1.0
	110	0.5
	115	0.25
	120	0.125
	130	0.03

* Sound levels below 85 dBA in themselves are not considered a problem. However, levels between 80 and 85 do contribute to the total exposure and thus are used in calculations. Source: Table G-16, 29 CFR 1910.95, Occupational Safety and Health Administration General Industry Standards, 1986.

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4.10.1 CALCULATING NOISE EXPOSURE

When daily noise exposure is composed of two or more periods of different noise levels, their combined effect should be considered, rather than the individual effect of each. If the sumCa time-weighted average (TWA)Cof the following fractions $C_1/T_1 + C_2/T_2 \ldots C_n/T_n$ exceeds 1, then the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specific noise level, and T_n indicates the total time of exposure permitted at that level.

For example, for two hours exposure to 80 dBA:

- ! C_1Ctotal exposure time at specified levelCis 2 (two hours of exposure to 80 dBA);
- ! T_1Ctotal exposure time permittedCis 32 (from the table above, 32 is the total exposure time permitted for 80 dBA); therefore
- ! C_1/T_1Cone fraction of the time-weighted averageCis 2/32.

Determine the time-weighted average for a worker with the following exposure amounts:

Sound Level (dBA)	Exposure Amount (hours)	Exposure Limit *
80	2	32
85	1	16
90	4	8
94	1	4

* Values are taken from table on previous page.

The TWA is 2/32 + 1/16 + 4/8 + 1/4 = 0.875

Recent rulemaking by OSHA requires a continued, effective hearing conservation program whenever worker noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (dBA). The TWA for eight hours of exposure to 85 decibels is 8/16 or 0.5. In the example average above, the exposure level was 0.875, which is greater than 0.5. Therefore, a hearing conservation program would be necessary in that instance.

4.11 HEARING CONSERVATION

The main elements of the hearing conservation program are:

- ! an audiometric testing program for those exposed above

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an 85 dBA TWA;

- hearing protection available for those exposed above an 85 dBA TWA;
- hearing protection required for those exposed above 90 dBA, or above 85 dBA and the worker shows a permanent significant hearing loss;
- reducing the noise level;
- informing exposed workers about noise hazards (or effects);
- informing exposed workers about the elements of a hearing conservation program;
- recordkeeping; and
- a facility/worker monitoring program.

4.11.1 AUDIOMETRIC TESTING PROGRAM

Audiometric testing not only monitors the sharpness or acuity of an employee's hearing over time, but also provides an opportunity to educate employees about their hearing and the need to protect it. The important elements of an audiometric testing program include baseline audiograms, annual audiograms, training, and follow-up procedures.

Audiometric testing must be provided to all employees who are exposed to an eight-hour time-weighted average sound level of 85 dBA. And the audiometric testing program follow-up should indicate whether hearing loss is being prevented by the employer's hearing conservation program. A professional audiologist (specialist dealing with individuals having impaired hearing), an otolaryngologist (physician specializing in the diagnosis and treatment of disorders of the ear, nose, and throat), or a physician must be responsible for the program.

Both professionals and trained technicians may conduct audiometric testing. The professional does not have to be present when a qualified technician is conducting testing. The professional responsibilities include overseeing the program and the work of the technicians, reviewing problem audiograms, and determining whether referral is necessary.

There are two types of audiograms required in the hearing conservation program: baseline and annual audiograms.

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4.11.1.1 Baseline Audiograms

The baseline audiogram is the reference audiogram against which future audiograms are compared. Baseline audiograms must be provided within 6 months of an employees's first exposure at or above an 8-hour TWA of 85 dB. Where employers are using mobile test vans to obtain audiograms, baseline audiograms must be completed within one year after an employee's first exposure to workplace noise at or above a TWA of 85 dB. Where mobile vans are used and employers are allowed to delay baseline testing for up to a year, after 6 months their employees exposed at or above 85 dB must be issued and fitted with hearing protectors to be worn until the baseline audiogram is obtained.

4.11.1.2 Annual Audiograms

The annual audiograms must be conducted within one year of the baseline. It is important to test hearing on an annual basis in order to identify changes in hearing ability so that protective follow-up measures can be initiated before hearing loss progresses. Annual audiograms must be routinely compared to baseline audiograms to determine whether the audiogram is accurate and to determine whether the employee has lost hearing ability (that is, if a standard threshold shift (STS) has occurred). STS is defined as an average shift in either ear of 10 dB or more at 2000, 3000, or 4000 Hz. An averaging method of determining STS was chosen because it diminishes the number of persons falsely identified as having STS who are later shown not to have had a change in hearing ability.

4.11.1.3 Audiogram Evaluation

If an STS is identified, employees must be fitted or refitted with adequate hearing protectors, shown how to use them, and required to wear them. Employees must be notified within 21 days from the time the determination is made that their audiometric test results showed an STS. Some employees with an STS may need to be referred for further testing if the professional determines that their test results are questionable or if they have an ear problem of a medical nature which is thought to be caused or aggravated by wearing hearing protectors. If the suspected medical problem is not thought to be related to wearing protectors, employees must be informed that they should see a physician. If subsequent audiometric tests show that the STS identified on a previous audiogram is not persistent, employees whose exposure to noise is less than a TWA of 90 dBA may discontinue wearing hearing protectors.

A subsequent audiogram may be substituted for the original baseline audiogram if the professional supervising the program determines that

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the employee's STS is persistent. This substitution will ensure that the same shift is not repeatedly identified. The professional may also decide to revise the baseline audiogram if an improvement in hearing has occurred. This will ensure that the baseline reflects actual hearing thresholds to the extent possible.

4.11.2 HEARING PROTECTORS

Hearing protectors must be available to all workers exposed to eight-hour TWA noise levels of 85 dBA or above. This requirement will ensure that employees have access to protectors before they experience a loss in hearing. As a general guideline, hearing protection may be needed if you have to raise your voice to be heard at arm's length. Hearing protectors must be worn by:

- employees for any period exceeding six months from the time they are first exposed to eight-hour TWA noise levels of 85 dBA or above until they receive their baseline audiograms in situations where baseline audiograms are delayed because it is inconvenient for mobile test vans to visit the workplace more than once a year; or
- employees who have incurred standard threshold shifts since these workers have demonstrated that they are susceptible to noise; and
- employees exposed over the permissible exposure level, an eight-hour TWA of 90 dBA or above.

Employees should decide, with the help of a person who is trained in fitting hearing protectors, which size and type of protectors are most suitable for their working environment. The protector selected should be comfortable to wear and offer sufficient noise attenuation to prevent hearing loss. While wearing hearing protectors, you will still be able to hear signals from machinery if the signals are louder than the background noise; however, the signal may sound different to you.
Hearing protectors must adequately reduce the severity of the noise level for each employee's work environment. The employer must re-evaluate the suitability of the employee's present protector whenever there is a change in working conditions that may cause the hearing protector being used to be inadequate. If workplace noise levels increase, employees must be given more effective protectors. The protector must reduce employee exposures to at least 90 dB and to 85 dB when a standard threshold shift has already occurred in the worker's hearing. Employees must be shown how to use and care for

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their protectors and must be supervised on the job to ensure that they continue to wear them correctly.

There are three basic types of protective devices for your hearing. Each is safe, comfortable, and allows you to move and work freely.

- The **soundband** is worn over the head or under the chin and fits into the outer ears. It is lightweight and easily cleaned.
- The **ear muff** is a cup-like device that covers the entire outer ear. It can be adjusted to fit comfortably and securely.
- **Ear plugs** are made in two types. The molded type plugs must be fitted the first time by a nurse or physician and must be properly cleaned after each use. Foam-type ear plugs fit in the ear canal and can be inserted without prior fitting but must be inserted properly. They are inexpensive, disposable, and more sanitary than other types.

4.11.3 REDUCING THE NOISE LEVEL

If the combined effect exceeds the allowable limits, the employer must use "engineering controls" (changes in the physical environment like noise enclosures, mufflers, quieter tools) or "administrative controls" (limits on individual worker exposure time) in order to comply with the law. While such controls are being implemented, workers must be provided with personal protective equipment (PPE) to protect their hearing. Hearing protectors are assigned a Noise Reduction Rating (NRR) developed by EPA. The NRR for each device is provided on its packaging.

4.11.4 TRAINING

Informing exposed workers about noise hazards (or effects) is one element of a hearing conservation program. Employee training is very important. When workers understand the reasons for the hearing conservation program's requirements and the need to protect their hearing, they will be better motivated to participate actively in the program and to cooperate by wearing their protectors and taking audiometric tests.

Employees exposed to TWAs of 85 dBA and above must be trained at least annually in the effects of noise, the purpose, advantages, and disadvantages of various types of hearing protectors; the selection, fitting and care of protectors; and the purpose and procedures of audiometric testing. The training program may be structured in any format, different parts being conducted by different individuals and at different times as long as the required topics are covered.

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4.11.5 RECORDKEEPING

Noise exposure measurement records must be kept for two years from the dates they were recorded. In addition, records of audiometric test results must be maintained for the duration of employment of the affected employee. Audiometric test records must include the name and job classification of the employee, the date, the examiner's name, the date of acoustic or exhaustive calibration, measurements of the background sound pressure levels in audiometric test rooms, and the employee's most recent noise exposure measurement.

4.11.6 FACILITY AND WORKER MONITORING PROGRAM

The Environmental Protection Agency (EPA) recommends that, for an eight-hour work day, workers should not be exposed to noise levels above a TWA of 95 dBA. EPA's goal is to reduce that level to 85 dBA. They also recommend that people should not be exposed to a TWA of 70 dBA for an entire 24-hour day. The hearing conservation amendment requires employers to monitor noise exposure levels in a manner that will accurately identify employees who are exposed to noise at or above 85 decibels (dBA) averaged over eight working hours, called an eight-hour time-weighted average (TWA). The exposure measurement must include all noise within an 80 dBA to 130 dBA range and must be taken during a typical work situation. This requirement is performance oriented since it allows employers to choose the monitoring method that best suits each individual situation.

Employees are entitled to observe monitoring procedures and they must be notified of the results of the exposure monitoring of their workplace. The method used to notify employees is left to the discretion of the employers.

Instruments used for monitoring employee exposures must be carefully checked or calibrated to ensure that the measurements are accurate. Calibration procedures are unique to specific instruments. Employers have the duty to ensure that the measuring instruments they are using are properly calibrated. They should follow the manufacturer's instructions to determine when and how extensively to calibrate each type of instrument.

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Table 2 Personal Protective Equipment{PRIVATE **}**

BODY PART PROTECTED	TYPE OF CLOTHING OR ACCESSORY	DESCRIPTION	TYPE OF PROTECTION	USE CONSIDERATIONS
Eyes and Face	Splash hood		Protects against chemical splashes. Does not protect against projectiles.	
	Safety Glasses		Protect eyes against large particles and projectiles.	Dark glasses may be necessary in bright (snow-covered) areas to protect from snow blindness.
	Goggles		Depending on their construction, goggles can protect against vaporized chemicals, splashes, large particles, and projectiles (if constructed with impact-resistant lenses).	
	Sweatbands		Prevents sweat-induced eye irritation and vision impairment.	
	Face shield	Full-face coverage, eight-inch minimum.	Protects against chemical splashes. Does not protect adequately against projectiles.	Face shields and splash hoods must be suitably supported to prevent them from shifting and exposing portions of the face or obscuring vision. Provides limited eye protection.
Head	Safety helmet (hard hat)	For example, a hard plastic or rubber helmet.	Protects the head from blows.	Helmet shall meet OSHA standard 29 CFR Part 1910.135.
	Helmet liner		Insulates against cold. Does not protect against chemical splashes.	
	Hood	Commonly worn with a helmet.	Protects against chemical splashes, particulates, and rain.	
	Protective hair covering		Protects against chemical contamination of hair. Prevents the entanglement of hair in machinery or equipment. Prevents hair from interfering with vision and with the functioning of respiratory protective devices.	Particularly important for workers with long hair.

Ears	Ear plugs and muffs		Protect against physiological damage and psychological disturbance.	Must comply with OSHA regulation 29 CFR Part 1910.95. Can interfere with communication. Use of ear plugs should be carefully reviewed by a health and safety professional because chemical contaminants could be introduced into the ear.
	Headphones	Radio headset with throat microphone.	Provide some hearing protection while enabling communication.	Highly desirable, particularly if emergency conditions arise.

Table 2 Personal Protective Equipment (continued)

BODY PART PROTECTED	TYPE OF CLOTHING OR ACCESSORY	DESCRIPTION	TYPE OF PROTECTION	USE CONSIDERATIONS
Full Body	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.
	Non-encapsulating 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 required between pants 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 non-encapsulating suit.	Provides additional splash protection of chest, forearms, and legs.	Whenever possible, should be used over a non-encapsulating suit (instead of using a fully-encapsulating suit) to minimize potential for heat stress. Used 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 (NFPA No. 1971, 1972, 1973), and boots.	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 consist of an outer shell, an inner liner, and a vapor barrier with a minimum water penetration of 25 lbs/in^2.	Decontamination is difficult. Should not be worn in areas where protection against gases, vapors, chemical splashes, or permeation is required.
	Proximity garment (approach suit)	One- or two-piece overgarment with boot covers, gloves, and	Protects against brief exposure to radiant heat. Does not protect against	Auxiliary cooling and an SCBA should be used if the wearer may be exposed to

	hood of aluminized nylon or cotton fabric. Normally worn over other protective clothing such as chemical-protective clothing, firefighters' bunker gear, or flame-retardant coveralls.	chemical permeation or degradation. Can be custom-manufactured to protect against some chemical contaminants.	a toxic atmosphere or needs more than 2 or 3 minutes of protection.
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 hearing protection.

Table 2 Personal Protective Equipment (continued)

BODY PART PROTECTED	TYPE OF CLOTHING OR ACCESSORY	DESCRIPTION	TYPE OF PROTECTION	USE CONSIDERATIONS
Full Body (continued)	Radiation-contamina-tion 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 radia- tion is detected on site, consult an experienced radiation expert and evacuate all 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 exa-cerbate heat stress problems and impair mobility.
	Flotation gear	Life jackets or work vests. (Commonly worn underneath chemical protective clothing to prevent flotation gear degrad-ation by chemicals.)	Adds 15.5 to 25 lbs (7 to 11.3 kg) of buoyancy to personnel working in or around water.	Adds bulk and restricts mobility. Must meet USCG standards (46 CFR Part 160).
	Cooling garment	One of three methods: (1) A pump circulates cool, dry air through-out the suit or por-tions of it via an air line. Cooling may be enhanced by use of a vortex cooler, refrig-eration coils, or a heat exchanger. (2) A jacket or vest having pockets into which packets of ice are inserted. (3) A pump circulates chilled water from a water/ice reservoir and through circula- ting tubes, which cover part of the body (generally the upper torso only).	Removes excess heat gener-ated by worker activity, the equipment, or the environment.	(1) Pumps that circulate cool air require 10 to 20 ft^3 (0.3 to 0.6 m^3) of respirable air per minute, so they are often uneconomical for use at a waste site. (2) Jackets or vests pose ice storage and recharge problems. (3) Pumps circulating chilled water pose ice storage problems. The pump and battery add bulk and weight.
Hands and Arms	Gloves and sleeves	May be integral, attached, or separte from other protective clothing.	Protect hands and arms from chemical contact.	Wear jacket cuffs over glove cuffs to prevent liquid from entering the glove. Tape-seal gloves to sleeves to provide additional protection.
		Overgloves	Provide supplemental pro-	

			tection to the wearer and protect more expensive undergarments from abra-sions, tears, and contamination.	
		Disposable gloves	Should be used whenever possible to reduce decontamination needs.	

Table 2 Personal Protective Equipment (continued)

BODY PART PROTECTED	TYPE OF CLOTHING OR ACCESSORY	DESCRIPTION	TYPE OF PROTECTION	USE CONSIDERATIONS
Feet	Safety boots	Boots constructed of chemical-resistant material.	Protect feet from contact with chemicals.	
		Boots constructed with some steel materials (e.g., toes, shanks, insoles).	Protect feet from compression, crushing, or puncture by falling, moving, or sharp objects.	All boots must at least meet the specifications required under OSHA 29 CFR Part 1910.136 and should provide good traction.
		Boots constructed from nonconductive, spark-resistant materials or coatings.	Protect the wearer against electrical hazards and pre-vent ignition of combust- ible gases or vapors.	
	Disposable shoe or boot covers	Made of a variety of materials. Slip over the shoe or boot.	Protect safety boots from contamination. Protect feet from contact with chemicals.	Covers may be discarded after use, facilitating decontamination.

Table 3 Respirators

TYPE OF RESPIRATOR	ADVANTAGES	DISADVANTAGES
ATMOSPHERE-SUPPLYING Self-Contained Breathing Apparatus (SCBA)	! Provides the highest available level of protection against airborne contaminants and oxygen deficiency. ! Provides the highest available level of protection under strenuous work conditions.	! Bulky, heavy (up to 35 pounds). ! Finite air supply limits work duration. ! May impair movement in confined spaces.
ATMOSPHERE-SUPPLYING Positive-Pressure Supplied-Air Respirator (SAR) (also called air-line respirator)	! Enables longer work periods than an SCBA. ! Less bulky and heavy than an SCBA. SAR equipment weighs less than 5 pounds (or around 15 pounds if escape SCBA protection is included). ! Protects against most airborne contaminants.	! Not approved for use in atmospheres immediately dangerous to life or health (IDLH) or in oxygen-deficient atmospheres unless equipped with an emergency egress unit such as an escape-only SCBA that can provide immediate emergency respiratory protection in case of air-line failure. ! Impairs mobility. ! MSHA/NIOSH certification limits hose length to 300 feet (90 meters). ! As the length of the hose is increased, the minimum approved air flow may not be delivered at the facepiece. ! Air line is vulnerable to damage, chemical contamination, and degradation. ! Requires supervision, monitoring of the air supply line.
AIR-PURIFYING Air-Purifying Respirator (including powered air-purifying respirators (PAPRs).	! Enhanced mobility ! Lighter in weight than an SCBA. Generally weighs 2 pounds (1 kg) or less (except for PAPRs).	! Cannot be used in IDLH or oxygen- deficient atmospheres (less than 19.5 percent oxygen at sea level). ! Limited duration of protection. ! Only protects against specific chemicals and up to specific concentrations. ! Use requires monitoring of contaminant and oxygen levels. ! Can only be used (1) against gas and vapor contaminants with adequate warning properties, or (2) for specific gases or vapors provided that the service is known and a safety factor is applied or if the unit has an ESLI (end of service life indicator).

Table IV Assigned protection factor classifications of respirators for protection against particulate exposures[1]

{PRIVATE } **Assigned**

Protection Factor	Type of Respirator
5	Single-use or quarter mask[2] respirator
10	Any air-purifying half-mask respirator including disposable[3] equipped with any type of particulate filter except single use[2,4]
	Any air-purifying full-facepiece respirator equipped with any type of particulate filter[5]
10	Any air-purifying[2] half-mask respirator (including disposable) equipped with appropriate gas/vapor cartridges[2]
	Any supplied-air respirator equipped with a half-mask and operated in a demand (negative pressure) mode[2]
25	Any powered air-purifying respirator equipped with a hood or helmet and any type of particulate filter[4]
	Any supplied-air respirator equipped with a half mask and operated in a demand (negative-pressure) mode[2]
25	Any powered air-purifying respirator with a loose-fitting hood or helmet[3]
	Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode[3]
50	Any air-purifying, full-facepiece respirator equipped with a high-efficiency filter[2]
50	Any air-purifying full-facepiece respirator equipped with appropriate gas/vapor cartridges or gas mask (canister respirator)[2]
	Any powered air-purifying respirator equipped with a tight-fitting facepiece and a high-efficiency filter[4]
	Any supplied-air respirator equipped with a full facepiece and operated in a demand (negative-pressure) mode[2]
	Any supplied-air respirator equipped with a tight-fitting facepiece and operated in a continuous-flow mode[3]
	Any self-contained respirator equipped with a full facepiece and operated in a demand (negative-pressure) mode[2]
1,000	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode[2]
2,000	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode[2]
10,000	Any self-contained respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode[2]
	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode[2]

Table V Assigned protection factor classifications of respirators for protection against gas/vapor exposures

{PRIVATE } **Assigned**

Protection Factor[1]	Type of Respirator
10	Any supplied-air respirator equipped with a half-mask and operated in a demand (negative-pressure) mode[2]
25	Any powered air-purifying respirator equipped with a loose-fitting hood or helmet[3]
	Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode[3]
50	Any powered air-purifying respirator equipped with a tight-fitting facepiece and appropriate gas/vapor cartridges or canisters[3]
	Any supplied-air respirator equipped with a tight-fitting facepiece and operated in a continuous-flow mode[3]
1,000	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode[2]
2,000	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode[2]
10,000	Any self-contained respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode[2]
	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode[2]

[1] Only high-efficiency filters are permitted for protection against particulates having exposure limits less than 0.05 mg/m^3.{PRIVATE }

[2] The assigned protection factors (APFs) were determined by Los Alamos National Laboratories (LANL) by conducting quantitative fit-testing on a panel of human volunteers.

[3] An APF factor of 10 can be assigned to disposable particulate respirators if they have been properly fitted using a quantitative fit test.

[4] APFs were based on workplace protection factor (WPF) data or laboratory data more recently reported than the LANL data.

[5] The APF was based on consideration of efficiency of dust, fume, and/or mist filters.

[1] The assigned protection factor (APF) for a given class of air-purifying respirators may be further reduced by considering the maximum use concentrations for each type of gas and vapor air-purifying element.

[2] The APFs were determined by Los Alamos National Laboratories (LANL) by conducting quantitative fit-testing on a panel of human volunteers.

[3] The APFs were based on workplace protection factor (WPF) data or laboratory data more recently reported than

the LANL data.