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COPPER-BASE ALLOY

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The present application is a continuation-in-part of my application Serial No. 290,070, filed May 26, 1952, now abandoned, for copper-base alloys and the production thereof and relating to alloys in which copper is the preponderant element and which contain nickel and zinc.

My invention is essentially concerned with improving alloys consisting of nickel from 4.0 to 22.5%, zinc from 4.0 to less than 20.0% and copper, the quantity of nickel not exceeding twice the quantity of zinc and preferably being not less than ⅘ and not more than ¾ of the quantity of zinc. These alloys are hereinafter referred to as the "basic alloys." The percentages of the alloying elements herein and in the claims are stated by reference to weight.

I have found that the addition of cadmium above a certain minimum quantity and within certain proportions not only enables corrosion resistance to be improved but also enables high hardness, tensile strength and elongation values to be obtained with the requisite mechanical working and annealing, but that some of such alloys will respond satisfactorily to subsequent heat treatment or treatments and to further mechanical working still further to increase the hardness and tensile strength without undue reduction of the elongation value.

It has been proposed to add aluminium to copper-nickel-zinc alloys, e. g., U. S. patent specification No. 2,101,625 in an amount from 0.5% to 3.0% to increase hardness, but this increase is stated to be obtained only when nickel and aluminium are present together in the alloy.

The hardening effect of aluminium is again mentioned in U. S. patent specification No. 2,101,930 when the aluminium is present from 0.5% to 3.0% together with nickel, and the patentee stating that if the aluminium is omitted, little or no hardness is obtained by heat treatment at low temperatures (heating for two hours at a temperature of 450° C. is referred to). In this specification it has been proposed to add cadmium from 0.05% to 3.0%, primarily to enhance corrosion resistance, the amount employed in each example being 0.5%.

The improved alloys according to my invention are substantially free from aluminium which has deleterious effects on the aforesaid basic alloys leading for example to "hot-shortness" in the case of hot rolling the alloys, and to striations in cold rolling and polishing due to particles of aluminium having failed to go into solution, segregated at the grain boundaries and also being present in the form of abrasive aluminium oxide and rendering the alloys prone to brittleness and inter-crystalline failure.

I have found that in the absence of aluminium the addition of cadmium to the said basic alloys has the property of itself causing greatly improved tensile strength and hardness at least comparable to those obtained by the aluminium-containing alloys. Moreover, the addition of cadmium to at least some of the said basic alloys renders the alloys readily responsive to heat treatment at low temperatures after being mechanically worked,

e. g., rolled, and in some cases will cause increased hardness of the alloys when treated at temperatures as low as 100° C. and I have in some cases even obtained optimum results as to hardness when the temperature is as low as 250° C. to 300° C. Moreover I have obtained the increased hardnesses with heat treatments of as little a duration as half an hour.

To the foregoing ends, improved alloys according to the present invention are substantially free from aluminium and comprise not less than 4.0% or more than 22.5% nickel, not less than 4.0% to less than 20% zinc, not less than and preferably more than 0.5% and not more than 3.5% of cadmium and not less than 55 percent of copper, the quantity of nickel being, preferably, not less than ⅘ and not more than ¾ of the quantity of zinc, and, in any event, not exceeding twice the quantity of zinc. The mechanical properties, e. g., ductility may be further improved by the addition of iron from 0.01 to 2.50 percent.

Alloys according to my invention, having a rich gold colour and lustre and with a texture enabling them to take a high polish, consist of copper and the following additional metals, viz.,

Range 1

	Percent
Nickel	4.00 to 8.00
Zinc	4.00 to 8.00
Cadmium	1.25 to 2.25
with or without	
Iron	0.01 to 1.00

and I have obtained good results with an alloy (hereinafter referred to as alloy "A") consisting of copper and the following additional metals:

	Percent
Nickel	6.00
Zinc	5.90
Cadmium	1.75
Iron	0.20

The colour varies according to the composition and alloys with a pleasing silver-like colour and lustre and of a texture enabling them to take a high polish are produced and high corrosion resistance obtained by employing nickel and zinc in the higher amounts in the maximum ranges herebefore mentioned, i. e., alloys consisting of copper and the following additional metals:

Range 2

	Percent
Nickel	15.00 to 22.50
Zinc	15.00 to 19.75
Cadmium	0.75 to 2.75
with or without	
Iron	0.01 to 1.00

One alloy (hereinafter called alloy "B") within the limits just referred to consists of copper and the following additional metals:

	Percent
Nickel	17.45
Zinc	19.00
Cadmium	2.25
Iron	0.30

The improved alloys may be produced free from inclusions, blowholes and other faults by ordinary known melting or casting methods, and in melting practice particularly during pouring it is desirable to avoid undue air currents in the neighbourhood of the molten metal.

The alloys after casting may be mechanically worked, e. g., rolled in the case of sheet material until the required gauge is reached. The alloys may also be extruded through dies. Annealing may be done after each

working in the usual manner at the customary temperature for the present type of alloy, e. g., in the range of from 550° C. to 880° C., the alloy being air-cooled from this temperature, but quenching has also proved satisfactory with some of the alloys.

The improved alloys can be produced in the form of sheet, strip, tube, pipe, wire, bar, rod, or other forms and a great variety of articles may be formed or machined therefrom, e. g., by cold or hot drawing and stamping, pressing, forging, cutting, piercing, drilling and turning. Many of the said alloys are capable of taking spring temper and can be soldered, brazed or welded.

Some of the improved alloys are responsive and may be subjected to heat treatment at low temperatures to increase the hardness and tensile strength, and this heat treatment may be followed by mechanical working still further to increase these values.

Comparative tests have been made between alloy "A" and a tri-partite alloy consisting of 88 percent copper, 6 percent nickel and 6 percent zinc (hereinafter termed alloy "Z") which has a gold colour and good lustre. Alloy "Z" can be mechanically worked and annealed at a temperature from 450° C. to 750° C. and when reduced by mechanical working, e. g., rolling, hardens and acquires good tensile strength and elongation values.

These tests showed that alloy "A" in the fully annealed condition had a tensile strength of 20–24 tons per sq. inch, a diamond point hardness of 75 to 80, and an elongation of 50–60 percent in 2 inches, whereas the corresponding figures for alloy "Z" were: tensile strength 15–18 tons per sq. inch, a diamond point hardness of 62 to 70 and an elongation of 45–50 percent in 2 inches. Alloy "A" was rolled by the customary methods to a tensile strength of 45 tons per sq. inch and a diamond point hardness of 220–235 whereas the corresponding figures for alloy "Z" were 32–36 tons per square inch and 125–135 diamond point hardness. At such tensile strengths and hardnesses alloy "A" had an elongation of 15–20% in two inches whereas alloy "Z" had an elongation of 7–10% in two inches.

Further examples of alloys ("C," "D," "E" and "F") within the range 2 according to the invention and which are particularly useful are constituted approximately as follows:

	C Percent	D Percent	E Percent	F Percent
Copper	58.50	64.80	58.50	64.00
Nickel	20.10	15.70	21.25	16.20
Zinc	19.50	18.00	19.00	18.00
Cadmium	1.50	1.20	0.95	1.80
Iron	0.30	0.30	0.30	Nil

The alloys "C," "D," "E" and "F" when reduced by rolling to the percentages shown without intermediate annealing, had the results in diamond point hardnesses set out in the table below:

Percent reduction of area	Alloy "C"	Alloy "D"	Alloy "E"	Alloy "F"
0	136	91	89	90
10	168	(1)	140	(1)
20	186	154	165	(1)
30	209	166	183	(1)
40	227	181	190	(1)
50	230	200	205	(1)
60	235	208	221	(1)
70	250	220	240	255
80	270	236	256	275
90	283	(1)	268	293

[1] No reading taken.

A feature of the invention consists in giving the alloys a heat-hardening treatment at a temperature up to 500° C. preferably following reduction, e. g., rolling. This heat treatment may be followed by further reduction, e. g., rolling, if desired.

I have found that heat hardening is particularly effective in relation to alloys wherein the nickel lies between 15% and 22.50% with the copper content not exceeding 70% and the addition of cadmium kept to the limits of 0.75% to 2.0%, zinc making up the remainder with or without the addition of iron, the latter preferably not exceeding 0.30%. In these heat hardening ranges good ductility has also been obtained.

Specimens of alloy "C" (hereinafter termed "C[1]" and "C[2]") were taken at 90% and 40% reduction, of alloy "D" at 80% reduction, alloy "E" at 90% reduction and alloy "F" at 70% reduction and subjected to such heat treatment with the results in diamond point hardness as shown in the table set out below:

Temperatures, °C.	Alloy "C[1]"	Alloy "C[2]"	Alloy "D"	Alloy "E"	Alloy "F"
As rolled	283	227	236	268	255
100	296	(1)	240	285	(1)
150	(1)	(1)	245	302	(1)
200	310	(1)	258	308	(1)
250	(1)	244	264	325	295
300	356	270	262	333	(1)
350	(1)	293	264	317	(1)
400	363	208	210	225	(1)
450	(1)	210	156	194	(1)
500	262	206	130	156	(1)

Note.—All heat treatment times were of half an hour duration.
[1] No reading taken.

Tensile strengths increased correspondingly with the hardness results and ultimate tensile strengths of over 60 tons per sq. inch were recorded.

Considerable springiness was achieved, and bending tests proved that the alloys respond well, bending through 180° without cracking.

Each of the heat operations hereinbefore described were followed by air cooling but I found quenching, e. g., water quenching, after annealing in certain cases, e. g., alloys "D" and "E," to be satisfactory.

Improved elongation and ductility was observed when the alloys were rolled to full hardnesses with intermediate annealing in place of the reduction by rolling without this method as was carried out for the tests shown in the tables.

By the expression "an alloy consisting essentially of" in the claiming clauses hereof, I mean an alloy which contains the elements expressly therein mentioned in the expressly mentioned amounts and without aluminium save for unavoidable traces, but which may also contain at least one optional element added for those purposes described in metallurgical publications, e. g., up to 10 percent of cobalt to promote strength at high temperature, up to 7.5 percent of lead to promote machineability, up to 5.0 percent of chromium to promote wear resistance, up to 5.0 percent of rhodium to promote water repellance, and up to 3.0 percent of silicon, manganese, titanium, vanadium, beryllium or molybdenum to promote hardness or toughness, or of tantalum to promote resistance to chemical corrosion, or of tellurium for facilitating machining, or of zirconium to promote electrical conductivity, provided that the total of all these optional metals does not exceed 12½ percent of the alloy, and that magnesium, phosphorus, and silver are absent (save for unavoidable traces) or magnesium and phosphorus if present are less than 0.25 percent and 0.1 percent respectively, the addition of silver tending to reduce the susceptibility of the alloys to hardening and furthermore to lessen their corrosion resistance.

Whilst impurities of the unwanted elements in minute quantities cannot always be avoided, these elements should not be added, and their presence even as impurities is undesirable. Moreover it is a feature of the invention that the results aimed at can be obtained by the presence of the elements copper, nickel, zinc and cadmium (with or without iron) without any additional elements, as is shown in the examples herein, and this is

the form I prefer my improved alloys to take, since the fewer the elements that are employed to obtain the desired results, the better in general are the alloys.

What I claim is:

1. An alloy consisting essentially of from 4.0% to 22.5% of nickel, from 4.0% to less than 20% of zinc, more than 0.5% and up to 3.5% of cadmium and not less than 55% of copper, the quantity of nickel not exceeding twice the quantity of zinc.

2. An alloy consisting essentially of from 4.0% to 22.5% of nickel, from 4.0% to less than 20% of zinc, more than 0.5% and up to 3.5% of cadmium, from 0.01% to 2.5% of iron and not less than 55% of copper, the quantity of nickel not exceeding twice the quantity of zinc.

3. An alloy otherwise according to claim 1 save that the upper limit of nickel is 8.0%; and of zinc is 8.0% and the lower and upper limits of cadmium are respectively 1.25 and 2.25%.

4. An alloy otherwise according to claim 1 save that the lower limit of nickel is 15.00%, of zinc is 15.00% and the lower and upper limits of cadmium are respectively 0.75 and 2.00%.

5. An alloy consisting essentially of copper and 6.00% of nickel, 5.90% of zinc, 1.75% of cadmium and 0.20% of iron.

6. An alloy consisting essentially of copper and 17.45% of nickel, 19.00% of zinc, 2.25% of cadmium, and 0.30% of iron.

7. An alloy consisting essentially of copper and 20.10% of nickel, 19.50% of zinc, 1.50% of cadmium, and 0.30% of iron.

8. An alloy consisting essentially of copper and 15.70% of nickel, 18.00% of zinc, 1.20% of cadmium and 0.30% of iron.

9. An alloy consisting essentially of copper and 21.25% of nickel, 19.00% of zinc, 0.95% of cadmium and 0.30% of iron.

10. An alloy consisting essentially of copper and 16.20% of nickel, 18.00% of zinc, and 1.80% of cadmium.

11. An alloy consisting essentially of from 4.0 to 22.5% of nickel, from 4.0 to less than 20% of zinc, from 0.75 to 3% of cadmium and not less than 55% of copper, the quantity of nickel not exceeding twice the quantity of zinc.

References Cited in the file of this patent

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