Tech Brief

Copper Beryllium Alloys

Heat Treating Copper-Beryllium Parts

Heat treating is key to the versatility of the copper-beryllium alloy system. Unlike other copper-based alloys which acquire their strength through cold work alone, wrought copper-beryllium obtains its high strength, conductivity and hardness through a combination of cold work and a thermal process called age hardening.

+1.800.375.4205 | materion.com/copperberyllium

Age hardening is often referred to as precipitation hardening or heat treating. The ability of these alloys to accept this heat treatment results in forming and mechanical property advantages not available in other alloys. For example, intricate shapes can be fabricated when the material is in its ductile, as-rolled state and subsequently age hardened to the highest strength and hardness levels of any copper-based alloy.

Heat treating the copper-beryllium alloys is a two-step process which consists of solution annealing and age hardening. Because Materion performs the required solution anneal on all wrought products prior to shipping, most fabricators' primary concern is the age hardening process. The following text details this process and overviews the available copper-beryllium alloys. Specific heat-treating procedures for wrought and cast products, recommended heat treating equipment, surface oxidation information and general solution annealing practices are also included.

COPPER BERYLLIUM ALLOYS

Copper-beryllium alloys are available in two basic classes, shown in Table 1. High-strength copper beryllium is very strong and offers moderate to good conductivity. High-conductivity copper beryllium, on the other hand, features maximum conductivity and slightly lower strength levels.

Table 1: Copper-Beryllium Alloys - Designations and UNS Numbers

High Strength Copper Beryllium		High Conductivity Copper Beryllium	
Wrought	Cast	Wrought	Cast
25 (C17200) 190 (C17200)* 290 (C17200) M25 (C17300) 165 (C17000)	275C (C82800) 20C (C82500) 21C (C82510) 165C (C82400)	3 (C17510) 10 (C17500) 174 (C17410)* Brush 60 (C17460)* 390 (C17460)*	3C (C82200)

* These alloys are supplied only in the mill hardened condition and require no further heat treatment.

Both the high-strength and high-conductivity copper beryllium are available as strip in the heat-treatable and mill-hardened tempers. Mill-hardened tempers are supplied in the heat-treated condition and require no further heat treatment.

Age-hardenable copper beryllium is produced in tempers ranging from solution annealed (A) to an as-rolled condition (H). Heat treating maximizes the strength and conductivity of these alloys. The temper designations of the standard age-hardenable copper-beryllium tempers are shown in Table 2.

Table 2: Temper Designations - Alloy 25 Strip and Wire

Materion Brush Performance Alloys Designation	ASTM Designation	Description
A	TB00	Solution annealed
1/4 H	TD01	Cold worked, Quarter hard
1/2 H	TD02	Cold worked, Half hard
3/4 H	TD03	Cold worked, Three-quarter hard
H	TD04	Cold worked, hard
AT 1/4 HT 1/2 HT 3/4 HT HT	TF00 TH01 TH02 TH03 TH04	The suffix "T" added to Materion Brush Performance Alloys temper designations indicates that the material has been age hardened by the standard heat treatment.

continue

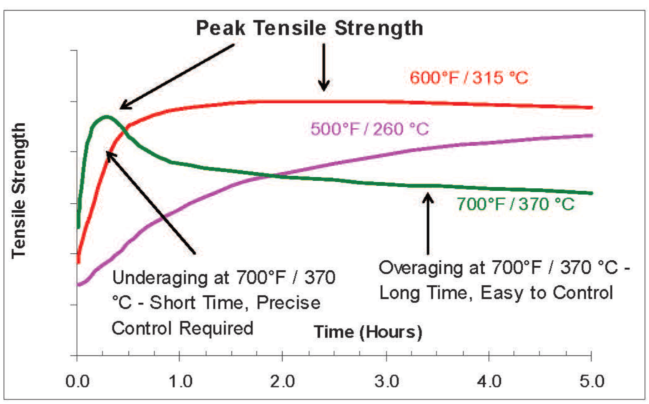
AGE HARDENING COPPER-BERYLLIUM ALLOYS

Copper beryllium achieves its maximum levels of strength, hardness and conductivity through age hardening. During the age hardening process, microscopic, beryllium-rich particles are formed in the metal matrix. This is a diffusion-controlled reaction, and the strength will vary with aging time and temperature.

Recommended or standard age hardening time and temperature combinations have been determined for each copper-beryllium alloy. These standard times and temperatures allow parts to reach peak strength in two to three hours, without the risk of strength decrease due to extended temperature exposure. As an example, the Alloy 25 response curves in Figure 1 indicate how low, standard and high aging temperatures affect both peak properties and the time required for the alloy to reach peak strength.

In Figure 1, at the low temperature of 550°F (290°C), the strength of Alloy 25 increases slowly, and peak strength is not reached until approximately 30 hours. At the standard temperature of 600°F (315°C), Alloy 25 exhibits virtually no change in strength after three hours of exposure. At 700°F (370°C), peak strength is reached in 30 minutes and declines almost immediately. In short, as aging temperature increases, the time necessary to reach peak strength decreases, as does maximum obtainable strength. This response is similar for all copper-beryllium alloys, but at different standard temperatures.

Figure 1: Alloy 25 - Response to Age Hardening Heat Treatment for Three Temperatures



Copper beryllium can be age hardened to varying degrees of strength. The term "peak aged" refers to copper beryllium aged to maximum strength. Alloys not aged to maximum strength are underaged, and alloys aged beyond maximum strength are overaged. Underaging copper beryllium can result in increased uniform elongation, relative to peak or overaged parts. Overaging increases the alloy's electrical and thermal conductivity and improves dimensional stability. Copper beryllium never ages at room temperature, even if material is stored for significant lengths of time.

Allowable variances in age hardening time are dependent on furnace temperature and final property requirements. To peak age at the standard temperature, furnace time is typically controlled to ±30 minutes. For high-temperature aging, however, more precise time control is required to avoid overaging. For example, the aging time of Alloy 25 at 700°F (370°C) must be controlled to ±3 minutes to hold peak properties. Similarly, underaging requires tight control of the process variables because of the sharp initial increase of the aging response curve. In the standard age hardening cycle, heating and cooling rates are not critical.

However, to assure that the recorded aging time does not begin until parts reach temperature, a thermocouple can be placed on the parts to determine when desired temperature has been achieved.

Standard age hardening times and temperatures for the high-strength copper-beryllium alloys and the high-conductivity copper-beryllium alloys are detailed in the following sections.

HIGH-STRENGTH WROUGHT COPPER-BERYLLIUM ALLOYS (ALLOYS 25, M25 AND 165)

Age hardening temperatures for high-strength wrought copper beryllium vary from 500°F (260°C) to 700°F (370°C). The time required to reach peak properties at the lower temperature is longer than at the higher temperature. The standard age hardening treatment is 600°F (315°C) for two to three hours; two hours for cold worked alloys and three hours for annealed alloys. Figure 2 shows the effect of time and temperature on the mechanical properties of Alloy 25 1/2 H temper.

Contact the Technical Service Department for a complete set of detailed aging response curves.

HIGH-STRENGTH CAST BERYLLIUM-COPPER ALLOYS (ALLOYS 275C, 20C, 21C AND 165C)

The standard age hardening cycle for the high-strength casting alloys, both annealed and as-cast, is three hours at 625-650°F (320-340°C). However, to develop the highest strength for the as-cast products, a separate solution anneal should precede the age hardening.

continue

HIGH-CONDUCTIVITY WROUGHT ALLOYS (ALLOYS 3 AND 10) AND HIGH-CONDUCTIVITY CAST ALLOY 3C

The standard age hardening cycle for both the wrought and cast high-conductivity alloys is 900°F (480°C) for two to three hours; two hours for the cold-rolled alloys and three hours for the cast and annealed wrought alloys. The high-conductivity alloys are noted for their excellent electrical and thermal conductivity. They obtain their moderate strength through age hardening, but at a higher temperature than the high-strength alloys.

Because their mechanical properties change only slightly with time, few high-conductivity applications benefit from either underaging or overaging. As an example, the heat-treating curves for Alloy 3 demonstrate the effects of aging on the mechanical properties (see Figure 3).

DEGREASING PRIOR TO HEAT TREATMENT

Prior to heat treating, copper beryllium parts should be degreased to remove any residual lubricants or other oils. If not removed, these deposits can be baked onto the surface, which can cause discoloration, solder wetting problems or difficulties with plating deposition or adhesion. Furthermore, baked-on lubricants can mask the base metal during post-heat treatment pickling, which can cause an uneven surface appearance and varying reflectivity.

Trisodium phosphate (Na_3PO_4) and other alkaline solutions work well for degreasing. Ultrasonic agitation provides the best results. Vapor degreasing is also very effective. Even high-pressure soapy water at 125°F (52°C) can be effective. Be sure to rinse the parts well after degreasing to prevent potential alkaline attack of the base metal at high temperatures.

AGE HARDENING EQUIPMENT AND ATMOSPHERES

RECIRCULATING AIR FURNACES

Recirculating air furnaces, with temperature controlled to ±15°F (±10°C), are recommended for the standard age hardening of copper-beryllium parts. These furnaces are designed to accommodate both large and small batches of parts and are ideal for reels of stamped parts aged on carrier strips. However, care must be exercised when aging large batches of parts. Because of their sheer thermal mass, large batches of parts will likely not have all parts at the proper temperature for the same length of time. As a result, underaging or short aging cycles of large batches of parts should be avoided.

STRAND AGING FURNACES

Strand aging furnaces, using a protective atmosphere as the heating medium, are suitable for processing large quantities of material in coil form. This process is generally used by metal producers and performed in long furnaces where material can be uncoiled into the furnace, passed through heating and cooling zones, and re-coiled upon exiting the furnace. The advantages of this type of furnace include good time and temperature control, better part to part uniformity and the ability to control special cycles for underaging or high temperature/short time aging and selectively hardening a portion of a part.

SALT BATHS

Also recommended for age hardening wrought products are salt baths. Salt baths offer rapid and uniform heating and are recommended at any temperature in the hardening range. They are particularly advantageous for short time, high-temperature aging. However, this can be a messy process, and requires good cleaning of the parts after aging to remove the salt and prevent potential galvanic corrosion later, particularly in recesses or crevices in the parts.

VACUUM FURNACES

Vacuum aging of copper-beryllium parts can be done successfully, but caution must be exercised. Because true vacuum furnace heating is by radiation only, it is difficult to uniformly heat large loads of parts. Parts on the outside of the load are subject to more direct radiation than those on the inside. As a result, the temperature gradient produces a variation in properties after heat treatment. To assure uniform heating, load size should be limited, and parts must be shielded from the heating coils.

Alternatively, vacuum furnaces, backfilled with an inert gas such as argon or nitrogen, can be used. Again, parts must be shielded unless the furnace is equipped with a recirculating fan. Be careful that the incoming inert gas is not blowing directly onto the parts, or it may cool them and reduce the effectiveness of the heat treatment.

SURFACE OXIDE

During aging, the copper-beryllium alloys develop a surface oxide composed of beryllium oxide and, depending on the alloy and furnace atmosphere, copper oxides. These oxide films vary in thickness and composition and are often transparent.

Surface oxidation of beryllium during age hardening cannot be suppressed, even in a pure hydrogen atmosphere or a hard vacuum. However, some atmospheres can minimize the copper oxidation. For instance, a low dew point (-40°F/-40°C)

continue

atmosphere of approximately 5 percent hydrogen in nitrogen will minimize oxidation and economically aid in heat transfer. Air atmospheres contribute the most to surface oxide and reducing atmospheres the least.

Note that when hot parts are removed from the furnace, they will rapidly oxidize when exposed to air, no matter how carefully controlled the furnace atmosphere is. For this reason, it is best to let the parts cool below 150°F/65°C before removing them to minimize oxidation.

Although oxide films are not detrimental to the base alloy, they should be removed if parts are to be plated, brazed, or soldered. For specific information on cleaning copper beryllium, consult the "Cleaning Copper Beryllium" Tech Brief.

SOLUTION ANNEALING

To elicit an effective age hardening response, copper beryllium must be solution annealed and quenched prior to aging. In addition to preparing the alloy for age hardening, annealing softens the alloy for further cold work and regulates grain size. Materion performs this required anneal on all wrought products at the mill. Therefore, customers usually do not need to anneal prior to age hardening. Furthermore, solution annealing will cause expansion and distortion of machined parts and can cause the generation of hazardous oxides on the surface, which will require great care to prevent the oxides from becoming airborne. For these reasons, Materion does not recommend solution annealing by customers, except for castings and weld repairs, unless it is a last-resort effort to salvage parts that would otherwise be discarded.

If solution annealing is required, it is a high temperature soak: 1450°F (790°C) for the high-strength alloys and 1650°F (900°C) for the high-conductivity alloys. Annealing must be carefully controlled as excess time or temperature may cause grain growth. Solution annealing should be immediately followed by a water quench. As a precaution, large quantities of metal should not be annealed without first conducting a furnace simulation test. Thin sections, such as fine wire, require an annealing time of about 3-5 minutes. Fifteen minutes to one hour is required for thin-walled tube and small castings. Thick sections (above about one inch/25 mm) usually require 1-3 hours. A heat-up time of one hour per inch (25 mm) of thickness must be added to the soak time. If you need assistance in establishing an annealing cycle, call the Materion Customer Technical Service Department.

Because most salts will attack copper beryllium at temperatures in the solution annealing range, solution annealing should not be performed in a salt bath.

When peak aging copper-beryllium castings and weldments, the customer must always solution anneal prior to age hardening. However, if peak properties are not required, castings can be age hardened from the as-cast condition without the solution anneal.

QUENCHING AFTER SOLUTION ANNEALING

Once the parts have seen the proper soak time at the solution annealing temperature, the parts should be immediately quenched to keep the newly recrystallized grains in the microstructure from growing excessively large. Cold water is the recommended quenching medium).

HEAT TREAT DISTORTION

Age hardening results in a slight volume decrease of approximately 0.6%, or approximately 0.2% decrease in length, width and thickness. Solution annealing results in a corresponding growth. Variations in residual stress can cause this shrinkage or expansion to occur to different degrees in different directions, potentially resulting in distortion of parts. Please see the Tech Brief "Shape Distortion of Copper Beryllium During Age Hardening" for more information and tips on controlling distortion.

THERMAL STRESS RELIEF

Copper beryllium may be thermally stress relieved by heating the high-strength alloys to approximately 400-450°F (200-230°C) for 1.5 to 2 hours. The high-conductivity alloys require a higher temperature, about 600-650°F (315-340°C). Remember that these processes will reduce, but not necessarily eliminate, residual stress in the parts.

HEAT TREATING CAST OR MACHINED PARTS

Solution annealing results in a slight volume increase and age hardening results in a slight shrinkage. Both of these processes have a potential to cause distortion of the parts as well. Therefore, these parts should only be cast or machined to near net shape before any heat treatment. Finish machining should be done after the heat treatment processes are complete.

HEAT TREATING STAMPED PARTS

Stamped parts are typically detached from their carrier strips and batch heat treated. However, any subsequent processing can only be done using a vibratory feeder process. If precise plating or soldering is required after heat treatment, then entire reels of parts may be heat treated without removing them from the carrier strip. To minimize distortion, you can coin the outside diameter of bends or emboss long thin beams to increase stiffness. This will help to provide repeatable and predictable movement during heat treatment.

continue

To minimize the potential for damage and distortion while heat treating reels of stamped parts, it is best to use an interleaf between successive wraps of the reels. The interleaf will protect the parts from mechanical damage while allowing them to move to accommodate shrinkage. The interleaf should be stainless steel, with a thermal expansion coefficient closely matched to copper beryllium. For extremely small parts with very tight tolerance, a copper-beryllium interleaf may be used so that it shrinks at exactly the same rate as the parts. Standoffs/spacers should be stamped out of the carrier strip to keep the parts from being crushed during the reel winding process. A large inner diameter on the reel minimizes the stresses induced by winding and controls coil set.

When heat treating multiple reels of parts, be sure to allow sufficient space between the reels for the furnace atmosphere to circulate. This is best achieved by hanging the reels from a rack vertically in the furnace, as opposed to horizontal "pancake-style" stacking.

MILL-HARDENED ALLOYS

In applications not requiring severe forming, fabricators can eliminate the heat treating and cleaning of the heat-treatable alloys by specifying mill-hardened copper beryllium. Materion performs a special heat treatment on mill-hardened product which delivers maximum formability at desired strength levels.

See the Materion Tech Briefs "Strip Temper Selection" and "Formability of High-Performance Strip Alloys" for more information.

HIGH-STRENGTH MILL-HARDENED ALLOYS

The high-strength, mill-hardened copper-beryllium alloys are Brush Alloy 190 and 290. Both alloys fall within the C17200 designation and are available in several tempers. Alloy 290 provides improved formability at a given strength level.

HIGH-CONDUCTIVITY MILL-HARDENED ALLOYS

The high-conductivity, mill-hardened copper-beryllium alloys are Brush Alloys 3, 10, 174, Brush 60®, 390®, and 390E. The mechanical properties of mill-hardened Alloys 3 and 10 are equivalent to the peak aged properties of the AT or HT age-hardenable tempers. Alloys 174, Brush 60, 390 and 390E are available only in mill-hardened tempers. Consult the "Guide to High Performance Alloys" for additional data on all mill-hardened tempers.

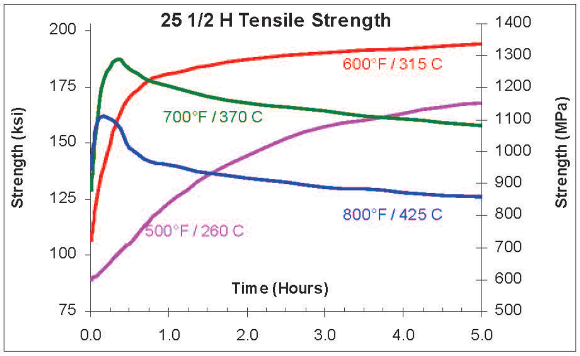
SAFE HANDLING OF COPPER BERYLLIUM

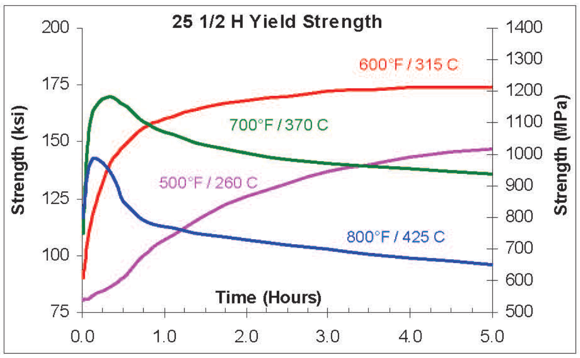
Please refer to the Materion Corporation publications "Safety Facts 6 - Safety Practices for Heat Treating Copper Beryllium Parts", and "Safety Facts 105 - Processing Copper Beryllium Alloys."

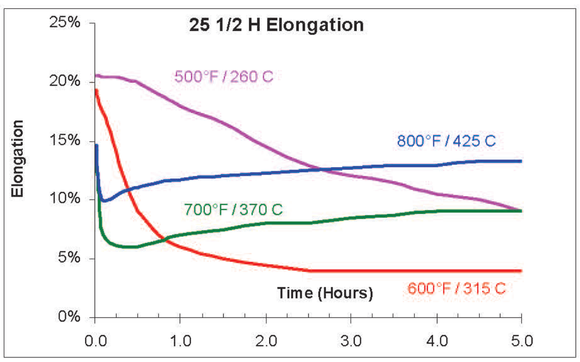
Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. 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 the Materion Technical Service Department at +1.800.375.4205.

continue

Figure 2: Alloy 25 ½ H Aging Response Curves







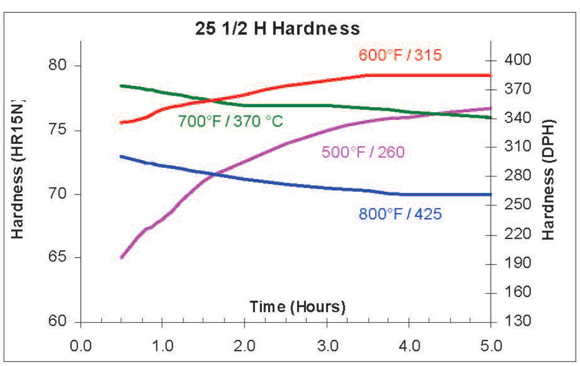
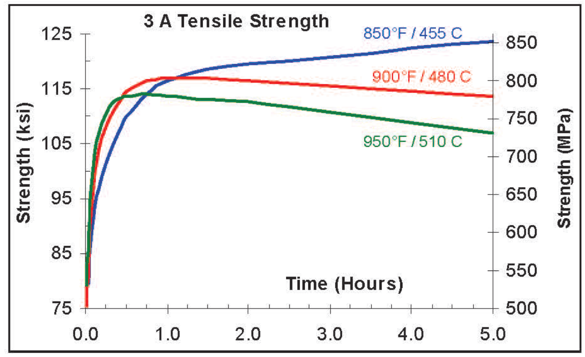
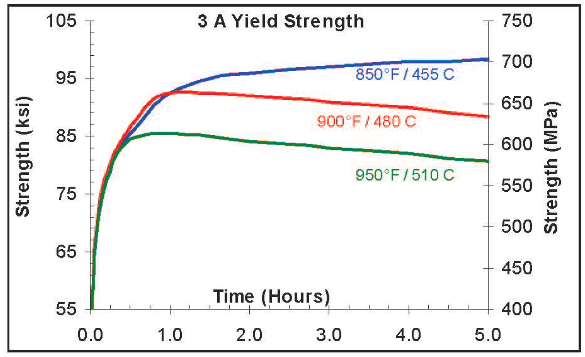
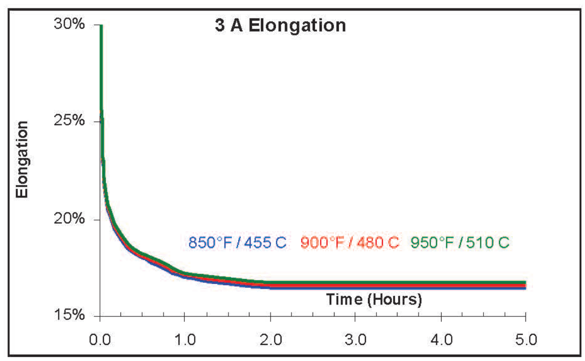
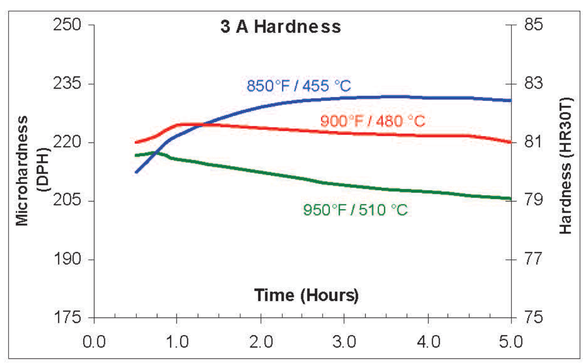


Figure 3: Alloys 3 A and 10 A Aging Response Curves









MATERION Global Headquarters
6070 Parkland Boulevard
Mayfield Heights, OH 44124 USA

Contact Us:
materion.com/ContactPAC
+1.800.375.4205

