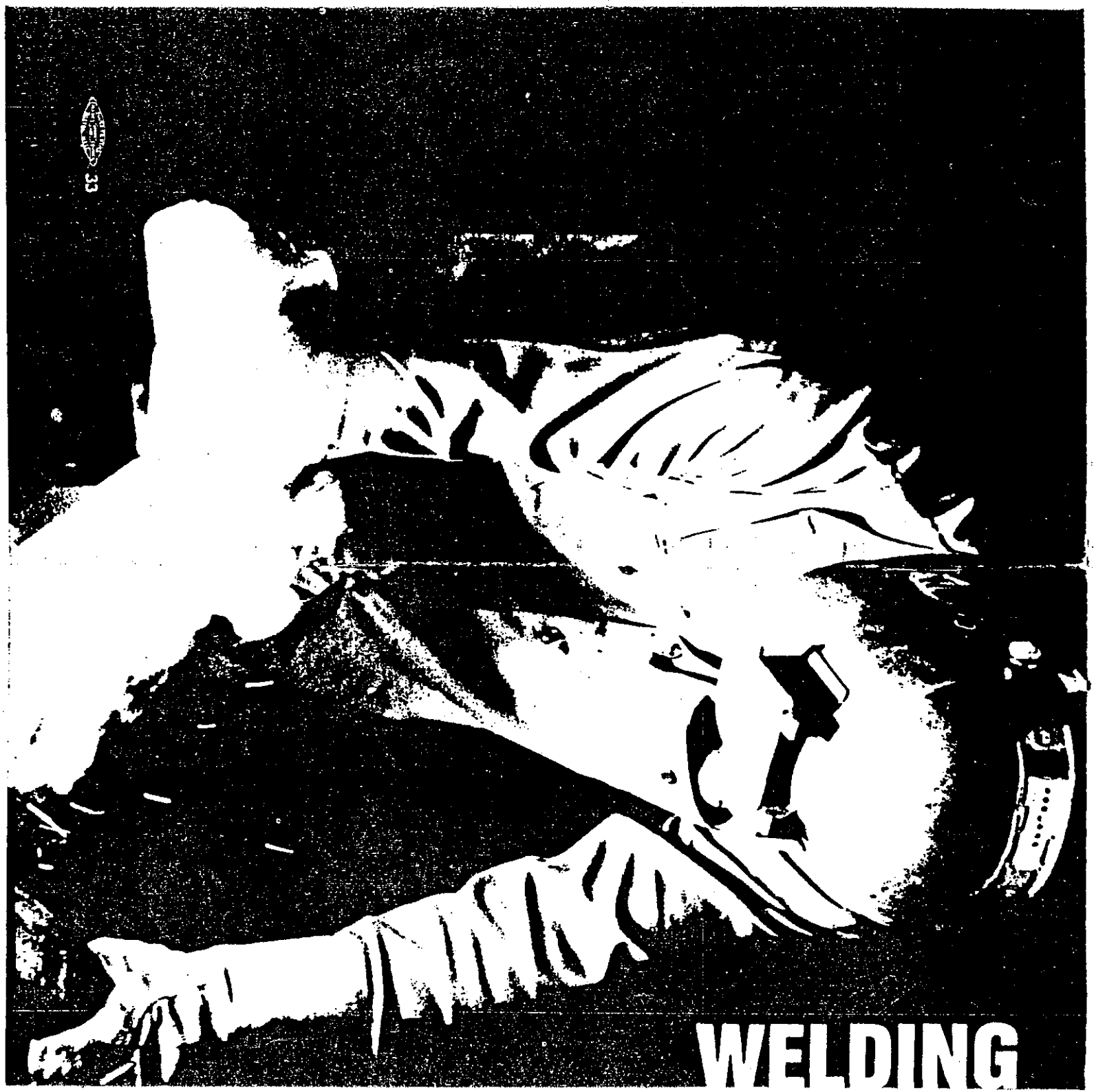

WELDING

Welding
(Hazards & Controls)

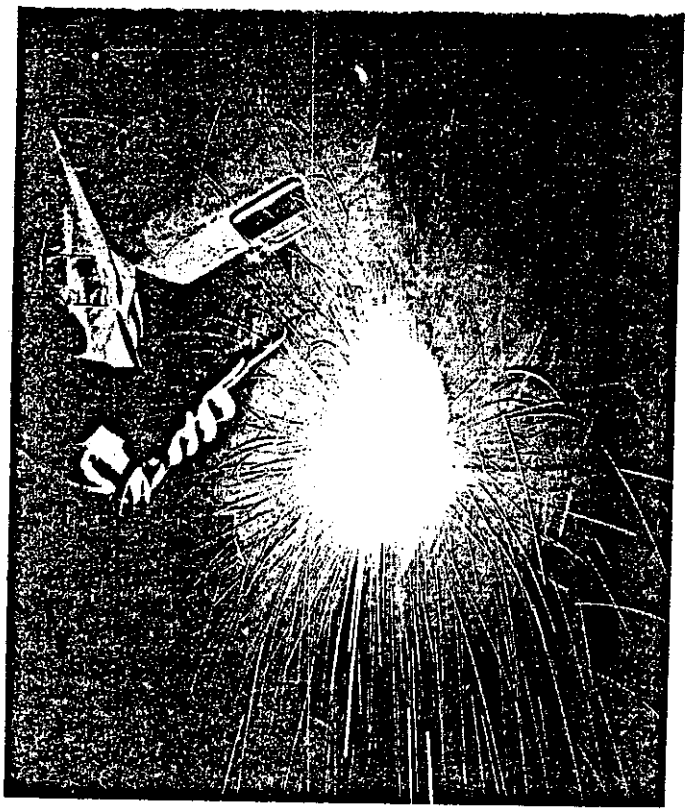
Written by
RICHARD A. YOUNGSTROM, C.I.H.
IUE Local 201 Health & Safety Committee, Inc.

Designed & Typeset by
the mediaplace, inc.
Photographs taken from the American Welding Society Journal

This booklet is dedicated to IUE Local 201 welders at the General Electric Co. and other welders who often do not know the hazards of their work and whose health has been impaired by exposures on the job.

This material has been funded in whole or in part with Federal funds from the Occupational Safety & Health Administration, US Department of Labor, under grant #EAF1D112. Individuals undertaking such projects under Government sponsorship are encouraged to express freely their professional judgement. Therefore, these materials do not necessarily reflect the views or policies of the US Department of Labor, nor does mention of trade names, commercial products, or organizations imply endorsement by the US Government.

Welding is a widespread industrial process used in applications ranging from maintenance to production work involving the use of automated machinery and robots. It basically involves the use of heat to fuse pieces of metal together. Throughout its history, most development of welding has been concerned with solving engineering problems concerned with the quality of the weld; little attention has been given to the quality of the working environment of the welder. This booklet is designed to provide workers with basic information about the health and safety hazards of welding and what can be done to reduce the risk of becoming injured or sick on the job.



Contents

Hazards of Welding

Although there are about 80 different types of welding and allied processes, the most common is arc welding. Arc welding includes "stick" welding (the most common), MIG, TIG (Heliarc), fluxcored, plasma and sub-arc welding. Other types of welding use electrical current, laser light, electron beams, friction, ultrasonic sound, chemical reactions, heat from fuel gas and other means to produce welds.

Electrical

The basic welding process involves completing an electrical circuit through an arc which is formed between the electrode and the work. This arc is the source of heat which produces the weld. Although arc welding is generally done with low voltage (less than 100V), as with all electricity, there is a hazard of electric shock. However, environmental conditions, (hot weather, cramped locations, dampness) during the actual welding can create conditions where shocks are possible. While a small shock itself is not extremely hazardous, accidents such as falls can easily result from reaction to shock.

Hot Metal

Hot metal and sparks are also hazardous. All welding produces intense heat which causes burns and, depending on combustible or flammable materials in the vicinity, can produce fires or explosion.

Light

The intense light normally associated with arc welding is another hazard. Not only is there intense visible light which can produce eye injuries, invisible ultraviolet light (UV) is also produced. UV light can create a short lived but acute problem for anybody exposed to it called "arc eye" or "welders flash." This condition usually occurs many hours after exposure to UV radiation and feels like sand is in your eyes.

Shipyard Workers Discover Phosgene Hazard

Two welding department stewards from shipbuilders Local 5 at the General Dynamics/Quincy shipyard discovered that a widely used anti-spatter spray was hazardous to welders and other workers. The "Arc Air" spray, used in MIG welding operations, contained chlorinated hydrocarbons which were broken down into phosgene—a World War 2 "nerve gas"—by the action of the UV (ultraviolet) light from the arc. Phosgene can cause death from pulmonary edema (fluid in the lungs) at high doses and permanent lung damage at lower level chronic doses.

After some initial delay, General Dynamics agreed to recall all cans of Arc Air Spray and use only anti-spatter products without chlorinated hydrocarbons.

Credit: ***MASSCOSH*** *Survival kit*

Gases

Gases are associated with welding processes as a fuel in gas welding and cutting, as a shielding gas and as a product of the heat and light of the arc. UV radiation is not only harmful itself, it can also produce some harmful gases in the welding environment. Ozone, for example, is a harmful but sweet smelling gas produced by UV acting on oxygen in the air. Another gas associated with UV radiation is phosgene, produced by the interaction of UV radiation and chlorinated hydrocarbon solvent vapors (such as trichloroethylene, perchloroethylene and others). Other gases found in welding operations include oxides of nitrogen (NOx) created by the high temperatures of the arc, carbon monoxide from incomplete combustion or when carbon dioxide is used as a shielding gas and other gases when paint or other surface coatings are heated.

Fume or Particles

Perhaps the most important hazard associated with welding is welding "smoke," which, if breathed for long enough time and in sufficient concentration, can produce many different chronic lung problems. Welding smoke is actually a mixture of very fine particles and gases. The particles come from vaporized metal from the base metal being welded, the electrode coating and filler metal and surface coatings like lead paint or zinc primer. The composition of the smoke is variable and depends on the kind of metals involved and the type of flux coatings used. Exposure to the welding smoke also means exposure to many different materials at the same time and little research has been done on these combinations of exposure.

What is Welding Smoke?

The smoke or welding fume is made up of many ingredients. The very high temperatures of the arc or other heat source cause the metals and any other materials near the heat to melt, vaporize and go into the air. As this metal cools it condenses back to the solid form as very small particles less than 1 micron in size. A micron is one millionth of a meter or about 1/25,000 of an inch; human hair by comparison is over 100 microns thick.

Non metals from the flux and surface coatings (containing fluorides, silica and sometimes asbestos) also become airborne. These particles stay suspended in the air and are small enough to be breathed into the deepest most vulnerable parts of the lung.

The heat and the light also act on the shielding gas and the atmosphere (air) to create various gases. These particles and gases rise in the heated air around the weld and form the visible smoke plume.

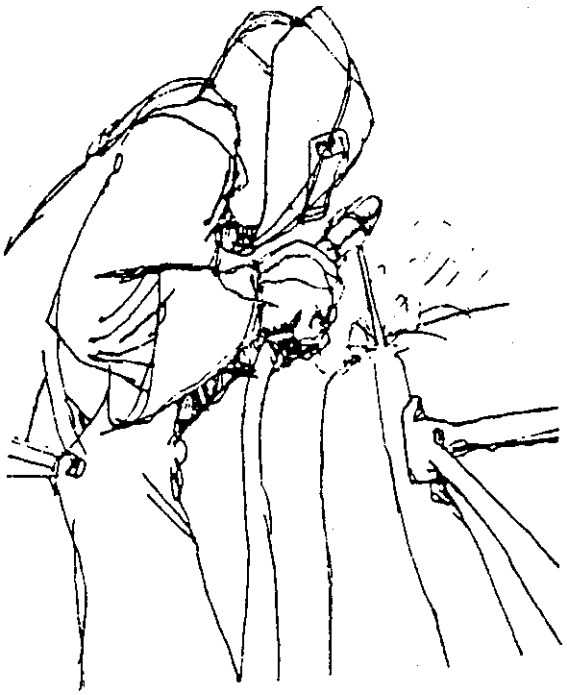
Is There a Cancer Hazard In Welding?

For many years it has been known that many of the materials that welders are exposed to have caused cancer in other workers or are suspect human carcinogens: chromium, nickel and arsenic are human carcinogens; beryllium, cadmium, cobalt, copper, lead, selenium and zinc have produced cancer in animals.

More recently, four epidemiological studies of welders, flame cutters and burners have shown that welders not only have a greater incidence of chronic lung disease but have a significant increase in cancer of the lung and other parts of the respiratory system. The studies, from Washington State, Los Angeles and Great Britain, involved many thousands of welders who died between 1950 and 1976. These studies clearly show an increased risk of respiratory cancer for welders, but what materials are responsible for this risk? Although it has not been proven, chromium and nickel in stainless steels and other high alloy metals appear to be likely suspects.

What can be done? Although the proof may not be strong enough for OSHA to issue new standards and regulations, welders and their unions should push for better environmental controls whenever nickel and chromium are encountered in the welding environment.

In 1979, scientists studied a group of 8,000 members of a Boilermakers local in Seattle. This group included 3,247 welders who had been union members between 1950 and 1976. Among all these workers, there was a 31% greater than normal risk of death from lung cancer, a 67% greater risk of death from pneumonia, and a 25% greater risk of death from other respiratory diseases (emphysema, chronic lung disease, etc.) For those workers with more than 20 years experience, the risks were greater still: 69% excess risk for lung cancer and 61% for all other respiratory diseases.



Finding The Hazards: Three Questions

To evaluate the health hazards of any particular welding operation, three different types of information are needed. You should ask yourself the following questions:

1 What kind Of Welding Is Being Done?

Different processes have different characteristics and produce different hazards. For example, MIG and TIG welding have a more intense UV radiation than stick welding; electron beam welding may involve a radiation hazard; plasma and air arcing are very noisy; and so on.

2 What Materials Are Being Welded Or Are Exposed To The Heat?

With mild steel, most of the smoke is iron oxide but when welding is done on stainless steel, particles of chromium and nickel are also present. Any surface coatings, such as plated surfaces (zinc from galvanized parts, for example), paint, preservatives, oil, or solvent residue, will also vaporize and become part of the smoke. Make sure you know what is being welded or heated before you start; welding, even for a short time, on a cadmium plated surface, for example, can be fatal.

3 Are You Welding In A Phone Booth, Or, Under What Conditions Is The Welding Being Done?

It is important to note the size of the space, whether it is open or confined, how long the welding is going on, how many welders are working there, whether ventilation is available and being used and so on. Several workers welding in a small area with no ventilation for a short time would be exposed to very high concentrations of welding smoke. Under these conditions burns, electrical shocks, trips, or other accidents could also easily occur. If very hazardous materials are being welded or heated, the situation could even by life threatening.

With this as a general instruction, the following pages describe the most common welding processes and the hazards of the various materials found in the welding environment.

Common Welding Processes

Process	Used For	Shielding	Smoke/Fume	Light/Radiation	Specific Hazard
Stick (SMAW)	Gen. purpose, more than 50% of all welding	electrode coating	high	moderate-variable	depends on electrode, e.g. (low hydrogen-fluorides) (hard facing-manganese) (stainless-chromium and nickel)
MIG (GMAW)	High production/ automation	inert gas (Argon, Helium), Carbon Dioxide	moderate	high-esp. with reflective metal and Argon shield	ozone carbon monoxide (with CO_2 shield) stainless-chromium & nickel
TIG (GTAW)	high precision	inert gas	low	high	ozone, light
Plasma (PAW)	process can be used to weld, cut, metal spray	gas	moderate/ high	moderate/high	noise, electrical shock, potential x-radiation
Flux core (FCW)	high production/ automation, (like MIG with flux filled wire)	wire filling with or without gas	high	moderate/high	high fume levels
Sub Arc (SAW)	horizontal welds high production	granular flux	low	no visible arc unless have "breakthrough"	generally low hazard
Flame cutting	cutting plate, weld preparation	none	moderate	low	compressed gas cylinders Oxides of Nitrogen lead (paint) zinc (galvanized)
Air arc	"gouging", weld preparation	none	very high	high	noise, high fume levels

Other Processes And Hazards (Arc-less)

Laser Welding uses a focused beam of light (somewhat like concentrating sunlight with a magnifying glass) to form very precise welds in many materials. *The major hazard of this powerful beam is to the eyes,* especially the *invisible* lasers of ultraviolet or infrared light, causing partial blindness when hit with the beam. Special eye protection (specific to the wavelength of the laser) must be used and care must be taken with any reflective surface since the original and reflected beam are dangerous.

Electron beam welding is similar to laser welding, with high precision and deep penetration welds produced in any material by a focused beam of electrons. Since this is exactly how x-rays are produced, shielding must be present to protect operators from this hazard (film badges should also be used). The high voltages required (in the 100,000 volt range) also present an electrical hazard especially during maintenance or malfunction.

Spot welding is an arc-less process which makes localized welds with pressure and the heat produced by resistance to an electrical current. This is generally a less hazardous process although flying sparks can become imbedded in the skin and elsewhere.

Soldering and Brazing technically are not welding processes because the temperature is not high enough to melt the base metal; a filler material is melted and holds the parts together. The major concern is the materials that are used: lead is the principal ingredient in solder; many silver solders contain cadmium; and fluxes containing fluorides are used.

Gas welding uses a fuel gas, like acetylene, and oxygen to produce heat for welding; flame cutting is similar. The major hazards are the use and handling of compressed gas cylinders including breaking off the valve and creating a rocket, fire and explosion.

Cylinders and equipment must be handled, maintained, stored and used properly (see OSHA standard for detailed requirements.) When welding be particularly alert to backfires and flashbacks, both of which indicate potentially dangerous situations which should be corrected immediately.

Hazardous Materials Found In Welding

The principal source of each material is designated as B = base metal, E = electrode or wire, S = surface coating, G = gas.

Acetylene (G) is a commonly used fuel for gas welding, cutting and brazing. Like the inert gases used in welding (argon, helium) it can displace the oxygen in the air, but the major hazard is its explosion potential. It is explosive over a wide range of concentrations and is unstable above 15 psi gauge pressure.

Aluminum (B,E) is a major component of metal and filler metals. Inhalation of aluminum dust or aluminum oxide fume is not considered particularly hazardous. Aluminum particles deposited in the eye may cause damage to the cornea.

Antimony (B) is an ingredient in many specialty metals. Antimony and its compounds irritate the skin and mucous membranes. Symptoms of overexposure include metallic taste and general stomach distress.

Arsenic (B,S) may be encountered as a component of various alloys (used as a hardening agent) or as an impurity. It may also be found in paint (especially green and yellow colors). Arsenic compounds cause skin irritation and inflammation of the mucous membranes and respiratory system. The NIOSH criteria document also reports liver problems and cancer of the skin, lung and lymphatic system from occupational exposure to arsenic.

Asbestos (E) can be found in the flux coating of some welding rods (such as E6010) but manufacturers are generally eliminating this ingredient because of the widespread publicity concerning asbestos hazards. Asbestos gloves, capes, leggings, blankets and pads are also commonly used in welding operations. Asbestos exposure causes serious diseases such as lung scarring called asbestosis as well as *cancer of the lung, the lining of the lung (mesothelioma), stomach and colon.*

Beryllium (B) is often found as an alloying element in copper and other base metals. *It is extremely toxic.* Exposure to beryllium can cause dermatitis and chemical pneumonia as well as chronic lung disease and other problems. NIOSH also considers beryllium to be a carcinogen. *Extreme care must be exercised in welding any material that contains beryllium.*

Cadmium (S,E,B) is often found as a rust preventative coating, as an alloy with other metals, as filler metal in silver soldering (Brazing) and as the yellow pigment in some paints. Exposure to large amounts of cadmium can cause anemia, kidney malfunction and chemical emphysema. Cadmium is suspected of being a carcinogen (prostate). *Extreme care must be used when welding or silver soldering metals that contain or are coated with cadmium.*

Carbon Monoxide (G) is formed by the incomplete combustion of carbon containing materials (like welding on oily parts) or by the breakdown of carbon dioxide shielding gas. It will also be found around engine driven welding machines. Carbon Monoxide is colorless and odorless and cannot be detected by smell. Common symptoms of overexposure include headache, pounding of the heart, flashes before the eyes, ringing in the ears and nausea.

Chlorinated Hydrocarbon Solvents (S) Various solvents are used in cleaning operations like vapor degreasing. The vapors from these solvents

can be decomposed by the heat and UV radiation from welding to produce irritating gases like phosgene (see listing).

Chromium (B,S) is the primary alloying element in stainless steel (as much as 30%) and may be found in yellow/orange paint. Chromium compounds have been associated with dermatitis, skin ulcers, irritation of the nasal passages, kidney and liver damage, lung congestion and erosion and discoloration of the teeth. *Some chromium forms (hexavalent) are associated with increased risk of lung cancer.*

Cobalt (B) is an alloying element in high strength and high temperature alloys and is sometimes found in blue paints. The NIOSH criteria document on cobalt reports lung scarring, lung sensitization leading to asthma and skin problems from exposure.

Copper (B,E) is the major component of brass and bronze and is found in other alloys. Air arc electrodes are copper clad as are some MIG wires. Copper fume can cause metal fume fever (flu-like symptoms), irritation of the eyes and upper respiratory tract and discoloration of the skin and hair.

Fluorides (E) are contained in the coatings of certain welding rods like the low hydrogen types (also called basic or lime ferritic). Low hydrogen coatings are used for all the higher alloy coated electrodes. Fluorides are also used in some brazing flux materials. Fluoride exposure can cause irritation, gastro-intestinal symptoms of nausea, vomiting and diarrhea, and long term exposure causes bone abnormalities.

Iron (B,E) is the principal ingredient in steel manufacture and iron oxide is the major element in the smoke from any ferrous metal welding. Long term deposits of iron oxide in the lung, called siderosis, are detectable but not thought to be disabling. Iron oxide (from mining operations) has been associated with lung cancer.

Lead (S,B) is found in paints and preservative coatings, as an alloy in some bronzes and in various other uses. A major source of lead exposure is flame cutting of scrap material painted with lead paint. *Lead can cause serious health effects.* It is a cumulative poison which affects the stomach and digestive system, central nervous system, kidneys and blood. Symptoms include metallic taste, loss of appetite, nausea, stomach cramps and insomnia. Later, anemia and a general weakness develops. *Chronic overexposure to lead impairs the reproductive systems of both men and women.*

Magnesium (B) is an element alloyed with aluminum and other metals and used in aircraft structural parts and in tool making. Magnesium is an irritant to the eyes, nose and throat and can cause metal fume fever as well as digestive disorders.

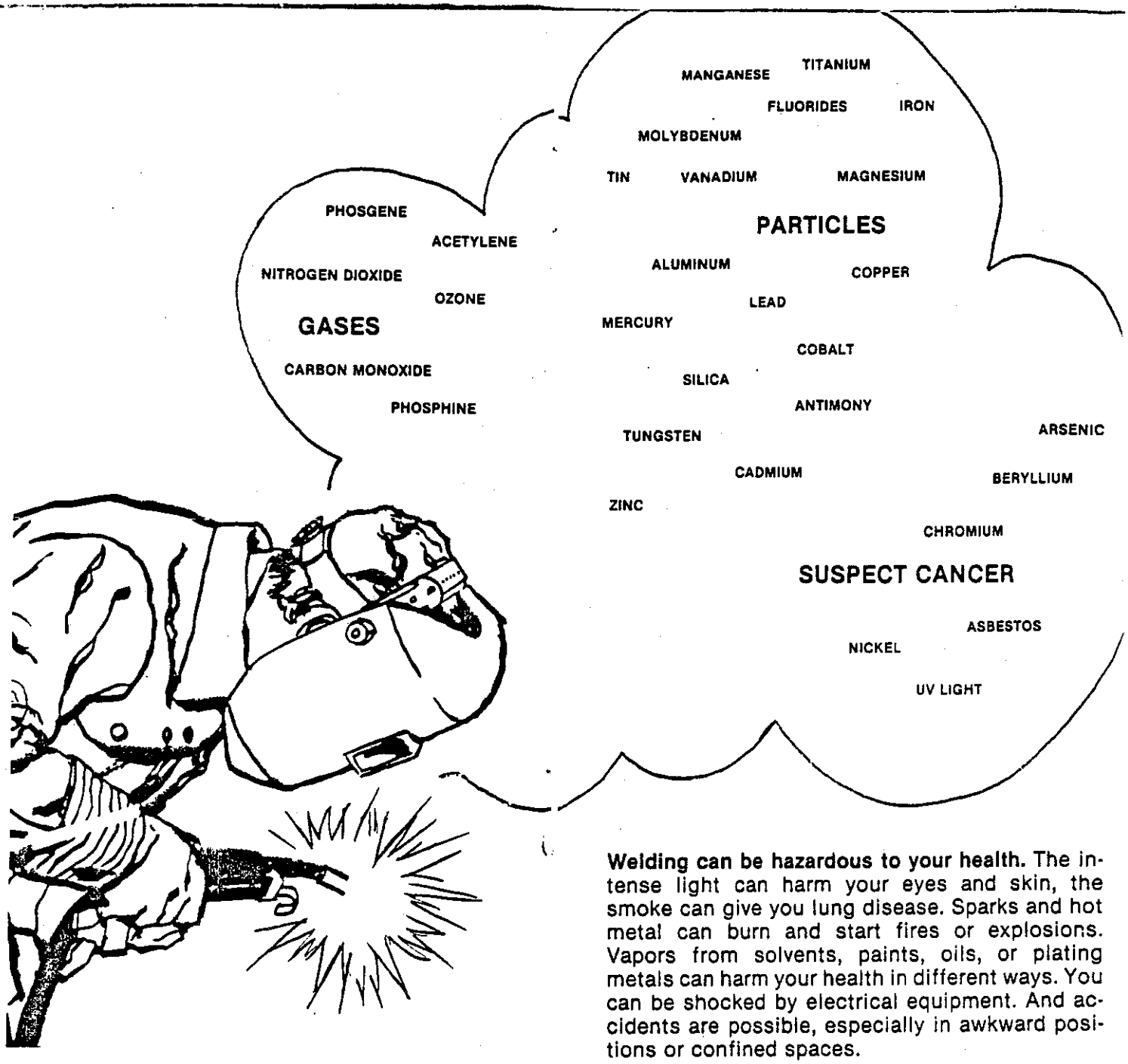
Manganese (E,B) is often contained in welding rod flux coatings and is used as an alloying material. Exposure to manganese fumes can cause irritation, mucous membrane irritation as well as manganese poisoning, a chronic neurological disorder which produces weakness, difficulty walking, mental confusion and speech disturbances.

Mercury (S) compounds are used to prevent rust and to inhibit foliage growth (marine paints). Mercury vapors are produced when these coatings are exposed to heat or flame. Exposure can produce fever, difficulty breathing, nausea, vomiting and excessive tiredness. Long term exposure can produce tremors, emotional instability and kidney damage.

Molybdenum (B) is an ingredient in some types of steel. It may produce eye and mucous membrane irritation but no instances of toxic effects have been reported in industry.

Nickel (B,S) is another major alloying material of stainless steel and copper and is also used for plating. *Nickel is a carcinogen associated with nasal, lung, throat and kidney cancer.* Nickel is a

B = base metal, E = electrode, S = surface, G = gas



Welding can be hazardous to your health. The intense light can harm your eyes and skin, the smoke can give you lung disease. Sparks and hot metal can burn and start fires or explosions. Vapors from solvents, paints, oils, or plating metals can harm your health in different ways. You can be shocked by electrical equipment. And accidents are possible, especially in awkward positions or confined spaces.

potent skin irritant and causes a dermatitis called "Nickel Itch."

Nitrogen Oxides (G) especially nitrogen dioxide, are formed by the heat of the arc or flame on the air in the vicinity of the heat source. The gas is mildly irritating to the eyes, nose and upper respiratory tract but is hard to detect. Dangerous concentrations can be inhaled without discomfort, but produce serious lung problems (pulmonary edema) several hours after exposure. Flame cutting in confined spaces can be particularly dangerous.

Ozone (G) is produced by the ultraviolet light from the arc acting on the oxygen in the air. It has a characteristic "electric" smell and decomposes rapidly once the arc welding stops. Ozone is irritating to the respiratory tract and may produce headache, chest pain and dryness in the mouth and throat.

Paints (S) Various painted or primed surfaces may be encountered in welding and cutting operations particularly in shipyards, demolition and maintenance work. Although not always possible, as a general rule, welding should be done *before* painting or the paint should be removed before welding.

There are various kinds of paints such as acrylic, cresol-formaldehyde, epoxy, phenol-formaldehyde, polystyrene, polyurethane, polyvinyl-butyral and PVC, which decompose when heated to produce toxic materials. These products include carbon monoxide and specific aldehydes (such as formaldehyde) from most paints and specific products from some of the paints: acrolein (a highly irritating gas) from polyvinyl-butyral; nitrogen dioxide, ammonia and "epoxy residues" from epoxy; styrene from polystyrene; methyl methacrylate from acrylic; nitrogen dioxide, hydrogen cyanide and isocyanates from polyurethane; cresol and phenol from those resins and hydrogen chloride and phosgene from PVC. The pigments in the paint or primer include metals such as aluminum, cadmium, chromium, iron, lead, magnesium, titanium and zinc.

Phosgene (G) is formed by the decomposition of chlorinated solvent vapors by the ultraviolet light from welding. *Welding should never be done near a vapor degreaser or on parts still wet with solvent.* In low concentrations phosgene has a sweet but *not* pleasant odor sometimes described as musty. Symptoms include tearing and respiratory tract irritation. Acute exposure can produce dizziness, chills, discomfort and cough, which may not show up for 5-6 hours.

Phosphine (G) or hydrogen phosphide can be produced when steel coated with phosphate rustproofing is welded. This gas is irritating to the eye, nose and skin and acute exposures produce headache, dizziness and pulmonary irritation. Chronic exposure may produce sight and speech disturbances.

Silica (E) can be found in the coatings of some welding rods in the form of silicates and free silica. Free silica, also called cystalline silica or quartz can cause lung scarring called silicosis, a serious and disabling disease.

Silver (E) is a major ingredient in many silver solders. The health effects of silver exposure are a permanent discoloration of the eyes and skin.

Tin (B) is an alloy of brass and bronze. Tin oxide accumulates in the lung but is not considered toxic or disabling.

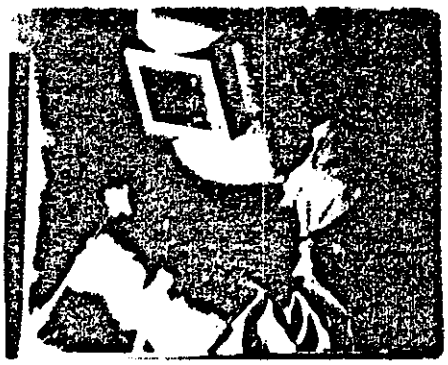
Titanium Dioxide (E,B) is a major ingredient in welding rods designated as rutile. Titanium is also a major alloying material used for lightweight, high strength parts such as aircraft or aerospace applications. Some titanium compounds can be irritating but are generally considered low in toxicity.

Tungsten (E) is a high melting point metal used as the elctrode in the TIG or "Heliarc" welding

process. These electrodes are termed non-consummable to distinguish them from stick welding electrodes or MIG wire which is consumed or melted into the weld. In practice, these electrodes are slowly consumed and are a small part of the welding fume. Occupational exposure to tungsten and tungsten carbide can cause disease but this is unlikely in welding. However, tungsten electrodes often contain 2% *thorium*, a radioactive material. Although only small amounts may be present in TIG welding fume, inhaling radioactive material allows the material to continually irritate the lung and may cause lung cancer.

Vanadium (B) is an element used in some specialty steels as well as electrode coatings. The NIOSH criteria document reports respiratory tract irritation, bronchitis, discoloration of the tongue, dermatitis and skin irritation from occupational exposure. Vanadium has been found as a residue in oil fired boilers.

Zinc (B,S) is a metal which is used as an alloying material for brass and other metals but is also used extensively for galvanizing. Welding on zinc coated parts produces large quantities of zinc oxide fume which causes metal fume fever (also called Monday Fever, galvo, zinc chills and others). This condition is like having the flu for one day, and is easy to misdiagnose. It is very uncomfortable but not thought to have any long term effect.



Confined Spaces

Confined spaces can be defined as any area that is relatively small (or has many people working together), has limited egress and restricted air flow or ventilation. The OSHA shipbuilding standards (29CFR 1915, 1916 and 1917) define a *confined space* as"...a compartment of small size and limited access... which by its size and confined nature can readily create or aggravate a hazardous exposure." These can be useful definitions but don't let definitions take the place of common sense; welding inside any tank, for example, is always dangerous.

It is obvious why these areas are especially dangerous, but it is useful to explore these reasons in more detail. The work may involve a particularly hazardous material or surface coating, like lead or zinc based paint, or may involve the use of a welding process that produces a lot of fume. In a small space dangerous concentrations can build up very quickly.

Second, welding processes use oxygen and in confined spaces may reduce the level of oxygen below safe levels. Welding smoke or shielding gas can also displace the air. Both conditions can cause unconsciousness or death from suffocation.

Third, there is little chance for escape in case of fire or explosion. Sparks can ignite combustible materials like paper or wood and touch off explosive vapors which may have been created by the heat from the process. A small fire which could easily be extinguished in the open can be life threatening in a confined space.

Finally, confined spaces may involve exposure to safety hazards like tripping over or falling against structural members and often increase the hazard of electrical shock or electrocution. Many confined spaces are metal and part of the electrical circuit. In addition, the heat and small space means increased sweating and the moisture decreases the resistance to electrical current.

Control Methods and Practice

Elimination/Substitution

Most welding hazards can be controlled with proper engineering and planning of the job. The first stage in any attempt to control welding (or any) hazard is to determine whether the job has to be done the way it is being done. If there are hazards, they should be eliminated by changing the job or by using substitute materials. For example, if welding is being done on painted parts, ask why the parts must be welded when they are painted. Can the welding be done at a different stage in the process or can the coating be removed?

Other examples of engineering controls using substitution include:

- using the sub arc process where possible to minimize the light and fume created by the visible arc;
- using cadmium free silver solders;
- using asbestos free electrodes, gloves and hot pads;
- using a water table under plasma arc cutting to reduce fume and noise levels;
- grinding parts instead of air arcing.

Automation

In many industries the welding process is being automated. This ranges from MIG welders mounted on tracked rails to fully automated robots on the assembly line. In some cases the automated process produces greater production, higher smoke levels and more hazardous conditions, but the introduction of robots is often justified on health and safety grounds. *The workplace is safer for the welder because the welder is no longer there!* Technological

improvements in the workplace are important, but workers and their unions must be prepared to deal with the issue of job elimination.

Ventilation/Shielding

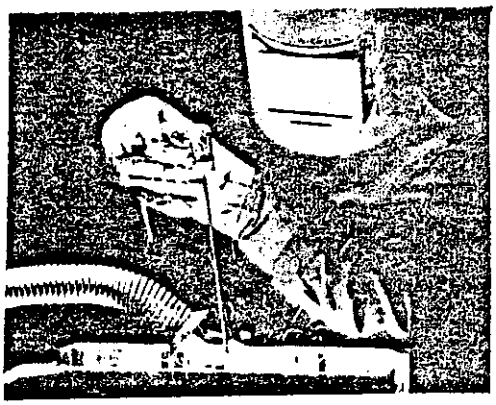
If elimination or substitution is not possible, hazards should be contained at their source. Light from an arc can be shielded, smoke can be removed by local exhaust ventilation or the use of a "sucker" placed as close as possible to the arc. (Use of a sucker can increase UV radiation and ozone formation, so some additional steps might be needed to reduce these hazards.)

General exhaust ventilation, with a pedestal fan, a blower or an open window, provides some relief but, except for ozone, is not as effective as local exhaust ventilation. (Ozone, created by the light, is out of the range of local ventilation at the arc.)

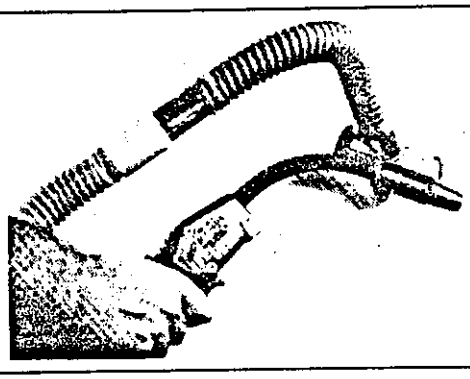
Local exhaust ventilation can be used in several different ways. The welding can be done in one location with a moveable hood, vented outside, positioned where the welder needs it. A second system is like a portable vacuum cleaner which can be moved around with the welder and placed close to the arc where it is needed. These devices often have filters which clean and recirculate the air. These filters must be maintained properly so that dirty air is not recycled. Another system can be used with MIG, flux core, plasma and other types that use electrode wires. These devices are built into the gun or attach directly to the gun and exhaust the fume at the point where it is generated. Complaints about the weight of the gun and about disturbing the gas shield can be overcome by using lighter materials and providing welder controlled adjustments in the exhaust rate.

Other shielding methods include barriers to protect other people in the area from viewing the welding arc and avoiding shiny surfaces for welding booths by painting with non reflective, light colored zinc oxide or titanium dioxide base paints. The welding

ventilation off



ventilation on



helmet shields some of the fume, especially those with a curved front. Some welders attach a leather flap to the helmet to improve shielding from the light of the arc and to keep the welding smoke from coming up under the helmet.

Work Practices

Work practices can also be used to minimize exposure to welding hazards. *These should be used along with engineering controls not in place of them.* Use of ventilation and other control devices should be made an integral part of the job because piece work jobs, for example, provide an incentive to short-cut health and safety. Training of welders in the health and safety aspects of the job provides an incentive to minimize exposure and an example to other welders. If the welder knows what he or she is working with, precautions such as positioning to avoid the rising smoke plume and avoiding the smoke of other welders will be practiced.

Personal Protective Equipment

The nature of welding makes certain personal protective equipment necessary for protecting the welder:

- All welding requires some form of eye protection (darker shades for more intense light) plus safety glasses, protective clothing (woolens are best, synthetics worst), gloves, headcap, hard toed shoes, button down shirt pockets, cuffless pants, etc.
- Depending on the type of welding and the position of the work other equipment may be needed. Heavy duty welding might require leather gauntlet gloves, jacket, apron and spats. Overhead or vertical welding will require a cape or other shoulder protection. Ear plugs are sometimes worn as protection from flying sparks as well as for noisy air arcing, grinding and plasma welding or cutting. Hard hats are needed when there is an overhead hazard and life lines can be important in dangerous confined spaces or when there is a falling-hazard.

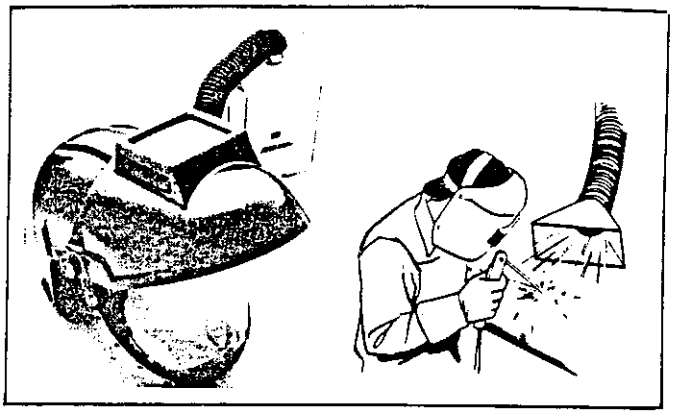
- Other workers in the area should have safety glasses (preferably tinted) with side shields.

Respirators

The above equipment is essential and must be provided, but *Respirators should only be used if other engineering controls are not feasible or during the time they are being installed.* It might also be appropriate to use a respirator for a short time job and, of course, it is better to use some protection rather than be exposed to hazardous fumes.

If respirators are used they must be specific to the hazard, properly fitted and properly maintained. In addition, operators must be examined by a doctor to determine if they can safely use a respirator. OSHA General Industry Standard 1910.134 details the minimum program for use of respirators.

Two respirators are worth mentioning. A disposable type respirator (3M 9920) which filters out dust, *fume* and mist, has been approved by NIOSH. It is comfortable and will filter out the very small particles of welding fume, *but not the gases.* The other type of respirator, made by Racal and others, is a type of helmet. It provides a flow of filtered air, providing respiratory protection and cooling without the fitting problems of other respirators. This system has been adapted for welding applications.



Racal helmet Local exhaust ventilation

OSHA Standards

OSHA standards can often be used to bring pressure to change conditions on the job, even without calling for an inspection. There are standards for safety aspects of welding; however, the standards for air contaminants are for separate materials in the fume. There is no standard for total welding fume and no standard related to combined effects of materials in the fume.

The General Industry Standards apply unless there are more specific standards for an industry, e.g. Maritime or Construction.

General Industry

29 CFR 1910.252 Welding, Cutting & Brazing (see selected requirements, pg. 31).

Paragraph
(a) Oxygen fuel systems
(b) Arc welding and cutting equipment
(c) Resistance welding equipment
(d) Fire prevention and protection
(e) Protection of personnel . . . eye protection, work in confined spaces.
(f) Health protection and ventilation . . . precautionary labels (cadmium, fluorides), general ventilation; local ventilation; special precautions for fluoride compounds, zinc, lead, beryllium, cadmium, mercury, cleaning compounds, cutting of stainless steel and first aid equipment.
(g) Industrial applications.

29 CFR 1910.1000 Individual standards for air contaminants (see table).

Maritime

29 CFR 1915 (Ship Repairing), 1916 (Shipbuilding), 1917 (Shipbreaking)
Subpart D—Welding, Cutting & Heating

Section .31 Ventilation and protection in welding, cutting and heating.
Section .32 Fire prevention
Section .33 Welding, cutting and heating in way of preservative coatings
Section .34 Welding, cutting and heating of hollow metal containers and structures
Section .35 Gas welding and cutting
Section .36 Arc welding and cutting
Section .37 Uses of fissionable material in shipbuilding

Construction

29 CFR 1926. Subpart J—Welding & Cutting

1926.350 Gas welding and cutting
1926.351 Arc welding and cutting
1926.352 Fire prevention
1926.353 Ventilation and protection in welding, cutting, and heating
1926.354 Welding, cutting, and heating in way of preservative coatings.

Selected requirements from OSHA General Industry Welding standards (29CFR 1910.252)

Section .252(a) Oxygen—fuel systems

Only approved apparatus such as torches, regulators, etc. shall be used.

Compressed gas cylinders shall be legibly marked with the gas content.

Cylinders shall be stored upright in ventilated, dry locations at least 20 ft. from combustible materials such as oil.

Valve protection caps shall always be in place, hand tight, except when in use.

Oxygen cylinders and fuel gas cylinders must be stored separately at least 20 ft. apart.

All Oxygen cylinder apparatus must be kept free of oily and greasy substances (fire hazard).

Cylinders shall not be placed where they can become part of an electrical circuit.

Other requirements for manifolding of cylinders, service piping, acetylene generators, calcium carbide storage.

Section .252(b) Arc welding and cutting equipment

Persons designated to operate arc welding equipment shall be qualified and trained to operate the equipment safely.

Only specially designed machines shall be used when exposed to conditions such as corrosive fumes, excessive humidity, oil vapor, flammable gases, vibration, shock, dust and weather.

Open circuit (no load) voltages should be as low as possible but not to exceed 80V for a/c manual welding or cutting and 100V for automatic (machine or mechanized) arc welding or cutting and d/c welding.

Input power terminals, terminals for welding leads and live metal parts shall be enclosed and protected from accidental contact.

PART 1910

OCCUPATIONAL SAFETY AND HEALTH STANDARDS

SUBPART Q—WELDING, CUTTING, AND BRAZING

CAUTION

CONTAINS FLUORIDES

This flux when heated gives off fumes that may irritate eyes, nose and throat.

1. Avoid fumes—use with

(2) Ventilation for general welding and cutting.

(i) General. Mechanical ventilation shall be provided when welding or cutting is done on metals not covered in subparagraphs (5) through (12) of this paragraph. (For specific materials, see the ventilation requirements of subparagraphs (5) through (12) of this paragraph.)

(a) In a space of less than 10,000 cubic feet per welder.

(b) In a room having a ceiling height of less than 16 feet.

(c) In confined spaces or where the welding space contains partitions, balconies, or other structural barriers to the extent that they significantly obstruct cross ventilation.

...minimum rate of 2,000 cubic feet per minute per welder, except where local exhaust hoods and booths as per subparagraph (3) of this paragraph, or airline respirators approved by the U.S. Bureau of Mines for such purposes are provided. Natural ventilation is considered sufficient for welding or cutting operations where the restrictions in subdivision (i) of this subdivision are not present.

(3) Local exhaust hoods and booths. Mechanical local exhaust ventilation may be by means of either of the following:

(i) Hoods. Freely movable hoods intended to be placed by the welder as near as practicable to the work being welded and provided with a rate of airflow sufficient to maintain a velocity in the direction of the hood of 100 linear feet per minute in the zone of welding when the hood is at its most remote distance from the point of welding. The rates of ventilation required to accomplish this control velocity using a 3-inch wide flanged suction opening are shown in the following table:

Welding zone	Minimum air flow, cubic feet/minutes	Duct diameter, inches
6 inches from arc or ...rch	160	3
8 inches from arc or ...rch	275	3½
10 inches from arc or ...rch	425	4½
12 inches from arc or ...rch	600	5½

...en brazing with cadmium bearing materials ...n cutting on such materials increased rates ...lation may be required.

...rest half-inch duct diameter based on 4,000 ... minute velocity in pipe.

...d enclosure. A fixed enclosure with ...nd not less than two sides which ...nd the welding or cutting opera... ...nd with a rate of airflow sufficient ...tain a velocity away from the ...f not less than 100 linear feet per

(4) Ventilation in confined spaces.

(i) Air replacement. All welding and cutting operations carried on in confined spaces shall be adequately ventilated to prevent the accumulation of toxic materials or possible oxygen deficiency. This applies not only to the welder but also to helpers and other personnel in the immediate vicinity. All air replacing that withdrawn shall be clean and respirable.

(ii) Airline respirators. In such circumstances where it is impossible to provide such ventilation, airline respirators or hose masks approved by the U.S. Bureau of Mines for this purpose shall be used.

(iii) Self-contained units. In areas immediately hazardous to life, hose masks with blowers or self-contained breathing equipment shall be used. The breathing equip-

Before starting to weld the following shall be checked: proper hook-up of machine, grounding of machine frame, leaks of water, gas or engine fuel, switching equipment for machine shutdown, and wear and damage to cables.

Cables shall be uncoiled before use, should not be looped around the body and shall not be used with splices within 10 ft. of the holder.

Section .252(c) Resistance welding equipment

All press welding machines shall be guarded similar to that required for punch presses.

The hazard of flying sparks shall be eliminated by installing shield guards.

Section .252(d) Fire prevention and protection

Whenever possible, welding, cutting and brazing shall be done in designated areas designed for fire protection.

Appropriate fire extinguishers must be on hand for instant use.

A fire watch shall be required whenever welding or cutting is done in an area where more than a minor fire might develop.

A responsible individual must be designated to authorize welding or cutting (hot work).

No work shall be done on used drums, barrels, tanks or other containers until they have been thoroughly cleaned (purging with inert gas is also recommended).

Section .252(e) Protection of personnel

Welders and helpers working on platforms, scaffolds or runways shall be protected against falling.

All welders, helpers and attendants shall be provided with proper eye protection (proper shade no. should be selected).

When work permits, the welder should be enclosed in an individual booth or with non-combustible screens which allow air circulation at floor level.

Confined Spaces are intended to mean "a relatively small or restricted space such as a tank, boiler,

pressure vessel or small compartment of a ship." Ventilation must be provided, welding machines and gas cylinders must be left outside. If entrance is through a manhole, an attendant with a preplanned rescue procedure must constantly observe the welder and be able to quickly remove the welder in case of emergency.

Section .252(f) Health protection and ventilation

The amount of contamination welders are exposed to depends on the size of the space, the number of welders and the materials involved plus other factors such as atmospheric conditions, heat generated and presence of volatile solvents.

Precautionary labels are required for all filler metals, brazing filler metals containing cadmium, and fluxes containing fluorine compounds (fluorides).

Ventilation (general) at the rate of 2000 cubic feet per minute per welder is required (1) in a space of less than 10,000 cubic feet per welder, (2) when the ceiling height is less than 16 feet, and (3) in confined spaces (cross ventilation obstructed).

Special ventilation and/or respiratory protection is required in confined spaces; when fluorine compounds, zinc, lead, berylium, cadmium and mercury are encountered; for cleaning compounds; and when cutting stainless steel.

First aid equipment and trained employees shall be present.

Section .252(g) Industrial applications

Requirements for transmission pipeline and mechanical piping systems.

Air Contaminant Standards and Guidelines

Substance	OSHA standards	NIOSH criteria documents	ACGIH TLV's 1981	Others Soviet Union 1972	Others Czechoslovakia 1969	Others Sweden 1981
Acetylene	(none)	—	[1]	—	—	—
Aluminum	15	—	5	—	—	—
Antimony	.5	.5	.5	.3C	.5	.5
Arsenic (Ca)	.01	.002	.2	.3C	.05	.05
Asbestos (Ca)	2 fibers/cc (10C)	.5 fibers/cc	[2]			1
Beryllium (Ca)	.002 (.005C)	.0005	.002	.001C	.002	.002
Cadmium fume	.1 (.3C)	.04 (0.2C)	.05C	.1C	.05	.02
Carbon monoxide	50 ppm	35 ppm (200C)	50 ppm	18C	36	35
Chromium (Ca)	1	.001 [3]	.05	—	—	.05
Cobalt	.1	—	.1 [4]	.5C	.1	.05
Copper fume	.1	—	.2	1C	—	.2
Fluorides	2.5	2.5	2.5	.1C	2.5	2
Iron Oxide fume	10	—	5	—	—	3.5
Lead	.05	.1	.15	.01C	.1	.05
Magnesium oxide fume	15	—	10	—	—	—
Manganese fume	5C	—	1	.3C	2.5	1
Mercury	.1	.05	.05	.01C	.05	.05
Molybdenum	15	—	10	6C	—	—
Nickel (Ca)	1	.015	1	.5C	.01	.1
Nitrogen dioxide	5 ppm C	1 ppm C	3 ppm	2C	5	5C
Ozone	.1 ppm	—	.1 ppm	—	—	.1
Phosgene	.1 ppm	.1ppm(.2C)	.1 ppm	.1C	.05	.05C
Phosphine	.3 ppm		.3 ppm	.07C	.3	—
Silver	.01	—	.1	—	—	—
Tin Oxide	15	—	10 [5]	—	—	—
Titanium dioxide	15	—	10	—	—	—
Tungsten	(none)	—	1	—	—	5
Vanadium pentoxide fume	.1C	.05C	.05C	.1C	.05	.05C
Zinc Oxide fume	5	5 (15C)	5	6C	5	5

OSHA standards, or PEL's, are the **legal** limits of exposure. Except for Arsenic, Asbestos and Lead (for which new standards have been developed), these standards were taken from the *1968* ACGIH TLV list or from ANSI standards between 1966 and 1971.

NIOSH Criteria Documents are **recommendations** to OSHA based on current scientific information.

ACGIH TLV's are industrial hygiene **guidelines** updated each year.

Notes for Table

All values are listed as milligrams per cubic meter (mg/m^3) (a weight of contaminant per volume of air) unless noted otherwise. All values are TWA's unless followed by a "C".

TWA means "Time Weighted Average", or the *average* exposure during the workday that cannot be exceeded.

C means "Ceiling" Value or a concentration that cannot be exceeded at any time.

ppm means Parts per million (a volume of contaminant per volume of air).

Ca means "Cancer". Materials with this designation have been determined to be human or suspect human carcinogens.

[1] Considered to be a simple asphyxiant (displaces oxygen in the air).

[2] Standard varies from 0.2 to 2 fibers/cc depending on the type of asbestos.

[3] This standard is recommended for the carcinogenic portion of hexavalent chromium (Cr VI). In the absence of other information showing that it is non-carcinogenic, all CR VI should be regulated to this value.

[4] 1981 Notice of Intended Changes lists 0.05 mg/m^3

[5] 1981 Notice of Intended Changes lists 2 mg/m^3.

Abbreviations

OSHA—Occupational Safety and Health Administration; **NIOSH**—National Institute for Occupational Safety and Health; **ACGIH**—American Conference of Governmental Industrial Hygienists; **ANSI**—American National Standards Institute; **TLV**—Threshold Limit Value. **PEL**—Permissible Exposure Limit.