Safety topic

SAFETY AND HEALTH

# Welding Health and Safety

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## Introduction

This guide provides a general understanding of welding and cutting processes and potential health hazards, as well as a summary of the Oregon Occupational Safety and Health Division (Oregon OSHA) regulations, OAR 437 Division 2 Subdivision Q: Welding, Cutting and Brazing (1910.251 -. 257).

## What is welding?

Welding is the process of joining metals using pressure, heat, flame, or electric arc.

## Welding and cutting processes

More than 80 processes are used in welding and cutting. In arc welding, an electric arc generates heat between an electrode and the surface of the base metal, producing coalescence, or fusion. In arc cutting, the heat of the arc melts or removes the base metal. Common processes are listed below:

| American Welding Society | Other names |
|---|---|
| Shielded metal arc welding (SMAW) | Stick rod, stick, coated electrode, manual |
| Gas metal arc welding (GMAW) | Short arc, MIG (metal inert gas), shielded welding, hard wire |
| Gas tungsten arc welding (GTAW) | Heli-arc, TIG (tungsten inert gas) |
| Flux-core arc welding (FCAW) | Semi-automatic |
| Submerged arc welding (SAW) | Sub arc, automatic welding |
| Plasma arc cutting (PAC) | Plasma cutting |
| Plasma arc welding (PAW) | Plasma welding |
| Carbon arc cutting (CAC) | Arc gouging, air-arcing |
| Oxy-acetylene welding or cutting | Torch welding or cutting, gas welding or cutting |

**Shielded metal arc welding (SMAW) (also known as stick welding)** produces coalescence by heating with an electric arc between a covered metal electrode and the surface of the base metal. Shielding is obtained from decomposition of the electrode covering. Filler metal is obtained from the electrode. The consumable electrodes usually consist of a low-carbon steel core with a coating of slag-making and gas-making agents, and may also include alloying and deoxidizing agents.

**Gas metal arc welding (GMAW) or metal inert gas (MIG) welding** produces coalescence by heating with an electric arc between a continuous filler metal electrode (typically a steel alloy wire) and the work. Shielding is obtained entirely from an externally supplied gas mixture. There are four major types of gas metal arc welding, depending on the shielding gas or type of metal transfer used. They include:

1. Micro-wire, using short circuiting transfer and allowing all position welding
2. Carbon dioxide, using shielding gas of carbon dioxide and larger electrode wire
3. Metal inert gas (MIG), using pure inert gas shielding on non-ferrous metals
4. Spray, using argon/oxygen shielding gas

**Gas tungsten arc welding (GTAW) or tungsten-inert gas (TIG) welding** produces coalescence by heating with an electric arc between a single tungsten electrode and the work. Shielding is obtained from an inert gas or an inert gas mixture. Filler metal may or may not be used. GTAW welding will make top-quality welds in almost all metals and alloys, and requires practically no post-weld cleaning. The arc and weld pool are clearly visible. There is no filler metal across the arc stream, so there is no weld spatter. Welding is possible in all positions, and no slag is produced that might be trapped in the weld.

**Flux cored arc welding (FCAW)** produces coalescence by heating with an electric arc between a continuous filler metal electrode and the work. Shielding is obtained from a flux contained within the electrode. Additional shielding may or may not be obtained from an externally supplied gas or gas mixture. The process may be semiautomatic (most widely used) or automatic.

**Submerged arc welding (SAW)** produces coalescence by heating with an electric arc or arcs between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular, fusible material on the work. No pressure is used, and filler metal is obtained from the electrode and sometimes from a supplementary welding rod. The process may be automatic (most widely used) or semiautomatic. Outstanding features include high welding speed, high metal deposition rates, deep penetration, smooth weld appearance, good x-ray quality welds, easily removed slag covering, and the ability to join a wide range of material thicknesses.

**Plasma arc cutting** cuts the metal by melting a localized area with a constricted arc and removing the molten material with a high velocity jet of hot ionized gas.

**Plasma arc welding (PAW)** is similar to gas tungsten arc welding (GTAW). However, by positioning the non-consumable tungsten electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope. The plasma is then forced through a fine-bore copper nozzle that constricts the arc. The plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 20,000 degrees celsius. PAW can be used to join all metals that are weldable with GTAW (such as most commercial metals and alloys).

**Carbon arc cutting or “arc gouging”** uses the heat of a carbon arc to melt the metal, which then is removed by a high-velocity jet of compressed air. The air jet is external to the consumable carbon-graphite electrode. It strikes the molten metal immediately behind the arc. Air carbon arc cutting and metal removal differ from plasma arc cutting in that they employ an open (unconstricted) arc, which is independent of the gas jet.

## Types of electrodes

**Solid electrodes**
Solid electrodes produce less fumes than flux-cored wore or coated electrodes. Fume production is directly related to the amount of consumed electrode. Electrodes are consumable (composed of steel, cooper, aluminum, various alloys, and other metals) or non-consumable (primarily tungsten).

**Covered and coated electrodes**
Covered and coated electrodes are the largest group of electrodes used in welding. The covering provides the flux from the weld. Major metals from the coatings include fluoride, nickel, iron, chromium, manganese, copper, and molybdenum. Fluoride tends to be the major component, ranging from 10 to 20 percent of the fume composition.

**Bare rods or wire**
Bare rods or wire are immersed in the flux material, which greatly reduces fumes. Bare rods or wire are typically composed of copper alloys, steel nickel alloys, nickel, or chromium-steel alloys.

## Health hazards

The most common health hazards from welding and cutting processes involve exposures to radiation, heat, noise, fumes, and gases, as well as ergonomic hazards. The following section briefly describes these potential hazards and discusses protective measures.

**Radiation**
Ionizing radiation is produced by the electron beam welding process and during the grinding (pointing) of thoriated tungsten electrodes for the gas tungsten arc welding (GTAW) process. To minimize ionizing radiation exposure from grinding dust, use local exhaust ventilation and respirators.

Non-ionizing radiation is produced by most types of welding and includes ultraviolet, infrared, and visible light. Eye injuries are the most common among welders because the eyes can be adversely affected by all three energy ranges. The severity of eye injuries depends on the length of exposure, intensity of the light source, and proximity to the source. Even brief exposure to an intense source can cause burns.

UV radiation can damage the cornea of the eye. Many arc welders are aware of the condition known as welder's flash, arc eye, or arc flash, which causes a sensation of sand in the eyes. The medical term for this condition is photokeratitis and photoconjuctivitis. Inflammation (swelling of the cornea) and eye irritation, also known as flash burns, do not become noticeable for several hours. Applying ice packs will normally relieve the pain. If pain persists, seek medical attention.

Starring at the blue color of the arc can cause photochemical changes in the retina, creating permanent vision loss unless proper protective filters are used. Never observe the arc without eye protection.

All workers should wear eye protection when standing near a welding operation. Safety glasses and welding hoods provide good protection from burns, light, and heat. Safety glasses with side shields protect from flying sparks, chips, and flash burns. Eye protection must meet OSHA's filter lens shading requirements (1910.133). Employers should reference the ANSI Z49.1:2012 Guide for Shaded Numbers.

The skin is susceptible principally to the effects of ultraviolet and infrared radiation. Skin warns us of infrared heat radiation by burning. Exposure to UV light can result in severe skin burns, often without prior warning. Severe erythema or "sunburn" can increase the risk of skin cancer for prolonged exposures. Wearing the proper protective clothing can prevent skin burns.

Whenever possible, isolate arc welding operations so that other workers are not exposed to direct or reflected rays. Walls, ceilings, and other exposed surfaces should have a non-reflective finish. Provide portable, fire-resistant screens or curtains. Screen height is normally six feet (1.8 m) but may be higher depending upon the situation. Mount screens about two feet above the floor, unless a lower level is needed to protect adjacent workers, and arrange so as not to seriously restrict ventilation.

## Electromagnetic fields (EMF)

All electric welding processes create EMFs. Although studies indicate no evidence of health problems from EMF, you should protect yourself by not placing your body between the welding electrode and work cables. Keep the welding power source and cables away from you, as practical. Do not coil a welding cable around your body. People with pacemakers should not go near welding or cutting operations unless they have consulted with their doctor.

## Heat

In welding and cutting operations, metal may be preheated to as much as 600 degrees Fahrenheit. However, heated metal can still cause damage even when it has lost its red color. Physiological effects may include skin burns, hyperthermia, and heat stress.

Heat hazards are usually controlled by a combination of engineering, work practices, and personal protective equipment. Common methods include:

- Using cooling fans to increase air flow and evaporative heat loss. Air flow should be across the worker from one side for optimum control.
- Using mechanical air-conditioning systems in conjunction with the makeup air system
- Increasing the general exhaust ventilation at points of high heat production
- Shielding the welder from the source of radiant heat, such as a preheated work surface
- Allowing frequent work breaks in a cooler area and ample access to cold drinking water

## Burns

Sparks, hot metal, spatter, and slag can all cause burns. It's important to wear appropriate protective gear, including dry gloves with no holes, a heavy shirt, and full-length cuffless pants. For oxy-acetylene cutting or welding that produces molten slag, shoes should be covered with spats to prevent the slag from entering and causing burns.

## Noise

Noise problems normally aren't directly associated with welding operations, except with plasma arc or air carbon arc welding. Although related operations, such as chipping and grinding, are common sources of noise. If excessive noise cannot be reduced by engineering controls, use appropriate hearing protection and provide regular audiometric tests to detect the onset of hearing loss.

## Inhalation hazards

Inhalation of fumes and gases poses a major health hazard for welders. The extent of exposure is determined by exposure time, concentration, and nature of the contaminant. Contamination is normally measured in milligrams per cubic meter ($mg/m^3$) of air for particulate matter. For gases, sometimes parts per million (ppm) in air is used.

All potential airborne exposures are exacerbated to some degree by smoking. Consequently, smoking in the workplace should be strongly discouraged.

### *Fumes*

Fumes are very fine solid particles created by condensation from the gaseous state. Welding fumes are composed of metals, metal oxides, and other compounds volatilized from either the base metal, electrode, or flux material. All welding processes produce fumes, but the quantity can vary widely depending on the process.

Welding fume particles are almost all less than one micrometer in diameter; fumes are present during welding whether a smoke plume is visible or not. Due to their small size, fumes are able to penetrate deep into the respiratory system to the alveoli.

The presence of certain toxic metals in fumes may be a more important factor in determining the degree of the hazard than the total quantity of fumes. Metals such as manganese, chromium, nickel, cadmium, zinc, and copper may be present as small fractions of the total fume but may represent the major hazard of the job. The major sources of the fume come from the electrode metal, flux material, and coatings on the base metal. Prolonged and repeated overexposure to these metals may potentially cause respiratory and/or neurological problems. Welding fumes have also been classified as "possibly carcinogenic" by the International Agency for Research on Cancer (IARC Group 2B).

Fume generation rates can be altered by voltage, arc length, current, electrode diameter, electrode polarity, shielding gas, base metal, fluxes, fillers, wire feed speed, humidity, and position of the weld. As the voltage, arc length, current, wire feed speed, and humidity increase, more fumes are generated. Thirty percent more fumes are generated by welding DC positive compared to DC negative or AC.

### *Gases*

Gases are produced in all welding processes. Gasses are produced from the decomposition of the shielding gases and fluxes and from interaction of ultraviolet light or high temperatures with atmospheric gases and the shielding gas. Ozone, nitrogen oxides, and carbon monoxide are the most common gases formed. Phosgene gas can be produced from chlorinated solvents decomposing in the welding arc.

Phosgene reacts with moisture in the lungs to form hydrochloric acid which is extremely toxic. To prevent this, prohibit using or storing solvents near welding operations. At the concentration normally encountered, these gases are not visible to the eye and, in the case of carbon monoxide, not detectable by smell. Gases are also used for welding processes. The concentration of gases from welding may potentially reach toxic levels in confined spaces or in areas with little or no ventilation.

A regulation addressing these exposures has been adopted by Oregon Occupational Safety and Health Administration (Oregon OSHA) titled: OAR 437 Division 2 Subdivision Q: Welding, Cutting, and Brazing. Review the Oregon OSHA regulations and follow specific requirements that pertain to your operations.

For a copy of the regulations, follow the link in the References section of this document to the Oregon OSHA website.

**Musculoskeletal injuries**

Welding and cutting processes place physical demands on the wrist, elbows, arms, shoulders, neck, and back, due to awkward postures and material handling. Employers should evaluate the work area and processes to ensure that awkward positions are eliminated or greatly reduced. Consider equipment design, product design, and set-up of the work area during the evaluation.

**Fire protection**

Conduct welding and cutting processes in areas that are non-combustible or in buildings constructed of non-combustible materials. Clear all combustible material within a radius of 35 feet. If the floor is made of a combustible material, keep it wet during welding or cutting. Use guarding to confine heat, sparks, and slag, and to protect immovable fire hazards. When welding or cutting a container that previously contained flammable or combustible material, thoroughly clean the container to eliminate flammable or toxic vapors.

Designate employees to watch for fire under the following conditions:

- An appreciable amount of combustible material in building construction or contents is closer than 35 feet to the point of operation.
- Easily ignitable combustible materials are more than 35 feet away.
- Combustible materials are adjacent to the opposite side of metal partitions, walls, ceilings, or roofs that are likely to be ignited by conduction or radiation.

Fire watchers are responsible for watching for fires during the processes and for a half hour after the processes conclude, sounding fire alarms when necessary, and extinguishing small, controllable fires. Train fire watchers on how to use fire extinguishers, and make extinguishers readily available.

Management is responsible for authorizing cutting and welding in the work areas. Prior to authorization, the area must be inspected and precautions put in writing. The supervisor should secure authorization for the cutting and welding from the management representative. If welding is conducted in a workplace or location that is covered under OSHA's Process Safety Management Standard, management may need to issue a hot work permit.

### Electrical hazards

Electric shock from welding and cutting equipment can result in severe injuries, burns, or death. Serious injuries or death can also occur if the electrical shock causes the welder to fall from an elevated location.

Train employees to observe safe electrical work practices according to OSHA's Electrical Hazard Training Standard (1910.332). Safe electrical practices should include:

- Do not touch live electrical parts.
- Have all installation, operation, maintenance, and repair work done by only by qualified individuals.
- Properly install and ground the equipment in accordance with national, state, and local codes.
- Wear dry, insulating gloves in good condition.
- Insulate yourself from the work piece and ground by wearing rubber-soled shoes or standing on a dry insulated mat or platform.
- Use fully insulated electrode holders.
- Do not touch holders connected to two welding machines at the same time.
- Do not use worn, damaged, undersized, or poorly spliced cables, welding gun cables, or torch cables. Make sure all connections are tight, clean, and dry.
- When using auxiliary power from welding generators, use a circuit protected from a ground fault circuit interrupter (GFCI).
- Turn off all equipment when not in use. Disconnect the power to equipment that will be left unattended or out of service.

## Hazard controls

### Substitution

Consider using a welding electrode with a less hazardous composition, without altering welding or metallurgical characteristics. Some manufacturers may have a "low smoke welding wire," which they claim meets the requirements for a given electrode class and generates less fume and smoke compared with the conventional consumable rods. Also, consider using bolts or rivets in place of welding or using robotic welding instead of manual welding.

### Ventilation

Local exhaust ventilation (preferred) captures fumes at the source and removes them from the workplace. Dilution ventilation injects large amounts of air into the workplace to dilute the contaminant but does not remove it. Fume hoods are not recommended as the fume is generally passed through the workers' breathing zone.

### Personal protective equipment (PPE)

PPE is used to reduce hazard exposure when engineering and administrative controls are not feasible or effective. Types of PPE include respiratory protection, eye protection, skin protection, and hearing protection. Additional required PPE may include hard hats and steel-toe boots.

*Respiratory protection*
Respiratory protection should be used only if exposures cannot be controlled below their respective occupational exposure limit through engineering. If respiratory protection is used, the employer must follow the OSHA 1910.132 "Respiratory Protection" standard. First perform an assessment to determine what type of respiratory protection, if any, is needed.

Respiratory protection used by welders for filtering metal fumes and dusts include:

- Disposable, single-use, NIOSH approved air-purifying respirators
- Half and full-face air-purifying respiratory protection with cartridges
- Powered air-purifying respirators (PAPR)
- Supplied-air respiratory protection

The OSHA welding, cutting, and brazing standard 1910.251-.255 includes the minimum requirements for protective measures, such as respiratory protection, for welding and cutting on hazardous metals. Specified metals include manganese, zinc, lead, cadmium, mercury, beryllium, and fluorine compounds. Review this information to determine the specific requirements for your operations.

*Eye protection*
Helmets or hand shields made of a material which is an insulator for heat and electricity should be used during all arc welding or arc cutting operations, excluding submerged arc welding. Flash goggles with side shields should be worn under the welding helmet or hand shield.

Goggles or other suitable eye protection should be used during all gas welding or oxygen cutting operations. All operators of resistance welding or resistance brazing equipment should use transparent face shields or goggles, depending on the particular job, to protect their faces or eyes, as required.

OSHA 1910.252 "Welding, Cutting and Brazing: General Requirements" includes the following guide for selecting the proper shade numbers:

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

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

*Skin protection*

Wear a double layer of non-flammable clothing (or equivalent) to prevent burns or other damage by ultraviolet light. Launder clothing regularly to prevent oil and grease buildup. Recommended PPE should include leather gloves; fire-resistant protective sleeves, fire-resistant jacket, or leather apron; and a fire-resistant skull cap under the welding helmet.

*Hearing protection*

Hearing protection is *recommended* when personal time-weighted average (TWA) noise exposures exceed 85 decibels for an eight-hour day and is *required* when noise levels exceed 90 decibels for an eight-hour day or 115 decibels at any time. Hearing protection can be ear plugs or ear muffs with a noise-reduction rating. To determine TWA exposures, personal noise monitoring is needed. Based on the results, a company hearing conservation program may be required, including audiometric testing, hearing protection, employee training, and recordkeeping. For more information, see the Oregon OSHA 1910.95 “Occupational Noise Exposure” standard.

## Confined spaces

Confined spaces are generally small or restricted spaces such as a tank, boiler, or pressure vessel. All welding and cutting operations performed inside confined spaces must be adequately ventilated to prevent the accumulation of toxic materials or possible oxygen deficiency. All air that is replaced must be clean and respirable. Oxygen should never be used for ventilation. Please refer to the OSHA code on confined spaces, OAR 437 Division 2 Subdivision J (1910.146).

The OSHA regulation for Welding, Cutting and Brazing (1910.251) specifies the ventilation, safety, and respiratory protection requirements for welding operations in confined spaces. Mechanical ventilation must be provided when welding or cutting is done in a space of less than 10,000 cubic feet per welder, in a room having a ceiling height of less than 16 feet, in confined spaces, or where the welding space has structural barriers that interfere with cross ventilation. These circumstances require a minimum of 2,000 cubic feet per minute per welder, except where local exhaust hoods and booths or airline respirators approved by the Mine Safety and Health Administration and NIOSH are provided.

Local exhaust hoods should be placed by the welder as near as practicable to the work being done and provide an exhaust rate of 100 linear feet per minute. A fixed enclosure with a top and at least two sides that surround the welding or cutting operations, and an exhaust rate of at least 100 linear feet per minute, could be used instead.

The OSHA standard specifies precautions that must be taken when welding or cutting involves fluorine compounds (fluxes), lead, zinc, manganese, beryllium, cadmium, mercury, or degreasing compounds. Please refer to 1910.252(c), which is in the OSHA standard OAR 437 Division 2, Subdivision Q: Welding, Cutting, and Brazing for the requirements.

## Oxygen-fuel gas welding and cutting

Mixtures of fuel gases and air or oxygen may be explosive. Take precautionary measures to prevent mixing prior to consumption, except at the burner or in a standard torch.

Operators of oxygen or fuel-gas supply equipment, including generators, and oxygen or fuel-gas distribution piping systems should be educated about these systems and understand potential hazards. Operating instructions and rules should be readily accessible.

## Equipment maintenance

Qualified maintenance personnel should conduct periodic inspections of welding equipment and keep a certified record of the inspections, including the inspection date, inspector's signature, and equipment serial number or other identifier.

## Specific requirements

**Compressed gas cylinders**
Compressed gas cylinders should be labeled with either the chemical or trade name of the gas contained. All cylinders with a water weight capacity of more than 30 pounds should be equipped with a means of connecting a valve protection cap or with a collar or recess to protect the valve. Valve protection caps should always be in place except when cylinders are in use or connected for use.

Store cylinders away from sources of heat. Inside buildings, store cylinders in a well-protected, well-ventilated, dry location at least 20 feet from highly combustible materials. Empty cylinders should have their valves closed.

The maximum quantity of fuel-gas that can be stored in cylinders inside a building is 2,000 cubic feet or 300 pounds of liquefied petroleum gas. For storage in excess of that amount, a separate room or building conforming to the code requirements is necessary. Never store oxygen cylinders near fuel-gas cylinders, such as acetylene or carbide, because of the potential fire hazard. Maintain a minimum distance of 20 feet between oxygen cylinders and other fuel-gas cylinders.

Securely lash all cylinders in place to prevent falling. Post a sign stating: "Danger! No smoking, matches, or open lights" near fuel-gas storage areas.

**Blowpipes/torches**
Install approved back-flow or flashback preventers between the blowpipe or torch and the hoses. Ignite torches with a friction lighter, stationary pilot flame, or other recognized source of ignition. Never use matches and other hand-held open flames.

Whenever welding or cutting is stopped for an extended period of time, such as a lunch break, the oxygen and fuel-gas cylinder or manifold valves shall be closed, torch valves must be opened momentarily to release gas pressure from the hoses and then closed, and the regulator pressure adjusting screws should be released. Never put a torch down unless the oxygen and fuel-gas have been completely shut off at the torch.

**Manifolding of cylinders**
Manifolds must be approved either separately for each component part or as an assembled unit. Store oxygen manifolds correctly according to their aggregate capacity. For example, an oxygen manifold with a capacity of more than 6,000 cubic feet of oxygen connected should be located outdoors or in a separate non-combustible building. The OSHA standard, 1910.253(c)(1,2,3, 4&5), discusses the requirements.

Portable outlet headers cannot be used indoors except temporarily when conditions preclude a direct supply from outlets located on the service piping system. Master shutoff valves for both oxygen and fuel-gas must be provided at the entry end of the portable outlet header.

Cylinder manifolds should be installed by a competent person. Use manifolds only with the gas for which they were intended. Flash arresters are required between each cylinder and the coupler block when acetylene cylinders are coupled. The maximum capacity of fuel-gas cylinders connected to a portable manifold inside a building is 3,000 cubic feet of gas.

Compressed gas regulations are in the OSHA standard for compressed gases, 1910.101, Compressed Gases (General Requirements). Regulations covering acetylene are in 1910.102, Acetylene. Additional regulations covering the storage, marking, and manifolding of cylinders are included in 1910.251-.257. This regulation includes standards for service, piping, hoses, and acetylene generators, and calcium carbide storage.

**Service piping systems**
Piping and fittings must be approved for the intended use. Pipe must be at least Schedule 40 and fittings must be at least standard weight. Types of pipe include steel, wrought iron, brass, copper, seamless copper, brass, or stainless steel tubing.

Install and maintain piping joints and distribution lines in a safe operating condition. Protect underground pipes and tubing and outdoor ferrous pipe and tubing from corrosion. Station outlets should be labeled with the name of the gas. Piping systems should be tested and proved to be gas tight. Service piping regulations are in 1910.253(d).

**Protective equipment, hose, and regulators**
Install approved protective equipment in fuel-gas piping to prevent back-flow of oxygen, passage of a flash back, and excessive back pressure of oxygen in the fuel-gas supply system. Install pressure relief devices on service piping systems to prevent pressure build-up. Install a check valve, hydraulic seal, pressure regulator, or a combination thereof at each station outlet to prevent back-flow.

Maintain pressure-reducing regulators in good repair. Replace cracked, broken, or otherwise defective parts, including gauge glasses. Protective Equipment, Hose and Regulator regulations are in 1910.253(e).

### Hose and hose connections

Hose connections must be securely fastened to withstand twice the pressure that it is normally subjected to without leaking. Repair or replace hose showing leaks, burns, worn places, or other defects rendering it unfit for service. Damaged hose cannot be repaired with tape.

To avoid accidentally interchanging fuel-gas hoses with oxygen hoses, hose connections should be significantly different from one another or clearly labeled.

### Acetylene generators

All generators must be labeled with the maximum weight and size of carbide necessary for a single charge, the manufacturer's name and address, and the name or number of the type of generator. Generators must be approved for the intended use. The location of the generator should be cleared for unobstructed operation and be accessible for maintenance.

Do not use portable acetylene generators within 10 feet of combustible materials other than the floor and in rooms with a ceiling height of less than 10 feet. They should be located at a safe distance from the welding position so that they will not be exposed to sparks, slag, or misdirection of the torch flame.

Outside generator houses and inside generator rooms for stationary acetylene generators must have explosion venting in exterior walls or roofs. Walls, floors, and roofs of generator houses must be of non-combustible construction. Generators installed inside a building must be enclosed in a separate room. Generator houses must be well-ventilated with vents located at floor and ceiling levels. All electrical apparatus must be approved for use inside acetylene generator rooms.

Allow only authorized personnel in outside generator houses or inside generator rooms. Post operating instructions should near the generator. Follow manufacturer operating and maintenance procedures.

Portable and stationary acetylene generator regulations are in 1910.253(f).

### Calcium carbide storage

Calcium carbide in quantities of 600 pounds or less can be stored indoors in a dry, well-ventilated location. Calcium carbide exceeding 600 pounds but less than 5,000 pounds can be stored in an inside generator room or outside generator house, or in a separate room in a one-story building. Calcium carbide exceeding 5,000 pounds should be stored in one-story buildings used for no other purpose or in outside generator houses. Calcium carbide in unopened metal containers may be stored outside. Calcium carbide regulations are in 1910.253 (g).

## Arc welding and cutting

All workers who will be operating arc welding equipment must be trained and qualified to operate the equipment. Arc welding equipment should be approved for the intended use. The maximum voltage for automatic arc welding and cutting machines is 100 volts. The maximum voltage for alternating-current manual arc welding and cutting machines is 80 volts. The maximum voltage for direct-current manual arc welding and cutting machines is is 100 volts.

On all types of arc welding machines, the control apparatus must be enclosed except for the operating wheels, levers, or handles. Terminals for welding leads should also be protected so that accidental electrical contact by personnel or by metal objects does not occur.

The installation of arc welding equipment, including the power supply, should be done in accordance with the requirements of the OSHA standard, OAR 437 Division 2 Subdivision S: Electrical. Regulations pertaining to arc welding and cutting are covered in 1910.54, Arc Welding and Cutting.

## Resistance welding

Workers using resistance welding equipment must be properly trained on how to operate the equipment. Proper guarding must be in place to protect the operator from accidentally activating automatic, air, or hydraulic clamps. All press welding machines must also be guarded so that the operator cannot accidentally get their fingers under the point of operation. Shields should be placed to prevent hazards from flying sparks.

Flash welding machines must be equipped with a hood to control flying flash. Fire-resistant curtains or suitable shields must be set up around the machine to protect people working nearby.

Regulations pertaining to resistance welding are covered in 1910.255.

## Appendix A: definitions

| | |
|---|---|
| **Arc** | A sustained, luminous discharge across a gap in an electric circuit; in arc welding, the path for current flow between the electrode and the work piece; the movement of electrons through the arc provides the major source of heat required in welding |
| **Base Metal** | The metal to be welded, brazed, soldered or cut |
| **Brazing** | Brazing is a process in which coalescence is produced by heating the work surface and a filler metal. The temperature is such that the filler metal is liquefied but the base metal is not. Once liquefied, the filler metal is distributed between the closely fitted surfaces of the joint by capillary action. Shielding of the joint is provided by a flux material which primarily prevents oxide formation. |
| **Electrode** | A component of the welding circuit through which current is conducted to the arc, the molten slag, or the base metal |
| **Filler Metal** | The metal to be added in making a welded, brazed, or soldered joint |
| **Flux** | Material used to prevent, dissolve, or facilitate removal of oxides and other undesirable surface substances |
| **Gas** | Fuel gas such as acetylene, natural gas, hydrogen, propane, methylacetylene propylene, or other synthetic fuel or hydrocarbon, burned (usually with oxygen) to provide the heat needed for welding, cutting, soldering, or brazing |
| **Grounding** | An electrical connection to earth for safety, as in grounding of welding machines |
| **Plume** | A cloud of visible smoke; in welding, the cloud of particulate and gas produced by some welding processes |
| **Rod** | A form of filler metal used for welding or brazing which does not conduct the electrical current |
| **Shielding** | Protection of the weld from contamination by means of flux, externally supplied gas, or gas generated from breakdown of the electrode covering. May also refer to the use of curtains and other barriers erected to prevent accidental observation of the arc by bystanders |
| **Shielding Gas** | Protective gas used to prevent contamination of a weld by air |
| **Slag** | Non-metallic materials released during the welding process. |
| **Soldering** | A process in which coalescence is produced, as in brazing, except that the filler metal used has a melting point below 800 degrees Fahrenheit. Flux is also used here to provide protection of the joint. |
| **Welding** | A localized coalescence of materials produced either by heating the materials to suitable temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler material |

## Appendix B: common metals and compounds

The following is a list of common metals and compounds found in welding fumes along with some of the potential health effects from overexposure.

**Aluminum** A common component of some alloys and filler materials. Shaver's Disease is caused by industrial exposure to aluminum fumes or dust, which results in respiratory distress and fibrosis with large blebs. Symptoms include productive coughing and wheezing, substernal pain, weakness and fatigue; spontaneous pneumothorax is a frequent complication. Autopsy findings include emphysema and interstitial pulmonary fibrosis.

**Beryllium** A contaminant in many steels. Inhalation of beryllium dust or fume may result in the production of an acute or chronic systemic disease known as Berylliosis. Beryllium compounds are cancer-causing in experimental animals.

**Cadmium** A component of some protective coatings, welding electrode coatings, and in some alloys. Acute effects include serious pulmonary irritation and delayed pulmonary edema. Chronic effects include emphysema and kidney damage. Because of possible systemic toxicity, exposure to cadmium fumes must be avoided.

**Chromium** A primary alloying agent in stainless and high-alloy steels. Excessive chronic exposure to some types of chromium (insoluble hexavalent form) has been associated with skin irritation and increased risk of lung cancer. Fume from chromium-containing stainless steel and certain chromium-containing welding rods can trigger eczematous eruptions on the hands of sensitive individuals.

**Copper** May be found in alloys (monel, brass, bronze), metal overlays, and in welding electrodes. Acute effects include irritation of the nose and throat, nausea, and metal fume fever.

**Fluorides** Found in some electrode coatings and flux materials. Acute effects include eye, nose, and throat irritation. Inhalation of fluoride fumes may produce respiratory tract irritation manifested by chills, fever, labored breathing, and cough. Chronic effects include pulmonary edema and skin rashes. Very high, long-term exposures have been reported to result in increased bone density and bone changes that interfere with joint function.

**Iron** Usually in the form of iron oxide, it is often the major component of welding fumes, since carbon steels are involved in most welding and iron is the major constituent. Inhalation of iron oxide fumes over an extended period of time may cause a condition known as siderosis, a benign form of pneumoconiosis. Pneumoconiosis is defined as the accumulation of "dust" in the lungs and the tissue reaction to its presence.

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| **Lead** | Primarily found in solder, brass, and bronze alloys and sometimes as a lead-based paint or coating on steels. Acute symptoms are seen only with very high exposures, well above those normally found in welding. Analysis for elevated blood-lead levels is indicative of overexposure. Chronic effects related to lead toxicity can include anemia, fatigue, abdominal pains, insomnia, reduced fertility, and kidney and nerve damage. |
| **Manganese** | Present in small quantities in most carbon/stainless alloys and welding electrodes. Manganese is mainly toxic to the central nervous system. Persons overexposed to manganese may develop fever and chills as described in the discussion of metal fume fever. Chronic manganese poisoning may occur after variable periods of heavy exposure. Symptoms may include muscle weakness, tremors, gait disorders, and other neurological effects. |
| **Molybdenum** | Found in steel alloys, usually in low concentrations. Exposure at higher levels can cause eye, nose, and throat irritation, as well as shortness of breath. |
| **Nickel** | Present in stainless steels and alloys such as monel, Inconel, and incoloy. Acute effects include eye, nose, and throat irritations. Some nickel compounds have been associated with increased risk of lung and sinus cancer. |
| **Tin** | Found in bronzes and some solder alloys, usually with lead. Exposure to dust and fume of tin oxide can produce a build-up of particulate in the lungs known as stannosis, a rare benign pneumoconiosis. |
| **Titanium** | Found in some stainless steels and other alloys, flux materials and coatings. Exposure to airborne concentrations of titanium can cause mild irritation of the respiratory tract. |
| **Vanadium** | A component of some steel alloys and welding electrode coverings. Acute effects include irritation of the eyes, skin, and respiratory tract. Chronic effects may include bronchitis, retinitis, pulmonary edema, and pneumonia. |
| **Zinc** | Major component in galvanized coatings and in some primers/coatings. Also found in brass and brazing/soldering filler metals. Inhalation of zinc oxide fume causes an influenza-like illness termed metal fume fever. This condition is characterized by chills, fever, nausea, vomiting, muscular pain, dryness of mouth and throat, headache, fatigue, and weakness. Symptoms last from 24 to 48 hours and then subside. |

## Appendix C: common welding gases

The following is a list of common gases that are used for welding processes or are a by-product of welding processes:

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| **Asphyxiants** | A number of gases, when present in high concentrations, displace the oxygen necessary to support life. Simple asphyxiant gases that could be found at welding and cutting operations are acetylene, propane, methane, hydrogen, helium, argon, and nitrogen. |
| **Carbon Monoxide** | Can be formed in the burning or decomposition of the electrode coating or flux material. It is a colorless, odorless gas that is a chemical asphyxiant. Acute symptoms include headache, dizziness, and mental confusion. Chronic symptoms are not significant at concentrations normally encountered in welding. |
| **Decomposition Products** | Residual cleaning and degreasing solvents, usually chlorinated hydrocarbons, may produce hazardous gases when exposed to the welding arc. Decomposition products may include phosgene, phosphine, hydrogen chloride, and chloroacetic acids. If other residual organics are present, decomposition may produce acrolein, formaldehyde, carbon monoxide, and acetaldehyde. Symptoms of exposure to most of these gases include eye and respiratory irritation, dizziness, and headache. |
| **Nitrogen Oxides** | Like ozone, formed in the arc by ultraviolet radiation. The oxides usually consist of nitrogen dioxide and nitric oxide, with nitrogen dioxide usually the predominant oxide present. Nitrogen dioxide is irritating to the eyes, nose, and respiratory tract at low concentrations. Higher concentrations may result in pulmonary edema and other serious lung effects. |
| **Ozone** | Formed in the welding arc by the action of ultraviolet radiation on oxygen in the air. Ozone has acute effects that may be severely injurious, including pulmonary congestion, edema, and hemorrhage. Very low concentrations cause headache and dryness of mucous membranes of the eyes following exposures of short duration. Chronic health effects include significant changes in lung function. |

## Resources

Oregon OSHA topic page: welding
http://osha.oregon.gov/Pages/topics/welding.aspx

Federal OSHA safety and health topics: welding, cutting, and brazing
https://www.osha.gov/SLTC/weldingcuttingbrazing/index.html

CDC/NIOSH workplace safety & health topic: welding and manganese: potential neurologic effects
http://www.cdc.gov/niosh/topics/welding/

American Welding Society
http://www.aws.org

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