VII. METHODS FOR PROTECTING WORKERS

A. Informing Workers of Hazards

Employers should provide information about workplace hazards before assignment and at least annually thereafter to all workers assigned to work in welding, brazing, and thermal cutting areas. The OSHA "Hazard Communication" regulation must be followed [29 CFR 1910.1200].

Appropriate written information on hazards (including material safety data sheets) should be kept on file and should be readily available to workers. This information should include a description of the potential health hazards associated with welding (e.g., exposures to noise, vibration, hot metal, optical and X-radiation, and carcinogenic agents such as chromium, nickel, and cadmium) and their possible adverse health effects (e.g., hearing loss, eye injury, burns, and cancer). Workers should also be informed of the most common types of accidents encountered while welding (e.g., explosions, fires, electrocution, and asphyxiation from oxygen-deficient environments). This information should list precautionary measures for minimizing exposure and injury, including work practices, engineering controls, and personal protective equipment. The file should also include a description of the environmental, medical monitoring, and emergency first aid procedures that have been implemented.

Workers should also be instructed about their responsibilities for following proper sanitation procedures to help protect their health and provide for their safety as well as that of their fellow workers.

Information on hazards should be disseminated to all workers through a training program that describes how a task is properly performed, how specific work practices reduce exposures or minimize the risk of injury, and how compliance with these procedures will benefit the worker. Frequent reinforcement of this training and routine monitoring of work practices are essential.

B. Engineering Controls

Because welding processes involve many chemical and physical agents, the hazards they pose cannot always be controlled using current engineering control methods. The processes are usually dynamic, making it difficult to use fixed systems to control exposures. In addition, because of the various characteristics of welding emissions (e.g., fumes, gases, radiation) and the extent and fluctuation of exposure at different processes, the evaluation of exposures is often imprecise, and appropriate controls are difficult to implement. Despite these limitations, engineering controls should be implemented wherever they can minimize the risk of exposure.

1. Optical (Radiation) Hazards

When feasible, welding should be performed in booths or screened areas constructed of one of the following materials: (1) metal, (2) flame-resistant fabric that is opaque to most optical radiation, or (3) transparent colored polyvinyl chloride material that is formulated with a flame retardant and a UV-visible absorber in the range of 200 to 3,000 nanometers (nm) [Tola et al. 1977; Moss and Gawenda 1978; Sliney et al. 1981]. The booths and screens should be arranged so that they do not restrict ventilation. Such equipment must conform to requirements of 29 CFR 1910.252(f)(1)(iii), "Screens."

To minimize ozone production, an opaque shroud should be placed around the arc to minimize the interaction between the optical radiation and the oxides of nitrogen that are generated during the process [Ferry and Ginther 1953; Ditschun and Sahoo 1983].

2. Chemical Hazards (Gases and Fumes)

Gases and fumes generated during welding may necessitate both local and general exhaust ventilation. Although local exhaust ventilation is preferred wherever possible, general ventilation may be used in some cases where the exposures are well characterized and local exhaust ventilation cannot be placed close to the source of emissions [ACGIH 1984].

Ventilation systems should meet the following minimum specifications:

- Exhaust hoods and ductwork should be constructed of fire-resistant materials.

- Systems should be equipped with alarms, flowmeters, or other devices to indicate malfunction or blockage of ductwork.

- The air velocity at the face of the duct should be sufficient to capture the emissions. Hood design should be such that captured emissions are carried away from the breathing zone of the worker.

- Provision should be made for clean make-up air; 29 CFR 1910.252(f)(4)(i) states, "All air replacing that withdrawn shall be clean and respirable."

Various designs of exhaust ventilation systems can provide effective control of fume and gas emissions. In general, local exhaust ventilation works well for welding processes that are conducted at a fixed location such as a workbench, or that are performed on parts of the same size and shape. The degree of effectiveness depends on the distance between the face of the duct inlet and the work, the design of the system, and the flow rate and volume of air exhausted. The use of side baffles or flanges at the duct inlet can increase the capture velocity. The effectiveness of the exhaust ventilation system declines as the distance between the work and the duct inlet increases; a distance of about 9 to 14 in. (24 to 36 cm) is adequate for capturing fumes and gases. After optimizing the design of the duct hood so that it can be placed as close as possible to the work, the flow rate should be adjusted to ensure an effective capture velocity.

When welding is performed at remote sites or with different-sized or very large parts, a flanged hood with a flexible duct may be appropriate. The hood face should be placed at a 0- to 45-degree angle to the work surface and positioned on the side opposite the welder. The use of a flexible duct system requires that the welder be properly instructed to keep the duct hood close to the emission source and to ensure that the duct is not twisted or bent.

An alternative to using an exhaust hood for gas-shielded arc welding processes is to exhaust the emissions by means of an extracting gun. Such extraction systems can reduce breathing zone concentrations by 70% or more [Hughes and Amendola 1982]. These systems require that the gun and shielding gas flow rates be carefully balanced to maintain weld quality and still provide good exhaust flow.

General ventilation can be used to supplement local exhaust ventilation. General ventilation may be necessary where local exhausts cannot be placed close enough to the work to be completely effective. The ACGIH [1984] recommends that where local exhaust cannot be used, 800 cubic feet per minute (cfm) of air be exhausted for every pound of welding rod used per hour.

In-line duct velocities for local exhaust systems that are used to control welding emissions should exceed 3,000 feet per minute (fpm) to prevent particulates from settling in horizontal duct runs. The recirculation of air from local exhaust systems may be appropriate depending on the potential toxicity of the emissions and the efficiency of the filter collection system. The recirculation of air from local exhaust systems is not recommended when the collected emissions are unknown or contain extremely toxic agents. Local exhaust systems must be equipped with flow or vacuum meters or other devices to monitor air flow. These exhaust systems should not be used if their failure to work properly will result in bodily harm before remedial action can be taken [Hughes and Amendola 1982].

For automated welding processes where the worker does not work directly over the source of emissions and there are no cross currents, canopy hoods could be used for collecting heated fumes and gases. When properly placed at the side of the worker and operated at a relatively low velocity, cooling fans can be used in some work environments to remove welding fumes from the breathing zone. Cooling fans have limited use and should be considered only when local exhaust is not possible. The use of a cooling fan in an indoor situation requires supplemental general ventilation.

3. X-Radiation

Electron beam welding processes should be enclosed and shielded with lead or other suitable materials that have a mass sufficient to prevent the emission of X-rays. All doors, ports, and other openings should be checked for X-ray emissions to ensure that all seals are working properly.

4. Noise

During plasma arc welding and cutting and during arc air gouging processes, a water table or other method of similar effectiveness should be used to control noise and airborne emissions.

a. Acoustic Shields

An effective noise reduction of up to 8 decibels (dB) can be achieved by placing an acoustic shield between the worker and the source of the noise [Salmon et al. 1975] usually constructed of safety glass or clear plastic (polycarbonate or polymethyl methacrylate), is placed. This shield is most effective when its thickness is at least three times the wavelength of the sound that is contributing to the noise. Thus shields can be effective barriers against the high-frequency sound emitted from the air ejection systems of plasma and metal spray guns.

b. Total Enclosure

A reduction of up to 20 dB can result when the machinery or process is totally enclosed. However, heat buildup is a potential problem and may require the installation of adequate ventilation. Vibration within these enclosures should be isolated from the floor. The enclosure must have ports for possible servicing of electrical, water, oil, and other systems. These ports should be sealed with sound-dampening materials (e.g., 1/8-in. or heavier rubber washers).

c. Other Recommendations

Personal hearing protection devices are recommended if engineering controls cannot maintain worker exposures at 85 dBA as an 8-hr TWA. Ear plugs (molded, foam, or acoustic wool) and earmuffs can significantly reduce a worker's noise exposure.

To determine whether the hearing protection device will be adequate, the manufacturers' data on noise attenuation should be compared with the actual reduction required. Employers can also use one of three methods developed by NIOSH and reported in the List of Personal Hearing Protectors and Attenuation Data [NIOSH 1976]. Additional information on hearing protection devices may be found in the Compendium of Hearing Protection Devices [Lempert 1984]. Extreme care must be taken in using the manufacturers' data, as it represents the maximum protection possible under ideal conditions. In a NIOSH study to determine the noise reduction provided by insert-type hearing protectors, 50% of the workers tested were receiving less than one-half the expected noise attenuation [Lempert and Edwards 1983]. Noise reduction was also less than expected when the Mine Safety and Health Administration (MSHA) conducted a study in which microphones were placed inside and outside the protective cup on muff-type protectors while the workers performed their normal tasks [Bureau of the Census 1984].

Whenever workers are exposed to noise levels exceeding 85 dBA as an 8-hr TWA, the employer must administer a continuing, effective hearing conservation program [29 CFR 1910.95(c)]. The program must include monitoring, worker notification, an audiometric testing program, availability of hearing protectors for workers, record-keeping, and a training program. Hearing protection becomes mandatory when workers' exposures exceed 90 dBA as an 8-hr TWA [29 CFR 1910.95(b)].

5. Oxyfuel Equipment

Ventilation systems and other control devices for oxyfuel equipment should be inspected at least weekly to ensure their effectiveness. Oxyfuel equipment for welding should be installed and maintained in a manner that prevents leakage, explosion, or accidental fire. Such equipment must conform to the requirements of 29 CFR 1910.252(a), "Installation and operation of oxygen-fuel gas systems for welding and cutting."

6. Fire or Electric Shock

Arc and resistance welding equipment should be installed and maintained in a manner that prevents fire or electric shock. Such equipment must conform to the requirements of 29 CFR 1910.252(b), "Application, installation, and operation of arc welding and cutting equipment," and to 29 CFR 1910.252(c), "Installation and operation of resistance welding equipment."

C. Work Practices

The prevention of occupational illness and injury while welding requires the use of well-designed work practices. These include wearing personal protective clothing; using safe work procedures for process operations; practicing good housekeeping, sanitation, and personal hygiene; handling compressed gases safely; and being informed on how to handle emergency situations. Together with engineering controls, such practices can reduce the health risks to workers. At a minimum, work practices must conform to OSHA standards (e.g., 29 CFR 1910.251-254, "Welding, Cutting, and Brazing" [OSHA]). Additional information on proper work practices is available in the ANSI Z49.1 standard, "Safety in welding and cutting" [AWS 1973] and in the National Safety Council's Accident Prevention Manual [McElroy 1980].

1. Specific Work Procedures

The manner in which a worker prepares for and carries out welding processes has a direct bearing on the type and extent of the exposure hazard. For example, Moreton et al. [1975] found that variations in the size of work area, ventilation, and work practices caused welders performing the same welding task to be exposed to breathing zone concentrations of fumes and gases that varied by a factor of up to six.

Other factors that affect the generation of fumes, gases, and optical radiation include the operating current and voltage, the diameter and angle of the electrode, and the type of shielding gas used. Some of these factors may not be up to the worker's discretion to change, and others may depend on product specifications or production schedules.

The type of welding process used on steel can affect fume generation rates. Flux-cored arc and shielded metal arc welding generate many more fumes than gas metal arc and gas tungsten arc welding. When shielded metal arc welding must be used, low-fuming electrodes may be acceptable substitutes for conventional types. The electrical current and the position of the electrode while welding both affect fume generation [Thrysin et al. 1952; Morita and Tanigaki 1977; Pattee et al. 1978]. An increase in the welding current tends to increase the rate of fuming, gas production, and optical radiation emission. Manufacturers of consumable electrodes usually specify a range of amperages that should be used during welding. The welder can minimize emissions by using the lowest acceptable amperage. In addition, holding the electrode as close to the work surface as possible and perpendicular to it will minimize the arc voltage used and thus decrease the rate of fuming [Kobayashi et al. 1976; Pattee et al. 1978].

Pattee et al. [1978] noted that when the contact-tube-to-work distance is increased, a greater metal deposition rate occurs, which in effect decreases the fume generation rate. However, fume rate tends to increase when the polarity is dc+ (i.e., reverse polarity) rather than dc- or ac [Kobayashi et al. 1976; Pattee et al. 1978] or when the thickness of the metal increases [Heile and Hill 1975; Kobayashi et al. 1976; Siekierzynska and Paluch 1972; Ulrich et al. 1977]. The type and moisture content of flux coating used on electrodes also affects the fume generation rate [Kobayashi et al. 1976], as does the composition of the shielding or plasma gas [Pattee et al. 1978].

Special precautions should be taken when working in areas not specifically designed for welding. Such precautions must include (1) observing fire precautions prescribed in 29 CFR 1910.252(d), (2) removing, shielding, or cooling any materials present that may produce toxic pyrolysis or combustion products, and (3) using appropriate personal protective clothing and equipment required for the specific hazard. Whenever possible, the workpieces to be welded should be positioned to minimize worker exposure to molten metal, sparks, and fumes.

2. Confined Spaces

Working in confined spaces can be extremely hazardous as a result of explosive, toxic, or oxygen-deficient atmospheres [NIOSH 1979]. Although a confined space may initially have good air quality, any subsequent welding in this space can cause a rapid buildup of toxic air contaminants, a displacement of oxygen by an inert or asphyxiating gas, or an excess of oxygen that might explode. Only by careful preparation can a worker be assured of working safely within a confined space. A complete set of recommendations for working in a confined space is presented in the NIOSH document Criteria for a Recommended Standard: Working in Confined Spaces [NIOSH 1979]. Some of the more pertinent recommendations are given below.

a. Before workers enter a tank, reaction vessel, ship compartment, or other confined space, a permit entry procedure should be set up. Authorization to permit entry should be assigned to a qualified person, and access should be permitted only when all necessary measures have been taken to protect the worker. The following precautions must be taken before permission is given:

- All pipes, ducts, and power lines connected to the space but not necessary to the operation must be disconnected or shut off. All shutoff valves and switches must be tagged and secured with a safety lockout device.

- Continuous mechanical ventilation must be provided when welding or thermal cutting is done in confined spaces. Oxygen must never be used for ventilation purposes [29 CFR 1910.252].

- Initial air monitoring must be performed to determine the presence of flammable or explosive materials and toxic chemicals, and to determine if there is sufficient or excessive oxygen. Depending on the monitoring results and the adequacy of the mechanical ventilation, continuous monitoring may be necessary during welding. Prohibit entry when tests indicate flammable concentrations greater than 10% of the lower flammable limit.

- Gas cylinders and power sources for welding processes must be located in a secure position outside the space.

- A designated worker must be stationed outside the confined work space to maintain visual and voice contact and to assist or rescue the entering worker if necessary. The designated worker must be equipped with appropriate protective gear and must remain in position throughout the time that any worker is within the enclosed space.

- The worker entering the confined space must be outfitted with a safety harness, a lifeline, and appropriate personal protective clothing and equipment, including a respirator.

- Lifelines must be attached so that the welder's body cannot become jammed in a small exit opening.

- When not in use, torches and other gas- or oxygen-supplied equipment must be removed from the confined space [29 CFR 1910.252(d)(4)(ii)].

- All welders and persons supporting those workers shall be trained in the following areas: emergency entry and exit procedures, use of applicable respirators, first aid, lockout procedures, safety equipment use, rescue procedures, permit system, and good work practices.

The type of respirator required depends on the concentration of oxygen and the contaminants that might be generated. Respirator requirements may range from none to a self-contained breathing apparatus with a full facepiece operated in pressure-demand or positive-pressure mode. Respirators must be selected in accordance with the most recent edition of the NIOSH Respirator Decision Logic [NIOSH 1987].

Even though continuous mechanical ventilation is required during welding processes in confined spaces, initial and continuous environmental monitoring is extremely important. Equipment used for monitoring of fumes and gases should be explosionproof, and continuous monitoring equipment should have an audible alarm or danger-signaling device to alert workers when a hazardous situation develops. All instruments should be calibrated periodically in accordance with the manufacturers' instructions. The results of each calibration must be recorded, filed by the employer, and made available for inspection for 1 year after the calibration date. Monitoring equipment must be reliable and have sufficient sensitivity to clearly identify a hazardous condition.

Oxygen deficiencies are of particular concern when welding in confined spaces. The normal 21% concentration of oxygen in air may be decreased in confined spaces by chemical or biological processes. When oxygen concentrations fall below 16.8% by volume, a worker may have difficulty remaining alert. Whenever the oxygen content falls below 19.5%, appropriate respirators must be used.

NIOSH respirator certification [30 CFR 11] requires that only self-contained breathing apparatuses or supplied-air respirators with auxiliary self-contained breathing apparatuses be used in atmospheres below 19.5% oxygen.

3. Preparation for Work

Before welding is performed in any work area, the worker should be aware of any potentially hazardous materials or conditions that may exist in that area. Before striking an arc or lighting a flame the worker must remove all nearby flammable materials if the piece to be welded or cut is not readily movable. A number of companies have a "permit system" that requires the supervisor's approval before welding is performed [Shell Chemical Company 1974; Toleen 1977]. Before issuing such a permit, the supervisor must check for conformance to OSHA regulations (such as 29 CFR 1910.252) and any specific company rules. Some of the most common company requirements include checking the serviceability of local firefighting equipment, moving all combustible materials at least 35 ft (10.7 m) from the work site, and assigning a worker (equipped with a suitable extinguisher and trained in its use) to perform a fire watch from outside the workspace. Combustibles that cannot be removed should be shielded with a nonflammable material. Shielding should also be provided to cover openings or cracks in floors, walls, and windows to prevent other workers from being exposed to sparks, hot metal and slag, and optical radiation.

The fire watch should be continued for at least 30 min after job completion to guard against smoldering fires. The workpiece and work area should also be free of substances that may be rendered more hazardous by the work. These include any halogenated hydrocarbons in the atmosphere that can be decomposed to phosgene or other harmful products by an arc or a flame [Frant 1974]. Polymer materials may also form hazardous fumes or gases when exposed to heat [Robbins and Ware 1964]. Finally, the worker should be informed of (1) any unusually hazardous constituents of the work materials such as beryllium, cadmium, chromium, nickel, etc., (2) any hazardous coatings such as lead paint, mercury, or zinc, and (3) any precautions and control measures necessary for minimizing potential health risks.

4. Containers

Drums, containers, pipes, jackets, and other hollow structures should be properly prepared and tested before welding [McElroy 1980]. Preparation of hollow structures varies depending on their contents. At a minimum, the following procedures should be undertaken to minimize the risk of accidental injury or exposure to toxic agents: remove all ignition sources; disconnect the structure from any pipes, hoses, or other connections; examine the interior for waste or debris; and cleanse the structure of flammable materials or materials that could produce flammable or toxic vapors upon heating. The appropriate cleaning process for containers depends on the materials present. For many types of materials, an adequate cleaning process consists of steaming the container, washing with caustic soda, and rinsing with boiling water. The container should be dried and inspected. Check for the presence of flammable or toxic gases or vapors. Vent the container to prevent a buildup of pressure in the interior. Further protection may be given by filling the container with water to within an inch or two of the area to be welded or cut, and/or purging the interior of the container with inert gas. Before cutting or welding is permitted, the area must be inspected by the individual responsible for authorizing welding processes [29 CFR 1910.252]. Preferably, such authorization should be in the form of a written permit.

5. Emergencies

The employer should formulate a set of written procedures covering fire, explosion, electrical shock, asphyxiation, and any other foreseeable emergency that may arise in welding processes. All potentially affected workers should receive training in evacuation procedures to be used in the event of fire or explosion. All workers who are involved in welding processes should be thoroughly trained in the proper work practices to reduce the potential for starting fires and causing explosions. Selected workers should be given specific training in first aid, cardiopulmonary resuscitation, and fire control. Procedures should include prearranged plans for transportation of injured workers and provision for emergency medical care. At least two trained persons in every work area should have received extensive emergency training. Necessary emergency equipment, including appropriate respirators and other personal protective equipment, should be stored in readily accessible locations.

D. Personal Protective Clothing and Equipment

1. Clothing

The employer should provide and require the use of protective clothing as follows:

- All welders should wear flame-resistant gauntlet gloves and shirts with sleeves of sufficient length and construction to protect the arms from heat, UV radiation, and sparks. In most cases, wool and leather clothes are preferable because they are more resistant to deterioration and flames than cotton or synthetics. Welders should not wear light-weight, translucent fabrics and fabrics that show severe wear with holes [USAEHA 1984].

- All welders should wear fire-resistant aprons, coveralls, and leggings or high boots.

- Welders performing overhead work should wear fire-resistant shoulder covers (e.g., capes), head covers (e.g., skullcaps), and ear covers.

- Workers welding on metal alloys that contain highly toxic elements (e.g., beryllium, cadmium, chromium, lead, mercury, or nickel), should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day. Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Any clothing treated for fire resistance should be retreated after each laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed on measures to minimize their health risk.

- Employers should ensure that protective clothing is inspected and maintained to preserve its effectiveness. Clothing should be kept reasonably free of oil or grease. Front pockets and upturned sleeves or cuffs should be prohibited, and sleeves and collars should be kept buttoned to prevent hot metal slag or sparks from contacting the skin.

- Workers and persons responsible for worker health and safety should be informed that protective clothing may interfere with the body's heat dissipation, especially during hot weather or in hot industries or work situations (e.g., confined spaces).

Therefore, additional monitoring is required to prevent heat-related illness when protective clothing is worn under these conditions.

2. Eye and Face Protection

The employer should provide and require the use of welding helmets with the following eye and face protection: approved UV filter plates and safety spectacles with side shields or goggles for workers exposed to arc welding or cutting processes; goggles or similar eye protectors with filter lenses for oxyfuel gas welding, brazing, or cutting; and goggles or similar eye protectors with transparent lenses for resistance welding and brazing. Hand-held screens for shielding the face and eyes should not be used since they may inadvertently be held incorrectly. A report prepared by C.E. Moss [1985] provides a compendium of protective eyeware that may be helpful in choosing appropriate eye protection. All welding helmets must meet the requirements of 29 CFR 1910.252(e)(2)(ii), "Specifications for protectors." Eye and face protectors should be periodically inspected and maintained by the employer. Eye and face protectors should be sanitized before being used by another worker. In addition, submerged arc welders must, where the work permits, be enclosed in an individual booth coated on the inside with a nonreflective material as set forth in 29 CFR 1910.252(e)(2)(ii).

3. Respiratory Protection

Engineering controls should be the primary method used to control exposure to airborne contaminants. Respiratory protection should be used by workers only in the following circumstances:

- During the development, installation, or testing of required engineering controls

- When engineering controls are not feasible to control exposure to airborne contaminants during short-duration operations such as maintenance and repair

- During emergencies

Respiratory protection is the least preferred method of controlling worker exposures and should not be used routinely to prevent or minimize exposures. When respirators are used, employers should institute a complete respiratory protection program that includes worker training at regular intervals in the use and limitations of respirators, routine air monitoring, and maintenance, inspection, cleaning, and evaluation of the respirator. Respirators should be used in accordance with the manufacturer's instructions. Each respirator user should be fit tested and, if possible, receive a quantitative, on-the-job evaluation of his or her respirator protection factor to confirm the protection factor assumed for that class of respirator. For additional information on the use of respiratory protection, refer to the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

Selection of the appropriate respirator depends on the types of contaminants and their concentration in the worker's breathing zone. Before a respirator can be selected, an assessment of the work environment is typically necessary to determine the concentrations of specific metal fumes and other particulates, gases, or vapors that may be present. As an interim measure until the environmental assessment has been made, the evaluator should conduct an initial review of precautionary labels on filler metals, electrodes, and flux materials to make a best estimate of the appropriate class of respirators. Respirator types shall be selected in accordance with the most recent edition of the NIOSH Respirator Decision Logic [NIOSH 1987b]. The following respirators should be used if a carcinogen is present at any detectable concentration, or if any other conditions are present that are considered to be immediately dangerous to life or health (IDLH):

- A self-contained breathing apparatus with a full facepiece operated in a pressure-demand or other positive-pressure mode.
- A combination respirator that includes a supplied-air respirator with a full facepiece operated in pressure-demand or positive-pressure mode and an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode.

When respirators must be selected for combinations of contaminants in different physical forms, combination cartridge and particulate filter air-purifying respirators may be acceptable under specific conditions as long as none of the agents are considered carcinogenic. The actual respirator selection should be made by a qualified individual, taking into account specific use conditions including the interaction of contaminants with the filter medium, space restrictions caused by the work location, and the use of welding helmets or other face and eye protective devices.

When welding is performed in confined spaces, the potential exists for a reduction in ambient oxygen concentrations. A self-contained breathing apparatus or supplied-air respirator with an auxiliary self-contained breathing apparatus must be used for oxygen concentrations below 19.5% (at sea level).

E. Labeling and Posting

In accordance with 29 CFR 1910.1200, "Hazard Communication," workers must be informed of exposure hazards, of potential adverse health effects, and of methods to protect themselves. Though all workers associated with welding processes should have received such information as part of their training, labels and signs serve as important reminders. Labels and signs also provide an initial warning to other workers who may not normally work near those processes. Depending on the process, warning signs may state a need to wear eye protection, hearing protectors, or a respirator; or they may be used to limit entry to an area without protective equipment. For transient nonproduction work, it may be necessary to display warning signs at the worksite to inform other workers of the potential hazards.

Labels on containers of filler metal, electrodes, and flux materials that are toxic shall include the following information: (1) the name of the metal and a warning describing its health hazards (for materials containing carcinogens, the warning should include a statement that fumes or gases from these materials may cause cancer), (2) instructions to avoid inhalation of or excessive skin or eye contact with the fumes of the materials, (3) instructions for emergency first aid in case of exposure, (4) appropriate instructions for the safe use of the materials, and (5) instructions for the type of personal protective clothing or equipment to be worn. Base metals that contain or are coated with materials containing carcinogens or other toxic metals (e.g., lead or mercury) should be clearly labeled or marked to indicate their contents before being welded. This same type of information must be posted in areas where welding is being performed.

All labels and warning signs should be printed in both English and the predominant language of non-English-reading workers. Workers who cannot read labels or posted signs should be identified so that they may receive information about hazardous areas and be informed of the instructions printed on labels and signs.

F. Sanitation

The preparation, storage, or consumption of food should not be permitted in areas where welding takes place. The employer should make handwashing facilities available and encourage the workers to use them before eating, smoking, using the toilet, or leaving the work site. Tools and protective clothing and equipment should be cleaned as needed to maintain a sanitary condition. Toxic wastes should be collected and disposed of in a manner that is not hazardous to workers or surrounding environments. No dry sweeping or blowing should be permitted in areas where welding is performed with materials containing carcinogens or other highly toxic metals. Vacuum pickup or wet mopping should be used to clean the work area at the end of each work shift or more frequently as needed to maintain good housekeeping practices. Collected wastes should be placed in sealed containers that are labeled as to their contents. Cleanup and disposal should be conducted in a manner that enables workers to avoid contact with the waste and to observe applicable Federal, State, or local regulations.

Uncovered tobacco products should not be permitted to be carried or used for smoking or chewing. Workers should be provided with and advised to use facilities for showering and changing clothes at the end of each work shift. Work areas should be kept free of flammable debris. Flammable work materials (rags, solvents, etc.) should be stored in approved safety cans.

G. Availability of Substitutes

Fume and gas composition may be affected by material substitution. Toxic agents in welding fumes and gases may require remedial action such as changing the electrodes, fluxes, or type of welding process if appropriate control measures cannot be implemented. Materials that may come into contact with welding processes (e.g., metals coated with oil and paint) should always be cleaned to prevent exposure to other toxic agents [DWI

1977]. Because impurities or contaminants are often contained in fluxes [Steel and Sanderson 1966] or base metal coatings [Pegues 1960], substitutions should be done cautiously to avoid introducing other toxic exposures. In practice, however, substitution is not always an alternative to minimizing exposures, since material and process selection usually depend on the type of weld required and the quality of the finished product.

VIII. RESEARCH NEEDS

Research is needed in several areas to evaluate the work-relatedness of disease symptoms in exposed workers who are associated with welding processes. The various chemical agents (fumes and gases) and physical agents generated during these processes need to be characterized, and their possible interactions need to be assessed. Long-term inhalation studies in animals, and morbidity and mortality studies of welders are needed to better define the relationship between exposure and respiratory disease, including lung cancer. Several studies have indicated that workers who smoke and weld have an increased incidence and severity of respiratory disease. This association should be clarified.

Several epidemiologic studies have shown statistically significant increases in the risk of lung cancer for workers who weld stainless steel. Thus the carcinogenic potential of stainless steel welding emissions needs to be better defined. Research is particularly needed to assess the carcinogenicity of chromium and nickel in the forms generated during this process. Comprehensive industrial hygiene evaluations are needed to quantitate exposure concentrations and ascertain past exposures. To make such evaluations, investigators must gather information on the types of welding performed, work practices and controls used, and composition of base metals, fluxes, and electrodes.

To simplify the task of repetitively characterizing work environments where welding processes are performed, researchers should pursue a means of indexing exposures by job type or process. Workplace exposures should be characterized by representative jobs and job sites with the use of personal and stationary samplers. The various components of the fumes and gases should be identified and quantified as a fraction of the total or respirable fumes. In addition, information should be gathered on the type of welding technology and welding consumables used. This information should take the form of a list of processes and their applications, the types of material they use, the nature of the workplace, and the type of job. Furthermore, the intensity of the work should be determined by estimates of arcing time per job shift, the number of electrodes consumed per unit of time, or the quantity of consumables purchased. Also, the use of any specific work practices or local exhaust ventilation should be recorded along with their effects on the extent and composition of the fume exposure.

Better control technology should be developed in the form of new welding processes and worker-protective measures to assure that the worker is protected to the greatest extent possible. The use of new metals, alloys, and complex composites of materials should be closely monitored and assessed for their potential to cause adverse health effects.

Recordkeeping and medical monitoring requirements proposed in this document need to be assessed for welders who change jobs frequently (e.g., welders in job shops or construction). Because of the short-term nature of these jobs, the recordkeeping and monitoring provisions of this document may not be readily implemented. Methods are also needed to prevent the replication of medical examination and monitoring records among various employers.