June 17, 1947. W. B. DRIVER 2,422,477

LOW TEMPERATURE HEATING ELEMENT

Filed Nov. 1, 1944

Fig. 1.

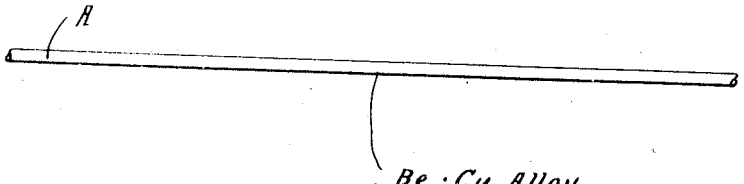


Fig. 2.

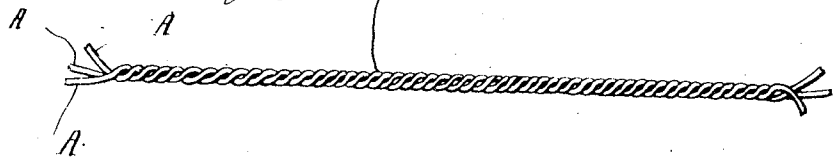


Fig. 3.

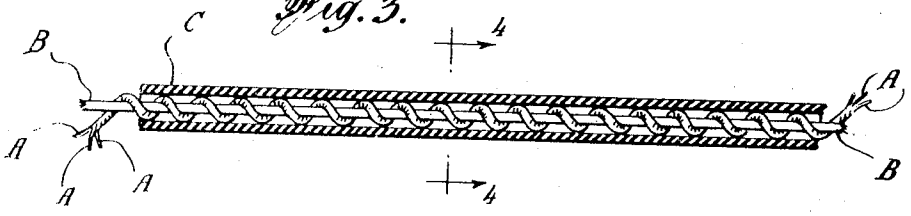
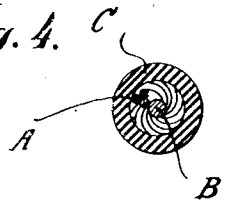


Fig. 4.



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LOW-TEMPERATURE HEATING ELEMENT

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3 Claims. (Cl. 201—64)

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This invention relates to electrical resistance heating elements and more particularly to such heating elements adapted for low temperature heating ranges approximating 100° to 300° F., and has for its object the provision of a heating element that is characterized by high flexibility and high endurance limit.

Another object is to provide a flexible heating element for use at relatively low heating temperatures approximating 300° F., that is characterized by having a high endurance limit and by having a crystal structure resistant to alteration with consequent change in electrical characteristics as a result of flexing.

Still another object is to provide a flexible electrical resistance heating element for use in electrically heated flying suits, blankets, heating pads, and the like articles of manufacture.

Other objects and advantages will be apparent as the invention is more fully hereinafter disclosed.

In accordance with these objects, I have discovered that beryllium-copper alloys of the cold workable-precipitation hardenable type in the solid solution or pure alpha phase, when in small section or small diameter, have the unexpected property of flexing without substantial work hardening at relatively low temperatures below about 300° F. down to atmospheric temperatures and that this property along with a favorable electrical resistance adapts these alloys for utilization as high endurance flexible heating elements in such articles of manufacture as electrically heated flying suits, blankets, heating pads, and the like, to impart to said articles a service life that is greatly in excess of such articles heated with electrical resistance elements comprised of any other type of alloy heretofore employed.

By the term "beryllium-copper alloys of the cold workable-precipitation hardenable type" is meant that group of alloys heretofore known in the art containing from .30 to 3.0% beryllium and from small fractional percentages up to 3% of other metals and metalloids which are characterized by being capable of being converted by a high temperature heat-treatment into a solid solution alloy which, after rapid cooling to atmospheric temperatures, is capable of being heat-treated at a lower temperature to precipitation harden. Many different compositions of beryllium-copper alloys are known that fall within this broad class of alloys, the particular amount of beryllium in the alloys varying somewhat with respect to the kind and amount of associated metal and metalloid present. The associated metals and metalloids generally present in such alloys include Fe, Co, Ni, Si, Ag, P.

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As a typical example of such alloys, the essentially binary beryllium-copper alloy containing 1.8 to 2.10% Be and not over .50% of either of the metals Co and Ni is the alloy most generally preferred in the art. This alloy is commonly referred to as the 2% Be alloy, the amount of Co or Ni present therein being so low as to have a negligible effect upon the expected phase change properties of the binary beryllium-copper alloy of the same composition.

Such 2% beryllium-copper alloys after suitable hot working following casting, in accordance with known prior art methods and final heat-treating at temperatures within the range 1400–1500° F., are converted into the cold workable solid solution phase and by suitable cold working and heat-treating methods also known in the art such material ultimately may be mechanically deformed into wire, sheet or strip, of the desired diameter or thickness and by a final heat-treatment at a temperature within the range 1400–1500° F. followed by rapid cooling may be converted interiorly into the solid solution phase for precipitation hardening heat-treatment within the temperature range 350 to 550° F.

Heretofore in the art it has been recognized that solid solution alloys of the type obtained in the 2% Be beryllium-copper alloys, after heat-treatment at 1400–1500° F. and quenching, are essentially unstable alloys and that the phase changes that occur in such alloys are time-temperature reactions which normally are accelerated by cold working strains. Beryllium-copper alloys in this condition, for example, have been found to be relatively stable at atmospheric temperatures and stable against phase changes at temperatures below about 300° F., but on cold working have been found to strain harden so rapidly that a percent reduction in area approximating 60% is about the maximum that may be applied thereto between solution-anneals at 1400–1500 F. to reconvert the cold worked metal to the unstrained solid solution phase. It is recognized generally that with increase in strain hardening the temperature of precipitation hardening decreases until at about 60% reduction in area precipitation hardening normally occurs in the cold worked metal at the usual temperatures reached during cold working, thereby hardening the metal sufficient to require solution-annealing before further cold working may be practiced.

However, I have discovered that at temperatures within the range atmospheric to about 300° F., the 2% Be beryllium-copper alloys flex with little or no strain hardening, with the result that the normal resistance of the alloy to phase changes at temperatures below about 300° F. is not altered by such flexing so that a relatively

long service life under variable flexing conditions may be obtained from such alloys.

Accordingly, by appropriate selection of wire diameter and length with respect to its electrical resistance, flexible heating elements comprised of such beryllium-copper alloys in the solid solution phase, may be formed for use with any given electrical load which are characterized predominately by a long life under variable flexing conditions along with a substantially constant electrical resistance characteristic.

One specific example of such heating element is illustrated in the attached drawings, wherein—

Fig. 1 shows a single conductor comprised of the preferred alloy of the present invention in its heat-treated condition;

Fig. 2 shows a stranded conductor comprised of a plurality of the conductors of Fig. 1;

Fig. 3 shows the completed heating element of the present invention; and

Fig. 4 is a sectional view along plane 4—4 of Fig. 3.

As a specific example of the preferred alloy composition for the conductor *a* of Fig. 1 of the present invention, but not as a limitation of the same, a beryllium-copper alloy containing Be 1.85%, Co .25% and balance Cu, has been found most suitable for the purposes of the present invention. This alloy in its solution-annealed condition normally has an electrical resistance of about 60 ohms per circular mil foot at a wire size of .003–.004 inch diameter.

Experimental tests have shown that this wire product withstands flexing in opposite directions alternately over a bend approximating a 90° angle at a rate of 60 cycles per minute, such alternate bends per minute for a length of time approximating 125 hours, or a total of 500,000 bends before fracture with less than 10% change in resistance. The closest total number of bends by any other wire heretofore proposed for such service use under comparable test conditions was 25,000–50,000 bends.

Electrical resistant tests on the beryllium-copper wire showed no variation or change in electrical resistance for 125 hours and thereafter only a small change up until shortly before the wire failed in the test in contrast to a relatively large and continuously increasing change in electrical resistance in all other such conductor wires subjected to the same test.

Referring to the drawings, a flexible electrical resistance element for heating devices of the type described, is preferably formed of a plurality of wires A of about the above diameter (.003 to .004 inch) twisted together helically to form an electrically conductive strand of the desired electrical resistance, which strand is helically wound upon a flexible glass wool or fiber core B of small diameter and held in helically wound position thereon by means of a flexible cover sheath C comprised of non-conductive material such as a vinyl resin (a co-polymerization product of vinyl chloride and vinyl acetate). In such a construction of the heating element the flexibility of the helical winding of the flexible strand of wire on the flexible core normally tends to lower the flexing angle on the strand, increasing thereby the normal life expectancy of the wire many times over that established by the above noted test on the individual wire before stranding.

As specific examples of this construction, a strand B comprised of 10 wires (.003" diameter) has an electrical resistance of about 1.3 ohms per linear foot, whereas a strand B comprised of only 6 wires (.003" diameter) has an electrical resistance of 2.3 ohms per linear foot. A strand comprised of 2 wires (.003" diameter) has an electrical resistance of 12 ohms per linear foot. The spacing between the turns of the helically wound strand may be varied widely without essential departure from the present invention as one skilled in the art will recognize.

It is believed apparent to those skilled in the art of beryllium-copper alloys that many of the alloys may evidence flexing without substantial work hardening at temperatures somewhat higher or somewhat lower than 300° F. due to the retardant and accelerating effects of the alloy constituents present therein on the phase changes and ratio thereof. Cobalt, for example, lowers materially the heat-treating temperatures of the binary alloy, whereas nickel does not lower such heat-treating temperature to the same extent.

Having hereinabove described the present invention generically and specifically, it is believed apparent to any one skilled in the art that the same may be widely varied without essential departure therefrom and all such modifications and departures therefrom are contemplated as may fall within the scope of the following claims.

What I claim is:

1. A flexible electrical resistance element for low temperature service use below about 300° F., said element consisting of at least one small diameter conductor composed of a beryllium-copper alloy of the cold workable-precipitation hardenable type, said alloy being in the solution-annealed condition.

2. A flexible electrical resistance element for low temperature service use below about 300° F., said heating element consisting of a plurality of small diameter conductors helically twisted together to form a strand, each said conductor consisting of a beryllium-copper alloy of the cold workable-precipitation hardenable type in the solution-annealed condition.

3. A flexible heating element for electrically heated flying suits, blankets, pads and the like, said heating element consisting of a plurality of small diameter conductors helically twisted together to form a strand, said strand being helically wound on a flexible electrically non-conductive core and covered with an electrically non-conductive sheath, said conductor consisting of a beryllium-copper alloy of the cold workable-precipitation hardenable type in the solution-annealed condition.

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