Beryllium Copper

An alloy in great demand for demanding applications

By L. Michael Halleran

There is a great parallel between metals and our civilized history. The use of a particular metal in day-to-day activities reflected the course of technology during a period of history and, quite often, influenced the rate at which a particular civilization advanced. Indeed, the metal copper has had a long, varied and extremely interesting history. Accordingly, it has served as the signpost of technological development over the centuries.

Copper was the first metal that man used for tools and implements. It is conceivable that the primary reason for the early development of practical applications for this versatile metal was that copper, like gold and silver, is sometimes found in a pure state. As such, it can be beaten into shape even when cold. The earliest use of copper was by the Sumerians and Egyptians some 7,000 years ago. Long before Europeans reached the continent of North America, American Indians were using copper for beads and tools. Today, copper and copper alloys are used extensively in the manufacture of a multitude of applications — electric power, water supply, air cooling, telecommunications, computers, consumer products and countless electronic devices. Copper is the most widely used of all metals for today's diverse technologies.

Copper is not only widely used but also simple to use. It is easily worked and ductile. It has pleasing color and luster, and forms alloys readily with many metals, increasing its versatility. There are more than 100 copper alloys, including zinc-brasses, tin-bronzes, nickel silvers and cupro nickels.

Choice among the alloys in the copper-based system is one with slightly less than 2 percent beryllium (Be). The beryllium allows this alloy to be processed into strength levels higher than all other copper alloys. Beryllium is an alkaline earth metal. As an ore, beryl, or aluminum beryllium silicate, is a hexagonal crystal and contains as much as 15 percent beryllium. It is mined sometimes with aquamarine (a blue beryl) and emerald. In its metal form, it is the lightest of all the rigid metals and among the strongest. It has very high resistance to heat and corrosion, a very precise elastic limit, low mass atomic absorption, high infrared reflectivity and conductivity equal to that of aluminum. Accordingly, alloys of beryllium and copper have become technology's material of choice in the manufacture of electrical and thermal conducting springs because of their strength, heat dissipation and resistance to fatigue.

Beryllium-copper alloys have many desirable properties facilitating their use in a variety of demanding applications. However, it is not commonly realized that there are two distinct families of properties. The first is high strength, and the second is high conductivity. The high-strength alloys (C17200 and C17000) are less dense (.298 lbs./cu. in.) than conventional specialty coppers. This often results in a yield of up to 7 percent more feet per pound than high-strength phosphor bronze. The high-conductivity beryllium-copper alloys (C17500 C17510 and C17410) are ideally suited to applications requiring high operating temperatures, or high strength and conductivity. The following are specific beryllium-copper alloy advantages:

- High strength-to-weight ratio
- High electrical and thermal conductivity
- Long service life
- Wide range of mechanical properties
- Wide range of tempers
- High resistance to stress relaxation
- High fatigue strength
- Good corrosion resistance
- Resistance to anelastic behavior
- Wide operating temperature range
- Nonsparking
- Easily fabricated
- Heat treatable
- Nonmagnetic

Beryllium copper is available in strip, wire, rod, bar, plate tubing, billet, casting ingot and extruded shapes. Beryllium-copper wire is one of the more widely used product forms of this feature-rich alloy. Wire can be drawn to fine sizes, or rolled in rectangles, squares, profiled shapes or fine ribbon. This, in conjunction with the diverse attributes of the alloy, creates wire applications which include, but are not limited to, long-travel coil springs; spring-loaded test probes; connectors; bandoleer connector compliant pins; axial-gripping electronic contacts; speaker leads; and miniature coined and cold-forged electronic contacts.

In general, beryllium copper displays many of the desirable plating and joining characteristics which are well documented for copper alloys. However, because of the ability that this alloy has to be heat treated and the high affinity that beryllium has in forming oxides at elevated temperatures, surface cleanliness is a critical factor if articles are to be subsequently plated or joined by soldering, brazing or welding.

Surface oxides, oil and the like must be thoroughly removed —preferably before and after the heat treatment process. Many applications permit using pretempered and/or pre-plated wire. Cautious selection

COMMON COPPER-BASED SPRING ALLOYS

Round and Square Wire

	Alloy	Tensile Strength* UTS	Conductivity %IACS	Thermal Conductivity Btu., sq. ft., ft./ hr.
Copper	C10200	60 ksi. min.	101	226
BeCu (pretempered)	C17200	140/220 ksi.	17-22	62-75
Brush 17410	C17410	100/130 ksi	40-60	120-150
Brass	C26000	120 ksi min.	25	70
Phos Bronze	C51000	145 ksi. min.	15	40
Grade C Bronze	C52100	140 ksi min.	13	36
CuNiSn	C72500	105/125 ksi.	11	31
Nickel Silver	C75200	99/111 ksi.	6	19

* Ultimate tensile strength values are size-dependent, and upper limits are for design purposes only and should not be considered a specification value.

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of the plating and condition of the starting wire can eliminate unnecessary processing steps.

Heat treating and/or stress relieving finished parts is very common in highly stressed coil springs. Many applications may permit the use of a fine coating of plating on wire to aid in coiling of pretempered (already heat treated) wire. Silver and gold possess a low coefficient of friction, which allows the reduction of surface forming stresses. Sometimes the reductions are significant enough that costly stress relieving may be omitted. Although there are great advantages in processing formed and heat treated parts, processing parts from both heat treated and pretempered wire are common practices.

Where a cyclic stress environment exists, such as with electronic and electric-contact springs, beryllium-copper wire has an extremely successful performance record. The alloy performs quite well in this area and also under conditions of high-impact stress. Accordingly, heavier sections of the alloy can be found in applications such as aircraft landing-gear bushings, where high fatigue strength and resistance to galling is of paramount performance. These applications are not dissimilar to that of computer printers where fine, gold-plated coil springs (.004-.0058 in. diameter) are used, in conjunction with a brass contact plunger, to produce spring-loaded contacts that interface with ink-release contacts in the ink-jet printer cartridge signaling ink release patterns.

Beryllium-copper alloys offer the design engineer a broad range of alluring attributes: high electric and thermal conductivity, wide operating temperature ranges, heat treatability and excellent resistance to fatigue. The fact that this alloy is nonsparking is a definite asset in spring design, where sparks are a major concern. Beryllium copper is nonmagnetic and is magnetically unaltered by heat treatment or cold work. It is also quite effective as an electromagnetic insulator/radio frequency insulator. The alloy is resistant to galling and provides inherent good wear resistance. It is selected as a material to be used in applications where abrasive contact with other surfaces occurs. These applications can include

COMMON COPPER-BASED SPRING ALLOYS

Strip and Flat Wire

	Alloy	Tensile Strength* *UTS*	Conductivity *% IACS*	Thermal Conductivity *Btu, sq. ft., ft./hr.*
Copper	C10200	52 ksi. min.	101	226
BeCu (pretempered)	C17200	120/170 ksi.	17-22	62-75
Brush 17410	C17410	100/130 ksi.	40-60	120-150
Brass	C26000	95/104 ksi.	25	70
Phosphor Bronze	C51000	100/114 ksi.	15	40
Grade C Bronze	C52100	110/122 ksi.	13	36
CuNiSn	C72500	80/95 ksi.	11	31
Nickel Silver	C75200	90/101 ksi.	6	19

*Ultimate tensile strength values are size-dependent, and upper limits are for design purposes only and should not be considered a specification value.

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use as test-probe tube plungers or as even larger, die casting plungers for aluminum die cast machines.

Beryllium copper is presently well known for the high reliability and long life it provides to springs for automotive electronics, windshield wiper switches, cruise control switches, power door locks, and power seat, dash and light switches. It is now finding its way to the other side of the fire wall with its use in springs and contacts from the high-temperature high-conductivity side of the beryllium-copper family.

The alloys C17410 and C17510 have been established as premier high-temperature copper-based materials. Sometimes known as RWMA Class III, beryllium-copper welding electrodes are used where high conductivity, good strength and resistance to welder tip mushrooming are important. It is also widely used as die-casting plunger tips, where resistance to shot sleeve wear and erosion from contact with the molten aluminum together make a very hostile environment. This alloy family has numerous spring and spring-contact applications in high-voltage circuit breakers and fuse switches — small and large. In some of these applications, the base metal is stress-loaded for years under extreme environmental conditions.

Beryllium copper even finds its way into surface-mount applications. Beryllium-copper wire finer than hair is formed into tiny gold-plated pads (like steel wool) and fixed in place for low-profile surface-mounted board-to-board connections. New generations of signal cable are created using the strength of fine filaments of beryllium copper in producing cantilevered silicon-chip testing probes

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Beryllium copper's feature-rich profile has determined its future as the alloy of choice for many of the technologies of today and for emerging technologies. End users, whether they are making cellular calls, printing reams of computer output or setting their auto's cruise control at a comfortable 55 miles per hour, have become more demanding in their performance expectations. Accordingly, design engineers and manufacturers of this wide array of technology-based products seek optimum performance from the materials and components found in their end products.

The demands of engineers and end users, as well as the extremes of applications and performance environments cry out for component materials that can deliver a wide array of features equal to the overall task. Beryllium copper is just such a material. Its market is worldwide and is only limited by the expansion of technology and its applications.

Some people have said that the expansion of technology is limited only by the availability of imagination; that's a statement which reads well and may be in fact true. However, from a practical perspective, many technological advances over the years have been slowed or even blocked by the unavailability of materials equal to the task. Beryllium copper is a material with such a wide array of positive properties, it becomes the natural partner of advancing technology. The future of beryllium copper is indeed bright.

L. Michael Halleran, who is known to everyone in the industry as Michael, was born in Bronxville, NY on October 21, 1943. He grew up in the precision wire business his father, L.W. Halleran, founded. He literally learned the business from the ground up, starting in the R&F plant as a floor sweeper and working his way through every step of the manufacturing process until he became the company's national sales manager.