Copper Alloys

Weld Tech News

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WELD TECH NEWS is a newsletter for welders working primarily in maintenance and repair. Each issue contains 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.

COPPER ALLOYS
Copper and its alloys are generally classified into eight major groups. These groups can then be further divided into cast alloys or wrought alloys. The eight groups are:

1. Coppers
2. High Copper Alloys
3. Brasses
4. Bronzes
5. Copper - Nickels
6. Copper - Nickel - Zinc Alloys
7. Lead Coppers
8. Special Alloys

CHARACTERISTICS OF COPPER

Due to their unique properties, copper and copper alloys are the major group of non-ferrous metals in commercial use (next to aluminum). Copper is one of the oldest metals known to man and can be found in the ground in a pure form. Production of copper wires dates back to the ancient Babylonians and Egyptians.

Copper's primary attributes are good corrosion resistance, good thermal conductivity, excellent electrical conductivity and decorative color. It can be fabricated by many processes. Copper is non-magnetic and spark resistant. It is alloyed primarily with aluminum, tin, zinc, nickel and/or silicon; all of which have various effects on its properties.

Copper has a melting temperature of 1981° F (1082° C) compared to that of low carbon steel at 2700° F (1482° C). Its thermal conductivity is about six times greater than steel but only one and one-half times that of aluminum. It is also denser than aluminum. Copper is slightly lower in electrical conductivity than silver, but is about 40% higher than aluminum. The Brinnell hardness (Bhn) of copper is 30 compared to 23 Bhn for aluminum and 130 Bhn for low carbon steel.
Fourteen alloying elements are common additions to copper and readily change its properties. For example, the copper alloys of brass and bronze have about 25% of the electrical conductivity of copper. These alloy additions can also serve to improve corrosion properties, mechanical characteristics, allow for heat-treat strengthening, deoxidize and improve machinability.

**COPPER AND HIGH COPPER ALLOYS**

Basically, commercially pure copper comes in two forms: oxygen-bearing copper and oxygen-free or deoxidized copper. Fusion welding of the relatively uncommon oxygen-bearing copper is not recommended due to the complication of the copper oxides. Oxygen-free copper is manufactured without oxygen contamination; it is readily weldable.
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High copper alloys are free machining coppers. Small additions of lead, sulfur and tellurium aid in the machinability of copper, but in amounts above 0.05% make welding difficult. These coppers are not normally welded.

Included in the high copper alloys would be the beryllium copper alloys. The low beryllium alloy contains 0.5%. The high beryllium type contains about 2%. This alloy allows for precipitation hardening. A refractory oxide film will rapidly form on the surface of this metal which requires cleaning prior to welding. Of special note for beryllium is that in the form of dust, vapor or fumes it is highly toxic and a serious health hazard. Welding this alloy would require special procedures.

Brasses

Brasses are copper alloys with zinc as the main alloying element. Zinc lowers the melting temperature, thermal conductivity, electrical conductivity and density of copper. Zinc increases strength, hardness and ductility of copper. Additional alloys of less than 4% can be manganese, tin, iron, silicon, nickel, lead or aluminum. These alloys improve certain corrosion and mechanical properties. Other names for these alloys are low fuming bronze, manganese bronze, commercial bronze and Muntz metal. Fusion welding of leaded brasses is not recommended.

Silicon Bronzes

The addition of silicon to copper, usually in a range of from 1.5 to 3.25%, creates the silicon bronzes which are found in many industrial applications. They may also contain up to 1.5% iron, manganese, zinc or tin. Silicon bronzes exhibit high strength, excellent corrosion resistance and are readily weldable. Silicon decreases electrical and thermal conductivity but increases ductility.

Aluminum Bronze

When 3 to 15% aluminum is alloyed with copper, aluminum bronze is formed. It may or may not have additional amounts of iron, silicon, nickel or manganese. Aluminum bronzes are easily weldable when the aluminum oxide film is removed due to their low thermal and electrical conductivity. They also have excellent resistance to sea water, oxidation and scaling at elevated temperatures.

Phosphor Bronze

The addition of 1 to 10% tin to copper creates what is commercially called phosphor bronze. The name comes from adding .003 to .004% phosphorus as a deoxidizer. An increase in tin content decreases thermal and electrical conductivity. Before welding these alloys should be annealed or stress relieved.
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Copper Nickel Alloys

These alloys have 5 to 30% nickel added to copper, with possible minor additions of iron, zinc, and manganese. They are low in conductivity but have moderately high tensile strength. They are ductile, tough and corrosion resistant. When welding, they must be kept free of contamination.

Nickel Silvers

By adding nickel to alloys of copper and zinc, an alloy which has a silvery appearance is formed. Its attributes are strength and corrosion resistance as well as being decorative. Welding is similar to that of the brasses.

Copper and Copper Alloys

How to solder, braze and weld

As a class of metals, the copper and copper alloys are all generally rated as being weldable with the arc welding processes being the most commonly used. Alloys with high zinc or lead contents are the most troublesome. In repair and maintenance welding the most commonly used processes in some order of importance would be GTAW, GMAW, SMAW, brazing and soldering.

In comparison to welding steels the copper and copper alloys have much higher thermal conductivity. This means that heat applied to a welding area spreads out more rapidly than with steel so greater heating is
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actually required. Copper also has a higher coefficient of expansion than steel so consideration must be made for joint expansion. The amount of preheating required on a base metal will depend on metal thickness and type of alloy. Large sections should be preheated broadly. Keep base metal off heat absorbing work areas.

<table>
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<tr>
<th>RELATIVE THERMAL CONDUCTIVITY</th>
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<td>(based on pure copper)</td>
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<table>
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<tr>
<th>Copper (99.95% Cu)</th>
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<tr>
<td>Carbon Steel</td>
<td>13</td>
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<tr>
<td>Beryllium Copper (1.7% Be)</td>
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<td>High Zinc Brass (35% Zn)</td>
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<td>Phosphor Bronze (5% Sn)</td>
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<tr>
<td>Aluminum Bronze (7% Al)</td>
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<tr>
<td>High Silicon Bronze (3% Si)</td>
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Within the temperatures required for welding copper and its alloys have a good affinity for oxygen and detrimental oxides can be formed. This requires good use of appropriate flux, proper shielding gas and deoxidizers in filler metals. Base metals should be thoroughly cleaned of scale, contaminants and moisture. Degreasing and chemical cleaning are generally appropriate. Mechanical cleaning with an uncontaminated stainless wire brush would be a basic preparation, although the aluminum bronzes and copper nickels may require more involved mechanical or abrasive cleaning.

In general, the copper alloys should be arc welded with filler metals that are similar in composition. However, due to the uniqueness of these metals, filler alloys of different composition may work well or better.

GAS TUNGSTEN ARC WELDING (GTAW)

GTAW or TIG welding of the copper alloys is highly effective and commonly used. It offers a very high arc heat as well as a narrow heat zone. It is generally used on relatively thinner base metal applications with up to 1/8” (3.2mm) thickness being the ideal. Thicker applications would generally require preheat when DCEN current is used. AC current with high frequency could be used on beryllium coppers and aluminum bronzes to overcome their particularly difficult oxide films. Argon is used for shielding gas on thinner applications with helium and helium-argon mixes used on thicker applications due to helium's greater heat input. For welding in positions other than flat, GTAW may be the optimal choice.
Venus-Tig is a copper alloy filler metal ideal for repair applications on brass and bronze base metals. It is also used for joining dissimilar combinations such as stainless to copper alloys. Superior results are obtained on galvanized steel without burning off the zinc coating and obtaining a corrosion resistant deposit. It is machinable and ideal for buildup and bearing surfaces.

Venus-Tig-C is a highly alloyed aluminum bronze filler that is the most universal of copper filler alloys. Suitable for joining a wide range of copper alloy types, it is also excellent in applications requiring the joining of dissimilar combinations as well as machinable build-up applications. It is also highly corrosion resistant.

**GAS METAL ARC WELDING (GMAW)**

Gas metal arc welding (MIG) of copper alloys is a good arc welding application because of its intense arc heat which is good for the high heat conductivity of these metals. It is usually used on applications where the base metal is more than 1/8" (3.2 mm) thick. On thicknesses greater than 1/2" (12.7mm) it is the most ideal. Any alloys having high zinc content are poor candidates for GMAW welding. Argon shielding is used in this process for thinner applications while a 75% Argon - 25% Helium mixture is preferred for base metal thicknesses above 1/4" (6.4mm).

Venus-Mig is a bronze alloy that gives smooth, dense and machinable deposits that are long wearing and low friction. It is ideal for joining bronze, brass, copper and galvanized steel. It will also join steel to copper alloys. Use with Argon or Argon-Helium mix gas for shielding.

**SHIELDED METAL ARC WELDING (SMAW)**

Shielded metal arc welding or stick welding of copper alloys is suitable for smaller repair jobs or applications where accessibility to the joint area is difficult. Welding in the flat position is preferred. The mechanical properties of these welds will tend to be less than those of the other methods. Stick welding copper alloys versus steels requires larger root openings and wider bevels in the joint. Higher preheat and tack welding are generally necessary.

Venus-A is a copper-tin alloy electrode ideal for joining or corrosion and wear resistant machinable deposits. It can be used to join brass, bronze and copper as well as dissimilar combinations. It will give a color match on bronze.

Venus-B is a high strength, high elongation copper tin alloy electrode which will run on A.C. current. It is especially suitable for joining copper, bronze and brass to steel. These very ductile deposits are highly corrosion resistant and are achieved with minimal spatter.

Venus-C has an exceptional aluminum bronze metallurgy with additional nickel and manganese. This makes for a most versatile alloy suitable for joining or overlays on silicon bronzes, aluminum bronzes, steel alloys and cast irons. It is ideal for dissimilar joining combinations and deposits requiring machinability and corrosion resistance.
The brazing process is highly suitable for joining copper and the copper alloys. Brazing alloys with a high silver content are especially suitable for a wide range of applications. These alloys are good on all copper alloys as their metallurgy allows a low melting temperature. Bronze type brazing alloys are best used on alloys where their higher melting temperatures are not detrimental. The silver bearing alloys are also advantageous due to their capillary action. For dissimilar joining applications, silver alloys are the choice.

Due to its higher heat and cleaner burning flame, acetylene is usually the preferred fuel gas for brazing copper alloys. In most cases the use of extra flux will ease application. Melting the silver bearing filler metal with base metal heat instead of direct flame heat usually provides the best results. Due to the heating involved brazing is not advisable on very large pieces.

**Jupiter-G** (yellow flux coated) is a low melting temperature 1590°F (866°C) bronze brazing alloy that exhibits high strength with good ductility. It is ideal for the appropriate copper alloys such as copper-nickel, copper-silicon and copper-tin where its melting temperature is not too high. It is also ideal for joining steel, cast iron and galvanized steel. The deposits are machinable. **Jupiter-GB** is the non-flux coated version. Both should be used with Brutus Flux.

**Venus-G** (cadmium free) is a bare silver brazing alloy that provides strong joints on copper, brass, and bronze. It has excellent wetting action and thin flow with a low melting temperature 1175°F (635°C). It is superior for applications involving copper tubing in refrigeration and piping. It contains phosphorus for deoxidizing and is self-fluxing on clean copper. Copper alloys and contaminated applications should be fluxed with Gemini Flux.

**Apollo-G** (orange flux coated - cadmium free) and **Apollo- GB** (bare) melt at 1085°F (584°C) and have a high silver content making it an ideal choice for applications on copper and all copper alloys. Its low melting temperature allows easy flow on copper alloys and minimizes heating problems. It has a wide melting range making it ideal for bridging large gaps in poorly fit up joints. This alloy can be used on all metals except aluminum and magnesium. Use with Gemini Flux.

**Gemini-G** (pink flux coated - cadmium free) and **Gemini- GB** (bare) are very high silver alloys that braze all metals except white metals. Their silver content and low melting temperature 1090°F (587°C) result in high fluidity making them superior for all copper and copper alloys. They also wet out easily on stainless and have excellent color match. For dissimilar joining applications they are the best choice. Ideal for food service and medical equipment. Use with Gemini Flux.

**SOLDERING**

Soldering is very suitable for copper and most copper alloys. The strength of joints is lower than the other processes and service temperatures cannot be high. Most difficult to solder would be copper-silicon alloys and especially copper-aluminum alloys. Fluxes should be used on precleaned surfaces. Rosin type flux is
suitable on coppers and some of the copper alloys. More corrosive type flux may be required on other copper alloys. Residual flux should be cleaned off.

Gemini-S is a silver bearing, lead and cadmium free solder. Its low melting temperature 420°F (215° C) and good fluidity make it a good choice for intricate applications on copper and copper alloys. It will also join other metals except white metals. It is corrosion resistant and high strength. Use with liquid Gemini Solder Flux (acid) or liquid Gemini Neutral Solder Flux (rosin).

Gemini-SA is an acid flux core version of Gemini-S and Gemini-SR is a rosin flux core version. On copper alloys additional appropriate flux will be necessary. Gemini-SSP is a paste form of Gemini-S in an acid type flux.