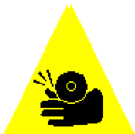
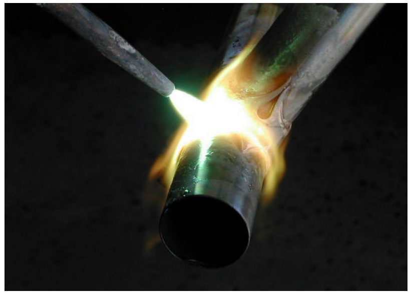
Safe Work Procedure **Brazing Safe Work Procedures** RSS 18.50.3			
Program/Services	**Safe Work Procedures**		**Department:** Risk and Safety Services
Personal Protective Equipment or Devices Used • Safety Glasses • Work Gloves • Work Boots • Close fitting clothing or protective clothing must be worn (no baggy clothing) • Respirator with HEPA filters • Long and loose hair must be secured and contained	**Training Requirements** • In class safety training • Hands-on shop training	**Applicable Documents**	**Effective Date:** April 25, 2019 **Date Reviewed** **Revision Date** / **Revision #** / **Authorized** Oct. 8, 2024 / 3 / Safety Advisor

EXPOSURE	**PINCH POINTS**	**COMPRESSED GASES**	**FIRE**	**FOOT INJURY**	**RINGS AND DANGLING JEWELLERY**
 Understand the chemical(s) you are working in the vicinity of. Consult the MSDS and wear the appropriate PPE.	 Use LOCK-OUT procedures when performing maintenance or conducting any work within 12" of an exposed pinch point. **NEVER** put your hands or feet near an exposed pinch point or gears!	 Do not • Drop • Keep near heat	 Complete a hot work permit where required.	 Approved protective footwear is required when there is the risk of foot injury due to slipping, uneven terrain, and abrasion, crushing potential, temperature extremes, corrosive substances, puncture hazards, electrical shock, and any other recognizable hazard.	 Rings and loose or dangling jewelry must NOT be worn.



Brazing

- Brazing is a metal-joining process whereby a filler metal is heated above the melting point and distributed between two or more close-fitting parts by capillary action. The filler metal is brought slightly above it's melting (liquidus) temperature while protected by a suitable atmosphere, usually a flux. It then flows over the base metal (known as wetting) and is then cooled to join the work-pieces together. It is similar to soldering, except the temperatures used to melt the filler metal are higher for brazing.

Fundamentals of Brazing

- In order to obtain high-quality brazed joints, parts must be closely fitted, and the base metals must be exceptionally clean and free of oxides. In most cases, joint clearances of 0.03 to 0.08 mm (0.0012 to 0.0031 in) are recommended for the best capillary action and joint strength. However, in some brazing operation, it is not uncommon to have joint clearances around 0.6 mm (0.024 in). Cleanliness of the brazing surfaces is also important, as any contamination can cause poor wetting (flow). The two main methods for cleaning parts, prior to brazing, are chemical cleaning and abrasive or mechanical cleaning. In the case of mechanical cleaning, it is important to maintain the proper surface roughness as wetting on a rough surface occurs much more readily than on a smooth surface of the same geometry.
- Another consideration that cannot be overlooked is the effect of temperature and time on the quality of brazed joints. As the temperature of the braze alloy is increased, the alloying and wetting action of the filler metal increases as well. In general, the brazing temperature selected must be above the melting point of the filler metal. However, there are several factors that influence the joint designer's temperature selection. The best temperature is usually selected so as to:
    - Be the lowest possible braze temperature
    - Minimize any heat effects on the assembly
    - Keep filler metal/base metal interactions to a minimum
    - Maximize the life of any fixtures or jigs used
- In some cases, a higher temperature may be selected to allow for other factors in the design (e.g. to allow the use of different filler metal, or to control metallurgical effects, or to sufficiently remove surface contamination). The effect of time on the brazed joint primarily affects the extent to which the aforementioned effects are present; however, in general, most production processes are selected to minimize brazing time and the associated costs. This is not always the case however since, in some non-production settings, time and cost are secondary to other joint attributes (e.g. strength, appearance).

Flux

- A variety of alloys are used as filler metals for brazing depending on the intended use or application method. In general, braze alloys are made up of 3 or more metals to form an alloy with the desired properties. The filler metal for a particular application is chosen based on its ability to: wet the base metals, withstand the service conditions required, and melt at a lower temperature than the base metals or at a very specific temperature.
- Braze alloy is generally available as rod, ribbon, powder, paste, cream, wire and preforms (such as stamped washers). Depending on the application, the filler material can be pre-placed at the desired location or applied during the heating cycle. For manual brazing, wire and rod forms are generally used as they are the easiest to apply while heating. In the case of furnace brazing, the alloy is usually placed beforehand since the process is usually highly automated. Some of the more common types of filler metals used are:
    - Aluminium-silicon
    - Copper
    - Copper-silver
    - Copper-zinc (brass)
    - Gold-silver
    - Nickel alloy
    - Silver

Atmosphere

As brazing work requires high temperatures, oxidation of the metal surface occurs in an oxygen-containing atmosphere. This may necessitate the use of an atmospheric environment other than air. The commonly used atmospheres are:

- Air: Simple and economical. Many materials are susceptible to oxidation and build-up of scale. Acid cleaning bath or mechanical cleaning can be used to remove the oxidation after work. Flux tends to be employed to counteract the oxidation, but it may weaken the joint.
- Combusted fuel gas (low hydrogen, AWS type 1, "exothermic generated atmospheres").
- Combusted fuel gas (decarburizing, AWS type 2, "endothermic generated atmospheres”).
- Combusted fuel gas (dried, AWS type 3, "endothermic generated atmospheres").
- Combusted fuel gas (dried, decarburizing, AWS type 4).
- Ammonia (AWS type 5, also called forming gas).
- Nitrogen hydrogen, cryogenic or purified (AWS type 6A).
- Nitrogen hydrogen-carbon monoxide, cryogenic or purified (AWS type 6B).
- Nitrogen, cryogenic or purified (AWS type 6C); Non-oxidizing, economical. At high temperatures can react with some metals, e.g. certain steels, forming nitrides.
- Hydrogen (AWS type 7); Strong deoxidizer, highly thermally conductive. Can be used for copper brazing and annealing steel. May cause hydrogen embrittlement to some alloys.
- Inorganic vapours (various volatile fluorides, AWS type 8); Special Purpose. Can be mixed with atmospheres AWS 1–5 to replace flux.
- Noble gas (usually argon, AWS type 9); Non-oxidizing, more expensive than nitrogen. Inert. Parts must be very clean, the gas must be pure.
- Noble gas hydrogen (AWS type 9A).
- Vacuum: Requires evacuating the work chamber. Expensive. Unsuitable (or requires special care) for metals with high vapour pressure, e.g. silver, zinc, phosphorus, cadmium, and manganese. Used for highest-quality joints, for e.g. aerospace applications.

Torch Brazing

- Torch brazing is by far the most common method of mechanized brazing in use. It is best used in small production volumes or in specialized operations, and in some countries, it accounts for a majority of the brazing taking place. There are three main categories of torch brazing in use: **manual, machine, and automatic torch brazing**.
- **Manual** torch brazing is a procedure where the heat is applied using a gas flame placed on or near the joint being brazed. The torch can either be handheld or held in a fixed position depending on whether the operation is completely manual or has some level of automation. Manual brazing is most commonly used on small production volumes or in applications where the part size or configuration makes other brazing methods impossible. The use of flux or self-fluxing material is required to prevent oxidation. Torch brazing of copper can be done without the use of flux if it is brazed with a torch using oxygen and hydrogen gas, rather than oxygen and other flammable gases.
- **Machine** torch brazing is commonly used where a repetitive braze operation is being carried out. This method is a mix of both automated and manual operations with an operator often placing brazes material, flux, and jigging parts while the machine mechanism carries out the actual braze. The advantage of this method is that it reduces the high labour and skill requirement of manual brazing. The use of flux is also required for this method as there is no protective atmosphere, and it is best suited to small to medium production volumes.
- **Automatic** torch brazing is a method that almost eliminates the need for manual labour in the brazing operation, except for loading and unloading of the machine. The main advantages of this method are: high production rates, uniform braze quality, and reduced operating cost. The equipment used is essentially the same as that used for Machine torch brazing, with the main difference being that the machinery replaces the operator in the part preparation

Silver Brazing

- Silver brazing, sometimes known as a silver soldering or hard soldering, is brazing using silver alloy based filler. These silver alloys consist of many different percentages of silver and other metals, such as copper, zinc, and cadmium.
- Brazing is widely used in the tool industry to fasten 'hard metal' (carbide, ceramics, cermet,) to tools such as saw blades. "Pre-tinning" is often done; the braze alloy is melted onto the hard metal tip, which is placed next to the steel and re-melted. Pre-tinning gets around the problem that hard metals are hard to wet.
- Brazed hard metal joints are typically two to seven mils thick. The braze alloy joins the materials and compensates for the difference in their expansion rates. In addition, it provides a cushion between the hard carbide tip and the hard steel which softens impact and prevents tip loss and damage, much as the suspension on a vehicle helps prevent damage to both the tires and the vehicle. Finally the braze alloy joins the other two materials to create a composite structure, much as layers of wood and glue create plywood.
- The standard for brazing joint strength in many industries is a joint that is stronger than either base material, so that when under stress, one or other of the base materials fails before the joint.
- One special silver brazing method is called pin brazing or pin brazing. It has been developed especially for connecting cables to railway track or for cathodic protection installations. The method uses a silver-and flux-containing brazing pin which is melted down in the eye of a cable lug. The equipment is normally powered from batteries.

Braze welding

- Braze welding is the use of a bronze or brass filler rod coated with flux to join steel work-pieces. The equipment needed for braze welding is basically identical to the equipment used in brazing. Since brazing welding usually requires more heat than brazing, acetylene or methylacetylene-propadiene (MAP) gas fuel is commonly used. The name comes from the fact that no capillary action is used.
- Braze welding has many advantages over fusion welding. It allows the joining of dissimilar metals, minimization of heat distortion, and

can reduce the need for extensive pre-heating. Additionally, since the metals joined are not melted in the process, the components retain their original shape; edges and contours are not eroded or changed by the formation of a fillet. Another effect of braze welding is the elimination of stored-up stresses that are often present in fusion welding. This is extremely important in the repair of large castings. The disadvantages are the loss of strength when subjected to high temperatures and the inability to withstand high stresses.

Cast Iron Welding

- The "welding" of cast iron is usually a brazing operation; with a filler rod made chiefly of nickel being used although true welding with the cast, iron rods is also available. Ductile cast iron pipe may be also "cad welded," a process which connects joints by means of a small copper wire fused into the iron when previously ground down to the bare metal, parallel to the iron joints being formed as per hub pipe with neoprene gasket seals. The purpose behind this operation is to use electricity along with the copper for keeping underground pipes warm in cold climates.

Brazing Procedures

Proper Clearances/ Proper Joint Design

Joint clearance is a principal factor in determining the mechanical strength of brazed joints. It is also a factor in eliminating harmful voids in the joint area and in establishing the capillary force required to fill the joint.

- During the brazing process, two closely fitted surfaces or parent metals are heated and a filler metal is introduced. As the filler metal becomes liquid, a pulling force draws the molten filler between the surfaces of the parent metals. This is known as capillary action. The coalescence of materials when cooled, is a strong, void-free braze joint. This sounds easy but the first step to ensure success begins in the design engineer's office. The design engineer has a working knowledge of what the braze joint will face in the field. With this input, a joint is designed with as little stress and the greatest strength possible. The joint integrity will be maximized by maintaining good fits or clearances between the parent metals.
- All metals expand/contract upon heating/cooling. When joining dissimilar metals, the expansion rate of each parent metal must be calculated and introduced into the joint design. If this is not included, a joint may be too tight or too wide during the heating process leading to lower strength conditions.

Cleaning of Metals to be welded

- The joint surface areas should be clean and free from oil, grease, or oxide contamination. Surfaces may be properly cleaned for brazing by brushing with a stainless steel wire brush, or by a stiff rubbing with emery cloth. If oil or grease is present, clean with a commercial solvent. Remember to remove small foreign particles, such as emery dust, by wiping with a clean, dry cloth. The joint surfaces MUST be clean.

Assembly and Fixturing

- After cleaning, maintaining alignment of the base metals during the heating cycle will assist capillary action. The easiest method is using gravity. In most cases the parts are self-supporting. More intricate methods might include fixtures such as clamps or vises. If you have a number of assemblies to braze and their configuration is too complex for self-support or clamping, it may be a good idea to use a brazing support fixture. In planning such a fixture, design it for the least possible mass and the least contact with the parts of the assembly. Try to use materials in your fixture that are poor heat conductors, such as stainless steel, Inconel or ceramics. Since these are poor conductors, they draw the least heat away from the joint. Choose materials with compatible expansion rates so you won't get alterations in the assembly during the heating cycle.

Fluxing of Parent Metals

- Most of the flux is conventionally made in a paste consistency; it's usually most convenient to brush it on. But as production quantities increase, it may be more efficient to apply the flux by dipping. When using White Silver Flux, apply it only with a brush. To prevent excess flux residue inside refrigeration lines, apply a thin layer of flux to only the male tubing and, if possible, rotate the fitting once or twice on the tube to ensure uniform coverage.

Brazing the Assembly

- This is the point where heat is introduced. Torch Brazing uses fossil fuels such as oxy-acetylene is a reliable method. This is most common in single assemblies or smaller production levels. It involves heating the assembly to brazing temperature and flowing the filler metal through the joint. In larger operations, multiple station turntables with multi-tip torches can increase production levels. The heat must be applied uniformly. Mass differences and conductivity of the base metals will affect the amount of heat and how much time is required. The heat is directed to a broad area surrounding the joint. Because filler metals follow the greater heat source, the key is getting the interior facing surfaces to the proper temperature. If you're brazing a small assembly, you may heat the entire assembly to the flow point of the brazing filler metal. If you're brazing a large assembly, you heat a broad area around the joint. **DO NOT** direct heat solely on the joint surface as it can lead to a premature flow of the alloy but not necessarily into the length of the joint. The joint might look adequate but it will have little strength. When using preforms, the alloy is replaced as close as possible to the joint.

Post-Braze Cleanup

- After completing the brazed assembly, it must be cleaned; the flux residues must come off. Fluxes are corrosive, If not removed they can eventually weaken a braze joint. The quickest and most economical method is a water quench. Once the filler has solidified, place the warm assembly in a hot water bath. This will normally "crack" the residue off. For more tenacious residues, agitate the water bath or use a jet spray to knock the flux off. Or simply wire brush the assembly while submerged in the bath. If the flux has been saturated during the heating cycle, the assembly will have a blackish discoloration. In most cases, an acid bath will be needed to assist the flux removal. Care must be taken in choosing a mild acid to avoid etching the joint.

RECORDS/VERIFICATION OF UNDERSTANDING

Records

- All training records will be maintained by the Department Leadership/Instructor.

Verification of Understanding

- A training master log will be maintained by Department Leadership/Instructor.

SUMMARY OF CHANGES

Revision #	Date	Change (include section #)	Issued By
1	03/04/2014	NEW	OHS Officer
2	04/25/2019	Review, Revisions, and New format	Safety Officer
3	10/08/2024	RSS update	Safety Advisor