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Welding, Cutting and Brazing SOP

Summary

This SOP briefly describes different types of welding, cutting and brazing, including electric arc, gas and thermite, and depending on the type of welding or cutting, a variety of hazards may be present. Typically, hazards include: heat and fire hazards, metal splatter, electric shock, explosion hazards, fumes and gases, radiation energy, and ergonomics. This SOP also includes a list of occupational exposure limits related to welding, cutting and brazing. This SOP details safe work practices to follow for welding, cutting and brazing procedure, including ventilation, eye and face protection and respiratory protection.

What are welding, cutting and brazing?

Source: https://www.osha.gov/Publications/OSHA_FS-3647_Welding.html

Welding joins pieces of metal by use of heat, pressure or both. Cutting involves heating the metal with a flame and directing a stream of oxygen along the line to be cut. The most common types of welding/cutting includes arc welding, metal inert gas (MIG), tungsten inert gas (TIG), plasma arc and gas (oxy-acetylene). Other welding processes may use oxy-acetylene gas, electrical current, lasers, electron beams, friction and chemical reactions. There are three main components needed to create a weld/cut. These are:

- A heat source such as an electric arc, a flame, pressure, or friction. The most common heat source is an electric arc. An arc is the physical gap between the end of the electrode and the base metal. The physical gap causes heat due to resistance of the current flow and arc rays. The arc melts to create the joint.
- Shielding, which is the use of gas or another substance to protect the weld from air as the weld is being formed. Oxygen from the air makes welds brittle and porous.
- Filler material, which is the material used to join to the two pieces together.

Welding is classified into two groups: fusion (heat alone) or pressure (heat and pressure) welding. There are three types of fusion welding: electric arc, gas and thermite. Electric arc welding is the most widely used type of fusion welding. It employs an electric arc to melt the base and filler metals. Arc welding types in order of decreasing fume production include:

- Flux Core Arc Welding (FCAW): filler metal electrode; flux shield.
- Shielded Metal Arc (SMAW): electrode provides both flux and filler material.
- Gas Metal Arc (GMAW or MIG): widely used; consumable electrode for filler metal, external gas shield.
- Tungsten Inert Gas (GTAW or TIG): superior finish; non-consumable electrode; externally-supplied inert gas shield.

Gas or oxy-fuel welding uses a flame from burning a gas (usually acetylene) to melt metal at a joint to be welded, and is a common method for welding iron, steel, cast iron, and copper. Thermite welding uses a chemical reaction to produce intense heat instead of using gas fuel or electric current. Pressure welding uses heat along with impact-type pressure to join the pieces.

Plasma arc welding: The plasma arc welding process is a gas-shielded process that utilizes a constricted arc between a non-consumable tungsten electrode and the work piece. The transferred arc possesses high energy density and plasma jet velocity. Shielding of the weld pool is provided by the ionized plasma gas that is issued from the torch orifice, which is supplemented by an auxiliary source of shielding gas. The plasma arc welding process can be utilized with or without a filler metal addition.

Oxy-fuel and plasma cutting, along with brazing, are related to welding as they all involve the melting of metal and the generation of airborne metal fume.

Brazing is a metal-joining process where only the filler metal is melted. Brazing uses higher temperatures for a similar process compared to soldering, while also requiring much more closely fitted parts than when soldering.

What are the hazards?

- Heat and Fire hazards: Metal conducts heat very well away from the weld/cut spot. The entire part can get hot quickly, especially when welding small parts. With rapid spot welding, the temperature of the part(s) can get high enough to cause burns. The welding arc should be treated as an open flame source as it may ignite flammable gases or vapors. **A hot works permit is required for welding, cutting and brazing work on campus. Obtain a hot work permit from EH&S prior to conducting welding and cutting work at UMass. The procedure to get a permit is simple: call the EH&S main line at 413-545-2682 and request one. A campus fire safety officer will then visit the work area and issue a permit.**
- Metal splatter
- Electric shock: Electric shock from electrical welding/cutting/brazing equipment can result in death or severe burns. Additionally, serious injury can occur if the worker falls as a result of the shock.
- Explosion hazards
- Fumes and Gases:
    - Fumes (metals): Aluminum, Antimony, Arsenic, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Molybdenum, Nickel, Silver, Tin, Titanium, Vanadium, Zinc.
    - Shielding gases: Argon, Helium, Nitrogen, Carbon Dioxide.
    - Process gases: Nitric Oxide, Nitrogen Dioxide, Carbon Monoxide, Ozone (the emission of high-energy UV light can cause surrounding air to break down into ozone), Phosgene, Fluorides from flux (brazing), Hydrogen Fluoride, Carbon Dioxide.
    - Health effects:
        - Acute exposure to welding fume and gases can result in eye, nose and throat irritation, dizziness and nausea. Workers in the area who experience these

symptoms should leave the area immediately, seek fresh air and obtain medical attention.
    - Prolonged exposure to welding fume may cause lung damage and various types of cancer, including lung, larynx and urinary tract.
    - Health effects from certain fumes may include metal fume fever, stomach ulcers, kidney damage and nervous system damage. Prolonged exposure to manganese fume can cause Parkinson's–like symptoms.
    - Gases such as helium, argon, and carbon dioxide displace oxygen in the air and can lead to suffocation, particularly when welding in confined or enclosed spaces. Carbon monoxide gas can form, posing a serious asphyxiation hazard.
- Radiant energy, including UV radiation: The high energy of the electrical arc between the electrode and work piece can emit radiation in the UV spectrum.
- Ergonomics: There may be ergonomic hazards associated with the welding/cutting operation related to awkward position or unsuitable work height.

Occupational Exposure Limits

The OSHA Permissible Exposure Limits (PELs, 8-hour Time Weighted Averages) for welding and cutting listed below are from Table Z-1 and Z-2 of 29 CFR 1910.1000. ACGIH Threshold Limit Values (TLVs, 8-hour Time Weighted Averages) listed below are from ACGIH® 2020 Threshold Limit Values.

Table 1. OSHA PELs and ACGIH TLVs of Welding, Cutting and Brazing Related Materials

Materials	OSHA PELs	ACGIH TLVs
Aluminum	Total Dust: 10 mg/m^3 Respirable fraction: 5 mg/m^3	Respirable fraction: 1 mg/m^3
Antimony	0.5 mg/m^3	0.5 mg/m^3
Arsenic	Inorganic compounds: 0.01 mg/m^3 organic compounds: 0.2 mg/m^3	Inorganic compounds: 0.01 mg/m^3
Cadmium	0.005 mg/m^3	0.01 mg/m^3 (total) 0.002 mg/m^3 (respirable)
Carbon Dioxide	5000 ppm Short Term: 30,000 ppm	5000 ppm Short Term: 30,000 ppm
Carbon Monoxide	25 ppm Ceiling: 200 ppm	25 ppm
Chromium (VI) compounds	0.005 mg/m^3	0.0002 mg/m^3
Cobalt	0.02 mg/m^3	0.02 mg/m^3 (Inhalable)
Copper	Fume (as Cu): 0.1 mg/m^3 Dusts and mists (as Cu): 1 mg/m^3	Fume (as Cu): 0.2 mg/m^3 Dusts and mists (as Cu): 1 mg/m^3
Fluorides (as F)	2.5 mg/m^3	2.5 mg/m^3
Hydrogen Fluoride	3 ppm	Ceiling: 3 ppm
Lead	0.05 mg/m^3	0.05 mg/m^3

Manganese	0.2 mg/m^3	0.02 mg/m^3 (respirable) 0.1 mg/m^3 (Inhalable) (for elemental and inorganic compounds)
Molybdenum	Soluble compounds: 0.5 mg/m^3 Insoluble Compounds - Total dust: 10 mg/m^3 Insoluble Compounds: 3 mg/m^3 (resp.)	Soluble compounds: 0.5 mg/m^3 (respirable) Insoluble Compounds: 10 mg/m^3 (Inhalable), 3 mg/m^3 (respirable)
Nickel	metal and insoluble compounds: metal 0.5 mg/m^3, insoluble 0.1 mg/m^3 soluble compounds: 0.05 mg/m^3	elemental: 1.5 mg/m^3 (Inhalable); insoluble inorganic compounds: 0.2 mg/m^3 (Inhalable) soluble inorganic compounds: 0.1 mg/m^3 (Inhalable)
Nitric Oxide	25 ppm	25 ppm
Nitrogen Dioxide	Short Term: 1 ppm	0.2 ppm
Ozone	0.1 ppm Short Term: 0.3 ppm	0.05-0.20 ppm depending on workload and time
Phosgene	0.1 ppm	0.1 ppm
Silver	0.01 mg/m^3	Metal, dust, and fume: 0.1 mg/m^3; Soluble compounds, as Ag: 0.01 mg/m^3
Tin	Inorganic compounds (except oxides): 2 mg/m3; also tin oxide; except SnH4. organic compounds (as Sn): 0.1 mg/m^3 Short Term: 0.2 mg/m^3	metal, oxide and inorganic compounds, except tin hydride and indium tin oxide, as Sn: 2 mg/m^3 (Inhalable) organic compounds (as Sn): 0.1 mg/m^3 Short Term: 0.2 mg/m^3
Vanadium	Respirable dust (as V2O5): 0.05 mg/m3, vanadium pentoxide Fume (as V2O5): 0.05 mg/m3	0.05 mg/m^3 (Inhalable) Vanadium pentoxide as V
Zinc oxide fume	5 mg/m^3	2 mg/m^3 (respirable) Short Term: 10 mg/m^3 (respirable)
Zinc oxide	Total dust: 15 mg/m^3 Respirable fraction: 5 mg/m^3	2 mg/m^3 (respirable) Short Term: 10 mg/m^3 (respirable)

For more information, please refer to OSHA PELs Table Z-1 (https://www.osha.gov/dsg/annotated-pels/tablez-1.html), Table Z-2 (https://www.osha.gov/dsg/annotated-pels/tablez-2.html), NIOSH Pocket Guide to Chemical Hazards (https://www.cdc.gov/niosh/npg/default.html) and ACGIH® 2021 Threshold Limit Values.

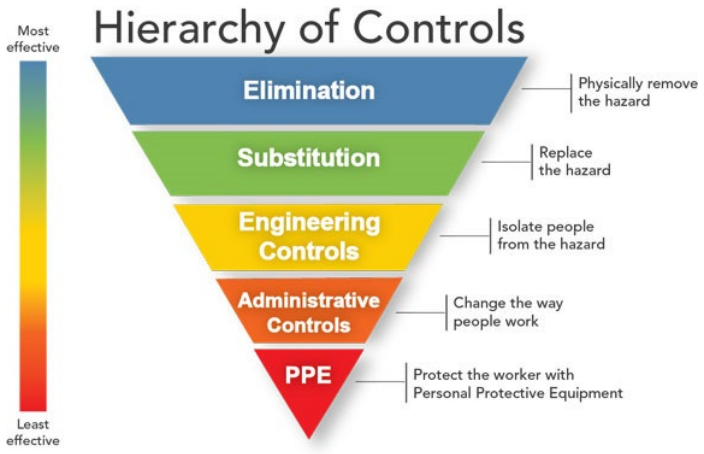
What Activities Could Pose a Risk?

- No adequate ventilation and lighting.

- Not wearing proper PPE.
- Use a bare hand or wet glove to change electrodes.
- Touch an energized electrode while you are in contact with the work circuit.
- Wear rings or other jewelry that could create an electrical ground to the electrode.
- Wear clothing made from synthetic or synthetic blends. The synthetic fabric can burn vigorously, melt and produce bad skin burns.
- Store flammable or combustible material near welding/cutting station.
- Work in one position for long periods of time.
- Strike an arc in the presence of other people whose eyes are not shielded.
- Use welding/cutting cables at currents in excess of their rated capacity.
- Strike an arc on a compressed gas cylinder.
- Force connections which do not fit easily.
- Reposition the voltage bars while power source is connected to the machine. To do so could cause a serious electrical shock and possible death.
- Make or break any connections or perform any maintenance while the welding/cutting machine is in operation. The high voltage created by this machine can cause death by electrocution.
- Use regulators or cylinder valves as hooks for hanging torches and hoses.

How Can Exposures Be Minimized?

When working with welding, cutting and brazing, or any other hazardous material, always conduct a thorough risk assessment and employ the hierarchy of controls to minimize risk. Some specific applications of the hierarchy of controls to the hazards of welding and cutting are listed below. Always apply the controls in the order of most effective to least effective (see graphic), and apply as many controls as possible to reduce the risk to the lowest achievable level.



Elimination/Substitution

- Use the least fume production welding/cutting/brazing type whenever possible.
    - Fume production: flux-cored arc welding (FCAW)> shielded metal arc welding (SMAW)> gas metal arc welding (GMAW) or MIG> gas tungsten arc welding (GTAW) or TIG
- Avoid using painted or coated parts whenever possible.

Engineering Controls

- Adequate task lighting that suits workers' needs.
- Ventilation: The worker should be located in an area with adequate ventilation. Ventilation is used for removing air contaminants from a workers' breathing zone, preventing the accumulation of flammable or combustible gases or vapors, and preventing oxygen rich or oxygen deficient atmosphere.
    - Natural ventilation: According to OSHA Regulations, when welding, cutting and brazing mild steels, natural ventilation is usually considered sufficient to avoid exposure provided that:
        - The room or welding area contains at least 10,000 cubic feet (about 22' x 22' x 22') for each worker.
        - The ceiling height is not less than 16 feet.
        - Cross ventilation is not blocked by partitions, equipment, or other structural barriers.
        - Welding is not done in a confined space.
    - Mechanical ventilation: According to OSHA 29 CFR 1910.252(c), spaces that do not meet requirements of natural ventilation should be equipped with mechanical ventilating equipment that exhausts at least 2,000 cfm of air for each worker, except where local exhaust hoods, or booths, or air-line respirators are used.
    - Local exhaust ventilation (LEV): LEV is the most effective means of removing contaminants from the worker's breathing zone. Keep fume hoods, fume extractor guns, snorkels and vacuum nozzles close to the plume source to remove the maximum amount of fume and gases. Portable or flexible exhaust systems can be positioned so that fume and gases are drawn away from the worker. Keep exhaust ports away from other workers.
        - OSHA requires this type of ventilation (or supplied air respiratory protection) when welding/cutting/brazing in a confined space involving the following substances:
            - Fluorine compounds (typically in fluxes and rod coatings)
            - Zinc (zinc-bearing base or filler materials or metals coated with zinc-bearing materials, including galvanized steel.)
            - Lead (lead-base metals or metals coated with lead-bearing materials such as paint)
            - Beryllium (beryllium-containing base or filler metals)
            - Cadmium (cadmium-bearing or cadmium-coated base metals)
            - Mercury (metals coated with mercury-bearing materials, including paint)
            - Cleaning compounds (possible toxicity or flammability hazard)
            - Degreasing (chlorinated hydrocarbons)
            - Stainless steels (oxygen cutting using either a chemical flux or iron powder or gas-shielded arc cutting)
- Screen: Screens should be mounted so that they are about 2 feet above the floor (unless work is performed at a low level and the screen must extend to the floor to protect nearby workers from

welding/cutting/brazing glare. When welding/cutting/brazing must be performed in a space entirely screened on all sides, the screens shall be so arranged that no serious restriction of ventilation exists.

Administrative Controls

- Perform Safety Check on all equipment.
- Ensure fire extinguishers is charged and available.
- The operator must be properly trained and instructed by an experienced worker.
- Ensure all equipment used is maintained in a safe condition. Identify and report defective equipment so that it can be repaired.
- Keep the work at a comfortable height.
- Do not weld, cut or braze on containers that are near combustibles or were used to hold combustible or flammable material - purge the containers first.
- Keep flying sparks, hot slag, hot objects and open flames away from hoses.
- Do not accumulate empty gas cylinders. Please contact vendors to return those. Please check compressed gases SOP (https://ehs.umass.edu/compressed-gases) for more information.
- Do not weld, cut or braze painted or coated parts. Remove surface coatings prior to work.
- Keep work area free of equipment, supplies and other items that could cause trips or falls.
- Use the lowest amperage possible when welding, cutting or brazing.
- Obtain a hot work permit from EH&S prior to conducting welding, cutting or brazing work at UMass. The procedure to get a permit is simple: call the EH&S main line at 413-545-2682 and request one. A campus fire safety officer will then visit the work area and issue a permit.
- Know the hazardous materials, such as gas, filler metals, base metals, etc. used in the process and read Safety Data Sheets (SDS) for recommendations.
- Clean base metals thoroughly and apply sufficient flux for brazing.

Personal Protective Equipment

- Eye and face protection: welding helmet, hand shield or goggles. Wear fire resistant head coverings under the helmet where appropriate. They can protect from radiation, hot slag, sparks, intense light, irritation and chemical burns.
    - All filter lenses and plates must meet the test for transmission of radiant energy prescribed in the ANSI standard Z87.2010.
    - Helmets and hand shields shall protect the face, forehead, neck and ears to a vertical line in back of the ears, from the arc's direct radiant energy, and weld splatter.
    - Welding helmets with filter plates are intended to protect users from arc rays and from weld sparks and spatters which strike directly against the helmet. They are not intended to protect against slag chips, grinding fragments, wire wheel bristles, and similar hazards which can ricochet under the helmet. Spectacles, goggles or other appropriate eye protection must also be worn to protect against these impact hazards.

- OSHA requires that when arc welding and cutting with open arcs, helmets or hand shields with filter lenses and cover plates shall be used by operators and nearby personnel viewing the arc also subject to wear proper protection. Spectacles with a shade 2 lens are recommended for general purpose protection for viewers. When resistance welding or brazing; operators of resistance welding must use face shields, spectacles, or goggles depending on the particular job to protect their faces and eyes from welding hazards.
- Table 2 – 4 list filter lenses for protection during different types of welding, cutting and brazing operations. A shade number indicates the intensity of light radiation that is allowed to pass through a filter lens to one's eyes. Therefore, the higher the shade number, the darker the filter and the less light radiation that will pass through the lens.

Table 2. Filter Lenses for Protection during Shielded Metal Arc Welding

Operation	Electrode Size – inch (mm)	Arc Current (Amperes)	OSHA Minimum Protective Shade Number	ANSI & AWS Shade Number Recommendations*
Shielded Metal Arc Welding (SMAW)	Less than 3/32 (2.4)	Fewer than 60	7	-
	3/32-5/32 (2.4-4.0)	60-160	8	10
	More than 5/32-1/4 (4.0-6.4)	More than 160-250	10	12
	More than 1/4 (6.4)	More than 250-550	11	14

Table 3. Filter Lenses for Gas Welding and Oxygen Cutting Operations

Operation	Plate Thickness Inches	Plate Thickness mm	OSHA Minimum Protective Shade Number	ANSI & AWS Shade Number Recommendations*
Gas Welding	Under 1/8	Under 3.2	4	5
	1/4 to 1/2	3.2 to 12.7	5	6
	Over 1/2	Over 12.7	6	8
Oxygen Cutting	Under 1	Under 25	3	4
	1 to 6	25 to 150	4	5
	Over 6	Over 150	5	6

Table 4. Filter Lenses for Protection during Other Welding and Cutting Operations

Operation	Arc Current (Amperes)	OSHA Minimum Protective Shade Number	ANSI & AWS Shade Number Recommendations*
Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)	Fewer than 60	7	-
	60-160	10	11
	More than 160-250	10	12

Operation	Arc Current (Amperes)	OSHA Minimum Protective Shade Number	ANSI & AWS Shade Number Recommendations*
	More than 250-500	10	14
Gas Tungsten Arc Welding (GTAW)	Fewer than 50	8	10
	50-150	8	12
	More than 150-500	10	14
Air Carbon Arc Cutting (CAC-A) (Light)	Fewer than 500	10	12
Air Carbon Arc Cutting (CAC-A) (Heavy)	500-1000	11	14
Plasma Arc Welding (PAW)	Fewer than 20	6	6-8
	20-100	8	10
	More than 100-400	10	12
	More than 400-800	11	14
Plasma Arc Cutting (PAC) (Light)**	Fewer than 300	8	9
Plasma Arc Cutting (PAC) (Medium)**	300-400	9	12
Plasma Arc Cutting (PAC) (Heavy)**	More than 400-800	10	14
Torch Brazing (TB)		3	3 or 4
Torch Soldering (TS)		2	2
Carbon Arc Welding (CAW)		14	14

** As a rule of thumb, start with a shade that is too dark to see the weld zone. Then, go to a lighter shade which gives a sufficient view of the weld zone without going below the minimum. During oxygen gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light (spectrum) of the operation.*

*** Values apply where the actual arc is clearly seen. Lighter filters may be used when the arc is hidden by the workpiece.*

- Insulated gloves and rubber-soled safety shoes can protect from electric shock, heat, burns, and fires.
- Clothing:
    - Fire/Flame resistant clothing and aprons to provide protection to the front of the body when additional protection against sparks and radiant energy is needed.
    - Dark clothing works best to reduce reflection under the face shield. Heavier materials such as wool clothing, heavy cotton or leather are preferred as they resist deterioration. Materials that can melt or can cause severe burn due to sparks that may lodge in rolled-up sleeves, pockets of clothing or pant cuffs are not recommended.

    - Clothing shall provide sufficient coverage and be made of suitable materials to minimize skin burns caused by sparks, spatter or radiation. Covering all parts of the body is recommended to protect against ultraviolet and infrared ray flash burn.
- If you feel you may need respiratory protection, please visit Respiratory Protection Program website (https://ehs.umass.edu/respiratory-protection-program) and contact EH&S for next step and more information.
- Hearing protection: ear muffs or ear plugs. Use fire resistant ear plugs where sparks or splatter may enter the ear.

References and Additional Resources

1. OSHA Fact Sheet, Controlling Hazardous Fume and Gases during Welding. https://www.osha.gov/Publications/OSHA_FS-3647_Welding.html
2. OSHA Fact Sheet, Eye Protection against Radiant Energy during Welding and Cutting in Shipyard Employment.
https://www.osha.gov/Publications/OSHAfactsheet-eyeprotection-during-welding.pdf
3. Indiana University, Welding, Cutting, and Brazing Safety Program. https://protect.iu.edu/environmental-health/occupational-safety/equipment/welding-cutting-brazing.html