



Welding Health and Safety

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This publication provides practical loss control and safety information to assist you in making your workplace safer. It is not legal advice. SAIF Corporation has made every effort to bring significant Oregon Occupational Safety and Health Administration (OR-OSHA) regulations to your attention. Nonetheless, compliance with OR-OSHA remains your responsibility. You should read and understand all relevant OR-OSHA regulations that apply to your job site(s). You may want to consult with your own attorney regarding aspects of OR-OSHA that may affect you.

Note: The information in this publication is time sensitive. Do not rely upon this document if its publication date is more than three years old. Please check the Employer Guide "Safety" section of our web site at www.saif.com/employer for a more recent, printable copy. You'll also find a variety of other valuable safety information designed to help your business prevent injuries and control costs.

Introduction

This guide was written to provide a general understanding of the different welding and cutting processes, the potential health hazards associated with welding and cutting and a summary of the Oregon Occupational Safety and Health Division (OR-OSHA) regulations, OAR 437 Division 2 Subdivision Q: Welding, Cutting and Brazing (1910.251 -. 257).

What Is Welding

The welding process joins metals together using pressure, heat, flame or electric arc. In the welding process, a filler metal and the work piece are heated to form the weld using an electric arc or combustion gas.

Welding and Cutting Processes

There are more than 80 processes used in welding and cutting. Arc welding is the process in which fusion is produced by heating with an electric arc that is generated between an electrode and the surface of the base metal. Arc cutting is the general process in which the cutting or removal of metals is done by melting with the heat of an arc between an electrode and base metal. The more common processes are listed below:

American Welding Society Nomenclature 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)

is an arc welding process which 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 include alloying and deoxidizing agents as well.

Gas metal arc welding (GMAW) or MIG (metal inert gas) welding is an arc welding process wherein coalescence is produced by heating with an 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 that is 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 TIG (tungsten-inert gas) welding

is an arc welding process wherein coalescence is produced by heating with an 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. The outstanding features of GTAW welding are that it will make top quality welds in almost all metals and alloys used in industry and practically no post weld cleaning is required. The arc and weld pool are clearly visible to the welder, there is no filler metal across the arc stream, so there is no weld spatter. Welding is possible in all positions, and there is no slag produced which might be trapped in the weld.

Flux cored arc welding (FCAW) is an arc welding process where coalescence is produced by heating with an 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 either semiautomatic, the most widely used, or automatic.

Submerged arc welding (SAW) is an arc welding process which produces coalescence by heating with an 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. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod. The process may be either automatic or semiautomatic, with the automatic method being most widely used. The outstanding features of the submerged arc process are high welding speed, high metal deposition rates, deep penetration, smooth weld appearance, good x-ray quality welds, easily removed slag covering and wide range of material thickness weldable.

Plasma arc cutting is the process in which the metal is cut 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 is an arc welding process similar to gas tungsten arc welding (GTAW). The electric arc is formed between an electrode (which is usually but not always made of sintered tungsten) and the work piece. The key difference from GTAW is that in PAW, by positioning the 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 which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 20,000 °C. Plasma arc welding is an advancement over the GTAW process. This process uses a non-consumable tungsten electrode and an arc constricted through a fine-bore copper nozzle. PAW can be used to join all metals that are weldable with GTAW (i.e., most commercial metals and alloys).

Carbon arc cutting "Arc Gouging" is an arc cutting process in which metals to be cut are melted by the heat of a carbon arc. The molten metal is removed by a blast of air. This is a method for cutting or removing metal by melting it with an electric arc and then blowing away the molten metal with 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, compared with flux-cored wire or coated electrodes. Fume production is directly related to the amount of consumed electrode. Electrodes are consumable (composed of steel, copper, 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 10-20% of the fume composition.

Bare Rods or Wire

Bare rods or wire are immersed in the flux material and fume generation is greatly reduced. Bare rods or wire are typically composed of copper alloys, steel nickel alloys, nickel or chromium-steel alloys.

Health Hazards

Welding and cutting processes pose several potential health hazards. The most common hazards involve exposures to radiation, heat, noise, fumes and gases. The following section briefly describes these potential hazards and discusses some protective measures for the specific hazards.

Radiation

Radiation is a process by which energy is transmitted through space or matter. There are two types of radiation associated with welding operations; ionizing and non-ionizing. Ionizing radiation is produced by the electron beam welding process and during the grinding (pointing) of thoriated tungsten electrodes for Gas Tungsten Arc Welding (GTAW) process. To minimize the ionizing radiation exposure from the grinding dust, local exhaust ventilation and respirators should be used.

Nonionizing radiation is the more common type of radiation produced by most types of welding and includes ultraviolet, infrared and visible light. Eye injuries are the most common injury sustained by welders because the eyes can be adversely affected by all three energy ranges (ultraviolet, infrared and visible light). The skin is principally susceptible only to the effects of ultraviolet and infrared radiation, and it warns us of infrared heat radiation by burning of the skin. Severe erythema or "sunburn" to the skin can increase the risk of skin cancer for prolonged exposures.

It does not require a long exposure to burn the eyes. The severity depends on the length of exposure, the intensity of the light source, and the closeness of the eye to the source. Even brief exposure to an intense source can cause burns. Inflammation (swelling of the cornea) and eye irritation, also known as flash burns, do not become noticeable for several hours. Application of ice packs will normally relieve the pain, but if it persists, medical attention should be obtained.

Staring at the blue color of the arc can cause photo chemical changes in the retina, creating permanent loss of vision unless proper protective filters are used.

The eyes should be protected from burns, light and heat. Safety glasses and welding hoods provide good protection. Safety glasses with side shields would protect from flying sparks, flying chips and flash burns. It is important that all workers wear eye protection when standing near a welding operation to prevent arc burns. If a worker is exposed to ultraviolet light, even though the light does not seem intense, burns can occur.

Ultraviolet (UV) radiation is generated by all of the arc welding processes. UV radiation can damage the cornea of the eye. Many arc welders are aware of the condition known as "welder's flash or arc eye or arc flash," a sensation of sand in the eyes. The medical term for this condition is photokeratitis and photoconjunctivitis. The arc should never be observed without eye protection. Skin exposure to UV can also result in severe burns, in many cases without prior warning.

Skin and eye burns from UV exposure can be prevented by the use of proper clothing and eye protection. It is important that welders wear clothing to cover their bare skin and use proper eye protection.

Eye protection must meet the filter lens shading requirements of the OSHA regulation for eye and face protection (1910.133). Employers should reference the ANSI Z49.1:2005 Guide for Shaded Numbers.

Whenever possible, arc welding operations should be isolated so that other workers will not be exposed to either direct or reflected rays. Working in the proximity of an exposed arc without eye protection for a correspondingly longer time can cause arc burn. Walls, ceilings and other exposed inner surfaces such as booths or rooms should have a dull finish produced by a non-reflective paint, and provided with portable fire resistant screens similarly painted or with fire resistant curtains/screens. The screens should be arranged so that no serious restriction of ventilation exists. The screens should be mounted so that they are about 2.0 ft above the floor unless the work is performed at such a low level that the screen must be extended closer to the floor to protect adjacent workers. The height of the screen is normally 6.0 ft (1.8 m) but may be higher depending upon the situation.

Heat

Most people realize that metal with "red heat" temperature can burn the skin. However, material can still cause damage at lower temperatures when it has lost red heat. In welding and cutting operations, hot metal is always present and in some cases the metal is preheated to as much as 600 degrees Fahrenheit to improve weldability.

Physiological effects of heat are skin burns, hyperthermia and heat stress when the body temperature rises to a very high level.

Heat problems are usually controlled by a combination of engineering methods, work practices and personal protective equipment. Some of the common methods are:

- Use cooling fans to increase the air flow over the worker and increase the evaporative heat loss. The air flow should be across the worker from one side for optimum control.
- Use mechanical air conditioning systems in conjunction with the makeup air system.
- Increase the general exhaust ventilation at points of high heat production
- Supply shielding between the welder and the source of radiant heat, such as a preheated work surface.
- Allow the welder to have frequent work breaks in a cooler area and to have plenty of access to cold drinking water.

Burns

The process of welding and cutting produces numerous potential burn hazards. Sparks, hot metal, spatter and slag may all cause burns to the welder. It is important that the welder wear appropriate protective gear including dry, hole-free gloves, a heavy shirt, and full-length cuff-less pants. If the welder is conducting a lot of oxy-acetylene cutting or welding that produces molten slag, the welder's shoes should be covered with spats to prevent the slag from entering the welder's shoes and causing burns.

Noise

Noise problems are not normally associated directly with welding operations except with plasma arc or air carbon arc welding processes. Probably the most common operations that produce relatively high noise levels are plasma arc cutting and air carbon arc cutting. Other operations associated with many welding operations, such as chipping and grinding, are common sources of noise problems.

In many cases, excessive noise associated with welding operations cannot be reduced by engineering controls. Therefore, appropriate hearing protection should be used and regular audiometric tests may be needed to detect the onset of hearing loss.

Inhalation Hazards

One of the major health hazards to welders is the inhalation of fumes and gases. The extent of exposure is determined by the exposure time, the concentration and nature of the contaminant in the breathing zone. 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 of the 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 so that 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 increases, more fumes are generated. 30% more fumes are generated by welding DC positive compared to DC negative or AC.

Gases

Gases are produced in all welding processes. Gases are produced from the decomposition of the shielding gases and fluxes, 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, solvent use or storage near welding should be prohibited. 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 (OR-OSHA) titled: OAR 437

Division 2 Subdivision Q: Welding, Cutting, and Brazing. Review the OR-OSHA regulations and follow specific requirements that pertain to your operations.

For a copy of the regulations, visit the Oregon Occupational Safety & Health Division's web site at www.orosha.org/subjects/welding.html.

Musculoskeletal Injuries

Welding and cutting processes place physical demands on the wrist, elbows, arms, shoulders, neck and back of the welder, due to awkward postures and material handling. It is recommended that employers evaluate the work area and processes to make sure that awkward positions are eliminated or greatly reduced. Consider equipment design, product design and work area during the evaluation.

Fire Protection

Welding and cutting processes pose a potential fire hazard. These processes should be conducted in areas that are non combustible or in buildings constructed of non-combustible materials. A radius of 35 feet around the welding area should be kept clear of all combustible material. If the floor is a combustible material, the floor should be kept wet during the welding or cutting process. Guarding should be used to confine the heat, sparks and slag, and to protect the immovable fire hazards. If welding or cutting is to be done on a container that contained flammable or combustible material, thorough cleaning should be done to ensure that there is no potential for flammable or toxic vapors.

As a precautionary measure, fire watchers (designated employees to watch for fire) are required when there is a potential for a major fire. Conditions that may require fire watchers include having an appreciable amount of combustible material in building construction or contents that is closer than 35 feet to the point of operation, having easily ignitable combustible materials more than 35 feet away, or having combustible materials adjacent to the opposite side of metal partitions, walls, ceilings or roofs and are likely to be ignited by conduction or radiation.

Fire watchers should be trained on how to use the fire extinguishers that are readily available. They will be in charge of watching for fires during the processes and for a half hour after the processes concludes, sounding off fire alarms when necessary and extinguishing small controllable fires.

Cutting or welding must be permitted only in areas that are or have been made fire safe. When work cannot be moved by practical means, as in most construction work, the area must be made safe by removing combustibles or protecting combustibles from ignition sources.

Management is responsible for authorizing cutting and welding in the work areas. Prior to authorization, the area must be inspected and precautions that should be followed be 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 a hot work permit may need to be issued by management before any welding activities can be conducted.

Electrical Hazards

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

Employees should be properly trained to observe safe electrical work practices according to OSHA's Electrical Hazard Training Standard (1910.332). The 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, it is recommended that you 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

Substitution is considered by using a welding electrode with a less hazardous composition, but 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 substitution may be from using bolts or rivets in place of welding or by using robotic welding instead of manual welding.

Ventilation

Two types of ventilation can be used to reduce fume exposures; local exhaust and dilution ventilation. Local exhaust ventilation is the preferred method of ventilation, where the fumes are captured at the source and are removed from the workplace. Dilution ventilation provides large amounts of air into the workplace to dilute the contaminant. Dilution does not remove the contaminant. Fume hoods are not recommended as the fume is generally passed through the workers breathing zone.

Personal Protective Equipment (PPE)

Personal protective equipment (PPE) is used to reduce employee exposures to hazards when engineering and administrative controls are not feasible or effective in reducing personal exposures. Types of PPE include; respiratory protection, eye protection, skin protection and hearing protection. Additional PPE that may be required, is hard hats and steel toe boots.

Respiratory Protection

Respiratory protection is the least desirable method of exposure control from welding fumes and gasses. This exposure control should only be used as a temporary control method until permanent control methods are in place. If respiratory protection is used, the employer must follow the OSHA 1910.132 "Respiratory Protection" standard.

To determine what type of respiratory protection is needed, an exposure assessment and PPE assessment must be performed. Once you have collected and reviewed the exposure data, you will be able to determine what your next steps are, which may or may not include respiratory protection.

The types of respiratory protection used by welders for filtering metal fumes and dusts are disposable single-use NIOSH approved air purifying respirator, half and full-face air-purifying respiratory protection with cartridges, powered air purifying respirators (PAPR) and supplied air respiratory protection.

There is a table in the standard that states the minimum requirements for protective measures, such as respiratory protection, when welding and cutting are done on some of the more hazardous metals. The specified metals include manganese, zinc, lead, cadmium, mercury, beryllium and fluorine compounds. This table should be reviewed to determine your specific requirements for the processes being conducted at your facility.

Eye Protection

Eye protection is important for welding, cutting and brazing. 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", has the following table as a guide for the selection of 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

The worker's skin should be protected by a double layer of non flammable clothing or equivalent to prevent burns or other damage by ultraviolet light. All clothing should be laundered regularly to prevent oil and grease buildup. Recommended personal protective clothing should include; leather gloves, fire resistant protective sleeves or a fire resistant jacket or a 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 8 hour day and required when noise levels exceed the 90 decibels for an 8 hour day or when noise levels exceed the maximum level of 115 decibels at any time. Hearing protection can be either ear plugs or ear muffs that have a noise reduction rating. To determine what employees TWA exposures are, personal noise monitoring is needed. Based on the personal noise exposure results, a company hearing conservation program may be required which would include; audiometric testing, hearing protection, employee training and recordkeeping. For more information, see the OR-OSHA 1910.95 "Occupational Noise Exposure" standard.

Special Welding Situations

Confined Spaces

Confined spaces are generally small or restricted spaces such as a tank, boiler or pressure vessel. All welding and cutting operations done inside of confined spaces must be adequately ventilated to prevent the accumulation of toxic materials or possible oxygen deficiency. 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 or 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 that can be placed by the welder as near as practicable to the work being done and that provide 100 linear feet per minute exhaust rate. A fixed enclosure with a top and not less than two sides, which surround the welding or cutting operations and with an exhaust rate of 100 linear feet per minute or more could also be used instead.

All welding and cutting operations that are in 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.

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. Precautionary measures should be taken to prevent mixing prior to consumption, except at the burner or in a standard torch.

It is important that the operators of the oxygen or fuel-gas supply equipment, including generators, and oxygen or fuel-gas distribution piping systems are educated about the systems they are in charge of and have an understanding of

the potential hazards. Operating instructions and rules should be readily accessible.

Equipment

Qualified maintenance personnel should conduct periodic inspections of welding equipment and keep a certified record of the inspections. This record should include the date of the inspection, the signature of the person who performed the inspection and the serial number or other identifier, for the equipment inspected.

That concludes the parts of the code that pertain to all welding, cutting and brazing operations. The code does have some requirements for specific welding, cutting and brazing processes. If you are doing oxygen-fuel gas welding or cutting, arc welding or cutting, or resistance welding, than some of the specific requirements will pertain to you. The following section reviews those requirements for the specified processes.

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 over 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.

Cylinders should be stored away from sources of heat. Inside of buildings, cylinders should be stored 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.

Oxygen cylinders should never be stored near fuel-gas cylinders, such as acetylene or carbide, because of the potential fire hazard. A minimum distance of 20 feet should be between the oxygen cylinders and other fuel-gas cylinders.

All cylinders should be securely lashed in place to prevent them from falling. A sign stating: "Danger - No Smoking, Matches, or Open Lights" should be posted near the fuel-gas storage areas.

Blowpipes/Torches

Approved back-flow or flashback preventers must be installed between the blowpipe or torch and the hoses. Torches must be ignited using a friction lighter, stationary pilot flame, or other recognized sources of ignition. Matches and other hand held open flames should never be used.

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.

A torch should never be put 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. Oxygen manifolds must be stored 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. Manifolds should be used only with the gas they were intended for. 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

The 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. Some of the types of pipe include steel, wrought iron, brass, copper, seamless copper, brass or stainless steel tubing.

Piping joints and distribution lines should be installed and maintained in a safe operating condition. Underground pipes and tubing and outdoor ferrous pipe and tubing should be protected from corrosion. The 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

Approved protective equipment should be installed in fuel-gas piping to prevent back-flow of oxygen into the fuel-gas supply system, passage of a flash back into the fuel-gas supply system, and excessive back pressure of oxygen in the fuel-gas supply system. Pressure relief devices should be installed on service piping systems to prevent pressure build-up. A check valve, hydraulic seal, pressure regulator or a combination thereof must be installed at each station outlet to prevent back-flow.

Pressure-reducing regulators should be kept in good repair. Cracked, broken or otherwise defective parts, including gauge glasses, must be replaced.

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. Hose showing leaks, burns, worn places or other defects rendering it unfit for service must be repaired or replaced. Damaged hose cannot be repaired with tape.

In order to avoid accidentally interchanging the fuel-gas hoses with the oxygen hoses, the connections for the hoses should be significantly different from one another or the hose connections should be 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.

Portable acetylene generators should not be used within 10 feet of combustible materials other than the floor and should not be used in rooms having 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 of 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.

Only authorized personnel should be allowed in outside generator houses or inside generator rooms. Operating instructions should be posted near the generator. Manufacturer operating and maintenance procedures should be followed.

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. The arc welding equipment should be approved for the intended use. There is a maximum allowable voltage for alternating-current machines and for direct-current machines. 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, whereas for direct-current manual arc welding and cutting machines it 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.

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 - 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	Soldering is 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.

The following is a list of some of the more 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. Not known to have any acute (short-term) or chronic (long-term) health effects
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.

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. 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.

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

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 which 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.

Additional Resources

1. American Welding Society (AWS)
550 N.W. LeJeune Road
Miami, FL 33126
800-443-9353
Web site: <http://www.aws.org>
2. American Industrial Hygiene Association (AIHA)
2700 Prosperity Avenue, Suite 250
Fairfax, VA 22031-4319
703-849-8888
Web site: <http://www.aiha.org>
3. American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
212-642-4900
Web site: <http://www.ansi.org>
4. Oregon Occupational Safety and Health Division (OR-OSHA)
350 Winter Street NE, Room 430
Salem, OR 97310
503-378-3272
Web site: <http://www.orosha.org>
5. Occupational Health and Safety Administration (OSHA)
200 Constitution Avenue, NW
Washington, DC 20210
800-321-OSHA (6742)
Web site: <http://www.osha.gov>

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