

Welding Copper Beryllium

Welding provides the highest strength bond when joining copper beryllium to itself or to other metals. As with any joining process, properly prepared surfaces, selection of equipment and materials, and sound practice are key to insuring a reliable bond. Common resistance and arc welding techniques, as well as less conventional welding methods, can be applied to copper beryllium. The metallurgical advantages that copper beryllium offers are not lost as a result of welding. In fact, the strengthening mechanism inherent to copper beryllium makes it possible to weld without permanently weakening the alloy.

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.

First, the alloy must be solution annealed so that the beryllium is dissolved into a solid solution and 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. The quenched 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 the quench, the temper is designated as a cold worked temper (such as H).

The second step is the age hardening (often called heat treating or aging) process, where hard, 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 depends upon aging time and temperature, and accounts for the alloy's high strength. When the 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).

The strength of an as deposited weld in copper beryllium will be significantly less than the base metal. Properties through the weld and heat affected zones will vary from the

as cast to the overaged condition. Uniform mechanical properties can be obtained after welding by solution annealing, quenching and age hardening the welded part. The cold worked tempers can be welded; however, only the property range of the AT temper is available after the solution anneal and age hardening steps. Whenever possible, welding on age hardened copper beryllium should be done in the overaged condition to avoid cracking the base metal.

A detailed explanation of these heat treating processes with the recommended times and temperatures for copper beryllium is provided in Materion Brush Performance Alloys' TechBrief titled, "Heat Treating Copper Beryllium".

SURFACE PREPARATION

Best results are obtained with a clean surface, free of dirt, oil, paint, grease, tarnish, and oxide. Conventional cleaning, such as solvent or vapor degreasing, is effective in removing organic contaminants. Aggressive brushing, abrasive blasting, or acid pickling is required for adherent contaminants such as oxides. Additional preparation information is available in Brush Wellman's TechBrief, "Cleaning Copper Beryllium".

Cleaned parts should be welded immediately. If a delay is unavoidable, they should be stored in a protected environment away from shop dust, acid and sulfurous or ammonia fumes.

FILLER METAL

Copper beryllium rod should be used as the filler metal in welding copper beryllium to other metals or to itself. Copper beryllium weld rod, trade named WeldPak[®], is

Materion Brush Performance Alloys

6070 Parkland Boulevard
Mayfield Heights, OH 44114 USA
phone: 216.486.4200 fax: 216.383.4005
e: BrushAlloys-Info@Materion.com

TECHNICAL INQUIRIES

ph: 800.375.4205

MATERION CORPORATION

www.materion.com

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available in three common sizes. Both the high strength and high conductivity copper beryllium use the same WeldPak filler. Alternatively, an aluminum bronze filler (ERCuAl A2) is often used in welding copper beryllium to steel. Filler metal must be clean, and stored in a fume free environment.

When high conductivity copper beryllium is welded using WeldPak filler, it is necessary to homogenize the part at 1475-1550°F (800-850°C) to prevent cracking during the subsequent solution annealing treatment.

WELDING PROCEDURES

Arc Welding - Because of the formation of refractory beryllium oxide films, the gas shielded arc welding techniques offer the only successful methods for fusion welding copper beryllium. With a matching filler metal, both TIG (GTAW) and MIG (GMAW) welding are suitable. TIG is commonly used for sections up to about 0.25 inch (6 mm) thick, while MIG welding is widely used for up to 2 inch (50 mm) thick material. Thin strip, less than 0.04 inch (1 mm) thick can be butt welded using the TIG torch only (without filler) or fine wire MIG. In general, the high thermal conductivity of copper alloys may necessitate preheating the work to maintain fluidity in the weld pool. When preheating is required, 400°F (200°C) is usually adequate.

For shielding gases, welding grade (low oxygen) argon or helium are used, either alone or mixed. Carbon dioxide or Hydrogen gas are not recommended. Gas mixtures such as 75% He-25% Ar, provide improved heat input, higher speeds, deeper penetration, and improved weld quality. Gas mixtures are beneficial for welding heavy sections but may burn through thin sections.

Thin section copper beryllium may be square butt welded, but thicknesses above 3/16 inch (4 mm) require a 60-90 degree V butt or a U butt. A 1/16 inch (1.5 mm) root gap should be allowed in all sections thicker than 1/16 inch. Periodic tack welds will prevent distortion and misalignment in long welds. Flange or lap weld configurations are desirable and the flat welding position is always preferred because of the high fluidity of the copper beryllium weld pool. When welding copper beryllium to other metals, the formation of complex phases in the weld can be minimized with small weld pools, characteristic of pulsed MIG welding.

The TIG welding electrode is a sharp thoriated tungsten rod designated EWTh1 or EWTh2. An AC power source is

usually preferred because the weld pool agitation assists in dispersing the oxide for smoother welding conditions and better welds. For use with a DC source, the straight polarity (electrode negative) condition carries higher current and prevents electrode erosion. TIG welding is well suited for small local repair work.

The high metal deposition rate in MIG welding favors this procedure for thick sections and larger jobs. The power source is DC, electrode positive. Typical MIG welding conditions are 24-32 volts, 250-450 amps, 0.5-1.0 in/min (10-15 cm/min) wire feed rate, 5-10 liters/min argon flow rate. For copper beryllium, use the high side of the manufacturer's recommended amperage range for copper alloys for finer, more uniform metal transfer.

Resistance Welding - Fast, low cost, dependable welds in thin sections of copper beryllium, to itself or other metals, are possible with spot, seam and flash butt resistance welding. In resistance welding, the weldability of a metal is inversely proportional to its conductivity. Copper beryllium is, therefore, more difficult to weld than mild steel. Compared to mild steel of the same thickness, copper beryllium requires secondary currents approximately 50% higher, shorter welding times and somewhat lighter electrode pressures.

Prior to hardening, electrical conductivity of copper beryllium is relatively low, 12-23% IACS. For best results, resistance welding should occur before age hardening. The conductivity of copper beryllium requires electrodes having an electrical conductivity of at least 75% IACS. RWMA Class 2 electrodes are recommended for the resistance welding of copper beryllium, but Class 1 materials are suitable for certain applications. Use water cooled electrodes to reduce marking or sticking of the work to the electrodes.

Electrical contacts are frequently attached to copper beryllium flat springs by resistance welding. Generally, the contact is precious metal, backed with steel, nickel or Monel®; the weld is made between the backing material and the copper beryllium.

Spot welding dissimilar metals necessitates compensation for the differences in electrical and thermal conductivities. Use electrodes of different contour or different conductivity to localize the heat at the interfaces rather than within the base metal of lowest conductivity. Table 1 classifies the

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resistance weldability of copper beryllium to other metals

Good	Fair	Poor
Cartridge brass Cupro-nickel Nickel silver Silicon bronze Phosphor Bronze	Copper Red Brass Aluminum Nickel Monel	Carbon Steel Stainless Steel Magnesium Zinc Tin

Table I - Weldability of Copper Beryllium to Other Metals

OXYACETYLENE AND FLUXED METAL ARC WELDING

Lack of suitable fluxes for copper beryllium prohibits oxyacetylene, oxy gas and flux cored arc welding. With these procedures, the stability of beryllium oxide leads to the ever present risk of inclusions and porosity in the weld.

ELECTRON BEAM WELDING

EB welding can be applied to joining almost any size, configuration and combination of metals. No filler is used. To protect the filament and prevent attenuation of the electron beam, welding is done in a vacuum (10⁻⁴ atm) chamber. The vacuum requirement demands clean surfaces and eliminates welding on alloys containing high vapor pressure elements such as cadmium and zinc. Dissimilar thermal conductivity alloys and different gauge strip present no problem when the beam is focused on the less conductive or thicker metal. The beam diameter and fusion zone can be as small as 0.04 inch (1 mm) with a 0.025 inch (0.6 mm) heat affected zone.

LASER WELDING

Like EB welding, laser welding concentrates considerable energy in a focused area for minimal fusion and heat affected zones. Laser welding requires precise fixturing for uniformity in weld properties. Unlike EB welding, lasers operate in air, although a nitrogen or argon shielding gas is

used for protection and for smoke removal. A clean surface is, of course, a requirement. Laser power controls the weld penetration, and 500 W is sufficient for 0.02 inch (0.5 mm) copper beryllium. Because a clean surface on copper beryllium is highly reflective of Nd:YAG laser wavelength, higher power is required. Reflectivity is less of a problem with the CO₂ wavelength.

BRAZING - Information on brazing is provided in Brush Wellman's TechBrief, "Brazing Copper Beryllium".

SAFE HANDLING OF COPPER BERYLLIUM

Please refer to the Materion Corporation publications "Safety Facts 1 - Safety Practices for Welding Copper Beryllium", "Safety Facts 6 - Safety Practices for Heat Treating Copper Beryllium Parts", "Safety Facts 9 - Ventilation of Beryllium Dust-Generating Operations" and "Safety Facts 105 - Processing Copper Beryllium Alloys."

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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