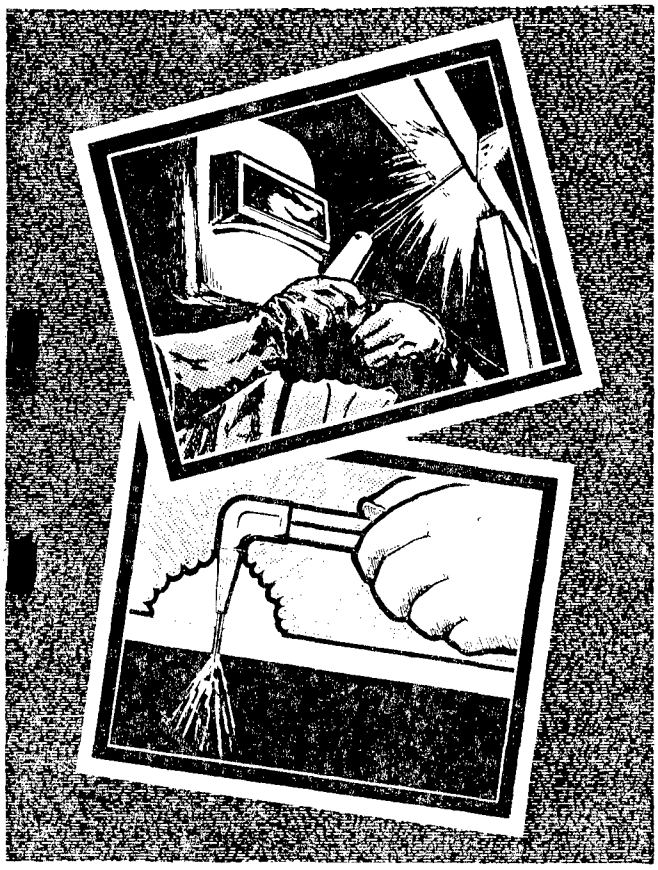
NIOSH

SAFETY and HEALTH in ARC WELDING and GAS WELDING and CUTTING



U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

Safety and Health in

ARC WELDING AND GAS WELDING AND CUTTING

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Public Health Service
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National Institute for Occupational Safety and Health
Division of Technical Services
Cincinnati, Ohio

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PREFACE

Many of the OSHA standards resulting from the Occupational Safety and Health Act of 1970 require employee training in the procedures, hazards, and safe work practices associated with a particular activity or operation. The standards for arc and gas welding and cutting require such training.

NIOSH has developed this guide for both employees and employers. For employees, it describes many of the health and safety hazards associated with arc and gas welding and cutting. For employers, it is useful in the training of employees in the health and safety hazards of these processes.

EMPLOYER NOTES

TRAINING FORMAT

People usually retain about 20 percent of what they hear, about 40 percent of what they see, and about 70 percent of what they both see and hear. For the best results from training, therefore, a program of lectures supplemented by audio-visual materials and demonstrations is recommended. For new employees, visits to welding and cutting areas are also recommended.

A general training format could include:

Lecture Material

- Training manual
- Slides and films from the National Safety Council, trade associations, equipment manufacturers, or the American Welding Society
- Instructor/student experiences related to operations
- Company operations manual for welding or cutting
- Demonstration of welding and cutting units

Field Activity

- Tour of welding and cutting areas

INSTRUCTION TECHNIQUES

Develop an informal atmosphere surrounding the training. Encourage a free flow of questions and answers. At the initial training session, determine the experience (present and past) of the group through informal discussion. Discover specific safety problems or situations they have encountered. Review the entire guide with the group and explain what material this session will cover and what the group will be expected to learn.

At the beginning of each subsequent session, also discuss what will be covered. At the end of every session, review the material presented.

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1 WORKSITE PREPARATION

Management is responsible for designating arc and gas welding and cutting areas. These areas must be protected against fire hazards posed by combustible and flammable materials. Welding and cutting in these areas should not be a hazard to workers in nearby areas. Worksite preparation should include consideration of the following points:

1. Combustibles must be located at least 35 feet from the worksite. If this is not possible, combustibles must be protected with flameproof covers or metal or asbestos shielding. Edges of covers at the floor should be tight to prevent sparks from going under them. Floors on which combustible materials such as paper clippings, wood shavings, or textile fibers accumulate must be swept clean for a radius of 35 feet.

2. Floors made of combustible material must be kept wet, covered with damp sand, or protected by fire-resistant shields. Welding areas should be inspected for floor openings or cracks through which sparks could fall onto other employees or combustible materials. Where welding or cutting is conducted near walls, partitions, ceilings, or roofs made of combustible material, fire-resistant shields or guards must be used to prevent fire.

   When welding is to be done on metal walls, partitions, ceilings, or roofs, combustibles on the other side should be relocated. If this is not possible, a "fire watcher" must be provided on the side with the combustibles. Where ducts and conveyor systems might carry sparks to distant combustibles, the combustibles must be suitably protected or the ventilation or conveyor system shut down.

3. Due to the potential for fires, explosions, and health hazards, cutting or welding must not be permitted:

   - in the presence of mixtures of flammable gases, vapors, liquids, or dusts with air, or inside improperly cleaned tanks or equipment which have previously contained such materials;

   - near large quantities of exposed, readily ignitible materials such as bulk sulfur, baled paper, or cotton;

   - near vapor degreasing operations, or spray booths (degreasing solvents, such as trichloroethylene, can decompose under ultraviolet radiation and become dangerous);

   - in areas not authorized by management.

   In welding areas where special precautions are necessary, a list of these precautions should be posted at the worksite. Regular inspections of all welding areas should be conducted to identify any changes that may affect safety—a new metal being welded, new welders on the job, or different equipment settings.

4. Welding areas, where practical, should be enclosed with fire-resistant curtains or tinted transparent shields. These protect workers in nearby areas from harmful rays coming from the electric arc and reduce the possibility of fire started by flying sparks. If shielding is impractical, nearby workers must wear appropriate protective eyewear.

B EQUIPMENT CHECK

1. Arc welding

All arc welding equipment must be designed to operate in the gases, dust, and light rays produced by the welding arc. Under unusual environmental conditions, such as the presence of corrosive fumes, steam or excessive humidity, oil vapors, inclement weather, or seacoast or shipboard operations, special safety features may be required. **Remember to follow all printed rules and operating instructions supplied by the manufacturer.** Dry all machines that have become wet. However, make sure you disconnect the primary power first. Other considerations:

— Connections and cables —

- Spread out coiled welding cable prior to use and check weld lead cables for damaged insulation and work lead cables for exposed conductors.
- Replace all weld lead spliced within 10 feet of the holder.
- Check electrode holders for loose or exposed connections to reduce the shock hazard.
- Check for leaks in gas hoses, if metal inert gas welding process is used.
- Do not coil or loop electrode cable around parts of your body.

— Grounding —

- Check to ensure that the welding machine frame is grounded, with special attention to ground connections.

- Do not ground to pipelines carrying gases or flammable liquids or conduits carrying electrical conductors.

- If the floors have been wetted down, special precautions must be taken against electrical shock.

- Do not ground to a building structure remote from the weld.

— Machine settings —

- If the process being used requires open circuit (no load) voltages higher than the voltages indicated in the following table, adequate insulation must be provided to prevent shock.

	Operation	
Type	Manual	Automatic (mechanized)
Alternating current	80 volts	100 volts
Direct current	100 volts	100 volts

- For a.c. welding under wet conditions or where perspiration is a problem, a reliable automatic control should be used to reduce the no-load voltage. This will prevent shock.

- Do not change the polarity switch when the machine is under load. The arcing due to the high current can burn the switch contact surface or cause serious burns to the welder.

- Check to see that the welding machine has a power disconnect switch. This allows immediate shutdown in case of emergency. A machine should not be used unless it has such a switch.

— Work procedures —

- Store electrode holders where they cannot make electrical contact with personnel, conducting objects, fuels, or compressed gas tanks.

- When no welding is to be done for any substantial period of time (e.g., for lunch or overnight), all electrodes must be removed from holders and the machine disconnected from the power source.

- Never strike an arc on a compressed gas cylinder. Keep electrodes, electrode holders, and any other live parts away from gas cylinders.

2. *Gas welding and cutting*

— Cylinder placement and storage —

- All cylinders stored inside must be located in a well-protected, well-ventilated, dry location. They must be at least 20 feet from highly combustible materials, sparks, open flames, excessive heat, and away from elevators, stairs, or gangways.

- When cylinders are not connected for use, valve protection caps must be in place unless the cylinder is not designed to accept a cap.

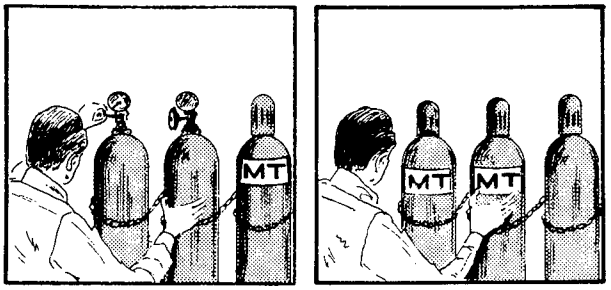
- Stored oxygen cylinders must be separated from stored fuel gas cylinders or combustible materials (especially oil or grease) by at least 20 feet or by a non-combustible barrier. This barrier must be at least 5 feet high and have a fire resistance rating of one-half hour.

- All cylinders must be legibly marked to identify their contents.

- Cylinders connected for use must be lashed or chained to prevent them from toppling over.

- Indoor storage of fuel gas is limited to a total of 2,000 cubic feet or 300 pounds of liquified petroleum gas.

- Be careful that cylinders are not placed so as to become a part of an electrical circuit.



- Mark empty tanks "MT", close the valves, and replace valve caps securely.

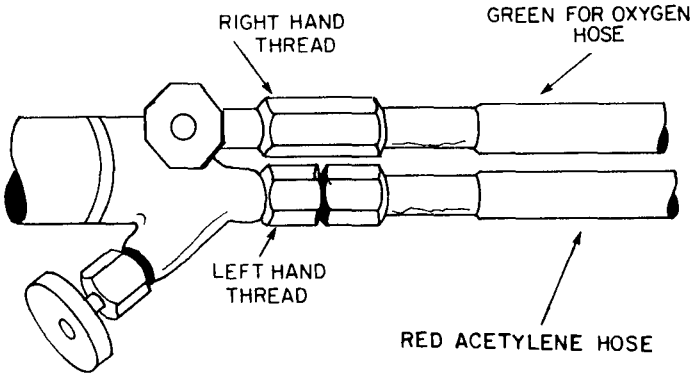
— Valve examination and regulator settings —

- The regulator is a delicate piece of equipment and must be handled carefully at all times. Pipe wrenches or pliers must not be used for attaching regulators to cylinders. Use an end wrench of proper size. Hammers or wrenches must not be used to open or close cylinder valves that are fitted with hand wheels. If a regulator "creeps", have it repaired at once. "Creeping" of a regulator is indicated by a gradual increase in pressure after the torch valves are closed.

— Hoses, torch valves, and connections —

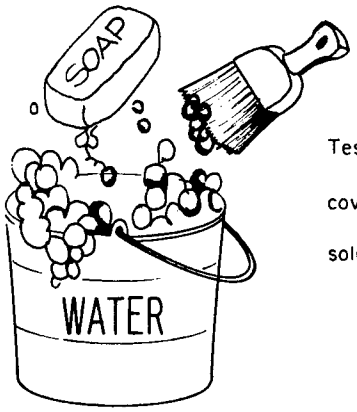
- Hoses showing leaks, burns, or worn places must be replaced or repaired.

- Hoses should be color-coded to avoid accidental mixing.



- Check hose connections for proper threading. Standard hose connections are threaded right-hand for oxygen and left-hand for acetylene or other fuel gas. This helps prevent an accidental switch of oxygen and fuel gas hoses.

- Test the hose for leaks by immersing it—under normal working pressure—in water or by using soapy water as illustrated. **Do not try to repair hoses with tape.**



Test connections for leaks by covering with a leak-test solution of SOAPY WATER.

- Use only approved bronze or brass fittings. Copper fittings must never be used on acetylene cylinders. Under certain conditions, the acetylene might react with the copper to produce an explosive compound.

- Do not use oil, grease, or similar substances on any torch or regulator. Oil and grease in the presence of oxygen may burn with explosive force, if ignited.

— Work procedures —

- Always point cylinder outlets away from each other before hookup. This will prevent improper mixture in case of leaks.

- To prevent injury from malfunctioning valves, never face a gauge while opening the cylinder valve—stand to one side.

- There is a proper way to light a welding torch. First, the hoses must be purged:

  Open the valve on the acetylene cylinder. This should never be opened more than one and one-half turns, and three-fourths of a turn is preferable.

  Open the acetylene torch valve one-fourth turn.

  Adjust the acetylene to working pressure (less than 15 psig or 30 psia) with the gas regulator screw.

  Close the acetylene torch valve.

  Follow the same procedure with the oxygen cylinder and torch:

  Slowly open the oxygen cylinder valve all the way.

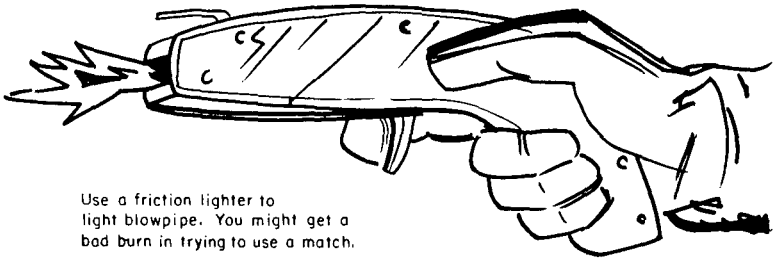
  Open the oxygen torch valve one-half turn.

  Adjust the oxygen to working pressure with the gas regulator screw.

  Turn off the oxygen torch valve.

  The final steps are the actual lighting of the torch:

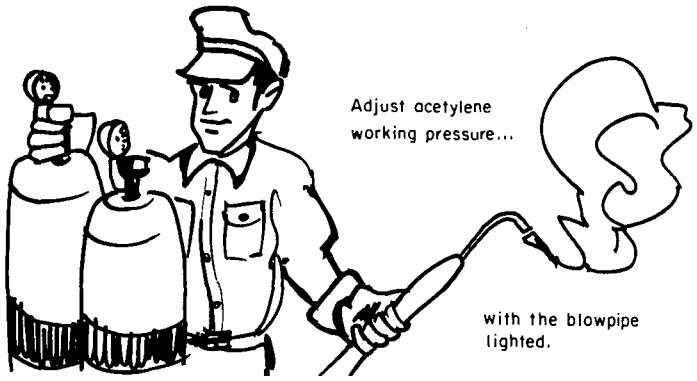
  Reopen the acetylene torch valve one-fourth turn and light the gas with a friction lighter. (Never use matches.)



Use a friction lighter to light blowpipe. You might get a bad burn in trying to use a match.

  Open the oxygen valve one-fourth turn.

  Adjust the flame.



- There is also a proper way to shut off the torch:

  Close the torch valves, *acetylene first,* then oxygen.

  Close the cylinder valves, again *acetylene first,* then oxygen.

  Open both torch valves to release the pressure.

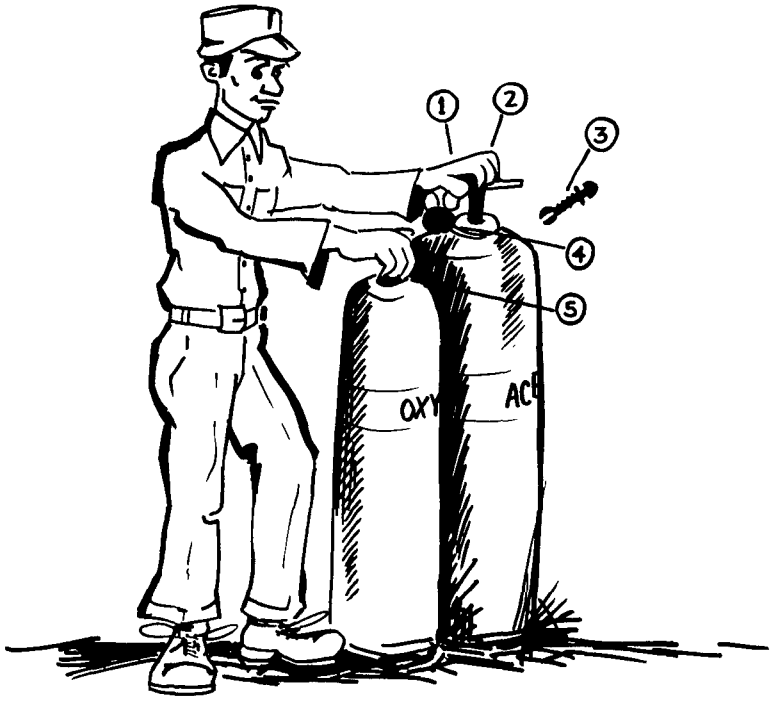
  Shut off the regulator adjusting handle until you no longer feel any spring tension.

  Close the torch valves.

This procedure reduces the possibility of regulator fires when the oxygen cylinder valve is open again. It will also prevent leaks of acetylene or oxygen while the equipment is not in use. A leak could cause a serious fire.

1. Keep hands and gloves free from oil and grease.

2. Stand to one side when "cracking" the valve.

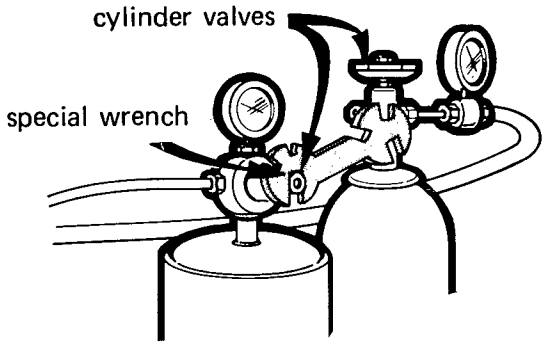


3. Use the right wrench when connecting an oxygen regulator.

4. Loosen the pressure adjusting screw of the regulator before opening cylinder valve.

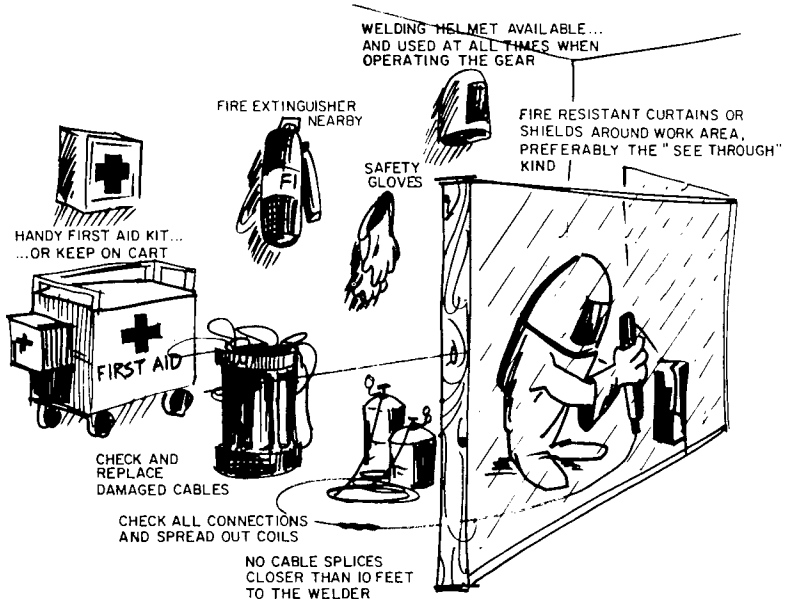
5. Open the cylinder valve only slightly at first.

- Leave the valve wrench on the acetylene cylinder whenever the valves are open. This permits emergency shut-off of the gas.



- Do not leave pressure in the hoses when leaving the area. Shut off the oxygen and acetylene at the cylinder.

- Never use a hard, sharp tool for cleaning tips, except where such tools may be specifically recommended by or supplied by the tip manufacturer. Use appropriate tip cleaners or a copper or brass wire.



3. Materials to be welded or cut

- No welding or cutting should be performed on used drums, barrels, tanks, or other containers until they have been cleaned thoroughly, eliminating all flammable materials and all substances (such as greases, tars, or acids) which might produce flammable or toxic vapors when heated. Use a cleansing agent appropriate for the gas or liquid which was in the container. Clean the container a second time with either water or steam.

- All hollow spaces, cavities, or containers should be vented to permit the escape of air or gases before preheating, cutting, or welding.

- Do not weld on or cut pipes or other metals in contact with combustible walls, partitions, ceilings, or roofs, if the work is close enough to start a fire by conducting heat through the metal.

C FIRE PROTECTION

1. Fire extinguishers

Fire extinguishing equipment must be provided and maintained in all welding and cutting areas. These extinguishers must be appropriate to the hazard present. All portable welding units should be equipped with a fire extinguisher. Inform your supervisor if this equipment is missing.

Fires in the workplace generally fall into one of the classes listed in the table below. Portable, hand-operated fire extinguishers may be charged with any of the several substances shown. It is important to identify the class of fire and to select and use an appropriate type of extinguisher.

	CLASS A	CLASS B	CLASS C
Fuels	Wood, paper, textiles	Flammable liquids, grease, gas, oil paints	Electrical equipment—motors, switches, etc.
Extinguisher requirement	Foam	Foam	
		Carbon dioxide	Carbon dioxide
	Soda acid		
	Pump tank		
	Gas cartridge		
	Multi-purpose dry chemical	Multi-purpose dry chemical	Multi-purpose dry chemical
	Ordinary dry chemical	Ordinary dry chemical	Ordinary dry chemical

It is also important to use the extinguisher properly:

Foam extinguisher: Don't play the stream into the flames. Allow the foam to fall lightly on the fire.

Carbon dioxide extinguisher: Direct discharge as close to the fire as possible. Start at the edge of the flames and move gradually forward and upward.

Soda acid, Gas cartridge extinguishers: Direct the stream at the base of the flames.

Pump tank extinguisher: Place a foot on the footrest and direct the stream at the base of the flames.

Dry chemical extinguishers: Direct at the base of the flames. CLASS A FIRES—follow up by directing dry chemical at remaining material that is burning.

2. *Fire watchers*

Fire watchers must be provided in locations where other than a minor fire may develop, and when:

- combustible materials, in building construction or contents, are located closer than 35 feet to the welding operation;

- combustibles are located more than 35 feet away but are easily ignited by sparks;

- wall or floor openings within 35 feet expose combustible materials in adjacent areas; or

- combustible materials are located on the opposite side of a metal wall, partition, ceiling, or roof.

D HEALTH HAZARDS

1. Definitions

- **Toxicity** - the ability of a substance to cause an injury or illness

- **Hazard** - the *likelihood* of a substance causing an injury or illness

The above definitions indicate that the toxicity of a substance—a fume, dust, gas, or liquid—is only one factor in determining its effect on the worker. In general, the specific health hazards of any welding or cutting operation depend on (1) the type of welding or cutting, (2) the type of filler metal, fluxes, coatings, and base metals being used, (3) the length of the exposure of the workers, and (4) the extent to which good industrial hygiene practices are used.

- **Acute exposure** - a rapid absorption of a substance into the body. The exposure is usually sudden and there is a critical period during which death or serious injury may occur unless prompt medical action is taken.

- **Chronic exposure** - absorption of small doses of a toxic substance over a long period of time. When the chemical is taken in faster than the body can eliminate it, accumulation in the body begins. Harmful effects from the chemical may become evident. These effects continue even after exposure has ended.

2. Routes of entry

- **Inhalation**

- **Ingestion**

- **Skin absorption**

3. *Chemical agents*

- **Acetylene** - Acetylene is one of the most commonly used fuels for gas welding, cutting, and brazing. It is capable of displacing oxygen from the atmosphere, reducing it to a level below that required by the body. The major hazard associated with acetylene, however, is its explosion potential. Because acetylene becomes unstable at excessive pressures, do not pressurize it above 15 psi gauge (or 30 psi absolute).

- **Aluminum** - In welding and cutting operations, aluminum is a major component of metals and filler metals. The inhalation of aluminum dust or its compounds, including aluminum oxide fumes, is not known to have any effects on man.

- **Antimony** - Antimony is used as an alloying metal in many specialty metals. Antimony and its compounds irritate the skin and mucous membranes. Skin contact with antimony can result in inflammation of the hair follicles. A greater infection may develop that produces scars. Symptoms of excessive exposure to airborne antimony are a metallic taste in the mouth, vomiting, loss of appetite, and general stomach distress.

- **Arsenic** - Arsenic may be encountered in welding and cutting operations as a component of various alloys. It is used as a hardening agent. Welding or cutting on metals that are painted with arsenic compounds can also be hazardous. Exposure to excessive concentrations of arsenic compounds produces inflammation of mucous membrane surfaces and an irritation of exposed skin. Common symptoms in exposed workers include skin irritation, irritation of the nasal passages, laryngitis, and mild irritation of the lungs and eyes.

- **Asbestos** - Asbestos is found in the coatings of some welding rods. Long-term exposure to high concentrations of asbestos fibers causes asbestosis, a disease of the lung. Under *normal* circumstances of welding with coated rods containing asbestos, hazardous concentrations are not produced. However, the welder should be sure that good ventilation is in operation during welding processes in which such rods are used.

- **Beryllium** - Beryllium is sometimes used as an alloying element with copper and other base metals. Acute exposure to high concentrations of beryllium can result in chemical pneumonia. Long-term exposure can result in shortness of breath, chronic cough, and significant weight loss, accompanied by fatigue and general weakness.

- **Cadmium** - Cadmium is used frequently as a rust-preventive coating on steel and also as an alloying element. Acute exposures to high concentrations of cadmium fumes can produce severe lung irritation. Long-term exposure to low levels of cadmium in air can result in emphysema (a disease affecting the ability of the lung to absorb oxygen) and can damage the kidneys.

- **Carbon Monoxide** - Carbon monoxide is a gas usually formed by the incomplete combustion of various fuels. Welding and cutting may produce significant amounts of carbon monoxide. In addition, welding operations that use carbon dioxide as the inert gas shield may produce hazardous concentrations of carbon monoxide in poorly ventilated areas. This is caused by a "breakdown" of the shielding gas. Carbon monoxide is odorless and colorless and cannot be detected. Common symptoms of overexposure include pounding of the heart, a dull headache, flashes before the eyes, dizziness, ringing in the ears, and nausea.

- **Chromium** - Chromium is the primary alloying agent in stainless steel. Chromium compounds are strong oxidizing agents and are extremely toxic and irritating to the skin, eyes, and mucous membranes. Although welding under *normal* operating conditions would not be expected to produce hazardous concentrations of chromium compounds, welding of stainless steel should be carried out in well-ventilated areas.

- **Chlorinated Hydrocarbon Solvents** - Various chlorinated hydrocarbons are used in degreasing or other cleaning operations. The vapors of these solvents are a concern in welding and cutting because the heat and ultraviolet radiation from the arc will decompose the vapors and form highly toxic and irritating phosgene gas. (See Phosgene.)

- **Cobalt** - Cobalt appears as an alloying agent in high-strength, high-temperature alloys. Inhalation of cobalt fumes can cause shortness of breath and coughing. In most cases, the symptoms disappear after exposure ends.

- **Fluorides** - Fluoride compounds are found in the coatings of several types of fluxes used in welding. Exposure to these fluxes may irritate the eyes, nose, and throat. Repeated exposure to high concentrations of fluorides in air over a long period may cause pulmonary edema (fluid in the lungs) and bone damage. Exposure to fluoride dusts and fumes has also produced skin rashes.

- **Iron Oxide** - Iron is the principal alloying element in steel manufacture. During the welding process, iron oxide fumes arise from both the base metal and the electrode. The primary acute effect of this exposure is irritation of nasal passages, throat, and lungs. Although long-term exposure to iron oxide fume may result in iron pigmentation of the lungs, most authorities agree that these iron deposits in the lung are not dangerous.

- **Lead** - The welding and cutting of lead-bearing alloys or metals whose surfaces have been painted with lead-based paint can generate lead oxide fumes. Inhalation and ingestion of lead oxide fumes and other lead compounds will cause lead poisoning. Symptoms include metallic taste in the mouth, loss of appetite, nausea, abdominal cramps, and insomnia. In time, anemia and a general weakness, chiefly in the muscles of the wrists, develop.

- **Magnesium** - Magnesium and magnesium-aluminum alloys, both found as alloys in steel, are used in the manufacture of structural parts for airplanes and in tool making. Welding and cutting on magnesium-containing metals produces magnesium oxide fumes, and exposure to these fumes can irritate the eyes, nose, and throat.

- **Manganese** - Manganese is a constituent of many arc welding electrodes. The welding process produces manganese dioxide fumes. In most cases, the concentrations generated are not hazardous. Nevertheless, cases of manganese poisoning have been reported. Symptoms of excessive exposure are weakness, instability, difficulty in walking, and monotonous and intermittent speech.

- **Mercury** - Mercury compounds are used to coat metals to prevent rust or inhibit foliage growth (marine paints). Under the intense heat of the arc or gas flame, mercury vapors will be produced. Exposure to these vapors may produce stomach pain, diarrhea, kidney damage, or respiratory failure. Long-term exposure may produce tumors, emotional instability, and hearing damage.

- **Molybdenum** - Molybdenum, a constituent of some grades of steel, is sometimes encountered during welding and cutting. Molybdenum does not present a health hazard in most operations.

- **Nitrogen Oxides** - The intense energy produced by the arc can create nitrogen oxides. The most significant form is nitrogen dioxide. This gas is mildly irritating to the eyes, nose, and upper respiratory tract at relatively low concentrations. It is hard to detect and dangerous concentrations can be inhaled without any discomfort, even to the point that injury to the lungs results.

- **Ozone** - Ozone is a gas that is produced by the ultraviolet radiation in the air in the vicinity of arc welding and cutting operations. Ozone is very irritating to all mucous membranes, with excessive exposure producing pulmonary edema. Other effects of exposure to ozone include headache, chest pain, and dryness in the respiratory tract.

- **Phosgene** - Phosgene is formed by decomposition of chlorinated hydrocarbon solvents by ultraviolet radiation. It reacts with moisture in the lungs to produce hydrogen chloride, which in turn destroys lung tissue. For this reason, any use of chlorinated solvents should be well away from welding operations or any operations in which ultraviolet radiation or intense heat is generated.

- **Phosphine** - Phosphine or hydrogen phosphide can be produced when steel coated with phosphate rustproofing is welded. Excessive concentrations of this gas are irritating to eyes, nose, and skin. Acute effects, besides irritation, include headache, dizziness, and pulmonary irritation. Chronic exposure may result in disturbances of sight and speech.

- **Silicon Dioxide** - Silicon dioxide (free silica) is found as a constituent in the coatings of several welding rods. Depending on the extent of welding, significant concentrations of airborne free silica can be generated. Long-term exposure to excessive concentrations of free silica can lead to silicosis, a development of tissues in the lungs which prevent normal breathing.

- **Zinc** - Zinc is used in large quantities in the manufacture of brass, galvanized metals, and various other alloys. Inhalation of zinc oxide fumes can occur when welding or cutting on zinc-coated metals. Exposure to these fumes is known to cause metal fume fever. Symptoms of metal fume fever are very similar to those of common influenza. They include fever (rarely exceeding 102° F), chills, nausea, dryness of the throat, cough, fatigue, and general weakness and aching of the head and body. The victim may sweat profusely for a few hours, after which the body temperature begins to return to normal. The symptoms of metal fume fever have rarely, if ever, lasted beyond 24 hours. The subject can then return to work without any apparent after-effects. Workers appear to be more susceptible to the onset of this condition on Mondays or on weekdays following a holiday than they are on other days.

4. Physical agents

- **Ultraviolet Radiation** - Ultraviolet radiation (UV) is generated by the electric arc in the welding process. Skin exposure to UV can result in severe burns, in many cases without prior warning. UV radiation can also damage the lens of the eye. Many arc welders are aware of the condition known as "arc-eye", a sensation of sand in the eyes. This condition is caused by excessive eye exposure to UV. Ultraviolet rays also increase the skin effects of some industrial chemicals (coal tar and cresol compounds, for example).

- **Infrared Radiation** - Exposure to infrared radiation (IR), produced by the electric arc and other flame cutting equipment, may heat the skin surface and the tissues immediately below the surface. Except for this effect, which *can* progress to thermal burns in some situations, infrared radiation is not dangerous. Most welders protect themselves from IR (and UV) with a welder's helmet (or glasses) and protective clothing.

- **Intense Visible Light** - Exposure of the human eye to intense visible light can produce adaptation, pupillary reflex, and shading of the eyes. Such actions are protective mechanisms to prevent excessive light from being focused on the retina. In the arc welding process, eye exposure to intense visible light is prevented for the most part by the welder's helmet. However, some individuals have sustained retinal damage due to careless "viewing" of the arc. At no time should the arc be observed without eye protection.

E ENVIRONMENTAL CONTROL

After checking to see that the welding and cutting equipment is mechanically and electrically sound, engineering and administrative controls for the contaminants produced by welding and cutting should be assessed.

1. *Dilution ventilation*
   For many welding and cutting operations, control by dilution ventilation will be sufficient. That is, enough fresh air is added to the contaminated air that hazardous concentrations do not develop. However, the effectiveness of dilution ventilation depends on several factors:

   - the size of the space in which welding or cutting is done, especially the height of the ceilings;
   - the total number of welders working within the space; and
   - the hazardous chemical or physical agents produced by the welding or cutting.

Dilution ventilation is necessary whenever welding or cutting is done in a work space of less than 10,000 cubic feet per welder, in a room less than 16 feet high, in confined spaces, or where the welding space contains partitions, balconies, or other structural barriers that obstruct cross-ventilation. Otherwise, natural ventilation should be sufficient for most welding and cutting activities.

When dilution ventilation is used, it must move at least 2,000 cubic feet of air per minute per welder, unless local exhaust hoods and booths are used to control fumes where they are produced.

When using dilution ventilation, there are several points to keep in mind:

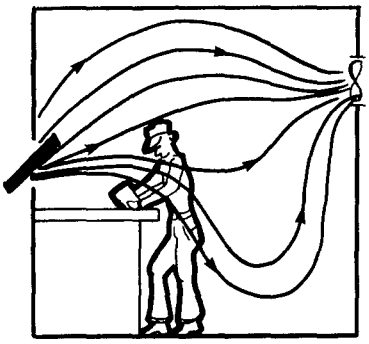
- exhaust openings should be located as close as possible to the source producing the contaminant;

- to keep the contaminants out of the breathing zone of the worker, **the fresh air applied to the work space should first pass through the worker's breathing zone,** *then* **across the work space** where the contaminant is produced **and into the exhaust system** as rapidly as possible;

- unless the exhausted air is discharged far away from the fresh air intake duct, the fresh air can become contaminated.

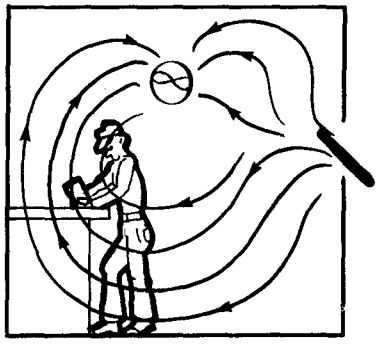
Examples of possible arrangements (both good and bad) for dilution ventilation of a work space are depicted in these figures:

GENERAL VENTILATION



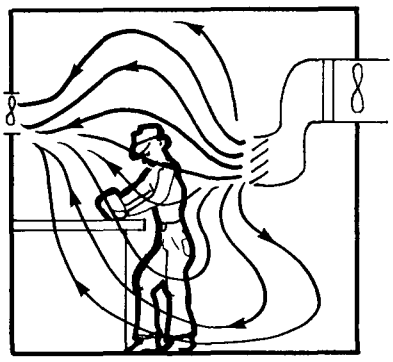
Poor General Ventilation

(Contaminant is driven into the worker's breathing zone and atmosphere)



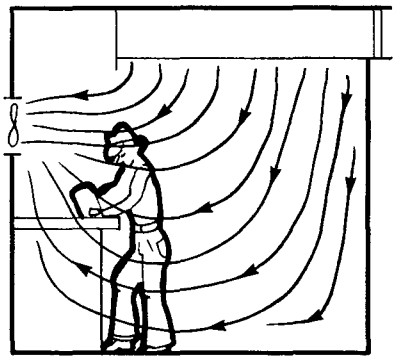
Fair General Ventilation

(Incomplete flushing of the room; contamination of general atmosphere)



Good General Ventilation

(Air enters at breathing zone height and keep contamination away from worker)



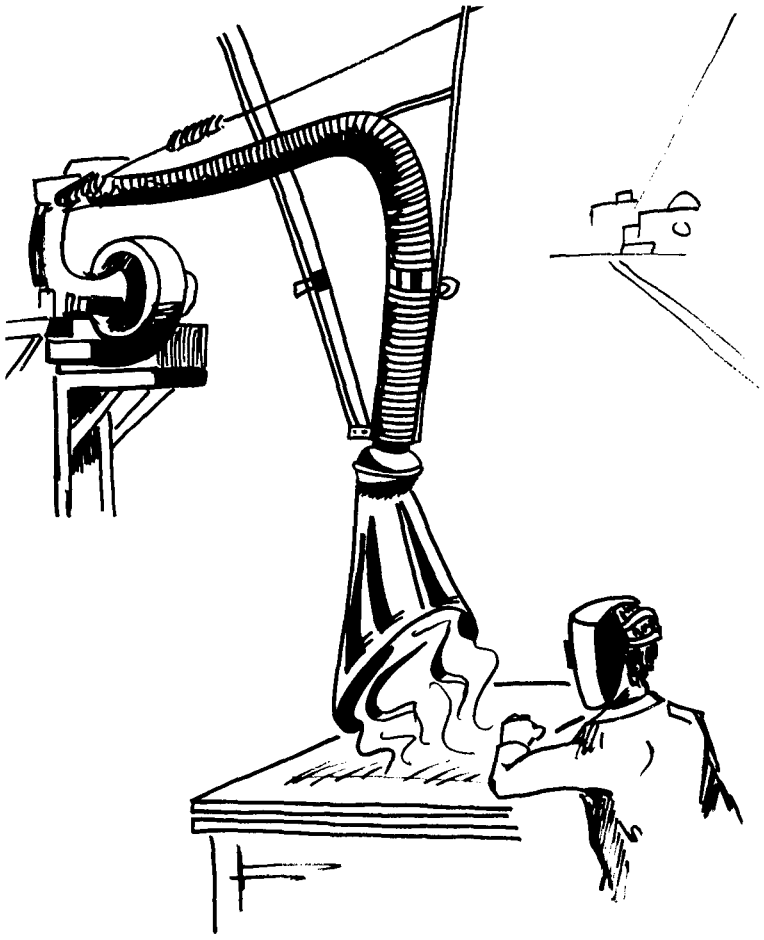
Best General Ventilation

(Low velocity diffusion through ceiling, immediate exhaust of contaminated air)

2. *Local exhaust ventilation*
   Local exhaust ventilation is the most effective means of control for airborne contaminants produced by welding or cutting. Local exhaust ventilation can be provided by several types of equipment: freely movable hoods, fixed enclosures (booths), down-draft benches, and extractor nozzles.

   - **Freely movable hood** - This consists of a movable hood, attached to a fan. The fan draws air from the work space and exhausts it outdoors, either directly or through a dust collection system. The hoods are normally constructed so that they can be moved into place by the welder as shown below.

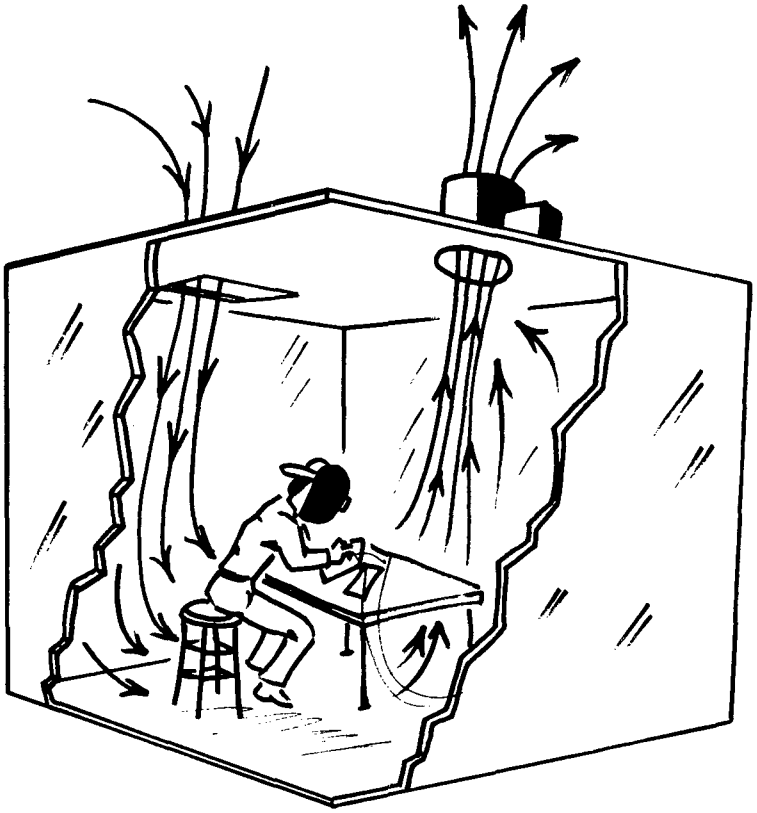
     The air handling system should move air at least 100 feet per minute across the welding site at even the most remote point from the exhaust opening. It is important that the exhaust hood be placed as near as possible to the work being done. A freely movable hood is useless if it is not moved when the welder



Movable exhaust hood

shifts his position. This form of ventilation, to be effective, is dependent on the conscious effort of the welder.

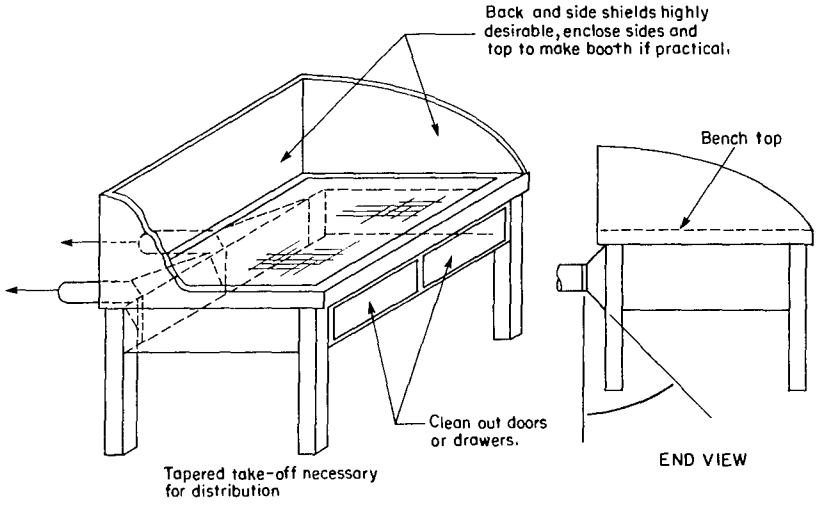
- **Fixed enclosures** - Many welding or cutting operations done in a fixed location can be provided with a fixed enclosure. This is a structure built around the welding or cutting operation which has a top and at least two sides. A means for drawing air through the work area is provided so that the work space is flushed continuously with fresh air.



Fixed welding enclosure

Within such an enclosure, **work should be arranged and conducted in such a way that the fresh air enters the enclosure through the worker's breathing zone and then passes through the work space** in which the contaminants are produced. For most fixed enclosures, the air should move at least 100 feet per minute across the entrance to the enclosure.

- **Down-draft benches** - A third type of local exhaust ventilation is the down-draft bench or table. The welding or cutting is performed on a bench or table which has an open grid as the work surface. Air is drawn downward through the grid, into the duct work and then exhausted, preferably outdoors. This prevents the contaminants from rising into the worker's

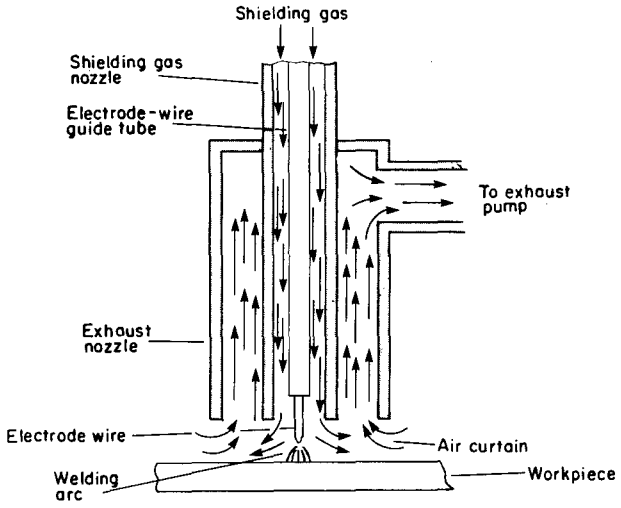


Typical downdraft bench.

breathing zone. However, to function properly, the work being done on the bench must **not** be of such a size that it covers most of the work surface. This would obstruct the airflow into the exhaust system.

- **Extractor nozzles** - A new development in local exhaust ventilation for welding is the extractor nozzle. This equipment is based on the idea that exhaust ventilation should be built into the semi-automatic welding processes, such as the metal inert gas type of welding process.

  In this system, a slotted exhaust chamber is installed as part of the welding equipment itself. The slotted exhaust chamber is positioned to allow the welder a clear view of the electrode. The contaminated air from around the welding operation is drawn through the chamber to an exhaust system.



Design concept for welding gun

3. *Administrative control*

   If engineering controls cannot be installed, or while they are being put into effect, administrative controls may be necessary to limit exposure. Work can be scheduled so that no individual worker is exposed to airborne contaminants above the acceptable concentration or time limit. In other words, if a particular operation presents exposures above acceptable limits if performed full-time, the exposure can be "shared" by splitting the assignment between two welders.

F PERSONAL PROTECTIVE EQUIPMENT

After environmental controls have been analyzed, personal protective equipment should be considered. Most welders recognize the need for personal protective equipment, particularly for the eyes and skin.

1. *Eye and face protection*
   One of the primary concerns in welding and cutting is the protection of the eyes, face, and neck against flying sparks and radiant energy. Ultraviolet, visible, and infrared radiation from the arc can harm the eyes. To properly protect the eyes and face, helmets must be used for all arc welding and cutting. Helmets must be designed to protect the face, forehead, neck, and ears from direct exposure to radiation from the arc.

   Proper filter plates have been identified by the National Bureau of Standards. The recommended filter plates are identified by shade number and are related to the type of arc welding or cutting operation below. This table is a guide which may be varied to suit individual needs.

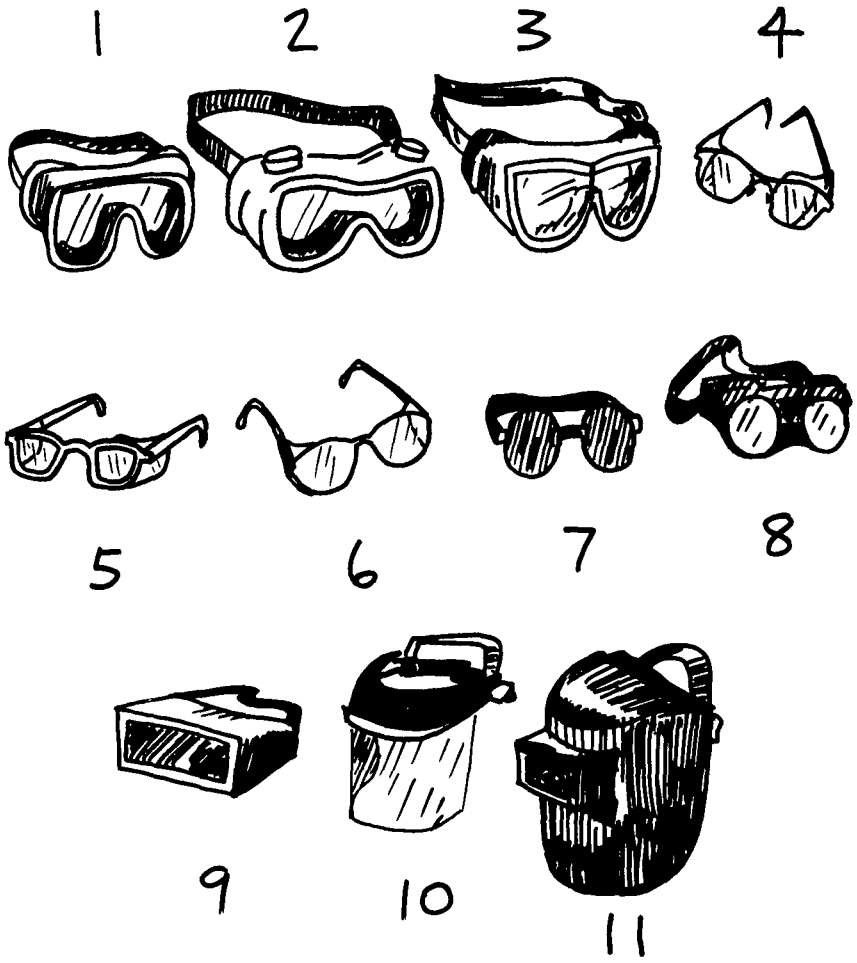
ARC WELDING OPERATION	SUGGESTED SHADE NUMBER
Shielded Metal-Arc Welding, up to 5/32-in. electrodes	10
Shielded Metal-Arc Welding, 3/16 to 1/4-in. electrodes	12
Shielded Metal-Arc Welding, over 1/4-in. electrodes	14
Gas Metal-Arc Welding (Non-ferrous)	11
Gas Metal-Arc Welding (Ferrous)	12
Gas Tungsten-Arc Welding	12
Atomic Hydrogen Welding	12
Carbon Arc Welding	14
Light Cutting, up to 1 in.	3 or 4
Medium Cutting, 1 to 6 in.	4 or 5
Heavy Cutting, over 6 in.	5 or 6

Goggles or other suitable eye protection must be used for gas welding or oxygen cutting. Spectacles with suitable filter lenses and without side shields are permitted during gas welding. Goggles should have vents near the lenses to prevent fogging. Cover lenses or plates should be provided to protect the filter lens and helmet. All glass used for lenses should be ground properly so that front and rear surfaces are smooth. Filter lenses must be marked so that the shade number can be readily identified. For gas welding, the following shade numbers are suggested.

Gas Welding (Light): base metal up to 1/8-in. thick..... 4 or 5
Gas Welding (Medium): 1/8 to 1/2-in..... 5 or 6
Gas Welding (Heavy): over 1/2-in..... 6 or 8

A general guide for the selection of eye and face protective equipment is presented below:

APPLICATIONS		
OPERATION	HAZARDS	RECOMMENDED PROTECTORS:
Acetylene-burning Acetylene-cutting Acetylene-welding	Sparks, harmful rays, molten metal, flying particles	7, 8, 9
Electric (Arc) Welding	Sparks, intense rays, molten metal	9, 11 (in combination with 4, 5, 6 in tinted lenses, available)
Spot Welding	Flying particles, sparks	1, 3, 4, 5, 9, 10



1. Goggles, flexible fitting, regular ventilation
2. Goggles, flexible fitting, hooded ventilation
3. Goggles, cushioned fitting, rigid body
4. Spectacles, metal frame, with sideshields
5. Spectacles, plastic frame, with sideshields
6. Spectacles, metal-plastic frame, with sideshields
7. Welding goggles, eyecup type, tinted lenses (illustrated)

7A. Chipping goggles, eyecup type, clear safety lenses (not illustrated)

8. Welding goggles, coverspec type tinted lenses (illustrated)

8A. Chipping goggles, coverspec type, clear safety lenses (not illustrated)

9. Welding goggles, coverspec type, tinted plate lens
10. Face shield (available with plastic or mesh window)
11. Welding helmets

2. *Skin protection*
Some type of protective clothing for the skin will be required for nearly all welding.

- Protective gloves, preferably the gauntlet type, should be worn regardless of the degree of welding performed. For light arc welding and cutting (low current densities), durable, flame-resistant cotton gloves may be used. For heavier work (higher current densities), gloves of leather or some other suitable flame-resistant material should be used.

- Flameproof aprons made of asbestos or other suitable materials should be used when additional protection against sparks and heat is needed.

- For heavy work, fire-resistant leggings should be used. In production work, a sheet metal screen placed in front of the welder's legs can provide further protection against sparks and molten metal. Cape sleeves or shoulder covers with bibs made of leather or other flame-resistant materials should be worn during overhead welding or cutting. Skull caps made from flame-resistant materials should be worn under helmets to prevent head burns.

- Woolen clothing is preferable to cotton because it is not readily ignited and also helps protect the worker from changes in temperature. Cotton clothing, if used, should be treated with a flame retardant. Clothing treated with non-durable flame retardant materials should be treated again after each wetting or cleaning.

- Sparks may lodge in rolled-up sleeves, pockets, or cuffs. Therefore, sleeves and collars must be kept buttoned and pockets should be removed from the front of clothing. The legs of trousers or coveralls should not be rolled up on the outside.

3. *Hearing protection*

Noise problems are not normally associated with arc welding and cutting. However, some operations, most notably plasma arc welding, produce relatively high noise levels. These levels are difficult to control with present technology.

- Exposure Limit

Federal law requires that workers' exposure to noise be reduced whenever the noise level exceeds 90 decibels. This level applies to an 8 hour per day, 40 hour per week exposure. If the noise level exceeds 90 decibels, the exposure time must be shorter. The table below gives the exposure time permitted for various noise levels:

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

In the event that noise limits are exceeded, administrative or engineering controls are required, if feasible. Similar administrative controls were discussed in the "Ventilation" section. But because engineering controls are not usually appropriate for noise from welding processes, personal protective equipment will usually be needed. There are three basic types of personal protective devices available for noise:

- The moldable insert type is made of materials such as rubber, plastics, or waxes, which are molded by the worker to fit the ear canal by rolling and shaping the material with the hands and inserting it into the ear.

- The pre-molded plug comes in a wide variety of styles and sizes, since the human ear varies tremendously from person to person. It is important that earplugs be fitted individually by trained people. To be effective, any type of plug must be fitted properly and remain correctly seated in the ear canal.

- The cup or muff type of hearing protector covers the entire external portion of the ear. This type of ear protection may interfere with the proper fit of the welding helmet (and vice versa), and so is probably of limited usefulness.

Another reason for wearing ear protection, not related to noise, is to prevent sparks from entering the ear canal. Such sparks can cause severe burns. Several cases of eardrum damage have been reported when welding in the vertical or overhead position.

4. *Respiratory protection*
The nature or location of the welding process may make ventilation difficult to use. Or, the welding process may produce an extremely toxic substance (cadmium or chromium, for example) in considerable quantities. In this case, it may be necessary to use respirators.

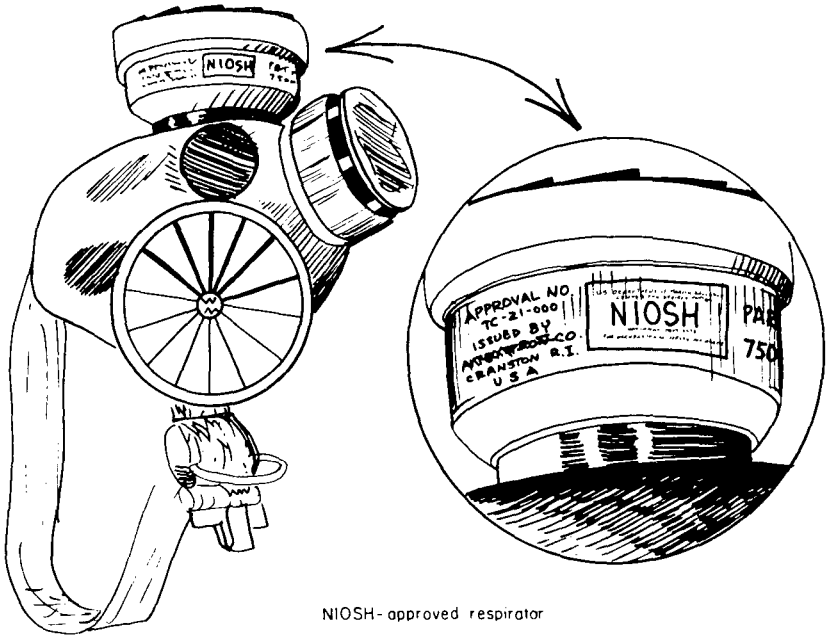
Common respirators are not suitable for welding. The welder's helmet and welding position interfere with the fit of the respirator. However, several companies have developed a "modified" welding helmet with a built-in respirator, or one which allows a respirator to fit underneath.

These figures illustrate some helmet/respirator schemes.

Belt - mounted respirator

Leather hood

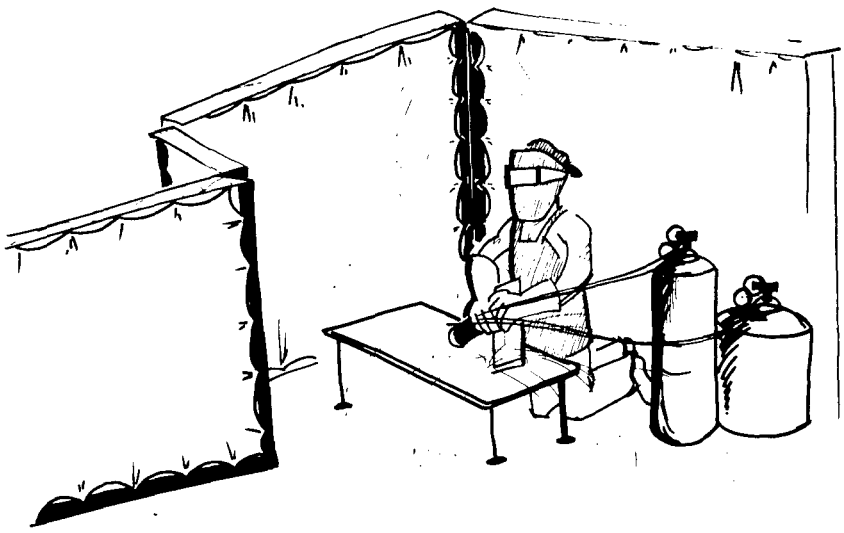
The respirator you wear must be approved by the National Institute for Occupational Safety and Health (NIOSH), or other competent authority, and also be approved for protection against the contaminant in the work area. The accompanying figure shows a respirator and cartridge and the printed approval by NIOSH.



NIOSH-approved respirator

5. Protective equipment - other considerations

- Non-combustible or flame-proof screens or shields must enclose the welding area to prevent exposure of nearby workers to ultraviolet and infrared radiation.



Individual welding booth

- Individual booths, painted with a substance such as zinc oxide or lampblack, are also recommended. The substance on the inside of the booth will absorb UV radiation.

- The screens and booths must not block circulation of air at floor levels.

G WELDING TECHNIQUES

To a great extent, the safety of a particular welding operation depends on the position of the welder and the arc or gas flow location. The welder's position, in turn, depends on the welding site. Typical sites include:

- Table top (horizontal)
- Vertical welding
- Inside motor housings
- Pipe welding in a ditch
- Inside a tank (confined space)

In many cases, welders expose themselves to welding fumes needlessly by working directly in line with the fume stream. It is true that the welding helmet does divert the fume stream from the welder's breathing zone—*but only when positioned properly.* If the helmet is not positioned properly, the fume will travel into the breathing zone inside the helmet.

H SPECIFIC REQUIREMENTS — VENTILATION AND RESPIRATORY PROTECTIVE EQUIPMENT

There are specific requirements concerning ventilation and respirators when welding or cutting on the following:

- stainless steel, lead, zinc, or cadmium;
- metals coated with materials (such as paint) which contain lead or mercury;
- fluxes or other materials containing fluorides.

These requirements are summarized below:

Welding or Cutting on Materials Containing or Coated with	*Location of Operation*		
	Confined Spaces	*Indoors*	*Outdoors*
Lead	A or B	A	C
Zinc	A or B	A	
Cadmium*	A or B	A or B	C
Beryllium*	A and B	A and B	A and B
Mercury*	A or B	A or B	C
Fluorine*	A or B		
Stainless Steels	A	A	A

*Unless atmospheric tests under the most adverse conditions have established that the workers' exposures are within acceptable concentrations defined by 1910.1000.

A = Mechanical local exhaust ventilation by means of either hoods or booths with sufficient airflow to maintain a velocity, away from the worker, of at least 100 linear feet per minute.

B = NIOSH approved supplied-air respirator, or equivalent.

C = NIOSH approved respiratory protective equipment, or equivalent.

I ADDITIONAL SAFETY AND HEALTH CONSIDERATIONS

1. Confined spaces

Within each confined space, ventilation must be provided to prevent the accumulation of toxic or combustible materials and to supply oxygen.

- All replacement air must be fit to breathe or an approved air-line or hose mask respirator must be worn. Oxygen must not be used for ventilation.

- Workers exposed to substances immediately hazardous to life must wear either hose masks with blowers or self-contained breathing equipment.

- Gas cylinders and welding machines must be left outside the space. Heavy equipment mounted on wheels must be securely blocked to prevent accidental movement.

- If the entry to the space is through a small opening or manhole or the atmosphere is immediately hazardous to life, means must be provided for quick removal in case of emergency. If safety belts and lifelines are used, they must be attached so that the worker may be easily removed. An attendant trained in rescue procedures must be continuously present outside to observe and assist if needed.

2. Labels

Information on symptoms of overexposure, first aid procedures, and control of employee exposure is usually provided for substances such as filler metals, fusible granular materials, and welding fluxes. This information is frequently printed on tags or on boxes or other containers. Become familiar with these directions and follow them.

3. *General work practices*

Welders or their helpers working on platforms, scaffolds, or runways must be protected by railings, safety belts, lifelines, or other equally effective safeguards.

Welding cables or other equipment must be placed so that they are clear of passageways, ladders, and stairways.

Each welder is responsible for marking the hot metal or providing some means of warning for others to keep away.

Hard hats or other head protection may be required where sharp or heavy falling objects or bumping in confined spaces are a hazard.

J FIRST AID

1. Program

There must be a first aid program where you work, providing adequate care to all employees during working hours. There should also be medical personnel available for further advice and consultation. If this is not possible, arrangements should be made with a consulting industrial physician or clinic. One or more persons should be designated as responsible for the whole first aid program.

A first aid program should consist of the following:

- first aid training for all employees;
- properly trained first aiders designated on every shift;
- a first aid unit and supplies or first aid kit;
- a detailed and explicit manual of first aid;
- posted instructions for calling a physician and notifying the hospital that a patient is on the way;
- posted method for transporting ill or injured employees and instructions for calling the ambulance or rescue squad;

- an adequate system of recording all cases in which first aid is rendered.

2. *Supplies*
Regardless of the type of work being done, an adequate supply of first aid equipment should be available. **The specific items and the number of each should be based on the recommendations of a physician.** Some suggestions are given in the table below:

Suggested Minimum First Aid Supplies

	NUMBER OF EMPLOYEES		
ITEM	*1-50*	*51-100*	*101-200**
Adhesive bandage, individually packaged	16	32	64
Burn compound, tube or package	1	2	2
Ammonia inhalant	1	1	1
Antiseptic swabs, individually packaged	10	20	30
3'' x 3'' gauze pads, individually packaged	10	20	30
2'' x 10 yd. gauze bandage	2	2	2
Triangular bandage	1	1	1
Adhesive tape, rolls	2	2	3
Scissors	1	1	1
Tweezers	1	1	1
Cleansing tissue, package	1	1	1
Antiseptic solution, aqueous mercury preferred	1	1	1
Mild soap, capped squeeze bottle	1	1	1
Elastic bandage	1	1	1
Rescusitation mouthpiece	1	1	1

*Greater than 200 employees: Provide additional first aid cabinets or increase supplies as demonstrated by past use.

3. *Treatments and procedures*

Electrical Shock

Use non-conducting materials to shut down the source of electricity. If this is impossible, pull the victim away from the electrical source, again using non-conducting materials (e.g., a wooden pole). Work with dry hands or gloves and stand on a non-conducting surface.

If the victim is not breathing, give artificial respiration. If he revives before medical treatment is available, avoid any undue strain, particularly on his heart. Keep the patient lying down and warm. Do not move him if there is any possibility he has internal injuries or fractures.

Ultraviolet Radiation

For mild exposures, apply cold creams or similar oils or greases (salad oil or shortening) to relieve the pain. Medicated creams, butter, or oleo margarines should not be applied. For severe and extensive cases, prompt medical treatment should be obtained. The injured area should not be further exposed to ultraviolet radiation, including sunlight, until the healing is complete. Ultraviolet burns of the eyes are extremely painful. First aid treatment should include cold compresses on the eye and the use of anesthetics or other medicines to relieve the pain.

The patient should wear dark glasses for additional relief until the healing is complete.

Exposure to Airborne Contaminants

Remove the victim from the contaminated area. Apply artificial respiration if breathing has stopped. Keep the patient warm and at complete rest and immediately call for professional medical treatment. It is particularly important for the physician to know the contaminants which might have been present in the workroom air.

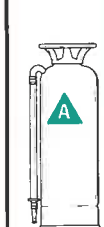
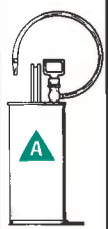
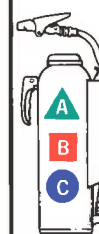
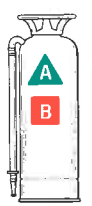
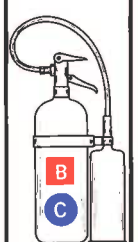
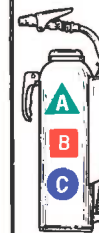
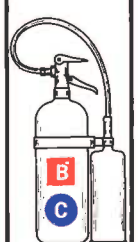
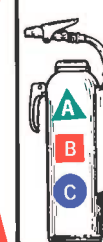
KIND OF FIRE

DECIDE THE CLASS OF FIRE YOU ARE FIGHTING. . .

. . .THEN CHECK THE COLUMNS TO THE RIGHT OF THAT CLASS

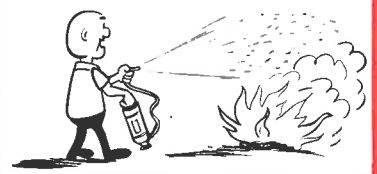
APPROVED TYPE OF EXTINGUISHER

MATCH UP PROPER EXTINGUISHER WITH CLASS OF FIRE SHOWN AT LEFT

FOAM	CARBON DIOXIDE	SODA ACID	PUMP TANK	GAS CARTRIDGE	MULTI-PURPOSE DRY CHEMICAL	ORDINARY DRY CHEMICAL
Solution of Aluminum Sulphate and Bicarbonate of Soda	Carbon Dioxide Gas Under Pressure	Bicarbonate of Soda Solution and Sulphuric Acid	Plain Water	Water Expelled by Carbon Dioxide Gas		
CLASS A FIRES USE THESE EXTINGUISHERS ORDINARY COMBUSTIBLES • WOOD • PAPER • CLOTH ETC.		X					X
CLASS B FIRES USE THESE EXTINGUISHERS FLAMMABLE LIQUIDS, GREASE • GASOLINE • PAINTS • OILS, ETC.			X	X	X		
CLASS C FIRES USE THESE EXTINGUISHERS ELECTRICAL EQUIPMENT • MOTORS • SWITCHES ETC.	X		X	X	X		

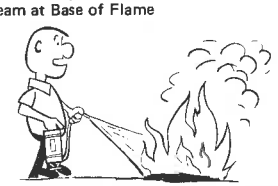
HOW TO OPERATE

FOAM: Don't Play Stream into the Burning Liquid. Allow Foam to Fall Lightly on Fire.



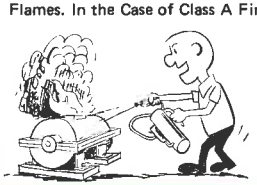
CARBON DIOXIDE: Direct Discharge as Close to Fire as Possible. First at Edge of Flames and Gradually Forward and Upward

SODA-ACID, GAS CARTRIDGE: Direct Stream at Base of Flame



PUMP TANK: Place Foot on Footrest and Direct Stream at Base of Flames

DRY CHEMICAL: Direct at the Base of the Flames. In the Case of Class A Fires, Follow Up by Directing the Dry Chemicals at Remaining Material That is Burning



IMPORTANT! USING THE WRONG TYPE EXTINGUISHER FOR THE CLASS OF FIRE MAYBE DANGEROUS!

TABLE I

K REFERENCES

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   1430 Broadway
   New York, New York 10018
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   - Z87.1 Practice for Occupational and Educational Eye and Face Protection
   - C87.1 NEMA EW-1 on Arc Welding Apparatus
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   - C1 National Electrical Code
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2. *National Fire Protection Association*
   470 Atlantic Avenue
   Boston, Massachusetts 02110
   - NFPA-51B Cutting and Welding
   - NFPA-70-1971 National Electrical Code

3. *The Welding Institute*
   Abington Hall
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   - Facts About Fume

4. *American Welding Society*
   United Engineering Center
   345 East 47th Street
   New York, New York 10017
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5. *National Safety Council*
   425 N. Michigan Avenue
   Chicago, Illinois 60611

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