Patented Mar. 1, 1932 1,847,929

UNITED STATES PATENT OFFICE

OTTO DAHL, OF BERLIN, GERMANY, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

COPPER ALLOYS

No Drawing. Application filed June 26, 1931, Serial No. 547,177, and in Germany July 31, 1930.

The present invention relates to copper alloys but more particularly to copper alloys having high electrical conductivity and mechanical strength. For many purposes, such for example as electrical conductors, current carrying springs, materials are required which are strong and have high electrical conductivity. Pure copper possesses the highest conductivity but has relatively low strength. No noticeable increase in the conductivity of copper can be attained by rolling, annealing or the formation of alloys. Copper may be strengthened in two ways, first, by working in the cold state and, second, by the formation of copper alloys. In the first case the increase in the strength takes place without any substantial alteration of the conductivity. The increase in strength is, however, restricted in a degree and in many cases does not meet desired requirements. Moreover, pure copper possesses the undesirable property of losing the increased strength, imparted to it by working in a cold state, on being heated even to moderate temperatures which may occur in parts through which the electric current flows for example temperatures of 100° to 200° C.

In the second case, the formation of alloys leads to an increase in strength per se. Thus by a sufficient addition or by an addition combined with cold working of the alloy a desired degree of strength may be attained. In addition to this the ability of the cold worked copper alloy to withstand moderate temperatures is increased. With the addition even of very small quantities of the second metal the temperature limit of the decrease in strength, i. e., the recrystallization limit, is extended about 100° to 150° C., that is, to 250°–350° C. On the other hand, the alloy formation reduces the conductivity of the copper and, in fact, the first additions have the strongest effect. Hence, in practice, it is always imperative in the event of a demand for a certain degree of conductivity and strength to consider carefully the influence of the alloy additions and of the cold working on the increase of the strength as against the influence of such additions on conductivity. The smallest excess over the quantity necessary for the increase in strength of the alloy may render the employment of the material substantially useless owing to loss of conductivity.

These disadvantages may be avoided to a great extent by means of the improved alloys and the process of treating those alloys hereinafter disclosed. The alloy additions are so selected that at the higher temperatures employed they are taken up by the copper in fixed solution just as are the additions hitherto employed, for example tin, cadmium and phosphorus. The alloy additions have the effect, if the alloys are cooled down sufficiently quickly from the higher temperature, and the mixed crystalline state thus preserved at ordinary temperatures, of producing an increase in the strength of the annealed alloys. Moreover, the desired increase in strength may be attained by cold working combined with sufficiently high additions. In this state however, just as with the additions heretofore employed the conductivity is greatly reduced according to the quantity of the addition.

The second property of the additions which is the determining factor in the selection of the additional metals may now be considered. The solubility of the additions should decrease with the falling temperature. As is known, only the quantity of the additions taken up in fixed solution has the effect of greatly lowering the conductivity. The additions present as constituent parts of the alloy in addition to the copper only change the conductivity in a slight degree corresponding to the regulation of the mixture. With the selection and behavior of additions as above noted which are only soluble in the copper at higher temperatures and at lower

temperatures are separated out of the copper as a second constituent part of the alloy, it is possible, in copper strengthened according to the desired measure by alloy formation and cold working to cause the additions to separate out by tempering at a relatively low temperature.

In this connection the temperature is selected so that in fact this constitutional alteration occurs in consequence of diffusion while, however, a decrease of the strength by recrystallization does not yet occur. Experience has shown that no decrease occurs in this connection, in the compacting of the alloy, on account of this separating-out. According to the experience gathered in connection with the improved alloys, it is not the additions dissolved in the mixed crystal which causes the greatest strength but the minute particles which separate out at low temperature. Thus by this heat treatment, only an increase in conductivity is brought about. In this connection besides the advantage that the attainment of this conductivity is possible, there is the further advantage that an addition of the alloying constituent beyond the necessary quantity is not very injurious since only the amount of the additions remaining in the mixed crystal has a cardinal influence on the conductivity.

The best results have been obtained when the metals employed as additions were each added in the proportion of the hypothetical formula Me_2Be or MeBe, i. e. when one gram atom of beryllium for example is present with one gram atom of chromium or with two gram atoms of chromium, or, in other words, when the beryllium content constitutes 1/6 or 1/12 of the chromium content. The sum of the additions amounts on the whole to 0.1 to 6% so that the alloys contain only a slight amount of beryllium, at the most about 1%. When cobalt is employed instead of chromium, it supplants the chromium at the ratio of the atomic weights, i. e. 59 parts of cobalt for 52 parts of chromium, that is to say, when the chromium is completely replaced by cobalt the beryllium content should amount to about 1/7 or 1/13 of the cobalt content.

Beryllium possesses the property that it has greater solubility in copper at higher temperatures than at lower temperatures. The variation of solubility is such that even at the lower temperatures about 0.5 to 0.8% of beryllium, is retained in fixed solution. Such a content is sufficient to reduce the conductivity to about

$$\frac{20\ m}{\Omega\ mm^2}.$$

By the simultaneous addition to the beryllium of chromium or cobalt, advantageously in the above mentioned proportions, this limit is reduced to about 0.05% with chromium and to about 0.1% with cobalt.

In this way, with a correspondingly correctly selected method of treatment, the principle which has been disclosed above, the following values of conductivity and hardness of the alloys are obtained. In this connection the hardness is given as a relative measure of the strength. The same amounts for copper in an annealed condition to about

$$\frac{45\ kg}{mm^2}$$

and with 80% rolling grade to

$$\frac{85\ kg}{mm^2}.$$

Contents of additions in %			Hardness and conductivity with the single treatment conditions			
			1 Quickly cooled from high temperature		2 As 1 with 1 hour 500° C. tempered	
Be	Cr	CrBe	λ	H	λ	H
0.075	0.425	0.5	32.2	54	47.1	84
0.15	0.85	1.0	27.8	60	43.0	88
Be	Co	CoBe			As 1 with 1 hour 550° C. tempered	
0.13	0.87	1.0	17.8	53	36.1	112
0.4	2.6	3.0	16.5	81	36.0	172
Be	Cr	CrBe	3 Quickly cooled down from high temperature and 60% rolled out		4 As 3 with 1 hour 500° C. tempered	
						H
0.075	0.425	0.5	31.5	92	47.5	108
0.15	0.85	1.0	27.0	103	43.5	120
Be	Co	CoBe				
0.13	0.87	1.0	17.3	98	36.5	145
0.4	2.6	3.0	15.1	130	36.2	188

The advantages of the alloys and the processes employed can be seen from the above table. Since increase of strength by alloy formation and increase of resistance of alloy formation run to a great extent parallel, the increase in conductivity as given in columns 1–4 inclusive is indicative of the improvement in that direction.

The table shows a considerable improvement in the heat resisting quality of the alloy. While the temperature limit for decreased strength of copper is 100° to 200° C. and for known copper alloys, e. g. silicon copper alloys, aluminum bronzes and brasses 250 to 400° C. for the present alloys it amounts to over 600° C. At 500° C. as the table clearly shows, an increase in strength is attainable.

The process herein set forth, i. e. annealing, quickly cooling and tempering, as also cooling, working, and tempering represents of course only certain specific steps. The processes can of course be modified according to the purposes desired. For example, the

cooling down can take place more slowly if less value is attached to the hardening of the alloy. For the highest strength of forging operation can be given in addition after the tempering treatment.

What I claim as new and desire to secure by Letters Patent of the United States, is:

An alloy consisting substantially of copper, beryllium and chromium, the beryllium and chromium constituting together not appreciably more than 6% of said alloy, the beryllium constituting not appreciably more than 1% of said alloy.

In witness whereof, I have hereunto set my hand.

OTTO DAHL.