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COPPER-NICKEL ALLOYS

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ABSTRACT OF THE DISCLOSURE

Corrosion-resistant copper-nickel alloy containing 25 to 35% nickel, 0.7% titanium, up to 0.6% beryllium with the balance copper. The titanium and any beryllium present in the alloy are related to each other and to the temperature at which the alloy is to be used, i.e., when the temperature of use is less than 600° C., beryllium is present in amounts of at least 0.3%. Above 600° C. the amount of titanium present plus the amount of any beryllium present is 0.5% to 1.2%.

The present invention relates to alloys and, more particularly, to copper-base alloys containing nickel.

It is well known that cupronickel alloys nominally containing 30% nickel have high resistance to attack by alkalis and, more importantly, to the corrosive effects of rapidly moving sea water and other briny solutions. These attributes coupled with their excellent resistance to stress-corrosion cracking have made them very attractive for use in condensers, as distiller, evaporator and heat-exchanger tubes and as ferrules.

Another potential use for the 70:30 cupronickel alloys is in desalinization equipment. This could be a very high volume use particularly since the demands for more and more fresh water have been growing steadily. But, in order to insure its application for sea water conversion and to maintain its continued use in condensers, evaporators, heat exchangers and other corrosion-resistant heat transfer equipment, the art has been endeavoring to improve the high temperature properties and/or characteristics of the cupronickels so that such equipment can be utilized at the higher temperatures needed for more economical operation. For example, at the present time, multistage flash distillation appears to be one of the more promising processes for the conversion of sea water. This process requires a great deal of heat and the handling of large quantities of very corrosive hot sea water with a minimum of damage to the equipment for efficient production of fresh water.

The problem of providing a material having the dual attributes of being capable of withstanding high temperatures plus being resistant to highly corrosive environments has been difficult to achieve and has led the art to try other metals and alloys. However, the attempts to substitute Type 304 and Type 316 stainless steels, which have fairly good high temperature properties and/or characteristics, for the 70:30 cupronickels have not been too successful because these steels have shown a tendency toward pit corrosion at the high heat needed in desalinization. Accordingly, the art has redirected their efforts to improving the cupronickels to solve the problems.

Prior art efforts to improve the cupronickels have not been too fruitful either since it is not enough that the material merely have the foregoing desirable attributes. In addition, they should be readily weldable and easily hot and cold workable into rods, tubes, tube sheets, nuts, bolts, etc. Although many attempts have been made to provide such cupronickel alloys, none, as far as we are aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that 70:30 cupronickels, which have high strength at temperatures up to 600° C. and higher, corrosion-resistance to hot sea and fresh water as well as good weldability and workability, may be economically obtained with relatively small amounts of additional alloying.

It is an object of the present invention to provide new 70:30 type cupronickel alloys having a unique combination of properties and/or characteristics.

Another object of this invention is to provide novel copper alloys having improved age-hardening characteristics.

The invention also contemplates new copper-nickel alloys having good room and elevated temperature properties and/or characteristics in wrought form together with good weldability.

It is a further object of this invention to provide improved copper-base alloys having good casting characteristics.

Still another object contemplated by this invention is the provision of copper-nickel alloys which have excellent strength at room and elevated temperatures yet are readily worked and fabricated into common and complex forms and shapes.

It is another object of this invention to provide cupronickel alloys having good strength in the stress-relieved (solution annealed) and aged condition as well as in the cold-worked and aged condition.

One of the other objects of this invention contemplates a special process for improving the strength of the 70:30 type cupronickels by the addition of one or more selected alloying ingredients in relatively small amounts without detrimentally affecting the workability, corrosion-resistance and/or weldability of these alloys.

Other objects and advantages will become apparent from the following description:

Generally speaking, the present invention contemplates the production of readily weldable and workable copper-nickel alloys having unexpectedly good metallurgical, physical and mechanical properties and/or characteristics over a wide range of temperatures including temperatures up to 600° C. and higher, e.g., 750° C., together with good resistance to corrosion in the presence of hot saline solutions. According to this invention, the copper-nickel alloys contain, by weight, 25% to 35%, e.g., 27% to 33%, nickel, up to 3% manganese, up to 1.5% iron, 0.1% to 0.7% titanium and up to 0.6% beryllium. However, the titanium and beryllium are related to each other and to the temperature of intended use of the alloy so that when the temperature of use is less than 600° C., the beryllium is present in amounts of at least 0.3%. On the other hand, when the temperature of use is at least 600° C., the amount of the titanium present plus the amount of any beryllium present is at least 0.5% but less than 1.2%. Advantageously, at temperatures in excess of 700° C., the alloy is substantially free of beryllium and the titanium content is between 0.5% and 0.7%. In addition to the foregoing elements in the amounts heretofore set forth, the alloys of this invention also contain copper which makes up the balance of the alloys aside from the usual impurities and residual deoxidizers. Advantageously, the copper employed is at least 99.5% pure.

The alloys of this invention containing the aforementioned ingredients in the aforementioned proportioned amounts are characterized by being producible in accordance with normal foundry procedures and by having good casting behavior, e.g., all the surfaces of the alloy are smooth in the as-cast condition. These alloys are further characterized by being age-hardenable and by having high strengths in the solution-annealed and aged condition as well as in the cold-worked and aged condition.

The age-hardenability of the present alloys is attributable to the titanium or the titanium plus beryllium contained therein provided that such element or elements are present in the amounts hereinbefore specified. Thus, titanium is always present in the alloys of this invention in amounts of at least 0.1% but not more than 0.7% If less than 0.1% titanium is present, the alloys do not have the proper aging response for optimum properties and/or characteristics. On the other hand, if more than 0.7% titanium is present, the alloys become embrittled and difficult to work. In addition, alloys containing more than 0.7% titanium surprisingly have less strength than those containing titanium in the amounts set forth herein. Advantageously, titanium is present in amounts of at least 0.15% except when the alloy is to be used at temperatures in excess of 600° C. and beryllium is not copresent. In this situation, titanium is present in amounts of at least 0.5% and, advantageously, in amounts of at least 0.6%.

Beryllium, when used in combination with titanium in the amounts and under the conditions specified, contributes very importantly to the properties and/or characteristics of the copper-nickel alloys of this invention. Thus, when the alloys are to be employed at temperatures of less than 600° C., beryllium is present in amounts of at least 0.3% while the titanium is present in amounts of at least 0.1%. On the other hand, when the temperature of use is at least 600° C., no beryllium need be present so long as there is at least 0.5% titanium present. However, if the titanium content is less than 0.5% beryllium must be copresent in amounts such that the sum of beryllium plus titanium is at least 0.5% but not more than 1.2%. Advantageously, the alloys of this invention are substantially free of beryllium, e.g., less than 0.01%, when the temperature of use is high, e.g., greater than 700° or 750° C. Apparently, beryllium forms a precipitate in such an alloy system at an aging temperature of between 500° and 600° C. However, if the aging temperature or temperature of use exceeds 600° C., the alloys appear to overage and the beryllium seems to agglomerate at the grain boundaries thereby weakening the alloy. On the other hand, titanium seems to provide the alloy system with continuing aging response between 600° and 650° C. and greater strength at temperatures in excess of 700° C. when beryllium is not copresent.

As was pointed out hereinbefore, the alloys of this invention may also contain, by weight, up to 3% manganese and up to 1.5% iron in accordance with the Defense Department specification Mil-C-15726D which calls for up to 1.5%, e.g., 1%, manganese and 0.4 to 0.7% iron. The manganese is added to improve weldability and to obviate the detrimental effects of any sulfur which may be present besides serving as a deoxidizer. Iron of course contributes to the strength of the alloy.

Silicon may be tolerated in the alloys of the present invention in amounts not exceeding 0.3%, e.g., 0.2% and, advantageously, not exceeding 0.1%. Above 0.3%, silicon causes hot-shortness rendering the alloys difficult to fabricate and limiting their use as castings only.

Advantageously, the cupronickel alloys of this invention are substantially devoid of carbon and such low melting point elements as zinc, bismuth, lead, sulfur, tin and phosphorus since they have an adverse effect on the otherwise good metallurgical and/or physical properties of these alloys. For example, zinc appears to have a tendency to concentrate in the grain boundaries and thus weakens the alloys. Accordingly, the amount of zinc that can be tolerated is less than about 0.01% and, preferably, it should not be present in any amount which is detectable by a spectrum analysis.

Bismuth embrittles the alloys of this invention and should be kept below 0.001% while lead should be kept below 0.01% since it also has an embrittling effect and may seriously impair forging behavior. Tin should not be present in amounts exceeding 0.1% as it will soften the alloy particularly at the higher temperatures of use. In addition, the presence of tin deteriorates the otherwise good welding characteristics of the alloys of this invention.

Phosphorus is another element having a deleterious effect on the alloy system and should be kept below 0.01% to insure good hot workability. Accordingly, the use of phosphorus-deoxidized copper scrap in the making of these alloys should be avoided. Carbon not only causes hot-shortness as does phosphorus, but also has a detrimental effect on the cold working of these alloys. Preferably, the amount of carbon present should be less than 0.08%, e.g., 0.05%.

Sulfur in the small quantities of the order of 0.01% renders nickel-containing copper alloys unworkable apparently because of the presence of a nickel-nickel sulfide eutectic of relatively low melting point that segregates at the grain boundaries. However, the bad effects of sulfur can be minimized by the inclusion of either magnesium or manganese during melting. Each of these elements has an affinity for sulfur and combines with any sulfur present to form small globules which have no embrittling effect during hot working.

In carrying the invention into practice, more advantageous results are achieved when the ingredients employed in the melt have a purity of at least 99.5% each and when these ingredients are present in the amounts at the specified temperatures of use as set forth in Table I.

TABLE I

Temperature of Use, ° C.	Ingredients, percent*			
	Nickel	Titanium	Beryllium	Ti and Be
Below 600	27 to 33	0.15 to 0.7	0.3 to 0.6	<1.2 (at least).
600 to 700	27 to 33	0.15 to 0.7	Up to 0.6	(0.5 to 1.2).
Above 750	27 to 33	0.5 to 0.7	<0.01	

*Balance copper and less than 0.05% carbon.

Each of the alloys, which may optionally also contain up to 1.5% manganese and up to 1% iron, set forth in Table I has an ultimate tensile strength (UTS) in excess of 90,000 pounds per square inch (p.s.i.) in the unaged but cold-worked condition when the amount of cold-working is at least 50% and a 0.1% offset yield strength (YS) of at least 40,000 p.s.i. after aging at the very high temperature of 750° C. for one hour and a YS of at least 90,000 p.s.i. after aging at 600° C. for one hour.

The invention also contemplates a process for improving the physical and metallurgical, including strength, properties and/or characteristics of copper-base alloys, containing, by weight, 25% to 35% nickel and optionally containing up to 3% manganese and up to 1.5% iron. This process comprises strengthening the alloys by age-hardening with 0.1% to 0.7% titanium and up to 0.6% beryllium with the proviso that when the alloy is to be employed at temperatures below 600° C., beryllium is present in amounts of at least 0.3% and when the alloy is to be employed at temperatures above 600° C., the sum of the titanium and any beryllium present is at least 0.5% but less than 1.2%. Advantageously, when the temperature of use is greater than 700° C., e.g., 750° C., no beryllium is added to the alloy but titanium is added in amounts of between 0.5% and 0.7%.

For the purpose of giving those skilled in the art a better understanding of the invention and a better appreciation of its advantages, a number of examples having varying amounts of alloying ingredients are hereinafter set forth. In each of these examples, a number of cupronickel alloys were prepared by melting copper and nickel together in a graphite crucible at a temperature of about 1400° C. Each melt was stirred until all of the nickel was dissolved. The temperature of each such melt was then lowered to 1350° C. and the other alloying element and/or elements were added and held at that temperature for 5 minutes.

The nickel used in these examples was of the electrolytic grade while the titanium addition was in the form of a copper-titanium master alloy nominally containing 24% titanium by weight. Any beryllium addition to the melt was also in the form of a copper-base master alloy in which the nominal beryllium content was 4% by weight. The copper used was a high-purity copper but copper of lesser purity, e.g., one that is 99.5% pure, is also usable within the scope of this invention as those skilled in the art will readily appreciate.

After melting, the copper-base alloys were poured into 1" diameter molds to form castings which were characterized by having good, clean, smooth surfaces. The melting and casting were done under a protective cover of argon. However, it is to be understood that either the melting or the casting can be successfully accomplished in air without departing from the teachings of the present invention.

Each of the foregoing castings was drilled to obtain samples for chemical analysis and found to have the compositions set forth in Table II.

TABLE II

Alloy Number	Composition, Weight Percent			
	Nickel	Titanium	Beryllium	Copper
1	29.5	0.64		Balance.
2	30	0.19	0.37	Do.
3	30	0.65	0.1	Do.
4	29.9	0.67	0.31	Do.
5	29.95	0.14	0.39	Do.
6	30.1	0.57		Do.
7	30.8	0.66		Do.
8	30.2	0.76		Do.
9*	30.1	0.67		Do.
10	30	0.15	0.4	Do.

*Also contained 0.88% iron and 0.98% magnesium.

EXAMPLE I

Four other copper-nickel alloys (outside the scope of the present invention but seemingly similar to those within the contemplation hereof) were prepared into 1" diameter cast slugs in a manner substantially identical to that employed for Alloys 1 through 10. After chemical analysis, it was determined that the four other alloys had a composition as set forth in Table III.

TABLE III

Alloy Number	Composition, Weight Percent						
	Nickel	Titanium	Beryllium	Silicon	Columbium	Tin	copper
11	29.4			0.52	0.17		Balance.
12	29.2	1.4					Do.
13	28.9	1.38				2.44	Do.
14	29	1.51	0.07			2.5	Do.

All fourteen alloys were then subjected to a hot-rolling operation by preheating each slug at 950° C. for 1 hour. Alloys 1 through 10, within the scope of this invention, were successfully rolled down to 0.25" diameter rods while Alloys 11 through 14, outside the scope of the invention, split. Accordingly, it is clear that the alloys falling within the present invention are hot-workable and useful in wrought form. In addition, it is clear that increasing the titanium beyond the upper portion of the range hereinbefore specified, e.g., as shown by Alloy 12, has a detrimental embrittling effect.

The hot-worked alloys of this invention were also subjected to a variety of treatments including heat treatments, e.g., solution annealing and cold working. These treatments are designated as follows:

Treatment A: Solution annealed at 1040° C. under charcoal for 30 minutes followed by a water quench; cold worked 71% to 0.133" diameter wires; and then solution annealed again at 1040° C. for 30 minutes under charcoal and water quenched.

Treatment B: Solution annealed at 1040° C. under charcoal for 30 minutes followed by a water quench; cold worked 78% to 0.116" diameter wires; solution annealed at 1040° C. for 30 minutes under charcoal and water quenched; and then cold worked 51.2% to 0.079" wires.

Treatment C: Solution annealed at 980° C. for 30 minutes under charcoal and water quenched followed by cold working 90% to 0.079" diameter wires.

Treatment D: Solution annealed at 980° C. for 30 minutes under charcoal and water quenched; cold worked 71% to 0.133" diameter wires; and then solution annealed again at 980° C. for 30 minutes under charcoal and water quenched.

Treatment E: Solution annealed at 1040° C. for 1 hour under charcoal and water quenched; cold worked 71% to 0.133" diameter wires; and then solution annealed at 1040° C. for 30 minutes under charcoal and water quenched.

Treatment F: Solution annealed at 1040° C. for 1 hour under charcoal and water quenched followed by cold drawing 90% to 0.079" diameter wires.

EXAMPLE II

In order to demonstrate the room temperature properties and/or characteristics of the present cupronickels in the unaged but cold-worked condition, specimen of these alloys were subjected to physical testing to rupture and the UTS and YS for each specimen were recorded in p.s.i. In addition, the elongation percent (%) in two inches was similarly noted. These results are set out in Table IV.

TABLE IV

Alloy Number	Treatment Designation	UTS, p.s.i.	YS, p.s.i.	Elongation, Percent
1	B	93,000	85,500	4
2	B	109,000	103,000	4
3	B	99,500	93,000	3
4	B	116,000	109,000	4
5	C	126,000	114,000	3
6	F	97,500	90,000	3
7	F	100,000	93,000	4
8	F	99,000	94,500	4
9	F	105,000	100,000	4

From Table IV, it is manifest that the alloys of the present invention have good room temperature strength together with adequate ductility in the cold-worked but unaged condition.

EXAMPLE III

To illustrate the beneficial high temperature properties and/or characteristics of the cold-worked alloys of the invention, specimens of these alloys were age-hardened after subjection to a treatment as specified for the various alloys in Table III. Each of the alloys was held at the aging temperature for one hour and water quenched. The results of mechanical testing after aging at the temperatures specified and quenching in water are set forth in Table V.

TABLE V

Alloy Number	Aging Temperature, ° C.					
	600		700		750	
	UTS, p.s.i.	YS, p.s.i.	UTS, p.s.i.	YS, p.s.i.	UTS, p.s.i.	YS p.s.i.
1	113,000	100,000	114,000	102,000	104,000	85,000
2	128,000	104,000	86,500	60,500	75,500	45,000
3	131,000	114,500	104,500	84,500	92,000	69,000
4	133,000	107,000	92,500	62,500	84,000	49,500
5	141,500	120,500	77,500	45,000		
6	109,000	101,500	1 6,000	88,000	93,000	75,500
7	114,000	104,500	111,000	94,000	97,500	79,500
8	111,500	104,000	102,000	87,000	73,500	69,500
9	113,000	104,000	109,000	93,500	97,500	79,500

In view of the test data compiled in Table V, it becomes clear that the alloys of this invention have very useful strength properties and/or characteristics at temperatures in excess of 600° C., e.g., 750° C. As a matter of fact, Alloy 1 had an ultimate tensile strength of 89,000 p.s.i. and a yield strength of 69,000 p.s.i. when tested to rupture after first heating the alloy to 780° C., holding at the temperature for one hour and water quenching. Similarly, Alloy 5 had an ultimate tensile strength of

68,500 p.s.i. when tested to rupture after first subjecting the alloy to the very high temperature of 800° C. for one hour followed by a water quench.

In order to draw a comparison and more fully demonstrate the excellent properties of the alloys of this invention, a number of copper-nickel prior art alloys and alloys outside the scope of this invention were prepared and tested in the manner hereinbefore described. Those prior art copper-base alloys and alloys not within the scope of this invention contained the alloying ingredients and the amounts thereof listed in Table VI.

TABLE VI

Alloy Number	Ingredients, Weight Percent (Balance Copper)						
	Nickel	Titanium	Beryllium	Iron	Manganese	Columbium	Others
15	30.4						
16	28.9						[1] 0.14
17	29.4					0.16	[2] 0.1, [2] 0.52
18	30.4	0.15					
19	29.4	0.21	0.1				
20	30.27						[3] 0.3
21	29.67						[3] 0.52
22	30			0.86	1.02		
23	30	0.45					

[1] Zirconium. [2] Silicon. [3] Chromium.

The alloys, excepting Alloys 20 and 21, itemized in Table VI were then subjected to one of Treatments A through F, heat treated for one hour at 700° C. and at 750° C., water quenched and then tested to rupture with the results listed in Table VI. Alloys 20 and 21 were only heat treated for one hour at 600° C.

TABLE VII

Alloy Number	Treatment Designation	Heating Temperature, ° C.			
		700°		750°	
		UTS, p.s.i.	YS, p.s.i.	UTS, p.s.i.	YS, p.s.i.
15	B	45,500	12,500	45,000	14,500
16	B	59,000	21,500	58,000	13,500
17	B	67,500	35,500	66,000	38,000
18	B	53,000	20,500	53,000	20,000
19	B	59,000	26,000	57,500	23,500
20*	C	66,000	36,000		
21*	C	85,000	70,000		
22	F	62,000	24,500	61,000	22,500
23	F	61,000	29,500	59,000	22,500

*Alloys 20 and 21 heated to 600° C. for 1 hour and water quenched.

From Tables V and VII, it is clear that each of Alloys 1 through 9 (within the scope of the invention) had better high temperature properties than any of Alloys 15 through 23 (outside the scope of the invention). For example, Alloys 1 and 9 had a yield strength at the higher temperature treatment more than twice as high as the highest yield strength of Alloys 15 through 23, all of which are outside the scope of this invention.

Furthermore, a comparison of Tables V and VII clearly delineates the effect of varying the titanium or the titanium plus beryllium content even slightly below the lower portion of the ranges set forth in this invention when the temperature of intended use is above about 600° C. This effect is best shown by Alloy 1 (within the scope of the invention) and Alloy 23 (outside this invention). The yield strength of Alloy 1, after a heat treatment at 750° C., is 85,000 p.s.i. which is more than three times the 22,500 yield strength of Alloy 23 containing 0.45% titanium even though Alloy 23 had been cold worked 35% more than Alloy 1.

EXAMPLE IV

The effect of titanium in conjunction with beryllium in amounts of at least 0.4% was shown by comparing the room temperature (unaged) specimens of Alloy 2 containing 0.19% titanium and 0.37% beryllium and Alloy 5 containing 0.14% titanium and 0.39% beryllium with Alloy 19 containing 0.21% and 0.1% beryllium for a total of only 0.31% of titanium and beryllium. Alloy 19 was found to have a yield strength of only 87,500 p.s.i. as compared to 103,000 p.s.i. for Alloy 2 and 114,000 p.s.i. for Alloy 5. When Alloy 19 was subjected to Treatment B in the same manner as Alloy 2, and then aged at 700° C. for one hour and water quenched, it exhibited a yield strength of only 26,000 p.s.i. while Alloy 2, having had identical treatment, had a yield strength of 60,500 p.s.i. which is more than 100% more than the yield of Alloy 19.

EXAMPLE V

In order to show the effect of the aging treatment unobscured by any cold-working, dead soft alloys within and without the scope of this invention were subjected to an aging treatment at varying temperatures for two hours, water quenched and tested to rupture with the results shown in Table VIII. The results of mechanical testing in the dead soft and unaged condition are also included therein.

TABLE VIII

Alloy Number	Treatment Designation	Aging Temperature, ° C.				
		Unaged	600	650	700	750
		0.1% Offset Yield Strength, p.s.i.				
1	A	14,500	60,500	43,000	52,000	39,000
2	A	28,000	74,000	42,500	34,000	32,000
3	A	18,000	50,500	53,500	47,500	40,500
4	A	38,500	93,500	84,000	59,000	48,500
5	D	29,500	45,000			
6	E	15,000	28,000	34,000	45,500	36,500
7	E	14,000	29,000	36,000	45,500	39,500
8	E	17,000	29,000	35,000	42,000	36,000
9	E		28,500	32,500	42,000	34,500
15	A	11,500	11,000	10,500	11,000	11,500
16	A	18,500	18,500	18,000	18,000	17,500
17	A	23,000	24,000	23,500	23,500	21,500
18	A	15,000	16,000	16,000	15,000	15,000
19	A	18,000	20,000	17,500	19,500	17,000
20	D	14,500	17,000			
21	D	21,000	21,500			
22	E	16,000	16,000	14,500	17,000	16,000
23	E	19,000	27,500	29,000	18,000	16,000

Table VIII shows that Alloys 1 through 9 have a definite age-hardening response while the alloys outside the scope of the invention, with the exception of Alloy 23, do not. While Alloy 23 does appear to age-harden, its strength falls off rapidly from an aging temperature of 650° C. upwards. Thus, at the 750° C. aging temperature its yield strength is only 16,000 p.s.i. which is less than half as much as any of Alloys 1 through 9. The ultimate tensile strengths of the alloys of this invention are also higher than those of the other alloys tested. For example, Alloy 4 in the 650° C.-aged condition had an UTS of 116,500 p.s.i. compared to 54,500 p.s.i. for Alloy 18

EXAMPLE VI

The high temperature properties and/or characteristics of the alloys of this invention are shown by stress-rupture tests which were conducted on Alloy 10. At a temperature of 300° C. and a stress of 84,898 p.s.i., the specimen did not rupture even after 2470.4 hours had elapsed. The minimum creep rate for this specimen was 1.2×10^{-7} inch per inch per hour. In other words, it would take over 11 years before a one-inch specimen would elongate 1%.

At a test temperature of 400° C. and the same stress, another specimen had a life-to-rupture of 77 hours and a minimum creep rate of 1.6×10^{-4} inch per inch per hour. At a stress of 65,306 p.s.i., the life-to-rupture was increased to 333.5 hours.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claim.

We claim:

1. An age-hardenable copper-base alloy having good strength over a wide range of temperatures together with

good corrosion resistance, weldability and workability which alloy consisting essentially of, by weight, 25% to 35% nickel, 0.3% to 3% manganese, up to 1.5% iron, not more than 0.08% carbon, 0.1% to 0.7% titanium, up to 0.6% beryllium and the balance copper; beryllium is present in amounts of at least 0.3% and when the temperature of use is at least 600° C. the amount of the titanium present plus the amount of the beryllium present being at least 0.5% but less than 1.2%.

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CHARLES N. LOVELL, Primary Examiner

U.S. Cl. X.R.

75—153, 164

PO-1050
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,488,188 Dated January 6, 1970

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, Table IV, line 3, the YS, p.s.i "93,000" should be --94,500--;

Claim 1, Col. 9, line 3 "0.3% to 3% manganese" should be --up to 3% manganese--;

Col. 9, lines 4 and 5 "up to 0.6% beryllium" should be --0.3% to 0.6% beryllium--;

Col. 9, line 5, after "copper;" delete the rest of the line, all of line 6 and line 7 through "600°C".

For purposes of clarity, claim 1 is rewritten in full with the above changes incorporated therein.

-- 1. An age hardenable copper-base alloy having good strength over a wide range of temperatures together with good corrosi resistance, weldability and workability which alloy consisti essentially of, by weight, 25% to 35% nickel, up to 3% manganese, up to 1.5% iron, not more than 0.08% carbon, 0.1% to 0.7% titanium, 0.3% to 0.6% beryllium and the balance copper; the amount of the titanium present plus the amount o the beryllium present being at least 0.5% but less than 1.2%

SIGNED AND
SEALED
AUG 4 - 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents