

PERSONAL PROTECTIVE EQUIPMENT

In discussing controls for hazards in many of the previous chapters, one alternative often noted was personal protective equipment. There are many activities where people wear protective equipment as a primary control or as a backup protection if other controls fail. In some cases, personal protective equipment is available to workers if conditions change such that hazards suddenly exist. There are many manufacturers of personal protective equipment. The personal protective equipment industry has approximately \$10 billion or more in sales each year in the United States.

28-1 GENERAL PRINCIPLES

Priorities

As noted in Chapter 9, personal protective equipment falls at the bottom of the list of priorities for controlling hazards. It is in the same priority class with procedures. In fact, its use is a procedure. Personal protective equipment is low in the priority list because it does not remove hazards. In general, personal protective equipment creates a barrier between the hazard and the wearer; the hazards, however, remain. Personal protective equipment also is low in the priority list because it requires user behavior to be sure that it is in place when needed; it is not automatically in place.

Problems

Personal protective equipment is essential protection for many hazards, although it may not be sufficient. There are several things that may prevent it from being adequate. One problem is effectiveness. One must have the right equipment for the hazard. Another problem is fit. Poor fit may result in inadequate protection. A third problem is use. Users must wear the personal protective equipment, even though the hazard it protects against is not present at all times. A fourth problem is maintenance. Some equipment has a limited life, has replaceable parts, or requires regular cleaning and testing.

Effectiveness For personal protective equipment to be effective, one must know the hazard. For example, some respirators only protect against gases, some protect only against particular gases, and others protect against particulates. Some glove coatings may dissolve in the presence of certain solvents, but be effective for others. Some hazards are life threatening; others are not. The proper equipment for the hazard or hazards at hand must be selected carefully.

Fit For personal protective equipment to be effective, it must fit the user. People come in various sizes and shapes. Respirators that do not fit the face or are placed over beards will leak and will not achieve the protection desired. Improperly adjusted hard hat suspensions can lead to injury if something strikes the hard hat. An acid suit and gloves that do not meet properly at the wrist will expose skin to possible contact with spilled acid. Poorly fitted equipment may create discomfort and discourage use.

Women have traditionally had difficulty getting personal protective equipment that fits well. With the increasing number of women in hazardous jobs, the availability of sizes for small women has improved.

Use Issuing employees personal protective equipment does not mean that it will be worn. Work rules and enforcement of them is one important means for gaining user compliance. Feedback on use increases use. Studies have shown that giving wearers results of hearing tests after use of equipment compared with nonuse contributed significantly to wearing of hearing protection. Worker acceptance also is an important factor in use. Workers need to participate in selection. Style and other choices as well as the chance to try different products and check their comfort will improve acceptance and use. Use of company logos or worker team logos can contribute to self-image and user acceptance.

Maintenance Proper maintenance is essential to ensure personal protective equipment effectiveness. Some respirators require testing and periodic replacement of valves, seals, filter elements, straps, canisters, and other components. Some personal protective equipment requires regular cleaning. Some personal protective equipment is designed for a single use and disposal and may be dangerous to reuse.

Regulations and Standards

Various government organizations require the use of personal protective equipment. Agencies include OSHA, The Mine Safety and Health Administration (MSHA), and others. There are National Highway Traffic Safety Administration (NHTSA) standards for seatbelts in vehicles (see Table 14-1). OSHA, for example, places the burden for proper personal protective equipment on the employer. Even if workers must buy their own equipment, the employer is responsible for it being proper for the hazard, being in good condition, working properly, and achieving a good fit.

There are several organizations that have recommendations and consensus standards on personal protective equipment design and performance: The National Institute for Occupational Safety and Health (NIOSH) has numerous criteria and performance publications and reports; American Society for Testing and Materials (ASTM) has standards for testing personal protective equipment; American National Standards Institute (ANSI) has several standards for design, performance, and use of personal protective equipment; Society of Automotive Engineers (SAE) has standards for seat belts in various vehicles.

Sources of Help

There are many publications that help buyers of personal protection equipment locate manufacturers and suppliers of these products. A major annual publication devoted to safety equipment is the Grey House Publishing Safety and Security Directory, which provides information on regulations and selection procedures. It also contains lists of suppliers and advertising from many of them. Another major publication for locating supplies and equipment of all kinds is the Thomas Register. In addition, many safety and indus-

trial hygiene magazines have an annual issue devoted to suppliers of personal protective equipment.

There are some computer programs that help check materials for certain types of protective equipment. Software users identify the environment, activity, or material and the software recommends the proper protection equipment and, if applicable, what materials they should have. There are data banks that recommend protective equipment for particular hazards. Some manufacturers, insurance companies, and other organizations publish charts and guides for selection of personal protective equipment.

Requirements

Personal protective equipment should meet several requirements: the equipment should not create additional hazards to the user; the materials of construction should hold up under reasonable use; they should withstand conditions for which they are intended; in some cases, they should be cleanable and they should be comfortable. Where possible, style and appearance are important for user acceptance.

User Involvement

User involvement in selection of personal protective equipment is important for acceptance and use. Users need to understand the hazards that create the need for the equipment and the dangers faced if the equipment is not worn. They need to learn the importance of the equipment in protecting themselves and to understand the rules related to enforcement of use. Users need training in proper use of equipment and proper care and maintenance. They need to test equipment for fit and comfort.

Ensuring Performance

Personal Protective Equipment Program It is essential for an organization to establish written policies and procedures for selection, management, use, and maintenance of personal protective equipment. The documentation should cover management of all aspects of the personal protective equipment program.

Inspection User acceptance and use of personal protective equipment are essential for equipment performance. Other factors, such as regular inspection for condition and function, help ensure performance, too. There should be a management plan and process to track inspection and condition of equipment.

Maintenance, Repair, and Cleaning There needs to be a maintenance and repair program. Personal protective equipment that is not in good condition or is not properly adjusted for fit needs corrective action. Filters in respirators need regular replacement, protective eyewear needs regular cleaning, some items need disinfecting, and some need decontamination.

Replacement Equipment that is not in good condition and not repairable must be removed from use. Disposable equipment intended for one time use should not be reused, and equipment that is not up to standards should be replaced.

Testing Inspection may not be enough to determine performance of some personal protective equipment; some equipment must be tested. For example, there are devices avail-

able to test respirator fit. Lifelines must meet periodic tests to be sure they meet load-carrying capacity.

Certification The buyer or user of personal protective equipment cannot always tell if purchased items meet published standards. There are certification programs for some equipment. NIOSH certifies the performance of some respirators. The Safety Equipment Institute in Arlington, Virginia, is a not-for-profit organization that tests and certifies a broad range of industrial safety products, including personal protective equipment. Its certification is voluntary for manufacturers of products. OSHA has established procedures for accreditation of testing laboratories.¹

28-2 HEAD PROTECTION

Hazards

One danger to the head is falling or flying objects. Falling or flying objects also can strike the neck and shoulder area. In tight spaces, one can bump the head against something and cause an injury. Bureau of Labor Statistics (BLS) data show that only 16% of workers receiving head injuries were wearing hard hats. There are also dangers of hair becoming caught in machines or hair being set on fire. Sanitation rules may require preventing hair from falling into food, and clean room work requires that hair and skin particles not contaminate the work.

Types of Head Protection

Helmets There are a wide variety of helmets or hard hats. Figure 28-1 has one example of a helmet. Helmets vary in materials of construction and features. Some can accommodate other protective equipment for eyes or hearing. ANSI Z89.1 classifies helmets as having a continuous brim all the way around (type I or hard hat) or having only a visor brim in the front (type II or hard cap). Different types and thicknesses of material vary in ability to prevent penetration of an object through the outer shell. Some materials for helmets have high dielectric properties and protect users who work around electrical lines and equipment; some helmet materials are conductive. Helmet materials are also rated for weight, flammability, and water absorption properties. ANSI standards divide helmets into class A, B, C, and D based on certain combinations of properties.

Headbands and suspension webs inside a helmet should have a 1¹/₄-in clearance between the helmet shell and the suspension. The suspension system will distribute the forces from a blow to the helmet over a large area of the skull and help absorb the energy of a blow, thereby preventing injury. For cold weather or sanitation reasons, many manufacturers offer liners and ear covers.

There are special helmets for firefighters, riot police, motorcyclists, athletics, and recreation activities. Each has special features and may have other standards for their design. For example, firefighters' helmets have extended brims at the rear to protect the neck from falling debris.

Hoods Hoods protect the head, face, and neck from heat, flame, sparks, molten metal, liquids, dusts, and chemicals. The type of hazard dictates the degree of protection and the kind of materials that are appropriate. Hoods may include hard hat protection and other features. Figure 28-1 illustrates one type of hood with an air supply line.



Figure 28-1. Examples of a helmet with visor (top) and a hood (bottom). (Photos provided by and reprinted with the permission of Mine Safety Appliances.)

Bump Caps Bump caps, which are lighter in weight than helmets, protect users from bumping their head on objects, not from falling objects. Bump caps are not substitutes for helmets. Many models accommodate eye protection, cold weather liners, and other protective equipment.

Soft Caps Soft caps protect users from sparks, open flames, heat, dust, and molten metal splashes. They are made with fire-resistant fabrics and materials.

Hair Nets and Caps Paper, fabric, or net caps or covers prevent hair from falling into food or assemblies that must not be contaminated. They also prevent hair from becoming caught in machinery. Beards may need similar protection.

28-3 EYE AND FACE PROTECTION

Hazards

Flying objects and particles, airborne dusts, splashing liquids, excessive light, and radiation may injure the eyes. People must have protection from these dangers. The same dangers may injure facial or neck tissues. The dangers are compounded when materials are hot or can react chemically with human tissue. Selection and use are complicated in some cases when the user already has corrective eye wear. Impact injuries to eyes can occur in many off-the-job activities and in athletics. Protection is important in all activities where hazards to eyes are significant.

Types of Eye Protection

Table 28-1 lists various eye and face protectors. The table forms a guide for selecting protectors for particular operations and hazards.

Spectacles To prevent frontal impact injuries, frames and lenses of eye glasses should meet performance standards of ANSI Z87.1. Lenses must meet specific criteria to be called safety lenses, and industrial standards are more stringent than those for safety lenses for home and recreational use. Some plastic and hardened glass lenses meet these specifications. Different materials withstand pitting, heat, and chemicals better than others. Shading in lenses can reduce glare.

Spectacles with Side Shields Where there is a danger of falling or flying particles entering the eye from the side, side shield protection is needed. Depending on the size and type of particle, side shields may be solid material, perforated (for ventilation), or wire mesh. Turning the head during grinding operations, for example, creates a danger of particles reaching the eye from the side. Spectacles suitable for welding and cutting must also have adequate radiation filtering in the lenses (see Table 28-2).

Goggles Goggles protect the eye from flying particles, splashes, molten metal, heat, and glare. There are many types, suitable for particular applications (see Table 28-1). Some activities need the protection of close-fitting eye cups; for others, different forms of goggles are suitable. Ventilation helps prevent fogging of goggles, but ventilation openings should be suitable for the hazards present because particles can pass through large holes. Goggles also protect prescription glasses that do not provide adequate protection. Goggles used for welding and cutting also must have adequate ultraviolet and optical

TABLE 28-1 Eye and Face Protection Selection Guide (29 CFR 1910, Subpart I, Appendix B)

Source	Assessment of Hazard	Protection
IMPACT: Chipping, grinding, machining, masonry work, woodworking, sawing, drilling, chiseling, powered fastening, riveting, etc.	Flying fragments, objects, large chips, particles, sand, dirt, etc.	Spectacles with side protection, goggles, face shields. See notes 1, 3, 5, 6, & 10. For severe exposure, use face shield.
HEAT: Furnace operations, pouring, casting, hot dipping, and welding	Hot sparks	Face shields, goggles, spectacles with side protection. For severe exposure use face shield. See notes 1, 2, & 3.
	Splash from molten metals	Face shields worn over goggles. See notes 1, 2, & 3.
	High temperature exposure High temperature exposure	Screen face shields, reflective face shields. See notes 1, 2 & 3.
CHEMICALS: Acid and chemicals handling, degreasing, plating	Splash	Goggles, eyecup, and cover types. For severe exposure, use face shield. See notes 3 & 11.
	Irritating mists	Special-purpose goggles.
DUST: Woodworking, buffing, general dusty conditions.	Nuisance dust	Goggles, eyecup, and cover types. See note 8.
LIGHT and/or RADIATION		
Welding: Electric Arc	Optical radiation	Welding helmets or welding shields. Typical shades: 10–14. See notes 9 & 12.
Welding: Gas	Optical radiation	Welding goggles or welding face shield. Typical shades: gas welding, 4–8; cutting, 3–6; brazing, 3–4. See note 9.
Cutting, torch brazing, torch soldering	Optical radiation	Spectacles or welding face shield. Typical shades: 1.5–3. See notes 3 & 9.
Glare	Poor vision	Spectacles with shaded or special-purpose lenses, as suitable. See notes 9 & 10.

Notes:

- Care should be taken to recognize the possibility of multiple and simultaneous exposure to a variety of hazards. Adequate protection against the highest level of each of the hazards should be provided. Protective devices do not provide unlimited protection.
- Operations involving heat may also involve light radiation. As required by the standard, protection from both hazards must be provided.
- Face shields should be worn only over primary eye protection (spectacles or goggles).
- As required by the standard, filter lenses must meet the requirements for shade designations in 29CFR 1910.133(a)(5). Tinted and shaded lenses are not filter lenses unless they are marked or identified as such.
- As required by the standard, persons whose vision requires the use of prescription lenses must wear either protective devices fitted with prescription lenses or protective devices designed to be worn over regular prescription eyewear.
- Wearers of contact lenses also must wear appropriate eye and face protection devices in a hazardous environment. It should be recognized that dusty and/or chemical environments may represent an additional hazard to contact lens wearers.
- Caution should be exercised in the use of metal frame protective devices in electrical hazard areas.
- Atmospheric conditions and the restricted ventilation of the protector can cause lenses to fog. Frequent cleansing may be necessary.
- Welding helmets or face shields should be used only over primary eye protection (spectacles or goggles).
- Non-side-shield spectacles are available for frontal protection only, but are not acceptable eye protection for the sources and operations listed for "impact."
- Ventilation should be adequate, but well protected from splash entry. Eye and face protection should be designed and used so that it provides both adequate ventilation and protects the wearer from splash entry
- Protection from light radiation is directly related to filter lens density. See note 4. Select the darkest shade that allows task performance.

TABLE 28-2 Filter Lens Shade Numbers for Protection Against Radiant Energy^a

Welding Operation	Shade No. ^b
Shielded metal-arc welding $1/16$, $3/32$, $1/8$, or $5/32$ inch electrodes	10
Gas-shielded arc welding (nonferrous) $1/16$, $3/32$, $1/8$, or $5/32$ inch electrodes	11
Gas-shielded arc welding (ferrous) $1/16$, $3/32$, $1/8$, or $5/32$ inch electrodes	12
Shielded metal-arc welding $3/32$, $7/32$, or $1/4$ inch electrodes	12
$5/16$ or $3/8$ inch electrodes	14
Atomic hydrogen welding	10–14
Carbon arc welding	14
Soldering	2
Torch brazing	3 or 4
Light cutting, up to 1 inch	1 or 4
Medium cutting, up to 6 inches	4 or 5
Heavy cutting, 6 inches and more	5 or 6
Gas welding (light) up to $1/8$ inch	4 or 5
Gas welding (medium) $1/8$ to $1/2$ inch	5 or 6
Gas welding (heavy) $1/2$ inch and more	6 or 8

^a29 CFR 1926.252.

^bNote: In gas welding and cutting where the torch produces a high yellow light, it is desirable to use a filter or lens that absorbs the yellow or sodium line in the visible light of the operation.

TABLE 28-3 Selecting Laser Safety Glass^a (OSHA Table E-3^b)

Intensity, CW Maximum Power Density (W/cm ²)	Attenuation Optical Density (O.D.)	Attenuation Factor
10^{-2}	5	10^5
10^{-1}	6	10^6
1.0	7	10^7
10	8	10^8

^aNote: This table lists the maximum power or energy density for which adequate protection is afforded by glasses of optical densities 5 through 8. Output levels falling between entries in the table require the higher optical density.

^bSee 29 CFR 1926.102(b)(2) for additional requirements for protection from lasers.

radiation protection (see Table 28-2). Goggles for use around lasers must have adequate protection for the energy and wavelength of the laser beam (see Table 28-3).

Face Shields Pouring liquids, working with molten metal, and other activities require protection of the face. A face shield has a large, transparent panel that extends over the front and sides of the face. A face shield alone is never adequate protection for the eyes. It is used in addition to eye protection.

Welding Helmets Welding helmets protect the face against ultraviolet radiation, sparks, and molten metal during electric arc welding. The helmet may have a window with radiation protection for the eyes (see Table 28-2).

Laser Safety Glasses Employees potentially exposed to laser beams need eye protection. One form of protection is laser safety goggles with adequate filtering capacity for the wavelength and intensity of the laser beams.

28-4 HEARING PROTECTION

Hazards

As noted in Chapter 23, exposure to excessive noise will produce temporary or permanent hearing loss.

Types of Hearing Protection

There are two kinds of hearing protection devices (see Figure 28-2): muffs, which fit over the ears to keep sound from entering the ears, and plugs of various types that are inserted into the ear canal. In either case, a good seal between the device and the head or ear canal is important. Plain cotton is not acceptable for hearing protection. The Environmental Protection Agency has a noise reduction rating (NRR) and labeling standards for hearing protectors.² These standards provide a reliable way to rate hearing protectors. The ratings are for continuous noise and may not represent the noise reduction from impulse noise. An NRR of 10 would have the effect of reducing the noise in an environment at 90dBA to an equivalent of 80dBA if the protectors fit properly. For frequencies less than 500Hz, an adjustment in rating is necessary. Manufacturers can provide performance data by octave for their products.

Muffs Muffs are best for severe noise environments and are more effective for high frequencies than for low ones. They have a cushion that fits against the head. There are various patented designs for attenuation. Muffs can be attached to helmets, and some manufacturers offer muffs with receivers and communication equipment built into them. They are also available with high dielectric material for work around high-voltage sources.



Figure 28-2. Example of ear muffs. (Photo provided by and reprinted with the permission of EAR Brand of Aearo Company, Indianapolis, IN.)



Figure 28-2. *continued* Examples of ear muffs. (Photos provided by and reprinted with the permission of EAR Brand of Aearo Company, Indianapolis, IN.)

Plugs There are many types of ear plugs. Some are reusable; others are disposable. There are custom molded ones that are molded in the ear canal of a user. Others have properties or features that adjust to the user. Plugs are more effective for high frequencies than low ones. Users will find some types of plugs more comfortable than others.

Combination For the most severe noise environments, a combination of both muffs and plugs will effect the greatest sound attenuation and protection.

28-5 RESPIRATORY PROTECTION

Hazards

The physiological function of respiration is essential to life. Lack of oxygen can produce syncope (fainting) or death. Excessive concentrations of certain gases and particulates can interfere with breathing. In addition, certain gases and particulates create health hazards if inhaled. An atmosphere that is *immediately dangerous to life or health* (IDLH) poses an immediate threat to life, irreversible adverse health effects, or impairment of a person's ability to escape from a dangerous atmosphere.

Types of Protection

There are two approaches to respiratory protection. One approach is to ensure that breathing air is of good quality. This is accomplished by supplying air that has the right mixture of oxygen and inert gases and is free of contaminants. An alternate approach is to clean the air before it is inhaled into the lungs. If there are particulates present, it may be possible to filter them from inhaled air. If there are undesired gases, it may be possible to adsorb them or chemically capture them before they are inhaled. The method selected depends on the degree of danger and potential failure of the equipment.

There are three classes of respirators: self-contained sources of breathable air; supplied-air respirators, which provide breathable air from other sources through a supply line; and air-purifying respirators, which remove particulates and gases from inhaled air. Examples of respiratory protective equipment are shown in Figure 28-3.

SCBA Self-contained breathing apparatuses (SCBA) are devices that provide clean, breathable air to a user. Users usually carry SCBA equipment on a backpack, and the packs have limited supplies and use times. A closed-circuit SCBA device recovers oxygen from expired breath to extend the time of use; open-circuit devices do not recover expired air.

Hose Mask This is one form of supplied-air respirator. An air line provides breathable air to a user from an outdoor source. A hose mask with a blower makes breathing easier during inhalation, because the blower aids the air flow in the line. The length of hose limits the distance a user can move from the supply. The wearer must be able to escape unharmed without the air of a respirator if the air line fails. This also limits the distance from a source. If air is compressed or pumped to a user, contaminants (such as compressor lubricating oil) must be removed from the breathable air.



Figure 28-3. Examples of respiratory protective equipment.



Figure 28-3. *continued*

Air-Line Respirator This is another type of supplied-air respirator. Breathable air is supplied directly to a respirator through a hose. Breathing regulators match the wearer's need.

Air-Supplied Suits and Hoods This type of supplied-air respirator directs air to the breathing zone of the user. It may supply a hood or a full body suit. The air may also provide cooling air to a full body suit. The source for the air supply is independent of the ambient atmosphere.

Air-Purifying Respirators These devices have filters, cartridges, or canisters that remove particulates and gases. They can have a full face piece, which covers the mouth, nose, and eyes, a half-mask device, which covers the nose and mouth, or a mouthpiece respirator, which covers the mouth only and requires users to wear a nose clip to prevent inhalation through the nose.

Canisters or Chemical Cartridge This is one type of air-purifying respirator. Breathing air moves through a container that removes gases or vapors. Because no single process removes all types of hazardous gases, canisters work on particular gas contaminants. Table 28-4 lists the color coding of canisters. Canisters must also have labels that state what

TABLE 28-4 Color Codes for Gas Mask Canisters (OSHA Table I-1^a)

Atmospheric Contaminants to Be Protected Against	Colors Assigned ^b
Acid gases	White
Hydrocyanic acid gas	White with 1/2-in green stripe completely around the canister near the bottom
Chlorine gas	White with 1/2-in yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gas	Green with 1/2-in white stripe completely around the canister near the bottom
Carbon monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with 1/2-in blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, except tritium and noble gases	Purple (magenta)
Particulate (dusts, fumes, mists, fogs, or smoke) in any combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with 1/2-in gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with 1/2-in gray strip completely around the canister near the top

^a29 CFR 1910.134(g).

^bGray shall not be assigned as the main color for a canister designed to remove acids or vapors. Note: Orange shall be used as a complete body or stripe color to represent gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

gases and gas concentrations they handle. Because an analysis of the contaminants in an environment is not always available, using canister respirators requires careful application. The kinds and concentration of contaminants may change over time and make a canister respirator ineffective.

Filter Respirators Respirators remove particulates through mechanical filters. There are filters for particular types and sizes of particulates. Filter respirators do not protect against gases and vapors. Some filter respirators have replaceable filters and some are disposable.

Other Respirators People may work in areas that are free of contaminants. However, a leak in a system may produce dangerous breathing atmospheres. In such situations, escape respirators issued to workers provide protection for the applicable danger for a very short time. Escape respirators are not intended for general use.

28-6 HAND, FINGER, AND ARM PROTECTION

Hazards

There are many hazards for hands, fingers, and arms. One hazard is hot or cold material and objects, in which case thermal insulation is needed to protect tissue. Some operations may create fire or flame hazards for the protective clothing, so the clothing must minimize the danger of catching on fire. Another hazard is sharp objects and equipment, such as

when handling sheared metal or metal objects with burrs or cutting meat with sharp knives and tools. The protective clothing must be tough and resistant to cuts and tears. Chemicals that can damage tissue or be absorbed through skin are other hazards. Protective material that prevents chemical penetration of materials is essential. Other hazards are damage to tissue from solvents or even water that dries oils from skin and causes cracking; bumping into objects that are sharp or pointed; and radiation burns, such as in welding. Slipping and loss of grip may require that protective clothing have slip-resistant properties. However in some operations, touch and feel are as important as the need for worker protection, and the protective clothing must minimize the loss of touch. Another hazard is electric shock. Sometimes protective clothing must provide electrical insulation. Hands may reach into biological or radiation boxes through protective gloves, and the material must provide the necessary protection.

Types of Protection

Gloves and Mittens Gloves and mittens cover the hands and fingers. The hazards present and the materials that create the hazards must be analyzed, and then the proper material for gloves or mittens can be selected. Most manufacturers of gloves and mittens produce their products in a wide range of materials. Many publish guides and give direct help in making selections.

Some types of gloves protect the fingers; others are fingerless and protect the hand. Some extend protection to the wrist and lower arm. There are gloves resistant to solvents, water, acids, caustics, salts, fats and greases, detergents, cuts, and abrasions. Some gloves are lined with cotton or other material for comfort and to reduce sweating; some are impregnated with lead to shield x-rays and other forms of radiation. Leather gloves stop sparks and molten metals found in welding and foundry operations. Some gloves are woven from steel or other metal for meat cutting operations.

Pads At home, people use hot pads to remove hot pans from a cooking oven. Workers in bakeries, foundries, and other hot processes may find pads more convenient than gloves.

Finger Guards and Cots Finger guards or cots cover an entire finger or a portion of a finger. They are suitable in operations where finger protection is needed, but full gloves are not desired.

Sleeves When protection must extend to the arms, workers may need special sleeves. Sleeves may cover the wrist and forearm only, may extend to the elbow or to the shoulder, or may have gloves and mittens attached. Materials for sleeves may be the same as those for gloves and mittens.

Creams and Lotions Lotions and creams provide some protection to hands and fingers from water, solvents, fats, irritants, and other substances. Lotions and creams can replace skin oils, soften chapped skin, and kill germs. Where severe exposures occur, protective gloves are more effective than creams and lotions.

28-7 FOOT AND LEG PROTECTION

Hazards

A major hazard for the foot is falling objects. In addition, there are hazards of contact with chemicals, slipping, and stepping on protruding nails, hot materials, or wet materials. There are also cutting hazards of tools, such as axes and chain saws, and dangers from cold. Where

these hazards are present, footwear and clothing for the legs can prevent many injuries. BLS analysis shows that in up to 75% of foot injuries, workers were not wearing safety shoes.

Types of Protection

Safety Shoes Standard safety shoes (see Figure 28-4a) have steel toes that meet crushing tests found in ANSI Z41.1. The standard calls for safety toes to withstand a 75-lb impact load and a 2,500-lb compression load. Safety shoes are available in almost any style of work or dress shoe. Safety-toe shoes are available in the form of rubber and plastic boots. Steel-toe shoes can sometimes create a hazard. Exposure to heat may store enough heat in the steel toe plate to cause radiation burns to the toes.

Metatarsal or Instep Guards For work involving heavy objects, one can attach metal guards that extend further over the foot rather than just over the toe. These guards are metatarsal or instep guards (see Figure 28-4b).

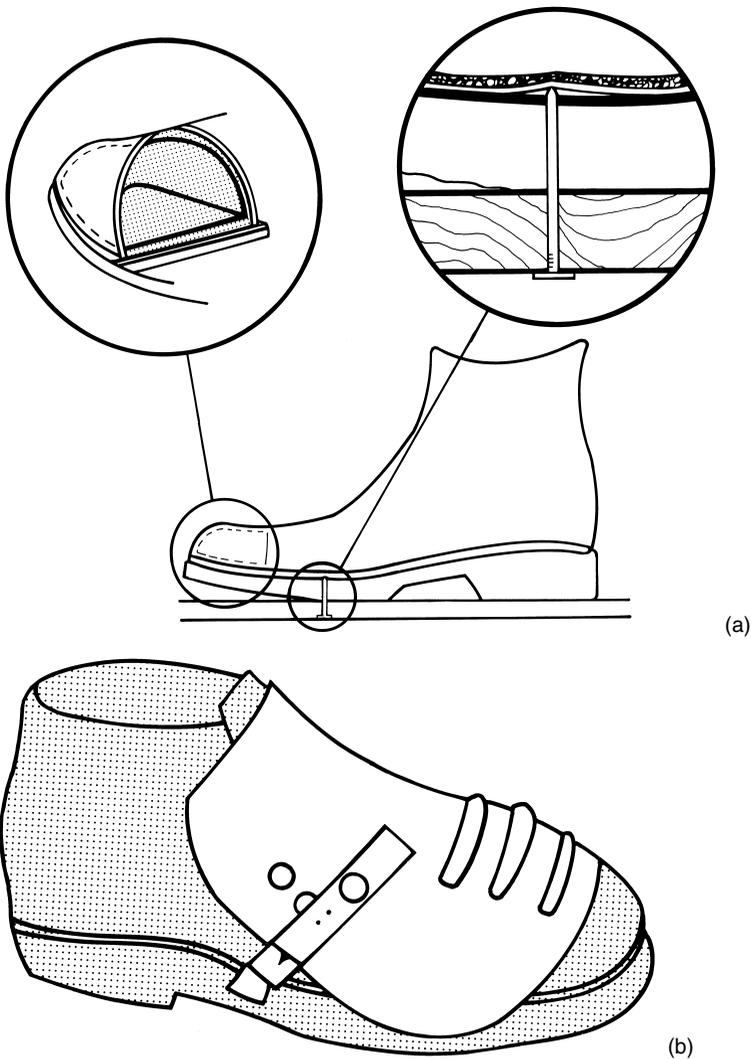


Figure 28-4. Foot protection: (a) exploded view of a safety shoe with safety toe and instep protector; (b) metatarsal guard.

Steel Insoles For those who work in construction or other locations where there is a danger of stepping on sharp objects that can penetrate the sole of a shoe, metal insoles that are usually built into the shoe structure provide protection.

Rubber or Plastic Boots For work with wet and muddy processes and exposure to chemicals, there are rubber and plastic boots. They may be ankle high or extend over the entire thigh. In some environments, waist-high boots are used.

Insulation For those who work in the cold, electrically heated insoles are available. For those who walk on hot surfaces or face the danger of splattered molten metal from welding or foundry work, shoes that have various forms of insulation or insulated soles are available. To provide for quick removal, some foundry shoes have quick release closures. The tops of foundry boots fit snugly around the lower leg to prevent any hot material from dropping into the shoe.

Shin Guards For operations that require protection of shins from falling or moving objects, there are padded shin guards. The guards are made from metal, plastic, or other materials.

Leggings and Leg Protection For loggers and others who work with chainsaws, piked poles, or axes, protective panels of metal and ballistic nylon protect the sides and top of the foot and the front and sides of the lower leg.

Conductive Soles and Nonsparking Shoes People who work in hospital operating rooms where there is a danger of fire or explosion from flammable gases can wear conductive shoes. When used with a conductive floor, any charge buildup on a person is removed. Spark-resistant shoes have no metal parts in them other than a steel safety toe. A shoe nail in an ordinary shoe may generate a spark that could be dangerous in an explosive atmosphere.

Nonconductive Shoes People who work with high-voltage electrical equipment can obtain shoes with electrical insulation. They prevent electrical shock and flow of current through the shoes.

Slip-Resistant Soles There are many surfaces where workers may slip and fall. Friction is created by the combined properties of two interfacing materials. Proper shoe soles and heels play an important part in preventing slips. (See Chapter 11 for additional information on slip resistance.)

28-8 BODY PROTECTION

Hazards

Hazards that require the use of personal protective equipment for the body include exposure to hazardous materials or biohazards. Substances may have many forms, such as liquid, dust, mist, or other forms. There are also dangers of work in confined spaces where atmospheres may not support life, dangers from fire or high heat sources that require protection, and dangers of sparks, molten metal, or hot or dangerous liquids that require special protective clothing. In many cases, there is a need to protect the body and wear other personal protection equipment at the same time. Full protective clothing creates a

minienvironment for a worker that is sealed from the surround. This closed environment requires supplying breathing air and removing heat and moisture from the suit. Many kinds of personal protective equipment and clothing for the body are made from disposable materials. For clothing contaminated by hazardous materials and biohazards, it may be more economical to dispose of the clothing than to decontaminate it properly for reuse. Work in explosive environments requires static-free fabrics for protective clothing.

Types of Protection

Coats and Smocks Coats and smocks extend to the knee or below. They create a barrier for spills of various substances on personal clothing. Depending on the fabric used, the coat or smock may be suitable for splatters of water, acids, oils, solvents, or other materials. The coats and smocks may be collected and cleaned for reuse or disposed of after use.

Coveralls Coveralls extend over the arms, body, and legs and some have hoods and boots. They may be useful in clean rooms or to provide greater protection than coats or smocks. Coveralls are usually one-piece garments, although in some applications, users may prefer a two-piece garment (pants and shirt or jacket).

Aprons Aprons cover the front of a person from the upper chest to below the knees. Aprons may protect against splatters of hazardous substances, molten metals, oils, greases, or other materials. The type of hazard determines the kind of fabric and coating appropriate for the application. Leaded aprons help prevent radiation from reaching the body of the wearer.

Full Suits When substances create a danger to life or may cause immediate or latent health problems, full body suits are useful. The full suit provides a barrier between the danger and the user.

Because of the gravity of the hazard, the integrity of the barrier is important. Tears or holes may allow contaminants inside the suit. The user of a full suit needs breathing air and, depending on activity level and duration in a suit, cooling and moisture controls also may be essential. Special suits are available for protection in radioactive environments.

Fire Entry and Proximity Suits People may need to approach or enter burning locations for rescue or critical tasks. They need insulation from the heat. There are two kinds of suits for fire: a proximity suit, which allows one to approach a fire, and an entry suit, which permits walking within the fire itself. The entry suit has heavier insulation. Both suits have a limited use time, and users need their own air supply. Fabrics normally are coated material to reflect radiant energy and to slow the rate of heat transfer from the fire. The insulation and suit fabric are noncombustible or are made from fire-resistant materials.

Cooling As noted in Chapter 18, the heat produced from metabolism must be removed or the body temperature will rise. The metabolic cost of an activity may double when wearing protective clothing. The environment within a closed suit will limit heat transfer from the body. If a suit must be worn for more than 15 or 20 min, cooling can be important. Cooling can be provided by pumping breathable air into the suit and distributing it before it is exhausted to the surround or returned to a remote location. There are self-

contained refrigeration or air conditioning units available for full body suits. There is special underwear with small tubes that allow coolant to flow to legs, arms, and body. There are also vortex coolers in which compressed air passes through a device that causes the air to spin in a vortex. The temperature of the air along the outer surface of the vortex drops as a result of rotation, and bleeding it off can provide a significant amount of cooling capacity. There are also air- and water-cooled helmets. A very large portion of the body's blood flow goes to the head and brain. Studies have shown that cooling the head alone can remove a large amount of heat from the body.

Rainwear Another kind of personal protective clothing is rainwear. There are many people who must work in wet outdoor conditions, and rainwear keeps users dry. Wet clothing increases body cooling. For cold weather, rainwear also may need insulation.

High-Visibility Clothing Vehicles may strike people working on road construction, parking cars, and managing vehicle traffic. There are luminescent orange vests, arm bands, and jackets that help make them visible.

Joggers, emergency workers, and others who could be struck at night by vehicles can wear reflective stripes on clothing and shoes. Visibility is important so drivers have time to react and avoid hitting someone.

Personal Flotation Devices For activities around or on the water where there is a danger of drowning, people need personal flotation devices. There are several types of personal flotation devices, including jackets and vests, which are worn in activities near water. The U.S. Coast Guard has standards for personal flotation devices.³

Puncture-Resistant and Cut-Resistant Clothing Police, security personnel, bomb squads, and others need protection from ballistic objects. Body armor clothing provides this protection. Workers using chainsaws need protection from chains cutting through clothing. For these hazards, there are fabrics that resist severe cutting and shearing. Workers in meat cutting operations need protection from powered saws and other cutting equipment. Clothes made from woven metal fabric give them some protection.

28-9 FALL PROTECTION

Hazards

Chapter 11 discussed the dangers of falls. There are a variety of fall protection devices available (Figure 28-5 shows one type of harness). Most interrupt falls in progress. Because they must interrupt a body in motion, the devices must withstand certain loads prescribed by standards.

Types of Fall Protection Equipment

There are several components that form a fall protection system, and together they prevent or limit falls. The person who could fall wears a safety harness. Safety belts are not often used. Some ANSI standards limit the deceleration force for body belts to 10 times the force of gravity. For full-body harnesses, the limit has been 35 times the force of gravity. A lanyard or lifeline attaches to the belt's D ring and must be securely anchored. Lifelines are anchored independently of any scaffolding a person is on. Safety belts or harnesses and lifelines also are used for rescue of people from confined spaces, grain bins, or similar



Figure 28-5. Example of a fall protection harness. (Photos copyrighted by and reprinted with the permission of Klein Tools, Inc.)

locations. With a lifeline, a rescuer can retrieve an incapacitated worker without endangering himself or others by entering the same location.

Safety Belt There are several classes of safety belts worn around the waist. Safety belts are useful for keeping someone from falling. When used for protection of falls, a belt can cause injury to the wearer during the stop or potentially slip free of the belt. Window washing safety belts have special fittings that attach to the window units.

Safety Harness There are several types of safety harnesses. One style has a belt at the waist and a harness over the chest and shoulders. Another style has additional loops that support the upper legs. A third style has a sling support that forms a seat, but it is not intended as a fall arresting harness. Compared with safety belts (not often used or allowed in some applications), harnesses distribute the forces over a greater portion of the body, and therefore are less likely to cause injury in an arrested fall.

Lanyard A lanyard is a short, flexible rope or strap that connects a safety harness to an acceptable anchor point or a grabbing device on a lifeline. Lanyards must be $\frac{1}{2}$ -in nylon rope or equivalent, have a static load capacity of 5,400 lb,⁴ and not have a fall distance of more than 6 ft. Some lanyards are designed to absorb energy in arresting a fall, thus reducing the impact load on a person.

Hardware All hardware must be free from sharp edges and must withstand 4,000-lb static loads.⁵ The most common hardware are D rings on safety belts and harnesses and snap hooks on lanyards.

Grabbing Device A grabbing device connects a body belt or lanyard to a lifeline. Some grabbing devices move freely along a lifeline when there is no load, but when there is a sudden load or movement, they lock onto the line.

Lifeline A lifeline is a rope that extends from an appropriate anchor point to a body harness or lanyard. The anchor point and lifeline must be capable of a static load of 5,400 lb.⁶

Fall Arrestor There are several patented fall-arresting devices. These devices are incorporated into a lanyard and create a controlled deceleration force for the person being stopped. They are used for longer free falls and where lanyards do not have elastic properties.

Climbing Safety Systems Workers climbing fixed ladders or poles need protection from falling. There are patented systems that attach permanently or temporarily to ladders on towers, bridges, antennas, or other equipment. A safety belt or harness connects to the climbing safety device. If a person falls, the device locks and stops the fall.

Safety Nets Safety nets may not be classified as personal protective equipment because they are not worn by workers. However, for workers involved in construction or bridge work, safety nets may be an important form of fall protection equipment. They do not replace lifelines and related fall protection equipment.

28-10 ELECTRICAL WORKER PROTECTION

People who work around electrical equipment face the danger of current flowing through them. Their personal protective equipment needs electrical insulating properties. Personal protective equipment must have nonconductive properties and must prevent current from flowing through it.

28-11 EMERGENCY SHOWERS AND EYE WASH FOUNTAINS

Hazard

Time is critical in responding to a spill of certain chemicals on the body or in the eyes. Flushing the affected area quickly with a lot of water will dilute or remove the dangerous substance and minimize injury.

Types of Equipment

There are three devices that must be readily available in areas where people work with substances that are dangerous to eyes. These devices are emergency showers (Figure 28-6a), eyewash fountains (Figure 28-6b), and eye- and facewash fountains. OSHA requires these devices for work areas, but does not specify exact locations. ANSI Z358.1 gives detailed requirements for design and location. Periodic testing ensures that the equipment meets standards. One should review location and signage periodically because operations change or signage may become defaced or damaged or be removed.

Emergency Showers An emergency shower is a unit that floods a person's entire body when an actuating valve is tripped. Most emergency showers are permanently installed to a water line to ensure an unlimited source of water. There are also portable units that have limited water supplies, but do provide at least 15 min of flooding. An emergency shower should be located not more than 10 s travel time away from potential users and should be clearly identified by signs and markings. In a spill emergency, there is not enough time to look for the shower. In some locations, showers need protection from freezing, and if conditions would make the water very cold, it should be heated enough to make it comfortable for use.

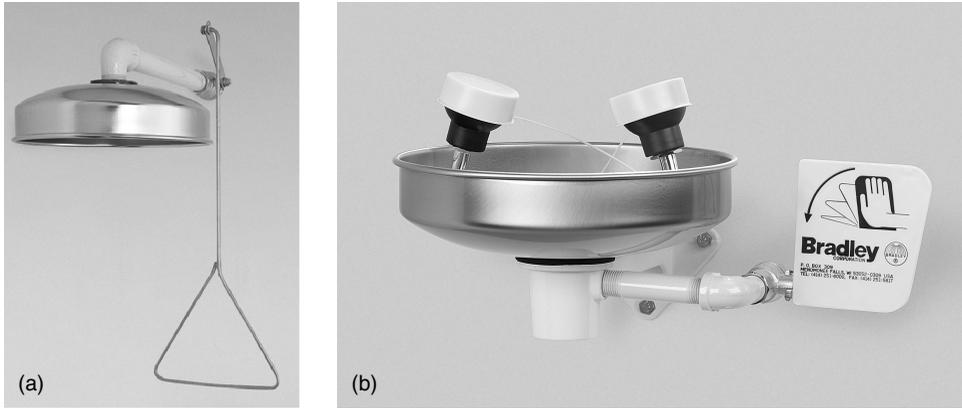


Figure 28-6. Examples of (a) a safety shower and (b) safety eyewash fountain. (Photos provided by and reprinted with permission of the Bradley Corporation, Menomonee Falls, WI.)

Emergency Eyewash Fountains When users bend over them, emergency eyewash fountains deliver two streams of water in an upward direction directly into each eye. An emergency shower cannot flush the eyes as well because the flow is downward. There are both fixed and portable eyewash units available. Fixed units have unlimited water supplies, whereas portable ones deliver a required flow rate of 1.51/min for 15 min. The fixture has room for holding both eyelids open to the streams of water and the control valve does not require a hand to hold it open. Again, fountains must be convenient to locations where there are dangerous materials, and there should be clear signs and markings because vision is probably impaired when foreign material enters the eyes and an emergency fountain is needed.

Emergency Eye- and Facewash Fountain Emergency eye- and facewash equipment floods the face and eyes. It has a higher flow rate than an eyewash fountain, but other design and location features are similar.

EXERCISES

1. A person wearing fall protection falls, and a fall-arresting device and lifeline interrupt the fall. The person weighs 185 lb and the arresting force is 1,263 lb. What G load does the person experience? Is it acceptable for a body harness?
2. Obtain literature, including performance and cost, on ear protection devices. Assume that disposable plugs are issued every day, reusable plugs are issued every 2 weeks, and muffs are issued once every 6 months. If a noise reduction of 15 dBA is required, find out which form of ear protection is adequate and which is most economical.
3. Select a job or operation, each having one of the following hazards:
 - (a) fall from a roof with a 5:12 pitch
 - (b) asbestos removal from community schools
 - (c) dishwashing operation in a major restaurant
 - (d) work in an operation where acid may splatter
 - (e) removal of steel parts by a cutting torch from inside an old, cylindrical container that is 12 ft high and 6 ft in diameter and has a 30-in access hole in the top
 Recommend personal protective equipment for these activities.

REVIEW QUESTIONS

1. Where does personal protective equipment fall in the priorities for controls for hazards?
2. Does personal protective equipment remove hazards?
3. What are three important problems in the use of personal protective equipment?
4. Where does one find standards for selection, use, maintenance, and testing of personal protective equipment?
5. Where can one obtain help in selection and application of personal protective equipment?
6. What can be done to ensure performance of personal protective equipment?
7. Briefly describe the functions and characteristics for each of the following:
 - (a) helmet
 - (b) bump cap
 - (c) hood
 - (d) hair nets and caps
 - (e) spectacles
 - (f) side shields
 - (g) goggles
 - (h) face shield
 - (i) welding helmet
 - (j) laser safety glasses
 - (k) ear muffs
 - (l) earplugs
 - (m) self-contained breathing apparatus
 - (n) supplied-air respirators
 - (o) air-purifying respirators
 - (p) canisters
 - (q) sleeve
 - (r) finger cots
 - (s) safety shoes
 - (t) steel insoles
 - (u) leggings
 - (v) nonconductive shoes
 - (w) aprons
 - (x) full body suits
 - (y) fire entry and proximity suits
 - (z) high visibility clothing
 - (aa) puncture-resistant and cut-resistant clothing
 - (bb) safety belt
 - (cc) safety harness

- (dd) lanyard
- (ee) grabbing device
- (ff) fall arrestor
- (gg) lifeline
- (hh) climbing safety system

NOTES

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| <ul style="list-style-type: none"> 1 29 CFR 1907. 2 40 CFR 211. 3 46 CFR 75. | <ul style="list-style-type: none"> 4 29 CFR 1926.104. 5 29 CFR 1926.104. 6 29 CFR 1926.104. |
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