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Brazing Copper Beryllium

Brazing is commonly used to join metals where high strength and resistance to high temperatures are required. Brazing copper beryllium is relatively simple and inexpensive. Most importantly, the strengthening mechanism inherent to copper beryllium makes it possible to braze without permanently weakening the alloy. Alloys such as phosphor bronzes or nickel silvers, which are strengthened only by cold work, will be permanently softened by brazing.

BRAZING

Brazing is defined as the joining process in which the filler or braze metal, which melts above 800°F (425°C) but below the melting point of the base metal, is drawn into the gap by capillary action. Brazing is intermediate in temperature between soldering and welding. For copper beryllium alloys, the typical brazing temperatures will be above the age hardening temperature and approximately equal to the solution annealing temperature.

COPPER BERYLLIUM METALLURGY

Depending upon the application requirements, copper beryllium alloys are available in two alloy classes: High Strength (C17000, C17200, C17300), and High Conductivity (C17410, C17460, C17500, C17510). Both alloy classes are strengthened by thermal treatments. (See Table 1).

First, the alloy must be solution annealed so that the beryllium is dissolved into a solid solution and is available to take part in the subsequent age hardening step. Solution annealing is always followed by rapid cooling to room temperature. Water quenching is used most often, although some thin section parts can be quenched by forced air. After quenching, parts are now in the annealed or A temper. In this condition, the parts are soft, easily formed, and have relatively low electrical conductivity. If the alloy is cold worked after quenching, the temper is designated a cold worked temper such as H. The solution anneal and quench steps are usually performed by the alloy manufacturer.

The second step is the age hardening (often called heat treating or aging) process, where hard, sub-microscopic, beryllium-rich particles are formed in the metal matrix at a temperature below the solution annealing temperature. The amount and distribution of the hard phase is dependent on the aging time and temperature, and accounts for the alloy's high strength. When an annealed or cold worked metal is age hardened, its strength and electrical conductivity increase, ductility or formability decreases, and the temper designation is followed by the letter T, such as AT or HT.

During brazing, if parts are exposed to temperatures above the age hardening temperature but below the annealing temperature, they will overage and the strength will decrease. Depending on the exposure time and temperature, the strength loss of overaged parts may be significant up to 50%.

Higher brazing temperatures, in the solution annealing range, will soften or anneal the parts. If the parts are quickly cooled from this temperature, they will respond to age hardening. When rapid cooling is not possible, parts may be reannealed and aged after brazing. In this case, care must be taken so that the solution annealing temperature does not exceed the melting point of the braze metal.

A more detailed explanation of the age hardening process in copper beryllium is provided in another TechBrief by Materion Brush Performance Alloys titled, “Heat Treating Copper Beryllium Parts”.

CLEANING BEFORE AND AFTER BRAZING

Surface cleanliness is essential to obtaining a sound braze joint. The mating surfaces must be free of dirt, oils, grease, tarnish, and oxide. A flux provides protection during brazing, but is not a substitute for adequate surface preparation. Solvent or vapor degreasing is effective on organic contaminants, but abrasive brushing or acid pickling is required to remove oxidation products. Additional cleaning information is provided in Materion Brush Performance Alloys’ TechBrief, “Cleaning Copper

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Beryllium".

Components should either be brazed immediately after cleaning or stored under protective conditions. When extended delays are unavoidable, the parts can be electroplated with gold, silver, or nickel to a thickness of at least 0.0005 inch (0.013 mm). Tin, solder or zinc precoatings do not provide adequate protection since they melt below the brazing temperature.

To avoid corrosion problems after brazing, flux residues should be removed with hot water and thorough brushing. Some fluxes may require warm, dilute sulfuric acid, which should be used carefully to avoid excessive base metal attack. Although galvanic series can not predict corrosion rates, the rate does depend on four factors one of which is the potential difference that can be estimated from the galvanic series. The first and most significant factor to consider is the environment. Sometimes the potential can reverse for a couple in different environments. This is the reason it is always favored to construct a galvanic series in the environment of interest. The second factor contributing to the corrosion rate is the potential difference between the couple. The farther apart from each other the two metals or alloys are in the table (i.e. the greater the potential difference between them), the more severe will be the attack on the active metal or alloy. The third factor deals with the ratio of the cathodic to anodic areas. A particularly unfavorable condition to set up between the couple is one in which there is a large cathode to small anode area ratio, because for a given current flow the current density will be larger for the smaller anode area. Hence the corrosion will proceed at a greater rate. The fourth factor is the distance from the junction between the couple. The greatest amount of corrosion will occur at the junction.

BRAZING ALLOYS

Aside from the requirements imposed by the configuration of the part and the copper beryllium alloy used, selection of the filler metal may also depend on such factors as corrosion resistance, strength, appearance, conductivity, flow characteristics and cost. Gold and copper base brazing alloys, because of their high melting temperatures are not generally used. Suggested brazing alloys for copper beryllium are described in Table 2. Some of the alloys in the table melt over a range, and it is the width of the range that determines the alloy's flow characteristics. A narrow melting range means the filler will flow more easily and be better suited for close tolerance brazing. Alloys with volatile constituents, such as zinc or cadmium, can not be used when vacuum brazing.

Brazing alloy cost is largely dependent upon silver content. Copper phosphorous brazing alloys offer important advantages, though they lack the strength of conventional high silver alloys.

When copper beryllium is brazed to steel, diffusion of beryllium into the brazing alloy can cause dewetting at the steel interface. A nickel containing filler such as BAg 3 should be used to avoid this problem.

FLUXES

The recommended flux for brazing high strength copper beryllium to itself or other common copper alloys, except aluminum bronze, is an alkali fluoride borate flux designated AWS 3A. It begins to melt and dissolve oxides at 600°F (315°C), is fully molten at 1100°F (590°C), and can be used at temperatures of 1145-1600°F (620 870°C). When brazing copper beryllium to aluminum bronze, use the chloride flux, AWS 4A. High temperature brazing operations, those using nickel silver fillers, require boron modified AWS 5A flux, which is effective above 1600°F (870°C).

BRAZING PROCEDURES

There are two general methods for brazing copper beryllium; these differ mainly by the temperatures at which they are performed. The low temperature process (below 1140°F using AWS BAg 1, for example) is recommended for joining relatively small parts of approximately equal size. Rapid heating and cooling cycles with less than one minute dwell at the brazing temperature are the keys to obtaining a good bond. Heat is applied only to the joint area and followed by forced air or water quench. Hardness readings, without re aging, can be held to within a few Rockwell B points of the starting hardness if care is taken to avoid overheating or prolonged heating.

High temperature brazing methods are used for large parts or parts of dissimilar size. All customary heating methods are applicable. The choice of heat source will be governed by the required heating rate, part configuration, production quantities and rates, and cost considerations. Torch and induction heating are often selected for rapid heating rates. Of course, care must be taken with alloys of different thermal conductivity's to ensure that all joint surfaces are

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uniformly heated. Rapid cooling of the parts from the brazing temperature will allow age hardening to the maximum mechanical properties of the alloy.

For high temperature brazing of high strength copper beryllium, the filler metal should melt at about 1400°F (760°C), a requirement met by AWS BAg 8. Assemblies should be heated to 1450°F (790°C) to allow the filler to flow. The assembly should be cooled to 1350 1375°F (730 745°C) before water quenching, followed by the usual age hardening at 600°F (315°C).

High temperature brazing of high conductivity copper beryllium alloys requires filler metals that flow between 1660 and 1740°F (900 950°C), e.g. AWS RBCuZn D (C77300) which melts at 1680°F (915°C). Lower melting alloys are not recommended unless considerable strength loss of the copper beryllium can be tolerated. Brazing high conductivity copper beryllium in the AT or HT condition, with filler metal melting at 1145°F (620°C), causes a loss of 10 15 Rockwell B points; more if the brazing time is extended.

Furnace brazing is more effective if the furnace is brought to temperature before the work is charged. Reducing atmospheres, such as dissociated ammonia, can decrease oxidation; however, a flux is still required to insure thorough wetting by the filler metal.

Resistance brazing takes advantage of copper beryllium's high electrical conductivity, allowing the heat to be generated in the low conductivity filler metal in the joint. This technique is used extensively in brazing precious metal contacts to copper beryllium springs. Simple configurations produce uniform current densities, hence, the uniform temperatures required for good bonding.

In induction brazing, care must be taken to insure that the coil design induces uniform temperatures at all joint surfaces. Note, higher conductivity alloys will heat at a slower rate.

Brazing and cleaning operations should be performed in a well ventilated area to prevent worker exposure to airborne particulate material.

DESIGN CONSIDERATIONS

Braze joint design is no different for copper beryllium than for other alloys. Common sense, embodied in a few general rules, prevails. Proper joint clearances are always a compromise between the need to permit flux escape and the need to provide sufficient capillary to draw in filler metal. Clearances must be uniform and preferably in the range of 0.0015 0.003 inch (0.04 0.08 mm). The preplaced flux is displaced by the filler metal. When possible, the filler flow should be assisted by slight sliding or vibration of the work pieces. Dimensional changes with temperature should be calculated to assure proper clearance at the brazing temperature.

Thermally induced strains must be considered when joining metals of differing thermal expansion coefficients. In the brazing range, copper beryllium's expansion coefficient is 9.7 x 10-6/°F (17.0 x 10-6/°C), about the same as other copper alloys and filler metals. Joining copper beryllium to steel may require a ductile filler alloy to accommodate thermal expansion mismatch.

SAFE HANDLING OF COPPER BERYLLIUM

Please refer to the Materion Corporation publications "Safety Facts 105 - Processing Copper Beryllium", and "Safety Facts 6 - Heat Treating Copper Beryllium Parts."

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Materion Brush Performance Alloys, Technical Service Department at 1-800-375-4205.

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Alloy Class	UNS Designation	Brush Alloy	% Beryllium	Age Hardening Range		Solution Anneal Range		Melting Temperature	
				°F	°C	°F	°C	°F	°C
High Strength Copper Beryllium	C17000	165	1.60-1.80	550-700	290-370	1400-1475	760-800	1630	890
	C17200	25, 190*	1.80-2.00	550-700	290-370	1400-1475	760-800	1600	870
	C17300	M25	1.80-2.00	550-700	290-370	1400-1475	760-800	1600	870
High Conductivity Copper Beryllium	C17410	174*	0.20-0.50	850-950	455-510	1650-1800	900-980	1875	1025
	C17450	171*	0.15-0.50	-	-	-	-	-	-
	C17500	10	0.40-0.70	850-950	455-510	1650-1750	900-955	1830	1000
	C17510	3	0.20-0.60	850-950	455-510	1650-1750	900-955	1830	1000

*Table 1. Properties of Copper Beryllium Alloys *These alloys are provided only in the mill hardened condition.*

AWS Designation	Composition	Melting Range	Brazing Range	Electrical Conductivity (% IACS)	Flux (per AWS B2.2-91)	Remarks
BAg-1	Silver 45% Cadmium 24% Zinc 16% Copper 15%	1125-1145°F (605-620°C)	1145-1400°F (615-760°C)	28	AWS 3A	Use for low-temperature brazing of either high conductivity or high strength copper beryllium, with heating times short as possible followed by rapid cooling.
BAg-8	Silver 72% Copper 28%	1435°F (780°C)	1435-1550°F (780-840°C)	77	AWS 3A	For combined brazing/solution annealing of high-strength copper beryllium. Holding times must be short; otherwise, fluidity will decrease from solution of copper into the euctectic brazing alloy.
BAg-3	Silver 50% Cadmium 16% Zinc 16% Copper 15% Nickel 3%	1170-1270°F (630-690°C)	1270-1500°F (690-815°C)	18	AWS 3A	Use for joining copper beryllium to steel. Tends to liquidate unless rapidly heated through it's melting range. In furnace brazing, the filler should be preplaced internally.
RBCuZn-D	Copper 48% Zinc 42% Nickel 10%	1690-1715°F (921-935°C)	1720-1800°F (940-980°C)	5	AWS 3B	For combined brazing/solution annealing of high-conductivity copper beryllium. Melting range may vary slightly, depending upon deoxidizer used.
BCuP-2	Copper 93% Phosphorus 7%	1310-1460°F (710-790°C)	1350-1550°F (730-840°C)	4	AWS 3B or 4	For high-strength and high-conductivity copper beryllium to other copper alloys containing no nickel or iron. Joint porosity may be a problem.
BAu-4	Gold 82% Nickel 18%	1740°F (950°C)	1740-1800°F (950-980°C)	6	None	Expensive. Used in high temperature vacuum brazing because no flux is required.

Table 2. Suggested Filler Alloys and Fluxes for Brazing Copper Beryllium

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