WELD TECH NEWS is a newsletter for welders working primarily in maintenance and repair. Each issue will contain useful information on materials (cast irons, steels, aluminum, copper alloys, etc.), welding products, welding techniques and safety. By collecting each issue, the reader will soon have a handy reference manual covering all aspects of welding, brazing and soldering for maintenance and repair.

**BRAZING**

*What It Is - How It Works*

Brazing is one of the oldest methods used by man to join metals. In spite of the many recent developments in metals joining technology, brazing is still the most effective and economical joining process for certain industrial applications.

The term brazing covers several processes for joining metal parts using a filler metal that melts at a lower temperature than the base metal. In brazing:

- the parts are joined without melting the base metal,
- the filler metal melts at a temperature above 840°F (450°C), and
- the filler metal wets the base metal surfaces and is drawn into, or held in, a close fitting joint by capillary attraction.

Soldering is similar to brazing, except that the filler metal melts at a temperature below 840°F (450°C).

If a brazing filler metal is used to build up an area, or to fill a groove or fillet without capillary flow into a tight fitting joint, the process is defined by the American Welding Society as braze welding, not brazing. In braze welding, the base metal may be melted somewhat.

Brazing filler metals can be used to join a wide variety of base metals. Since aluminum presents some special problems, we will publish a special future issue of WELD TECH NEWS on aluminum joining processes, including aluminum brazing.

Brazing processes can use many different heat sources, including gas torches, furnaces, induction coils, electrical resistance and baths of melted metal or salts, among others. Since most maintenance and repair brazing is done with a gas torch, this issue of WELD TECH NEWS will focus on torch brazing.

Following are some general principles that apply to most brazing jobs. The next article tells how to apply these principles to specific brazing projects.
Brazing requires the proper joint design, joint preparation, filler metal, brazing technique, and frequently flux.

*Joint design* should give good mechanical support and have correct clearance between the two parts. Samples of good and bad joint design are shown below. Whenever possible, the strength of the joint should not depend entirely on the filler metal, but also on the shape and fit of the base metal parts.

Clearance between the parts is critical. It must be as narrow as possible, to give a strong joint, but not so narrow that the molten filler metal cannot be drawn in. The joint design must allow any gases from the heated flux to escape and not form gas pockets in the joint.

*Joint preparation* includes cleaning and roughening the joining surfaces to help the capillary flow and let the filler metal properly wet the surface of the base metal. Grease, oil, dirt, and oxides should be removed by chemical or mechanical cleaning.

Fluxes chemically remove the last bits of surface oxide. They also coat the surfaces to prevent oxides from reforming when the parts are heated during brazing and while they are cooling afterward. The proper flux will be chemically active in, and below, the melting range of the filler metal. If the flux is overheated, its chemical activity will be weakened or destroyed.

Fluxes also serve as temperature indicators. When the flux starts to melt, it shows that the part is reaching brazing temperature and that the welder can start to apply the filler metal.

Fluxes can be coated on the filler metal rod or used as a separate powder or paste. For some applications, the filler metal is powdered and blended with special fluxes to form a paste that can be placed in a joint before heating.

*Filler metals* are carefully proportioned alloys, designed to melt at a relatively low temperature and to alloy with the surface of the base metal, even though the brazing temperature is below the melting temperature of the base metal. This surface alloying, or "wetting", helps the capillary flow of the filler metal into the narrow joint.

Pure metals and a few alloys melt at a single fixed temperature. Most filler alloys, however, melt in stages over a temperature range as wide as several hundred degrees. At the lower temperature in this range, called the "solidus", the filler metal starts to melt. At the upper temperature, called the "liquidus", the filler metal is completely liquid. In between the solidus and liquidus, the filler metal is soft or slushy, but will not flow easily into a tight joint. Alloys that have a wide difference between solidus and liquidus temperatures are easier to use for building up high deposits.

For complex metallurgical reasons, certain alloys melt at a lower temperature than any of the pure metals that go into the alloy. Many filler metal alloys are proportioned to lower their melting temperature, as well as for wetting ability, strength, capacity to flow easily into the joint, and resistance to forming undesirable surface alloys.
Alloys that work well in one application may have problems in other applications. Copper-phosphorus alloys, for example, work very well on copper and brasses, where the phosphorus helps reduce surface oxides and helps wettability. On steel or nickel alloys, however, phosphorus should not be used, because it forms undesirable brittle surface alloys that can weaken the joint. Another example is cadmium, which helps silver alloys form surface alloys with stainless steels. However, cadmium alloys should be avoided on surfaces that contact food, because of potential food contamination.

Sometimes filler metals must meet special service requirements, such as corrosive environments, high or low (cryogenic) temperatures, radiation stability, conductivity, repeated stress loadings, or color matching with the base metal.

Low temperature alloys and proper brazing technique, as discussed below, are frequently necessary to minimize carbide precipitation, stress corrosion cracking and loss of base metal heat treatment.

Carbide precipitation can occur in chromium alloys, such as stainless steels, if held too long at temperatures of 800°-1500°F (425°-815°C). This reduces corrosion resistance. If brazing is done quickly at low temperatures, very little carbide will be precipitated and corrosion resistance will not be damaged.

Stress corrosion cracking may occur in certain stainless steels, nickel alloys and copper-nickel alloys when molten filler metal contacts a highly stressed part. The part may be stressed from cold working before brazing (a deep drawn cup, a cold-formed channel, a cold forging) or it may be stressed by the way it is clamped in a brazing jig.

The Welding Shop

BRAZING TECHNIQUES - WHAT TO USE & HOW TO USE IT

For many maintenance and repair applications, brazing is the easiest way to join metal parts. For joining certain dissimilar metals, brazing sometimes is the only practical method. To help you achieve the best results, the following techniques have been developed by Rockmount engineers for use with the Rockmount alloys mentioned below.

Joint Design

Proper joint design is the first requirement. Sometimes the maintenance welder is asked to repair a badly-designed joint. However, if he understands the principles of good joint design, he can sometimes modify the joint to achieve the best results.

The joining surfaces must have enough area and the right clearances to make a strong, tight joint. Butt joints in thin stock, for example, should be avoided or should be reinforced, as shown below.

Parts subject to high stress, or to stress reversals, should be designed to avoid stress concentrations that may cause cracking in the base metal.
Joint clearance is important. Ideally, the clearance should be as small as possible but still open enough to permit filler metal to flow in and displace the flux. In most cases, this means a clearance of .002 - .005 inches or .05 - .13 mm. (One page of the WELD TECH NEWS is about .005 inches thick.)

If the joint is too tight, the filler metal may not flow in completely and trapped flux or gases may cause voids. If the assembly has a clearance larger than .005 inches, it can be brazed, but there will be some reduction in joint strength as the clearance increases.

When a part made of one metal is fitted into a part of a different metal, the joint clearance may change as the parts are heated to brazing temperature. If the inside part expands more than the outside part, the clearance will be reduced. If the outside part expands more, the clearance will be increased. When possible,
it is better to put the higher expansion material outside and size the parts to give a press fit at room temperatures.

In the following list of common metals, those at the beginning of the list have a higher thermal expansion rate than those further down the list: Magnesium, tin, aluminum, silver, brass, copper, stainless steel, nickel, low alloy steel, cast iron, titanium, tungsten carbide.

**Preparation**

Mating surfaces in a joint should be cleaned by wiping, degreasing or mechanical abrasion (sanding, blast cleaning or wire brushing). Do not polish the surfaces, since slightly roughened surfaces wet out better. Be careful that the cleaning does not remove so much material that the joint clearances become too large. If blast cleaning, use metal grit, since organic or ceramic grit may imbed in parts and resist wetting.

When necessary, apply flux to the joint, either from a flux container or by using the torch to melt a little flux off the end of the flux-coated rod.

If necessary, clamp or jig the parts to maintain alignment when heating or applying the filler metal. For small or irregular parts, some welders use Flamehold, a heat-resistant, clay-like compound, to hold the parts in position during brazing.

**Torch Adjustment**

Adjustment of the oxygen and fuel gas will vary depending on the materials being used. For silver alloys, a slightly carburizing flame (excess fuel gas) is used, as shown in Figure 2a below. For some other alloys, a neutral flame, as shown in Figure 2b, works best.

*Figure 2 — Torch flame adjustments. Dashed line shows location of part being heated.*
Brazing WTN #2

Brazing

Use the outer envelope of the flame, as shown above, to heat the braze area rapidly to brazing temperature. Do not use the inner cone for heating. With large parts, use auxiliary torches and/or multi jet ("rosebud") heating tips. The entire joint, inside and outside, should be heated uniformly before applying filler metal. Be careful not to overheat or melt the base metal.

Rockmount fluxes are designed to provide an indication of brazing temperature. When the flux becomes fluid, the joint is about ready for brazing. Move the torch sideways slightly and apply the filler metal. Do not push the filler metal into the flame, but let it melt from the heat of the parts. If the filler metal does not melt, apply more heat to the joint.

Once the filler metal flows, it will rapidly fill the joint with very little extra heat, if the joint is at uniform temperature. If the joint is very large, preheat close to brazing temperature and let the filler metal follow the torch tip around the joint. The molten filler metal will flow toward the heat source.

After cooling, examine the assembly. Remove any residual flux with warm water and/or mechanical cleaning. Make certain the flux is removed, since most flux residuals are corrosive. There should be a small, uniform fillet of brazing alloy around the joint. While this is not a guarantee, it generally indicates a sound joint.

Choice of Filler Metal

The most useful brazing filler metals are listed below in order of their melting temperatures. In general, the lower the melting temperature, the easier it is to braze. However, other factors must be considered, such as service temperature, strength, base metal metallurgy, joint clearance, and similar factors.

Most of the following filler metals can be used in a wide range of applications. Similarly, many jobs can be brazed with several possible filler metals. The final choice will depend on the best match of filler metal characteristics with the job at hand.

The most versatile low-temperature alloys are those containing silver, copper and often some tin, cadmium, or zinc. In general, as the silver content decreases, the melting range between the solidus and liquidus temperature increases, giving a wider “slushy” range.

**Gemini-G** is a flux coated, high silver alloy that can be used for brazing all metals except white metals. **Gemini-G** melts at 1090°F (587°C) and has high fluidity and a narrow melting range. It produces a joint strength of 88,000 psi. **Gemini-G** wets out easily on stainless steel and gives an excellent color match. It contains no cadmium, which makes it a good choice for food handling equipment and medical applications.

The flexible, pink colored, organic binder flux coating on **Gemini-G** provides all the flux required for many jobs. **Gemini-GB** contains the same alloy in a bare wire that can be used with **Gemini Flux**.
Brazing WTN #2

Apollo-G (orange flux-coated) and Apollo-GB (bare) melt at 1085°F (584°C), have slightly less silver than Gemini-G, and have a wider melting range between liquidus and solidus temperatures. This wider range makes it possible to bridge larger joint clearances, as is sometimes necessary in repair work. Apollo-G, like Gemini-G, can be used on all metals except white metals. It is cadmium free like Gemini-G.

Venus-G bare brazing rods provide excellent wetting and thin flow for strong joints for work with copper, brass, or bronze. Venus-G is a special silver alloy that melts at 1175°F (634°C) and is essentially self-fluxing on copper but should not be used on ferrous metals or nickel. It is especially useful in refrigeration and pressure piping where strong joints are required.

Gemini-Flux is an all purpose paste flux for use with all the above brazing alloys. In the case of the flux-coated rods and Venus-G, none may be needed.

Brutus-G (blue flux-coated) is a Rockmount nickel silver alloy brazing rod for use on all ferrous and non-ferrous metals, except white metals. It melts at 1575°F (857°C) and produces high strength (100,000 psi) thin joints for repairing machinery and equipment. Brutus-G has excellent wetting action and the thin flowing characteristics of some high silver alloys, although the brazing temperature and the strength are higher.

Jupiter-G (yellow flux-coated) and Jupiter-GB (bare) are bronze alloys designed especially for maintenance brazing. Unlike some bronze rods, Jupiter-G is non-fuming. Although its low melting temperature of 1590°F (864°C) and its high ductility (28%) make Jupiter-G especially suitable for work on cast iron, it can also be used on steels, brasses, bronzes, copper and galvanized pieces. Its versatility makes it especially useful for joining dissimilar metals.

Brutus Flux is designed to work in the temperature range of Brutus-G and Jupiter-G. It can be used with the bare rods or to supplement the flux on coated rods.

Effects of Heating

Using Rockmount filler metals with low melting temperatures - and heating the parts quickly (but uniformly) - both help to limit the total heat input. This will prevent carbide precipitation in stainless steels and reduce any loss of heat treatment in the base metal.

To eliminate stress corrosion cracking in a cold worked part, reduce any external stresses, such as clamping pressure in the brazing jig, and relieve the cold working stresses by heating the part 100° - 200°F above the normal brazing temperature and then letting it cool to brazing temperature before applying the filler metal.

Future issues of WELD TECH NEWS will discuss other materials and techniques that can help the maintenance welder do a better job more easily and effectively.
Brazing WTN #2

Safety Tips for Welders

BRAZING SAFETY

Fumes, fluxes, and fire are the three main hazards in brazing. The wise welder can easily manage all three, with a little knowledge and common sense.

Welding fumes and ventilation requirements were discussed in our last issue. In general, metal fumes are less of a hazard in brazing than in welding, because brazing temperatures are lower. However, some brazing alloys contain cadmium and some base metals are cadmium plated. These may produce toxic cadmium oxide fumes when heated. Zinc fumes can also be generated by some filler metals, or from brazing galvanized pieces. In both cases, the solution is to provide adequate ventilation and to prevent breathing the fumes. For occasional cadmium brazing in an open area, natural ventilation is generally sufficient. When brazing in a confined space, local exhaust or fresh air respirators should be used.

Paint, grease or similar substances on the base metal may release irritating or toxic fumes when heated. Cleaning solvents used to degrease parts can also generate toxic fumes. Carbon tetrachloride should not be used, since it is a cumulative health hazard, even in small quantities. If trichloroethylene or tetrachloroethylene vapors are heated by brazing or welding operations, they generate free halogens and phosgene, which are very toxic. These vapors are heavier than air and tend to remain near the floor.

The best method is to clean the parts thoroughly, using solvents where required, and then make sure that solvent vapors do not remain in the brazing area. This can be done by cleaning and brazing in different areas, or by insuring adequate ventilation.

Brazing fluxes often contain chemical compounds of fluorine, chlorine, and boron that are harmful if they are inhaled or contact the eyes or skin. The careful welder will simply avoid the flux fumes, handle fluxes carefully, and wash off any spilled flux promptly.

Since brazing fluxes are often water based pastes, carelessness in heating may produce some spatter. For this reason, and to prevent burns on the hands and eye damage from glare, it is wise to wear gloves and tinted safety glasses when brazing.

The dangers of fire are obvious when working with an open flame. A lit torch should never be left unattended. If the welder must lay his torch down momentarily, it should be set in a stable rest where the flame cannot heat any flammable material or, preferably, the torch should be turned off. All flammable material, especially plastic containers and solvents, should be removed from the brazing work area.

A future issue of WELD TECH NEWS will discuss safety requirements in working with oxy-acetylene torches, regulators and tanks.

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