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COPPER ALLOYS

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This invention relates to copper alloys.

An object of the invention is to improve the characteristics of such alloys.

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 present invention relates to the improvement of alloys of copper with the iron group metals or manganese by the addition of zirconium thereto.

Copper base alloys containing substantial quantities of elements taken from the iron group, have been used before. These materials have shown definite advantages as far as increase in hardness over that of pure copper, is concerned. However, in most cases, the addition of larger percentages from the iron group metal was connected with a very substantial loss of electrical properties. It has also been suggested to improve alloys of this type by adding, for instance, silicon in certain percentages, and subjecting the alloys to a heat treatment, more specifically called an age hardening treatment. It was found, however, that the most important of the elements of the iron group, namely iron, did not respond very effectively to heat treating. In other words, no appreciable increase in the physical properties resulted. It was found, furthermore, that alloys of this type had a tendency to produce a grain structure which showed considerable weakness after heat treating, particularly in the as cast condition. Furthermore, the alloys had a tendency to segregate.

According to the present invention, wherein these alloys are improved by the addition of zirconium, the improved alloys can not only be made of greater hardness than the alloys of the prior art, but also have a high electrical and thermal conductivity; they will retain their properties at high temperatures; they have an extremely fine grain structure; they have a high

resistance to corrosion and they may be very easily cast and hot and cold worked.

According to the preferred method of carrying out the present invention, an alloy is made containing copper, iron or a metal of the iron group, and zirconium, in substantially the following proportions:

	Per cent
Metal of the iron group-----	0.1 -30
Zirconium-----	0.05- 5
Copper-----	balance

In some cases manganese can be substituted for the iron group metal in the same proportions with satisfactory results.

It is possible, likewise, to improve the characteristics of other copper alloys containing an iron group metal or manganese together with small percentages of additional ingredients, by the addition of zirconium. For example, these alloys containing small proportions or even up to several percent of zinc, tin, calcium, lithium, magnesium, beryllium, silicon, phosphorous and silver, may be improved by the addition of zirconium in substantially the proportions indicated above. Although the cost of the alloy is thereby increased we have found that for some uses, the addition of beryllium in an amount from 0.05 to 3% is particularly beneficial.

For most purposes, particularly for electrical uses, the copper-iron-zirconium alloys may preferably have their ingredients present in the following range of percentages:

	Per cent
Zirconium-----	0.1 to 3
Iron-----	0.1 to 5
Balance substantially all copper.	

The addition of zirconium to the above alloys renders them susceptible to age hardening. The alloys can be made according to standard alloying methods.

A preferred method of alloying is to prepare a hardener alloy, containing a high percentage of zirconium, and then introduce a pre-determined amount of this alloy into a copper-iron or copper-iron group metal melt of the desired composition.

After the alloy has been prepared, according to such methods, the heat treatment may be carried out as follows:

The alloy in the form of a billet or a sand casting or any other form, is raised in temperature to above 700° C. The alloy is then cooled quickly (quenched) from this high temperature

and subsequently aged at a temperature below 700° C.

Another remarkable effect of the heat treatment is the improvement obtained in the electrical conductivity of the alloys. With some of the alloy combinations described it is possible to obtain conductivities close to 70% of that of pure copper.

In certain instances, the high electrical conductivity might not be essential and in such cases, higher percentages of the iron group metal may be used; for instance, if corrosion resistant properties are most important, it is desirable to have a high nickel content, and materials of this type are usually known as cupro-nickels.

By adding zirconium in substantially the proportions as mentioned above, we have found that the material will withstand a much higher temperature before it softens and furthermore, it will have a very fine grain which will make the material ideally suitable for drawing purposes. Cupro-nickels are used extensively for condenser tubing and in this application it must stand heat as well as corrosive attack. For both purposes, the addition of zirconium constitutes a marked improvement over the alloys of the present art.

The alloys may be cold worked after aging to further improve their characteristics. In some cases, however, it has been found advantageous to introduce the cold working operation immediately after quenching and before aging.

If the alloys are subjected to a heat treatment after they have been cold worked, a phenomenon occurs which is usually called recrystallization. Under certain conditions, the material might increase in grain size very considerably. Such increase in grain size will weaken the structure and the material will not flow very readily in deep drawing operations. Zirconium has been found to be a most effective grain reducing element, and at the same time, being responsible for the age hardening improvements connected with the heat treatment.

By way of example, some of the important properties of an alloy of the present invention having the following composition are indicated below:

	Per cent
(A) Zirconium	1.57
Iron	2.00
Copper	balance

After preparation a specimen of this alloy was heated to 950° C. and quenched from that temperature. As quenched it was found to have a Rockwell B hardness of 37 and an electrical conductivity of 23.5% of that of copper. Subsequent improvement in hardness and electrical conductivity upon aging at 450° is shown in the following table:

Aging time	Hardness (Rockwell B)	Conductivity
Hours		Percent
0	37	23.5
1	60	37.5
2	63	46.0
4	65	49.0
8	64	54.0
16	64	57.0
32	62	62.0

When this alloy was cold worked after aging

for 32 hours it showed further improvement in hardness as follows:

Reduction in thickness	Hardness (Rockwell B)
Percent	
0	62
5	70
10	74
15	79
20	80
25	81

Reduction in thickness	Hardness (Rockwell B)
Percent	
30	83
40	85
50	85.5

Results were also obtained of the effect of cold working this alloy after quenching but before aging. With these specimens, which were quenched from 950° C., cold worked to produce various reductions in thickness and then aged at 450° C., the following results were obtained:

Aging time	Hardness (Rockwell B) Reduction in thickness—			
	10	20	40	60
Hours	Percent	Percent	Percent	Percent
0	61	64	67	68
5	66	69	74	85
1	69	71	77	84
2	70	72	78	82
4	71	73	79	81

It will be noted that after 60% cold working the alloy will reach a hardness of 85 Rockwell B after aging 30 minutes at 450° C.

An example of a cobalt-containing alloy of the present invention is one having the composition:

	Per cent
(B) Zirconium	1.57
Cobalt	2.42
Copper	balance

The maximum hardness obtained after straight aging is 40 Rockwell B, while the conductivity is 53%. If cold working is applied after quenching, and before aging, the maximum hardness can be increased to 75 Rockwell B. Cold working after complete aging increases the maximum hardness to 77 Rockwell B.

Another example is the following alloy:

	Per cent
(C) Zirconium	0.70
Cobalt	2.31
Silicon	0.73
Copper	balance

It will be noted that this alloy has a substantial proportion of silicon present which increases its hardness and improves some of its other properties. The conductivity, however, is somewhat lower. After quenching from 950° C. and aging at 450° C. a Rockwell B hardness of 89 was obtained with 45% electrical conductivity.

The optimum hardness that can be obtained by cold working the material 60% after quenching and before aging, is above 90 Rockwell B. The material can also be cold worked after com-

plete heat treatment to approximately 95 Rockwell B.

An alloy which shows the beneficial effects of beryllium in addition to zirconium is:

	Per cent
(D) Zirconium	0.67
Cobalt	2.04
Beryllium	0.63
Copper	balance

The Rockwell B hardness after aging reached 105 maximum. The electrical conductivity exceeded 45%. Cold working after quenching and before aging did not appreciably increase the maximum hardness obtained after the regular heat treatment. Cold working after aging had but little effect on the hardness.

One nickel-containing alloy according to the invention is as follows:

	Per cent
(E) Zirconium	1.68
Nickel	2.26
Silicon	.06
Copper	balance

The hardness of this alloy after aging reaches 50 Rockwell B and the conductivity 43%. If cold work is applied after quenching, the maximum hardness after 60% reduction is 77 Rockwell B. The material responds to cold working after complete heat treatment and the hardness is increased from 50 Rockwell B to 76 Rockwell B.

A nickel-containing alloy showing a larger amount of silicon is, for example, the following:

	Per cent
(F) Zirconium	0.80
Nickel	1.96
Silicon	.70
Copper	balance

The maximum hardness after quenching from 950° and aging at 450° C. is close to 90 Rockwell B, while the maximum conductivity is above 30%.

The hardness is increased if, after quenching, severe cold working is applied. With a cold working about 60%, the ultimate hardness after aging is 95 Rockwell B. Cold working after complete aging does not seem to increase the hardness to a great extent.

As already stated, manganese can, in some instances, be substituted for the iron group metal. An example of such an alloy is:

	Per cent
(G) Zirconium	1.87
Manganese	2.04
Copper	balance

The maximum Rockwell B hardness after straight aging is 60 Rockwell B. The electrical conductivity is 18%. If cold work is applied after quenching, and before aging, the maximum hardness can be raised to 88 Rockwell B. Cold working after complete aging will raise the hardness to 85 Rockwell B. It will be noted that the electrical conductivity is very low in this case. However, for some applications, the conductivity is unimportant.

The zirconium raises the annealing temperature and at the same time provides a very fine grain structure which is particularly desirable if the material is to be worked into sheets.

The alloys of the type described are well suited for use at comparatively high temperature, since hardness and electrical conductivity are maintained for indefinite periods at aging temperatures indicated.

The alloys prepared as indicated above are well suited for a large number of applications. If small percentages, up to 5%, of iron group metal are used, they are very well suited for such applications as resistance welding electrodes, trolley wires, trolley wheels and electrical contactors in general.

Other important uses of these high strength alloys are applications where corrosion resistance is required. It has been found that nickel-zirconium-copper alloys are particularly useful in this connection.

Another important use of the alloys are applications where high heat conductivity and high strength at elevated temperatures are needed.

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 alloy composed of 0.1 to 3% zirconium, 0.1 to 5% iron and the balance copper.

2. An age-hardened alloy composed of .05 to 5% zirconium, .1 to 5% of a metal selected from the group consisting of iron, cobalt and nickel, and the balance substantially all copper, characterized by high hardness and high electrical conductivity and further characterized by the fact that its hardness and conductivity are not permanently affected by temperatures in the order of 450° C.

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