MATERION

Tech Brief

Copper Beryllium Alloys

Copper Beryllium Strip Temper Selection

Copper beryllium is a precipitation hardenable copper alloy. This means that it derives most of its strength from heat treatment as opposed to the cold work that is exclusively relied upon by most other copper alloys.

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Copper beryllium alloys possess a great advantage by providing a combination of high strength, good conductivity and excellent formability. The heat treating step also provides copper beryllium alloys with excellent resistance to stress relaxation, compared to the standard cold worked copper alloys.

COPPER BERYLLIUM ALLOYS

There are two classes of copper beryllium alloys. The high strength copper beryllium alloys (Alloys 25, 190 and 290), which have the highest strength of any copper alloy, are widely used in electronic connectors, switches and springs. These high strength alloys have electrical and thermal conductivities that are about 20% of pure copper. The high conductivity copper beryllium alloys (Alloys 3, 174, Brush 60® and BrushForm® 47) have about 50% of copper's conductivity at a lower strength level, and are used in power connectors and relays. Alloys 390® and 390E feature the strength of the high strength alloys coupled with the conductivity of the high conductivity alloys.

Copper beryllium is strengthened primarily by heat treatment. It is available in two forms – age hardenable and mill hardened. In the age hardenable form, the material is soft and ductile. It will form easily. It must then be heat treated to full strength and conductivity after the forming operations are complete. In the mill hardened form, the material is age hardened at the mill, so no further heat treatment is required. (In other words, it is purchased in the partially age hardened state.) However, the formability at a given strength level will not be as good as that of the heat treatable material.

AGE HARDENABLE COPPER BERYLLIUM TEMPERS

Alloy 25 is the age hardenable high strength copper beryllium alloy. Once it is heat treated, it will have a strength unsurpassed by any other copper alloy. Alloy 25 is available as solution annealed (the softest, most formable state) and cold rolled to various strength levels (¼ H, ½ H and H). The ¼, ½ and full hard designations refer to cold work only and have nothing to do with heat treatment. After aging for the proper time and temperature, the solution annealed (A) temper becomes AT. Similarly, the ¼ H becomes ¼ HT, the ½ H becomes ½ HT and the H becomes HT. These are the only outcomes of proper age hardening. It is not possible, for example, to heat treat ¼ H material to the ½ HT or HT conditions. Furthermore, Alloy 25 is not available in strip form in the age hardened (pre-heat treated) condition. This means that it is not possible to purchase Alloy 25 strip in the AT, ¼ HT, ½ HT or HT forms. It can only be purchased in the A, ¼ H, ½ H or H forms and then heat treated accordingly after forming. Once it is heat treated, no additional forming is possible, since it will be at maximum strength and minimum ductility (i.e., it will be too "brittle" to form). Please see Table 1 for reference. (Additional temper information is available in ASTM B601.)

Additional information on age hardening practices including the proper temperatures, times and atmospheres can be found in the Materion Brush Performance Alloys Tech Briefs "Heat Treating Copper Beryllium" and "Heat Treating Distortion of Alloy 25 Copper Beryllium".

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MILL HARDENED COPPER BERYLLIUM TEMPERS

If the high strength of Alloy 25 is desired, but heat treating is an obstacle, then mill hardened material should be purchased. The mill hardened versions of Alloy 25 are called Alloy 190 and Alloy 290. (All three alloys have the same composition, but are processed very differently and have different properties.) Alloys 190 and 290 are partially aged to less than peak strength and hardness before leaving the mill.

The strength to formability ratios of Alloys 190 and 290 will not be as good as that found in Alloy 25. The lowest strength tempers of 190 and 290 will have very good formability. At increasing levels of strength, however, the formability becomes progressively more limited. Alloy 190 XHMS is the strongest mill hardened temper, with a strength nearly equal to Alloy 25 HT. However, its limited formability restricts its use to flat or nearly flat parts.

The high conductivity copper beryllium Alloys 3, 174, Brush 60®, BrushForm® 47, 390 and 390E are available in mill hardened form only. No heat treatment needs to be performed on these alloys. However, the temper designations of these alloys is different from the high strength Alloy 25. In Alloy 25, age hardenable tempers end in A or H (solution annealed or cold worked) or in AT or HT (heat treated). The mill hardened Alloy 190 tempers end in AM or HM and the Alloy 290 tempers follow the modern ASTM convention of beginning with TM. The high conductivity alloys all end in HT, not HM. (This is a carryover from an obsolete age hardenable high conductivity alloy whose properties were identical whether it was mill hardened or age hardened after forming.)

SELECTING THE PROPER TEMPER

The first step in selecting a material is to decide on the high strength or the high conductivity family. If high strength is required, select Alloy 25 only if heat treatment after forming is a viable option. If it is not an option, or if the parts are very thin and thus susceptible to age hardening distortion, then Alloy 190 or 290 would be the proper choice. If current carrying capacity is an issue, then Alloy 3, 174, Brush 60, BrushForm 47, 390 or 390E would be the appropriate choice.

Once the alloy is selected, the next step would be to select the temper. This can be done by determining the maximum stress in the part and then selecting a material with a yield strength that exceeds this value. (If the part is subjected to cyclic loading, then the fatigue strength should be used instead of the yield strength.) If the stress level is unknown, then simply choose the highest strength temper that meets the formability requirements of the design. Table 2 lists the yield strength, fatigue strength, conductivity and formability of all the copper beryllium strip alloys. The meaning of each temper also is listed in the table. Please note that the temper designations for the age hardenable material are precisely defined. However, the temper designations for mill hardened material are not. This allows for proprietary processing.

SAFE HANDLING OF COPPER BERYLLIUM

Processing beryllium-containing alloys poses a health risk if safe practices are not followed. Inhalation of airborne beryllium can cause serious lung diseases in some individuals. Occupational safety and health regulatory agencies worldwide have set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Safety Data Sheet (SDS) before working with this material. The SDS and additional important beryllium health and safety information and guidance can be found at berylliumsafety.com, berylliumsafety.eu and Materion.com. For questions on safe practices for beryllium-containing alloys, contact the Materion Product Stewardship Group at +1.800.862.4118 or contact us by e mail at Materion-PS@Materion.com.

Age Hardenable (Heat Treatable) Copper Beryllium

Start with this temper...			perform this...	if you need this temper.		
Temper	ASTM Temper	Meaning	Heat Treatment	Temper	ASTM Temper	Meaning
A	TB00	Solution Annealed	3 hr @ 600°F	AT	TF00	A (TB00) peak age hardened
1/4 H	TD01	Cold-rolled 10.9%	2 hr @ 600°F	1/4 HT	TH01	1/4H (TD01) peak age hardened
1/2 H	TD02	Cold-rolled 20.7%	2 hr @ 600°F	1/2 HT	TH02	1/2H (TD02) peak age hardened
H	TD04	Cold-rolled 37.1%	2 hr @ 600°F	HT	TH04	H (TD04) peak age hardened

Table 1. Availability of Alloy 25 Age Hardenable (Heat Treatable) Strip

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Copper Beryllium Strip Alloys

Alloy	Temper	Meaning of Temper	ASTM Temper	Condition	0.2% Offset Yield Strength Range	10^8 Cycle Fatigue Strength Range	90° V-Block Bend Formability		Electrical Conductivity
					(ksi)	Fully Reversed	Long.	Trans.	(% IACS)
25 (C17200)	A	Solution Annealed	TB00	Before Heat Treament (as Received)	30 - 55	30 - 35	0.0	0.0	15 - 19
	1/4 H	"A" Cold Worked 10.9%	TD01		60 - 80	31 - 36	0.0	0.0	15 - 19
	1/2 H	"A" Cold Worked 20.7%	TD02		75 - 95	32 - 38	0.5	1.0	15 - 19
	H	"A" Cold Worked 37.1%	TD04		90 - 115	35 - 39	1.0	2.9	15 - 19
	AT	"A" After Heat Treatment	TF00	After Heat Treament (by Customer)	140 - 175	40 - 45	-	-	22 - 28
	1/4 HT	"1/4 H" After Heat Treatment	TH01		150 - 185	40 - 45	-	-	22 - 28
	1/2 HT	"1/2 H" After Heat Treatment	TH02		160 - 195	42 - 47	-	-	22 - 28
	HT	"H" After Heat Treatment	TH04		165 - 205	45 - 50	-	-	22 - 28
190 (C17200)	AM	Annealed (Mill Hardened)	TM00	Mill Hardened	70 - 95	40 - 45	0.0	0.0	17 - 28
	1/4 HM	1/4 Hard (Mill Hardened)	TM01		80 - 110	41 - 47	0.5	0.5	17 - 28
	1/2 HM	1/2 Hard (Mill Hardened)	TM02		95 - 125	42 - 48	0.5	1.0	17 - 28
	HM	Hard (Mill Hardened)	TM04		110 - 135	45 - 52	2.0	2.0	17 - 28
	SHM	Spring (Mill Hardened)	TM05		125 - 140	47 - 55	2.8	3.2	17 - 28
	XHM	Extra Hard (Mill Hardened)	TM06		135 - 170	50 - 57	4.0	5.0	17 - 28
	XHMS	Extra Spring Hard (Mill Hard-	TM08		150 - 180	50 - 60	5.0	10.0	17 - 28
290 (C17200)	TM02	1/2 Hard (Mill Hardened)	TM00	Mill Hardened	95 - 115	42 - 48	0.0	0.0	17 - 26
	TM03	3/4 Hard (Mill Hardened)	TM03		110 - 125	43 - 49	0.5	0.5	17 - 26
	TM04	Hard (Mill Hardened)	TM04		115 - 135	44 - 50	0.7	0.7	17 - 26
	TM06	Extra Hard (Mill Hardened)	TM06		135 - 155	47 - 57	1.5	1.5	17 - 26
	TM08	Extra Spring Hard (Mill Hard-	TM08		155 - 175	50 - 60	3.5	3.0	17 - 26
3 (C17510)	AT	Annealed (Mill Hardened)	TF00	Mill Hardened	80 - 100	38 - 44	1.0	1.0	45 - 60
	HT	Hard (Mill Hardened)	TH04		100 - 120	42 - 47	2.0	2.0	48 - 60
174 (C17410)	1/2 HT	1/2 Hard (Mill Hardened)	TH02	Mill Hardened	80 - 100	45 - 50	0.5	0.5	50 min.
	HT	Hard (Mill Hardened)	TH04		100 - 120	45 - 50	1.2	5.0	45 - 60
Brush 60® (C17460)	3/4 HT	3/4 Hard (Mill Hardened)	TH03	Mill Hardened	95 - 115	45 - 50	0.7	0.7	50 min.
	HT	Hard (Mill Hardened)	TH04		105 - 125	45 - 50	1.5	1.5	50 min.
BrushForm® 47 (C17460)	HT	Hard (Mill Hardened)	TH04	Mill Hardened	125 nom.	44 nom.	2.0(1)	2.0(1)	47 nom.
390® (C17460)	HT	Hard (Mill Hardened)	TH04	Mill Hardened	135 - 153	45 - 50	2.0(2) 5.0(3)	2.0(2) 5.0(3)	44 min.
390E	EHT	Extra Hard (Mill Hardened)	TH04	Mill Hardened	138 min.	-	0.5(4) 2.0(5) 2.5(6) 3.5(7)	0.5(4) 2.0(5) 2.5(6) 3.5(7)	42 min.

Notes:
(1) For strip 0.005" and thinner
(2) For strip 0.004" and thinner.
(3) For strip greater than 0.004" thick.
(4) For strip 0.002" and thinner
(5) For strip thicker than 0.002" up to 0.004"
(6) For strip thicker than 0.004" up to 0.006"
(7) For strip thicker than 0.006" up to 0.008"

Table 2. Copper Beryllium Strip Alloys and Temper Designations

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