July 12, 1938. F. R. HENSEL ET AL 2,123,629

ALLOY

Filed July 16, 1936

Fig. 1

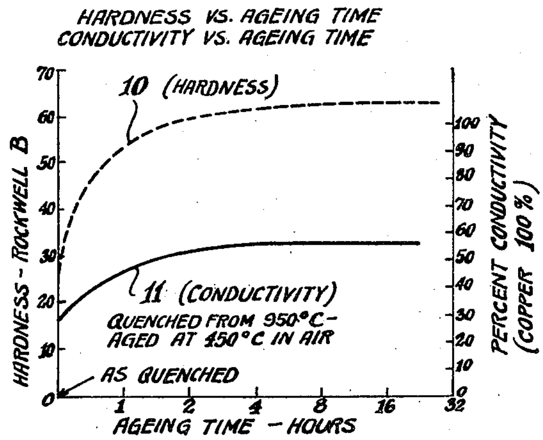


Fig. 2

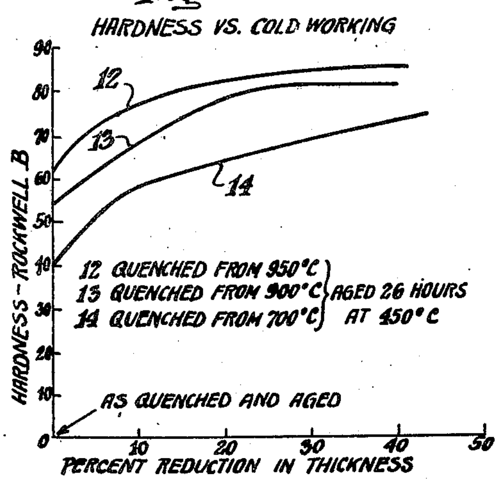


Fig. 3

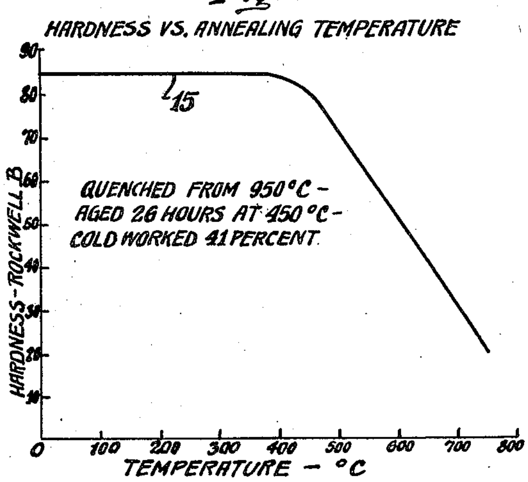
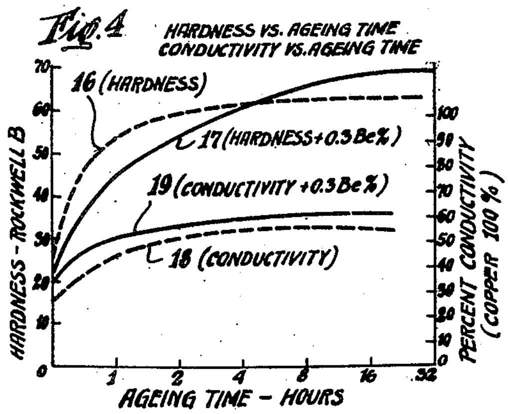
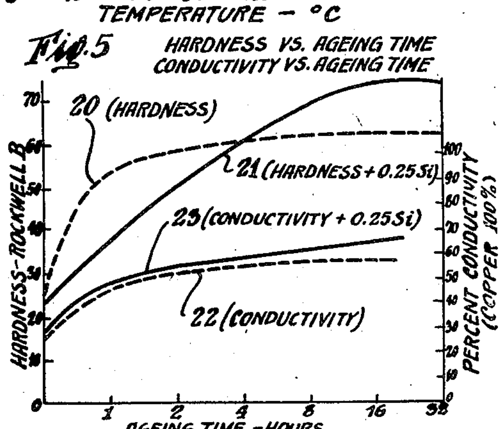


Fig. 4





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ALLOY

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2 Claims. (Cl. 219—4)

This invention relates to alloys and more particularly to copper base alloys of improved characteristics.

An object of the invention is to produce an improved copper base alloy.

A further object is to provide an alloy, the physical properties of which can be improved by heat treatment.

An additional object is to produce a precipitation hardened copper alloy.

Other objects of the invention will be apparent from the following description taken in connection with the appended claims.

The present invention comprises the combination of elements, methods of manufacture, and the product thereof brought out and exemplified in the disclosure hereinafter set forth, the scope of the invention being indicated in the appended claims.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the combination of elements without departing from the spirit of the invention.

The invention may be better understood from the following description when read in conjunction with the accompanying drawing in which:

Figure 1 is a graph illustrating the improvement in hardness and conductivity of the alloy disclosed herein with heat treatment;

Figure 2 is a graph illustrating the increase in hardness of the alloy with cold working;

Figure 3 is a graph illustrating the temperature resistant characteristics of the alloy;

Figure 4 is a graph illustrating the improvement in hardness and conductivity of the alloy with small additions of beryllium; and

Figure 5 is a graph illustrating the improvement in hardness and conductivity of the alloy with small additions of silicon.

We have found that by adding cobalt and phosphorus to copper an intermetallic compound of cobalt phosphide can be formed which has a variable solid solubility in the copper matrix. We have further been able to produce copper alloys containing these ingredients which may be greatly improved in hardness and electrical conductivity by a suitable age hardening process.

The alloy may be produced as follows:

Copper is melted under glass or charcoal slag and superheated. A hardener containing 75% cobalt and 25% copper is added as a convenient means to incorporate cobalt. Phosphorus is then added in the form of phosphor copper or some other suitable means.

In the molten condition, the alloy is extremely fluid and pours very easily.

The proportions of cobalt and phosphorus may each be varied over a considerable range of values and there may be an excess of either in some instances without deleterious effects on the alloy. The preferred weight ratio of phosphorus to cobalt is approximately 1 to 6. However, considerable age-hardening is obtained with a ratio of 1 to 3 and also with a ratio as high as 1 to 10.

A slight excess of phosphorus above the amount required to form certain intermetallic compounds of cobalt phosphide will ordinarily serve as a deoxidizing agent during the production of the alloy.

As previously stated the cobalt phosphide is suitable as an age hardening ingredient for copper or certain copper alloys. Additional ingredients may likewise be added in some instances to produce certain beneficial effects. Two examples of such additives are discussed later.

Where the cobalt and phosphorus are added to copper the ingredients may be present in the following ranges of proportions:

Cobalt	0.05% to 5%
Phosphorus	0.01% to 2%
Copper	balance

The preferred proportions, however, are substantially as follows:

Cobalt	2 to 3%
Phosphorus	0.2 to 0.75%
Copper	balance

After the alloy has been produced it may be heated to a relatively high temperature above 700° C. and preferably in the order of 800° C. to 1000° C. and then rapidly cooled from that temperature to room temperature or below, preferably by quenching in water. After the quenching operation the alloy, in such form as may be desired, may be given an aging treatment by baking at a temperature below 700° C. and preferably at a temperature in the order of 350° C. to 650° C. The aging may proceed for a considerable length of time according to the temperature used. The greatest improvement in hardness and electrical conductivity will be obtained during the first two or three hours if 450° C. is used as aging temperature but further improvement may be noted upon continuing the aging for 8 to 16 hours or more.

The improvement in hardness and electrical conductivity during aging is shown in the graphs (Figure 1) for a representative alloy made according to the present invention. This alloy has the following composition:

Cobalt	2.37%
Phosphorus	0.63%
Copper	balance

In Figure 1, curve 10 represents the increase in Rockwell B hardness of specimens of the above composition quenched from 950° C. in water and aged at 450° C. in air. It will be noted that the hardness was increased from about 26 Rockwell B immediately after quenching to about 62 Rockwell B after aging for 8 or more hours at 450° C.

Curve 11 in Figure 1 represents the improvement in electrical conductivity of the same specimens during the age-hardening treatment. It will be noted that the conductivity increased from about 27% of that of copper after quenching to 55 or 56% after aging for four or more hours. It will also be noted that in general there is little change in hardness or conductivity after four to eight hours of aging.

By varying the proportions of cobalt and phosphorus in the alloy it is possible to obtain electrical conductivities of at least 65% and hardnesses of 65 Rockwell B or better.

After the aging treatment the material may be cold worked, by rolling for example. Figure 2 illustrates the increase in hardness of specimens of the above-mentioned alloy quenched from various temperatures, each being aged for twenty-six hours at 450° C. Curve 12 represents the improvement in hardness of a specimen quenched from 950° C., aged at 450° C. and then cold rolled. It will be noted that the hardness was increased from about 62 Rockwell B after aging to about 85 Rockwell B after a 40% reduction in thickness. Curve 13 represents in a similar way the improvement in hardness of a specimen quenched from 900° C. and curve 14 for one quenched from 700° C. and aged and cold worked in the same manner. The electrical conductivity is not materially changed by the cold working operation.

Figure 3 illustrates the resistance of the alloy of the present invention to high temperatures. Curve 15 shows the relationship between hardness which is the product of aging and subsequent cold working and temperature for an alloy of the following composition quenched from 950° C. in water, aged twenty-six hours at 450° C. and cold worked to obtain a 41% reduction in thickness.

	Percent
Cobalt	2.41
Phosphorus	0.67
Copper	96.78

It will be noted that the cold worked alloy retains its hardness indefinitely at temperatures of 400° C. or greater.

The present alloy is easy to produce. In pouring the alloy it shows a clean stream and great fluidity.

No difficulty due to cracking or checking is encountered in the hot rolling and cold working of this alloy.

In the binary copper-cobalt system the solubility of cobalt in copper decreases with decreasing temperature, the cobalt being soluble in copper in the solid state only to a very limited extent. At 1000° C. 3.5% cobalt is held in solid solution by copper. At 600° C. only 0.9% cobalt is held in solid solution and at room temperature this percentage decreases to approximately 0.35%.

By adding phosphorus, cobalt phosphide is formed and this compound has a lower solid solubility in copper than does cobalt. The precipitation hardening effect is therefore greater. In age-hardened alloys the hardening ingredients greatly decrease the electrical conductivity to the extent in which they are held in solid solution. Cobalt phosphide, therefore, produces a higher electrical conductivity for the same amount of hardening than does straight cobalt since less of the phosphide is held in solid solution.

Another advantage accrues from the fact that the precipitated phase, consisting of cobalt phosphide or copper cobalt phosphide has in itself a substantial hardness. The hardness of this phase is much greater than the precipitated phase in binary copper-cobalt alloys. This makes for greater strength and higher hardness in the hardened alloy.

The alloy is particularly suitable for pressure exerting welding electrodes such as spot welding electrodes because of its combination of high hardness and electrical conductivity. This results in greater freedom from mushrooming in service. The electrodes are well adapted for the welding of terne and tin plate.

The alloy also makes excellent soldering iron tips due to its freedom from intercrystalline penetration of liquid metals. We have found it superior in this respect to most of the present copper base alloys.

The alloy is likewise well adapted to other applications where the combination of relatively high electrical conductivity combined with high strength and hardness at room or elevated temperatures is required.

In cases where somewhat higher hardness is desired additions of small amounts of beryllium or silicon may be made. Surprisingly, this also appears to improve the electrical conductivity slightly. When so used the beryllium content should preferably be within the range of 0.01% to 0.5% and where silicon is used it should also preferably be used within this range of proportions.

Figure 4 contains curves showing the comparative improvement in hardness and in electrical conductivity of the previously mentioned representative composition and a similar composition to which 0.3% beryllium has been added. Curves 16 and 18 represent the increase in hardness and conductivity respectively for the above mentioned representative alloy and are similar to curves 10 and 11 in Figure 1. Curves 17 and 19 respectively represent the increase in hardness and conductivity of the alloy containing 0.3% beryllium. It will be noted that the hardness of the beryllium-containing alloy, while initially less, eventually reaches a higher value than the hardness of the alloy without the beryllium. The conductivity of the beryllium-containing alloy is somewhat greater regardless of the aging time.

Figure 5 contains similar curves wherein 0.25% silicon is added instead of beryllium. Curves 20 and 22 correspond to curves 10 and 11 respectively of Figure 1. Curve 21 represents the increase in hardness of the silicon-containing alloy and curve 23 represents the improvement in electrical conductivity of this alloy. It will be noted that silicon has a very similar effect to beryllium.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. An electrical contacting element of the type comprising pressure exerting welding electrodes and the like composed of an alloy containing about .05 to 5% cobalt, .01 to 2% phosphorus and the remainder substantially all copper.

2. An electrical contacting element of the type comprising pressure exerting welding electrodes and the like composed of an alloy containing 2 to 3% cobalt, 0.2 to 0.75% phosphorus and the balance copper.

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