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COPPER BASE ALLOY

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This invention relates to an improvement in copper base alloys and particularly to an alloy whose principal constituent is copper plus various amounts of nickel, aluminum and zinc, accompanied in the present invention by small but essential amounts of cadmium.

Alloys have been made heretofore consisting essentially of copper, nickel, aluminum and zinc, with and without small amounts of manganese purposely added and are in use because of their valuable properties. The composition range of these alloys is approximately

	Percent
Copper	60. to 98.5
Nickel	.5 to 30.
Aluminum	.5 to 4.
Zinc	.5 to 39.
Manganese	0. to 1.

We have discovered that when small amounts of cadmium from about .05% to about 3.% are purposely added to these copper-nickel-aluminum-zinc alloys, new and valuable characteristics are obtained not heretofore found in said alloys.

An alloy or alloys made in accordance with the present invention are suitable for the same uses as the previously mentioned copper-nickel-aluminum-zinc alloys, and in addition have several new uses hereinafter mentioned. A considerable improvement in corrosion resistance, and especially resistance to oxidation at all temperatures below 500° C., is obtained with our improved alloy or alloys.

A very important advantage of an alloy embodying the essential features of the present invention is the excellent resistance which they offer to attack by corrosion. The improved alloys are almost impervious to intercrystalline attack or corrosion when exposed to steam and hot water under pressures as high as 130 lbs./sq. in. for long periods of time. This strong resistance to corrosion was found in the improved alloys even when stressed up to 80 percent of the ultimate tensile strength in a steam chamber with the steam pressure maintained at about 130 lbs. per sq. in. For example, an old type alloy wire containing about 65 percent copper, 5 percent nickel, 1.5 percent aluminum and 28.5 percent zinc, when tested in steam with a load equal to 80 percent of the ultimate tensile strength, as mentioned above, remained in the steam chamber only four hours before breaking. An improved alloy wire similar to the above, except that it contained about 0.50 percent cadmium, lasted 48 hours in the steam chamber before failure with a load equal to 80 percent of the ultimate tensile strength.

The improved alloys possess valuable corrosion resistance properties that are especially suitable for use in steam expansion joints, condenser tubes, flexible metal hose, welds, valves, tanks and the like and are also valuable for general structural and fabricating purposes.

After annealing or heat treating these improved alloys, the presence of a thin, light-brown film was noted on the surface of the wire. This film was also noted on annealed wire which had been pickled in dilute sulphuric acid (1 to 10), thoroughly rinsed in water and dried in an oven at about 100° C. This film appears to afford some protection against intercrystalline attack or corrosion, and is definitely associated with the presence of cadmium in the alloy.

Another very important advantage of an alloy embodying the essential features of the present invention is the great increase in tensile strength and hardness that may be obtained by heat treatment at low temperatures when the nickel content exceeds 3.0 percent and the aluminum content exceeds 0.50 percent. For example, such an alloy hot rolled and finished by the usual methods of cold rolling and annealing, had a tensile strength, cold drawn, of 126,500 lbs. per sq. in. After heat treating two hours at approximately 350° C. the tensile strength of the said cold drawn wire was increased to 152,900 lbs. per sq. in. Specimens of said wire when annealed at approximately 825° C. for 1 hour and quenched had a tensile strength of 70,400 lbs. per sq. in. which, after heat treatment for two hours at approximately 450° C., was raised to 114,500 lbs. per sq. in. This increase in strength, strangely enough, is accompanied by an increase in elongation. This increase in elongation means an increase in ductility and indicates greater resistance to fatigue of the hardened alloy made according to our invention as opposed to low percentage elongation or brittleness which is found in several age hardened alloys.

The importance of this age hardening or precipitation hardening is readily apparent. Articles may be fabricated from the annealed or wrought alloy, and when finished, may be hardened by low temperature heat treatment. Because the alloy is not susceptible to softening at temperatures up to 500° C., it is suitable for condenser tubes, parts for internal combustion engines and other uses subject to operating tem-

peratures below 500° C. The resistance of this alloy to wear, when hardened, is noteworthy.

An alloy made in accordance with the present invention comprises as essential ingredients the following metals; in about the ranges of composition stated:

	Percent
Copper	60. to 98.7
Cadmium	.05 to 3.0
Nickel	.5 to 30.0
Aluminum	.25 to 4.0
Zinc	.5 to 39.2
Manganese	0. to 1.0

Because it cannot be avoided without too much expense in refining the constituent metals, there may be and usually is some iron present. The iron content usually varies from 0.01 percent to about 0.20 percent.

Manganese in small amounts is oftentimes purposely added to these alloys, essentially for the purpose of fluxing and to improve or insure the soundness of the casting. It may be omitted, and when added is from .001 to about 1%.

In any event, the presence of manganese in amounts up to about 1% does not materially affect the excellent corrosion resistance obtained by the cadmium addition or the age hardening characteristics stated herein.

Tin in amounts up to about 1 percent may be added to the improved alloy or alloys to obtain a slight increase in strength and hardness. However, the addition of tin is not warranted insofar as corrosion resistance and age hardening are concerned, and it may be omitted.

The great increase in hardness is obtained only when nickel and aluminum are present together in the alloy and when the nickel content exceeds 3 percent. Our experiments have shown that at least 3 percent nickel must be present with at least 0.5 percent aluminum to obtain an alloy that can be hardened satisfactorily by heat treatment at low temperatures. If the aluminum is omitted, little or no hardening is obtained by heat treatment at low temperatures. If the cadmium is omitted, the resistance of the alloy to attack by corrosive agents and especially to intergranular attack by steam is lowered considerably.

Consequently, if one desires to obtain a corrosion resistant alloy which is also capable of being hardened satisfactorily by low temperature heat treatment, he must select from the following composition range:

	Percent
Copper	60. to 95.95
Cadmium	.05 to 2.0
Nickel	3.0 to 30.0
Aluminum	.5 to 3.0
Zinc	.5 to 36.45

For improving the soundness of the castings manganese may be added from .01 to about 1 percent.

If one desires only excellent corrosion resistance in an alloy of moderate strength and hardness but which cannot be hardened to any great extent by precipitation, the following composition range is suitable.

	Percent
Copper	60. to 98.7
Cadmium	.05 to 2.0
Nickel	.5 to 2.5
Aluminum	.25 to 3.0
Zinc	.5 to 39.2

For improving the soundness of the castings manganese may be added from .01 to about 1 percent.

In view of the fact that our improvement includes several copper - nickel - aluminum - zinc - cadmium alloys, it is difficult to state any single preferred alloy in the group. However, for informative purposes we are listing a few of the most important alloys which have been specifically improved by our invention. The composition of five of these alloys that can be readily cold worked and (or) hardened by heat treatment at low temperatures, if desired, are now given. For example:

	(a)	(b)	(c)	(d)	(e)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Copper	65.0	65.0	92.0	68.0	68.0
Cadmium	0.5	0.5	0.5	0.5	0.5
Nickel	18.0	5.0	5.0	10.0	15.0
Aluminum	1.5	1.5	1.5	1.5	2.0
Zinc	15.0	28.0	1.0	20.0	14.5

When manganese is added these alloys would be approximately as follows.

	(a)	(b)	(c)	(d)	(e)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Copper	65.0	65.0	92.0	68.0	68.0
Cadmium	0.5	0.5	0.5	0.5	0.5
Nickel	18.0	5.0	5.0	10.0	15.0
Aluminum	1.5	1.5	1.5	1.5	2.0
Zinc	14.85	27.95	.95	19.92	14.4
Manganese	0.15	0.05	0.05	0.08	0.1

Improved alloys of this type, either with or without the manganese, containing more than 60% copper that have been work hardened by drawing or rolling can be softened by annealing at approximately 825° C. and quenching in cold water. The annealed or work hardened metal, whether in the form of sheet, rod, tube, et al., can be readily fabricated into the finished product and then hardened to the extent desired by a suitable heat treatment in the range of temperatures approximately 300° C. to 550° C. This property of being hardenable is especially valuable for such articles as nuts, bolts, fuse bodies, primers, nipples, valves, springs, wire screens, hinges, chains, jewelry, tableware, coins, keys and clock parts.

Some of these improved alloys can be readily cold worked but cannot be hardened or only to a slight extent by precipitation at low temperatures. Such alloys are within substantially the following ranges.

	Percent
Copper	60. to 98.7
Cadmium	0.05 to 2
Nickel	0.5 to 2.5
Aluminum	0.25 to 4
Zinc	0.5 to 39.2

and

	Percent
Copper	60. to 98.7
Cadmium	0.05 to 2
Nickel	0.5 to 30
Aluminum	0.25 to 0.5
Zinc	0.5 to 39.2

When manganese is added to either of these groups it will be approximately from 0.01% to 1%.

Examples of specific alloys within these ranges

which we have found to be particularly useful are approximately as follows:

	(a)	(b)	(c)	(d)	(e)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Copper	68.0	68.0	65.0	65.0	68.0
Cadmium	0.5	0.5	0.5	0.5	0.5
Nickel	17.0	10.0	5.0	2.0	1.0
Aluminum	0.25	0.25	0.25	0.4	1.0
Zinc	14.25	21.25	29.25	32.1	29.5

When manganese is added these alloys would be approximately as follows:

	(a)	(b)	(c)	(d)	(e)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Copper	68.0	68.0	65.0	65.0	68.0
Cadmium	0.5	0.5	0.5	0.5	0.5
Nickel	17.0	10.0	5.0	2.0	1.0
Aluminum	0.25	0.25	0.25	0.4	1.0
Zinc	14.20	21.23	29.24	32.09	29.49
Manganese	0.05	0.02	0.01	0.01	0.01

Having thus set forth the nature of our invention, what we claim is:

1. An alloy comprising copper, cadmium, nickel, zinc and aluminum in proportions within the following ranges:

	Percent
Copper	60. to 98.7
Cadmium	.05 to 3.0
Nickel	.5 to 30.0
Aluminum	.25 to 4.0
Zinc	.5 to 39.2
Manganese	0. to 1.0

said alloy being characterized by superior resistance to intercrystalline attack or corrosion when exposed to steam or hot water.

2. An age hardenable copper base alloy characterized by superior resistance to intergranular attack when stressed or unstressed in steam wherein the improved hardness is obtained by heat treatment at temperatures ranging from 300° C. to 550° C. comprising amounts of copper, cadmium, nickel, zinc and aluminum in proportions substantially within the following ranges:

	Percent
Copper	60. to 95.95
Cadmium	.05 to 2.0
Nickel	3.0 to 30.0
Aluminum	.5 to 3.0
Zinc	.5 to 36.45

3. A heat treatable copper-zinc alloy containing from .5 to 36.% zinc, .05 to 3.0% cadmium, 3. to 30.0% nickel, and .5 to 3.0% aluminum, and balance substantially copper, and the nickel content being at least 3 times the alumium content, wherein improved hardness is obtained by heating the alloy to the neighborhood of 750° C. to 900° C., rapidly cooling and reheating to a temperature of about 300° C. to 550° C., and said alloy being characterized by superior resistance to intercrystalline attack or corrosion when exposed to steam or hot water.

4. A heat treated and artificially aged copper-base alloy containing from .5 to 36.% zinc, .05 to 3.0% cadmium, 3. to 30.0% nickel and .5 to 3.0% aluminum, the balance of the alloy consisting principally of copper and the nickel content being at least three times the aluminum content, wherein improved hardness is obtained by heating the alloy to the neighborhood of 750° C. to 900° C., rapidly cooling, cold working and reheating to a temperature of about 300° C. to 550° C., and said alloy being characterized by superior resistance to intergranular attack when exposed to steam or hot water.

5. An alloy composed of copper, cadmium, nickel, zinc and aluminum in proportions within the following ranges:

	Percent
Copper	60. to 95.95
Cadmium	.05 to 2.0
Nickel	3.0 to 30.0
Aluminum	.5 to 3.0
Zinc	.5 to 36.45

6. An alloy comprising approximately 65% copper, 5% nickel, 0.5% cadmium, 1.5% aluminum, and 28.% zinc.

7. An alloy comprising approximately 92% copper, 5% nickel, 0.5% cadmium, 1.5% aluminum and 1% zinc.

8. An alloy comprising approximately 65% copper, 18% nickel, 0.5% cadmium, 1.5% aluminum, and 15% zinc.

9. An alloy characterized by superior resistance to softening in service in steam and other atmospheres at temperatures up to 500° C. composed of from 0.5 to 36% zinc, 0.05 to 3% cadmium, 3 to 30% nickel, 0.5 to 3% aluminum, and the balance substantially copper.

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