

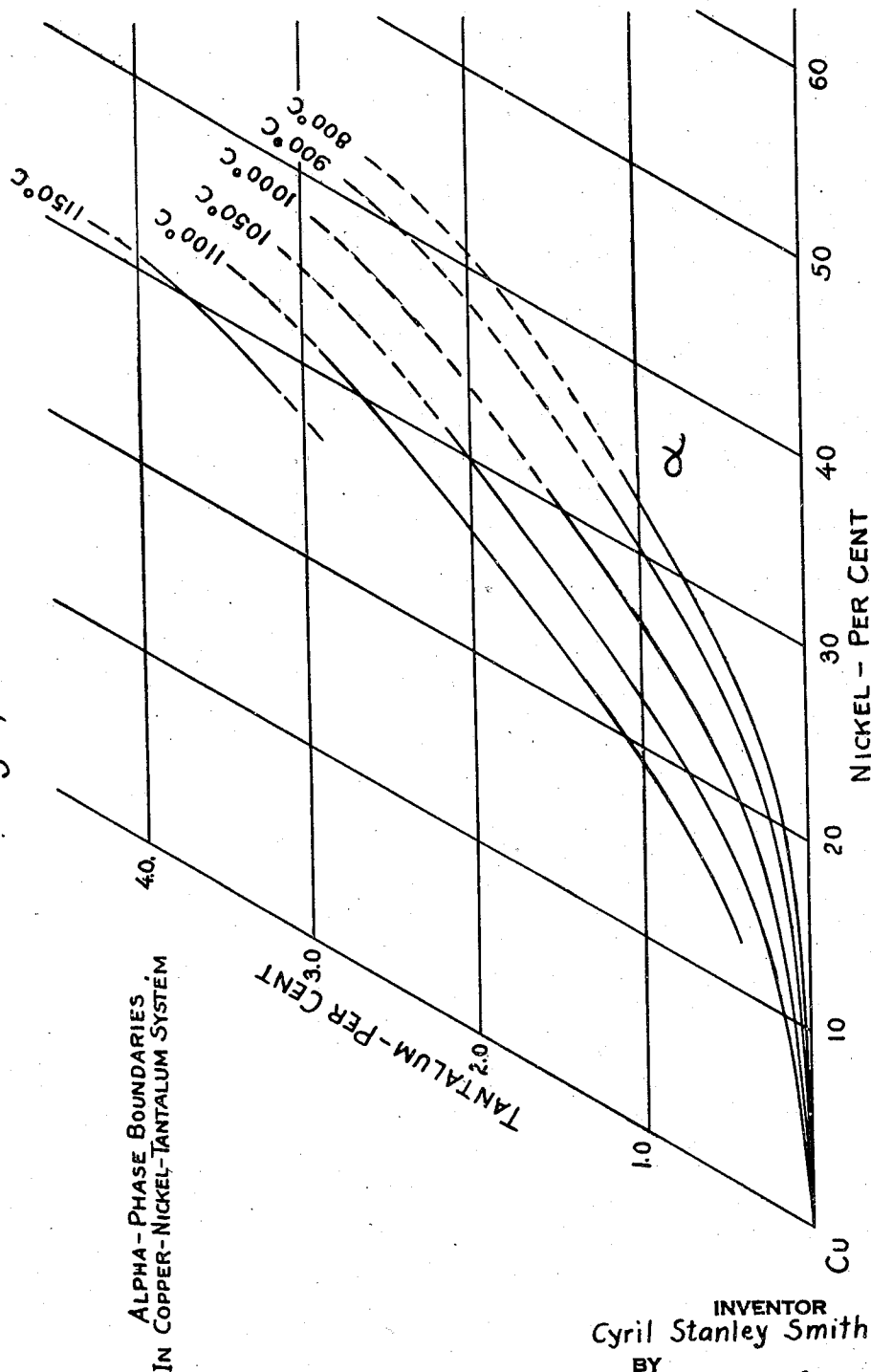
Nov. 4, 1947.

C. S. SMITH
PRECIPITATION HARDENABLE COPPER, NICKEL,
TANTALUM (OR COLUMBIUM) ALLOYS
Filed April 23, 1941

2,430,306

3 Sheets-Sheet 1

Fig. 1,



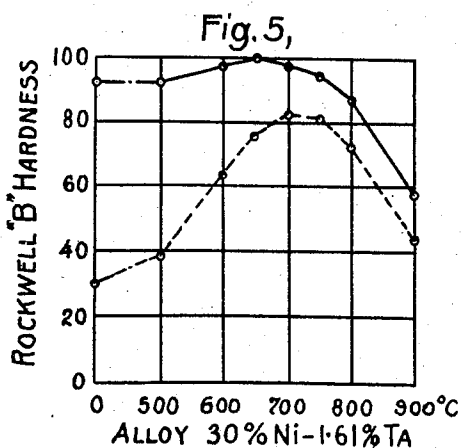
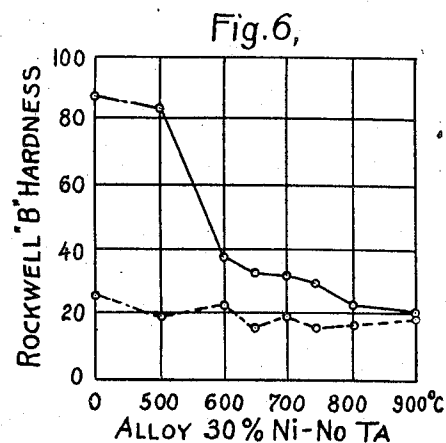
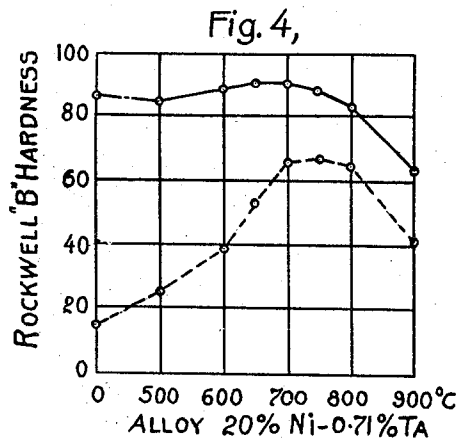
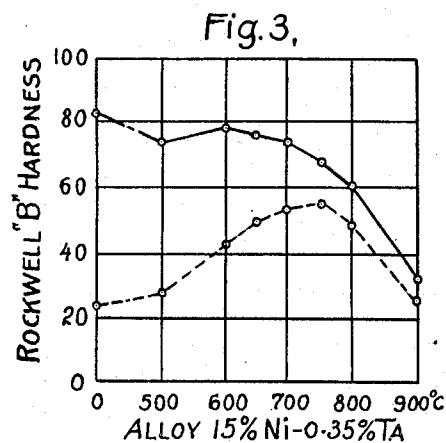
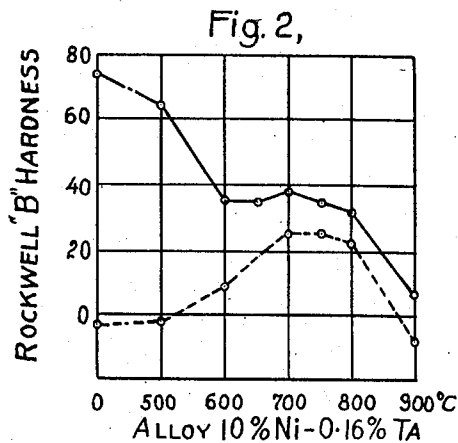
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3 Sheets-Sheet 2



—○—○— Denotes Alloy Quenched from 1100°C. and Reheated 3 Hours at Temperatures Indicated

—○—○— Denotes Alloy Quenched from 1100°C., Cold-Rolled 50% Reduction and then Reheated 3 Hours at Temperatures Indicated.

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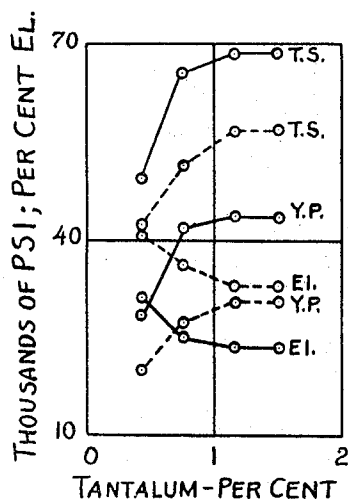
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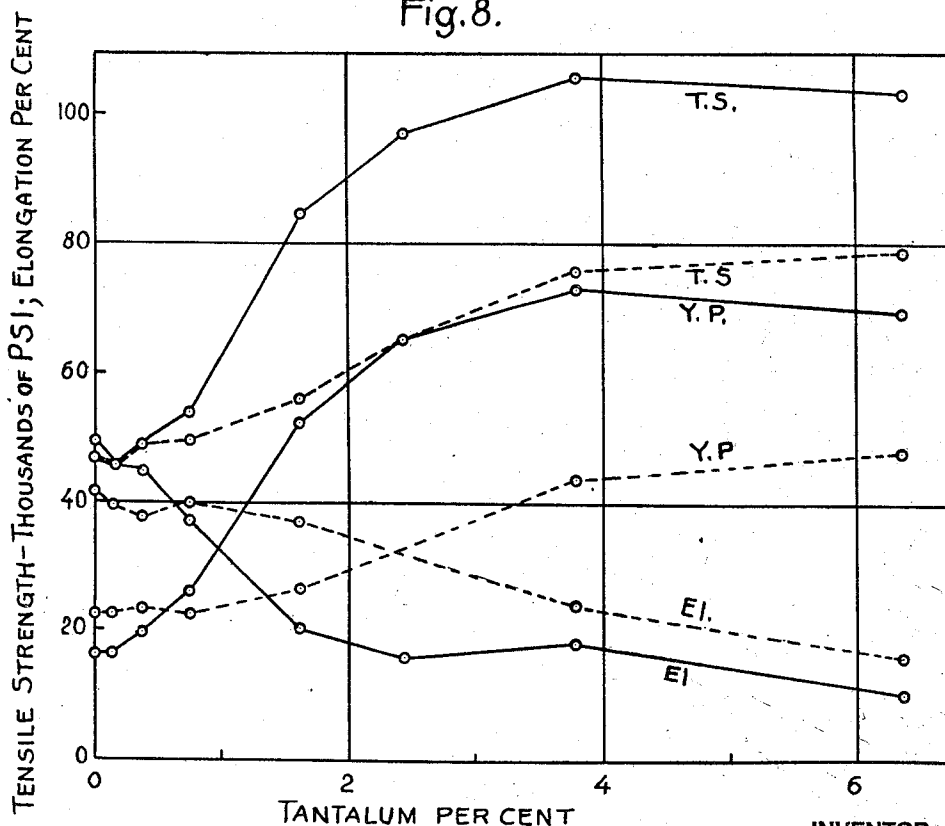
3 Sheets-Sheet 3

Fig. 7.



T.S. = Tensile Strength, p.s.i.
Y.P. = Yield Strength, p.s.i.
El. = % Elongation.
---○--- Denotes Properties of Alloy as Quenched from 1050°C.
—○— Denotes Property of Alloy after Quenching from 1050°C. and Reheating 3 Hours at 725°C.

Fig. 8.



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UNITED STATES PATENT OFFICE

2,430,306

PRECIPITATION HARDENABLE COPPER,
NICKEL, TANTALUM (OR COLUMBIUM)
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Application April 23, 1941, Serial No. 389,871

15 Claims. (Cl. 75-159)

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This invention relates to heat-treatable copper alloys, and has for its principal object to provide a heat-treatable alloy of copper and nickel. More particularly, the invention provides an improved alloy of copper and nickel containing a relatively small amount of tantalum (or columbium, which is the equivalent of tantalum in the alloys of the invention), either alone or in combination with other elements. The new alloys are characterized by high strength and hardness and particularly by the fact that they retain these properties at unusually high temperatures. The alloys are further particularly characterized by being precipitation hardenable, so that it is possible by heat treatment to improve their physical properties. When cold worked, the alloys are remarkably resistant to softening at elevated temperatures.

The alloys of the invention are composed of about 10% to 50% nickel, about 0.1% to 5% tantalum (or columbium), and the balance chiefly copper. At least about 10% nickel is necessary to provide a copper-nickel base alloy in which an effective amount of tantalum will dissolve, and more than about 50% nickel gives a base alloy in which tantalum is so soluble that effective heat treatment is not feasible. The combined amounts of copper plus nickel constitute at least about 80% by weight of the alloy, as pointed out more fully below. Within the range stated, alloys composed of about 15% to 35% nickel and about 0.4% to 3% tantalum, with the balance chiefly copper, are generally most useful, and especially satisfactory alloys are composed within the still narrower range of about 20% to 30% nickel, about 1% to 1.75% tantalum, and the balance chiefly copper.

In preparing heat-treatable alloys in accordance with the invention, the amount of tantalum employed within the range specified should be sufficient, in proportion to the amount of nickel present, to render the alloy susceptible to precipitation hardening. The amount of tantalum necessary for this purpose increases with increasing amounts of nickel, and should be sufficient in relation to the amount of nickel to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the accompanying drawings. Fig. 1 of the drawings is described more fully below.) If columbium, which is the equivalent of tantalum in the new alloys, replaces all or part of the tantalum, then the combined percentage of tantalum and columbium should be sufficient in relation to the amount of nickel so that the numerical value of said combined percentage falls on

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the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the accompanying drawing.

Impurities commonly associated with nickel, copper and tantalum in commercial forms may be tolerated in the new alloys, and additions of other elements may be made, either without detriment to the alloy, or with the attainment of some modification or improvement of its properties. Chief among the elements advantageously added in small amounts are silicon and aluminum. About 0.1% to 2% silicon, and about 0.1% to 2% aluminum, enhance the hardening characteristics of the alloy upon heat treatment.

In heat treating alloys according to the invention, the alloy is first heated to a temperature above about 950° C. but below its melting point to cause the tantalum to go into solid solution. The alloy is then rapidly cooled or quenched, and thereafter preferably is reheated to an elevated temperature of the order of 600° C. to 800° C. Such reheating causes precipitation of the tantalum from solid solution and thereby brings about precipitation hardening of the alloy with significant improvements in tensile properties and hardness.

Advantageously the alloy is cold worked after the rapid cooling or quenching and before reheating. Cold working at this stage materially improves hardness and tensile values achieved by subsequent reheating to effect precipitation hardening. Cold working at this stage has the effect of decreasing to some extent the temperature to which it is necessary to reheat the alloy for precipitation hardening, and accordingly reheating to a temperature of 500° C. to 800° C. is contemplated if the alloy has been cold worked preparatory to reheating.

Cold working of the cooled or quenched alloy brings about such improvement in the physical properties of the alloy that in some cases reheating after cold working may be omitted. It is also possible materially to improve the physical properties of the alloy by subjecting it to cold working after reheating to effect precipitation hardening.

As hereinafter pointed out, precipitation hardened alloys according to the invention are characterized by having a significant proportion of the tantalum (or columbium) present in the alloy in the form of a precipitated compound or phase. The invention will be better understood from the following description considered in connection with the accompanying drawings, in which

Fig. 1 is a plot of a series of isothermal sections through the ternary constitutional model of the system copper-nickel-tantalum;

Figs. 2 to 5 are a series of charts showing the effect of heat treatment in accordance with the invention on the hardness of various of the new alloys;

Fig. 6 is a chart showing the effect of corresponding heat treatment on a copper-nickel alloy containing no tantalum; and

Figs. 7 and 8 are charts showing the tensile properties of certain of the alloys of the invention.

Tantalum is not soluble in molten copper to an extent greater than about 0.04%. I have found, however, that tantalum may be dissolved in relatively larger quantities in alloys of copper and nickel. The solubility of the tantalum in the copper-nickel alloy increases as the nickel concentration increases, and is greater at high temperatures than at low temperatures, as is shown in Fig. 1. The isothermal lines in Fig. 1 show the maximum extent of the alpha solid solution at the various temperatures indicated between 800° C. and 1150° C. On the tantalum-rich side of these lines, the tantalum exists in the form of a compound (or phase) that I believe to approximate Ni_2Ta in composition. Below these lines the tantalum is entirely in solid solution, and the alloy is homogeneous in structure at the stated temperature, when in equilibrium.

It is the change in solubility of tantalum in the alloy at different temperatures which renders the new alloy susceptible to precipitation hardening. Thus, as appears from Fig. 1, a copper-nickel alloy containing 30% nickel will dissolve 2.7% tantalum at 1100° C., an amount that decreases to only 0.7% at 800° C. In order to take advantage of this difference in the solubility of tantalum at different temperatures to improve the properties of the alloy, the alloy is first heated to a high enough temperature to cause all of the tantalum to enter solid solution. The alloy is then rapidly cooled or quenched to hold the tantalum in solution. The quenched alloy thereafter is reheated to a sufficiently high temperature and for a sufficient period of time to cause precipitation of the tantalum from the solid solution, thereby bringing about precipitation hardening and attendant improvement in the physical properties of the alloy.

The effect of such heat treatment on the hardness of some typical alloys is shown in Figs. 2 to 5. These alloys were quenched from 1100° C. and reheated at the temperatures shown. The dotted lines show the hardness of the various alloys as reheated directly from the quenched condition, and the solid lines show the hardness of the same alloys treated by cold rolling 50% reduction after quenching but before reheating. The duration of the reheating treatment was three hours. For comparison, the hardness of a similarly heat-treated 70/30 cupronickel alloy without tantalum is shown in Fig. 6. The behavior of the alloys containing tantalum is more or less characteristic of precipitation hardening alloys, except for the astonishingly high temperature at which the hardening occurs. Thus, maximum hardness is developed in the quenched alloy of the invention by reheating between 700° C. and 800° C., which may be compared with a temperature of less than 100° C. for aluminum alloys, about 300° C. for beryllium-copper alloys, and about 500° C. for chromium-copper alloys. The latter temperature was the highest heretofore recorded for any alloys of copper.

Related to the high temperature of precipitation of the quenched alloys is the fact that the alloys, when cold worked after quenching, do not

commence to soften on annealing until very high temperatures are reached. This is shown clearly in Figs. 2 to 5, and has been confirmed by microscopic examination of alloys with 20% and 30% nickel containing tantalum, which alloys showed no signs of recrystallization after annealing for three hours at temperatures as high as 800° C. A cold-worked 30% copper-nickel alloy without tantalum will recrystallize at 500° C. to 550° C., as shown in Fig. 6. This high softening temperature is obtained with the new alloy whether or not it is reheated for hardening prior to the cold working, but it is advisable that the alloy be initially cooled rapidly from a temperature above about 950° C. to put tantalum in solution if the greatest effect is desired.

Figs. 7 and 8 show the tensile properties of alloys with 20% and 30% nickel, respectively, and with increasing amounts of tantalum. The increase in yield point and tensile strength produced by heat-treatment does not commence until over 1% tantalum is present in the 30% alloy, or about 0.6% in the 20% alloy.

Although particular reference has been made above to copper-nickel alloys containing tantalum, I have found that columbium is substantially the equivalent of tantalum in the new alloys, and that all or part of the tantalum may be replaced by a substantially equal amount by weight of columbium, with the production of an alloy having substantially the same physical properties and susceptibility to the same type of heat treatment as if tantalum alone is employed. I have found that some alloys prepared with the major part of the tantalum replaced by columbium are somewhat less ductile than corresponding alloys made with ferro-tantalum and containing the same total amount of tantalum plus columbium. The base hardness of the former alloy, moreover, was somewhat higher than the base hardness of the alloy prepared from ferro-tantalum, but the hardness, strength, and ductility after heat treatment was practically the same for both alloys.

In preparing the new alloys, no particular difficulties will be encountered by one familiar with the production of cupronickel. Many different practices may be employed. I have generally melted the copper and nickel together, then deoxidized by the addition of a small amount of manganese or magnesium, or both, and added the tantalum. The latter may be in the form of metallic tantalum, a nickel-tantalum alloy containing, for example, 50% tantalum, or as ferro-tantalum or ferro-columbium.

Commercial ferro-tantalum contains about 55% tantalum and about 13% columbium, but since columbium is substantially the equivalent of tantalum, the presence of columbium in the ferro alloy may be considered simply as that much more tantalum, insofar as its effect on the physical properties and heat treatment of the alloy is concerned. The addition of the ferro alloys is preferred at the present time, as they are relatively inexpensive and quite satisfactory as long as the tantalum plus columbium content is over about 60% and the aluminum impurity is not too high. When metallic tantalum is used, it may be added in the form of a powder mixed with a small quantity of flux (potassium tantalum fluoride is suitable for this purpose) and slowly poured on to a clean surface of the molten alloy. The tantalum may also be added as briquettes formed by compressing mixed powders of tantalum with copper or nickel, or other elements or alloys. Columbium may be added in a manner similar

to tantalum, or tantalum or columbium may be used together, as indicated above.

The alloys of copper, nickel, and tantalum may also be made by pressing and sintering powders by the well-known techniques of powder metallurgy.

Certain other elements may be added to the alloy with advantageous results. Silicon and aluminum constitute particularly beneficial additions. Silicon in an amount from 0.1% to 2% increases the extent of hardening of the alloy and is a desirable addition because it aids in the production of good castings, increases the strength and hardness of the alloy, and furthermore makes the resulting alloy somewhat more resistant to oxidation. Preferably about 0.75% silicon is added to achieve these benefits. Aluminum additions from 0.1% to 2% also improve the hardness of the alloy in the heat treated condition and are desirable when maximum hardness is sought. Ordinarily I prefer to add about 0.5% aluminum for this purpose, and if possible, avoid additions of more than 1%, because more than 1% aluminum makes the alloy hard to roll. It is possible, however, to add up to 2% aluminum and yet roll the alloy successfully if proper care is taken.

Many other elements may be added to the alloy in small amounts, or may be present as impurities, without adversely affecting the alloy. For example, it is possible to have in the alloy, without particularly disadvantageous results, up to 5.0% iron, up to 0.5% zirconium, up to 5% chromium, up to 3% manganese, up to 1% magnesium, up to 10% cobalt, up to 2% tin, up to 1% arsenic, up to 5% vanadium, up to 5% molybdenum, and up to 5% zinc. The foregoing elements in the amounts indicated have little or no effect on the properties of the alloy, and such elements probably can be tolerated in even larger amounts than specified. It is, of course, contemplated that the aggregate amount of impurities or additions such as those listed will be relatively small and will not exceed about 15% by weight of the alloy, and that the balance of the alloy over and above the nickel and tantalum (or columbium), will be chiefly copper. Generally, not less than about 45% copper will be present in the alloy even when high percentage of nickel are employed, and the total of the nickel and copper together will equal at least about 80% to 85% by weight of the alloy.

Alloys in the entire range disclosed above may be used either in the cast or worked condition, and either with or without heat treatment. The new alloys lend themselves readily to working, either hot or cold. Unlike many precipitation-hardening alloys, the copper-nickel-tantalum alloys may be worked in a fully precipitated condition. In general it is preferable to perform all hot rolling operations and processing anneals at temperatures of about 800° C. to 950° C., at which temperatures the alloys are soft and plastic although the tantalum-rich compound is largely precipitated in the alloy.

When it is desired to heat treat the alloy to develop maximum hardness or strength, the alloy is heated to a temperature preferably between about 950° C. and 1150° C., advantageously about 1050° C., to permit all or at least the greater part of tantalum to dissolve. A heating period of fifteen minutes to one hour more or less (ordinarily about thirty minutes), at this temperature is generally sufficient. This treatment is followed by rapid cooling or quenching of the alloy. Ordinarily it is most convenient to quench the

alloy in water, but it may be quenched in oil or in a blast of air or other gas, or it may simply be allowed to cool in air or other gas at ordinary room temperatures. In this manner the tantalum is held in solid solution. The alloy may then be further treated by reheating for an appropriate period of time at a temperature that will cause the desired precipitation hardening. A reheating temperature in the neighborhood of 600° C. to 800° C. is usually most satisfactory. The time required for the reheating treatment depends largely on the particular temperature chosen, and also to some extent on the composition of the particular alloy. As an example, however, an alloy containing 20% to 30% nickel and 1% to 2% tantalum has been subjected to successful reheating treatment by reheating at 700° C. to 800° C. for about three hours.

Frequently it is desirable to combine work hardening with precipitation hardening, and to this end the alloy may be cold worked after the high temperature quench and before the precipitation treatment. Such cold working is alone sufficient materially to increase the strength and hardness of the alloy, and moreover, it has the effect of increasing the strength and hardness achieved upon reheating to effect precipitation of the tantalum. The alloy may also be cold worked after the precipitation treatment, and in general the greatest possible strength is obtained by cold working at this stage. It is, of course, obvious that various combinations of working and heating treatment may be employed to enhance the properties of the alloy.

Although the greatest benefit from the addition of tantalum is secured after heat treatment, there is some advantage even when the heat treatment is omitted or when the amount of tantalum is below that necessary for hardening. The strength of copper-nickel alloys is slightly increased by tantalum in solid solution and to a greater extent by the particles of tantalum compounds that are formed without the special heat treatment. The addition of minor amounts of tantalum or columbium has a desirable scavenging effect in copper alloys. The well-known annealing embrittlement of cupronickel containing traces of carbon can be prevented by tantalum or columbium which convert the carbon to an insoluble harmless carbide.

The tensile properties of various of the new alloys, after being subjected to various heat and work treatments, are given in the following Table I in comparison with a cupronickel alloy containing no tantalum or columbium. All alloys listed in the table contained small amounts of manganese and magnesium as deoxidizers, with the balance copper. The values given in the table represent the average of two tests on a strip 0.05 inch thick. The key to the symbols used to denote treatment of the alloy is as follows:

H=Specimen quenched from 1050° C., rolled 6 B & S numbers, not reheated

HR=Specimen quenched from 1050° C., rolled 6 B & S numbers, reheated three hours at 650° C.

R=Specimen quenched from 1050° C., rolled 6 B & S numbers, reheated three hours at 725° C.

RH=Specimen quenched from 1050° C., reheated three hours at 725° C., cold rolled 6 B & S numbers.

Q=Specimen quenched from 1050° C., not reheated.

QR=Specimen quenched from 1050° C., reheated three hours at 725° C.

Table I

Alloy No.	Composition by Analysis						Treatment	Yield Point (0.5% Elongation under Load), lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 2 Inches, Per Cent
	Ni	Ta	Cb	Fe	Al	Si				
2648	29.61			0.39			H	78,300	81,400	2.8
2652	29.80	1.75		0.64			R	18,250	51,000	42.5
							Q	24,400	60,150	33.3
							QR	52,950	91,700	19.5
							RH	100,600	119,350	2.5
2703	29.71	2.03		0.10	0.55		HR	98,150	114,350	7.8
							Q	26,850	67,100	33.3
							QR	71,850	115,300	16.3
							RH	103,600	131,450	1.5
2704	29.81	2.09		0.10		0.84	HR	110,550	135,950	4.5
							Q	39,750	83,250	32.8
							QR	80,450	123,500	15.8
							RH	104,750	151,550	2.0
2649 ¹	29.92	1.30	0.30	0.49	0.89		HR	118,550	150,700	5.5
							Q	24,750	66,100	37.0
							QR	65,750	111,000	17.5
							RH	103,100	136,150	3.0
							HR	111,500	134,650	6.5
2650 ¹	29.88	1.45	0.34	0.56	1.19		H	94,950	103,500	2.8
2705 ¹	29.73	1.53	0.36	0.20	0.59	0.86	QR	73,050	97,700	6.0
							RH	103,450	164,550	2.3
							HR	109,350	160,700	2.3
2567 ²	30.0	0.36	1.64	0.88	0.22		Q	42,800	77,200	33.5
2670 ²	30.0	0.72	3.28	1.76	0.44		R	79,200	114,800	17.5
							Q	55,400	95,300	19.5
							R	93,200	131,800	12.5

¹ Tantalum and columbium added as ferro-tantalum.² Columbium and tantalum added as ferro-columbium. (Nominal composition given.)

In Table II are given the tensile strengths at elevated temperatures of certain of the alloys listed in Table I.

of wire, cable, rod, sheet, strip, tube, pipe, special shapes, and various formed or machined articles made from such items. They may be hot-forged,

Table II

[Tensile Strength at: °C.]

Alloy No. ¹	-100	25	200	400	500	600	700
	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.
2648	57,200	49,500	41,700	36,500	30,500	22,200	15,300
2649	118,800	110,200	103,800	74,000	57,000	40,000	28,500
2650	99,800	101,000	95,200	73,000	49,200	26,200	20,500
2652	102,800	95,200	86,700	58,000	46,000	28,000	18,000

¹ Tests on 1/2 inch diameter rods; Alloy 2648 annealed at 550° C. and air cooled, others annealed at 1,100° C., quenched and reheated three hours at 725° C.

For compositions of the above alloys, see Table I.

The foregoing Table II shows the suitability of the new alloys for elevated temperature service. For example, alloy No. 2649 in the heat treated condition is approximately twice as strong at any given temperature as the cupronickel alloy without tantalum (alloy No. 2648). It will be remembered that cupronickel is the strongest of the commercial alloys of copper that are regularly utilized for elevated temperature service.

The superiority of the new alloys has also been shown by creep or relaxation tests. Strips of various compositions 0.04 inch thick, were bent over a cast-iron block machined to a radius of 20 inches (computed maximum fibre stress approximately 20,000 lb. per sq. in. on material with a modulus of 20×10^6 lb. per sq. in.) and the assembly heated to 350° C. for various periods of time. After 184 hours at 350° C. a 70/30 copper-nickel alloy had taken a permanent set of 67% of the maximum possible, while alloys of similar composition but containing tantalum had taken only between 12% and 23% of the maximum possible set. The cold worked tantalum alloys were slightly superior in resistance to creep to the same alloys in the annealed condition, although the straight copper-nickel alloy followed the usual behavior of being less resistant to creep when cold worked. This behavior is undoubtedly due to the very high recrystallization temperature of the alloys containing tantalum.

The new alloys may be produced in the form

45 hot-pressed, or extruded. They may be made into bolts, screws, nuts, etc., where bending, forming, heading or other operations (either hot or cold) are required. They may be welded either autogenously or by electric or gas methods. They may be resistance welded, brazed, or furnace 50 brazed with copper or materials of lower melting point. The alloys also serve as welding rods to provide filler material for electric and gas welding, not only for welding material of the same composition but also for welding iron and steel, 55 cast iron, nickel-base alloys, and other material. Alloys of copper, nickel and tantalum form an oxide scale on exposure to air at elevated temperatures, but do so to a less extent than alloys of the same nickel content without tantalum. Additions of silicon have in some cases 60 further reduced the scaling to only one-fourth of that of a comparison copper-nickel alloy. Corrosion tests have shown that the addition of 2% 65 tantalum to a 30% cupronickel alloy does not lessen its resistance to corrosion by alternate immersion in a salt spray or by impingement of sea salt solution. The same tantalum-bearing alloy containing 1% silicon has slightly improved 70 corrosion resistance in hydrochloric and sulphuric acids.

The alloys are useful for many applications which require high strength combined with corrosion resistance and ready workability. They are particularly suitable for uses at elevated tem-

peratures under corrosive conditions, and may be employed in the cast or worked condition (with or without heat treatment) for power plant components and accessories such as pipes or conveyors for steam, turbine blades, valve bodies, valve stems and seats, boiler, superheater and condenser tubes and tube plates, and expansion joints. Other uses include Bourdon tubes; instrument springs; support wires, grids, plates and other parts for electron tubes; electrical resistance elements; internal combustion engine parts such as sparkplug electrode wires, valve seats, piston inserts, exhaust pipes; furnace and oven parts; wire screen cloth; a component of thermostatic bimetal; and many other applications.

The high recrystallization temperature of the alloy permits it to be silver soldered in the cold worked condition without loss of work hardness. Assemblies in which this alloy is combined with steel can be heat treated for hardening the steel without causing loss of work hardness or softening of the copper-nickel-tantalum alloy, and conversely the steel can be annealed to its minimum hardness without softening the copper alloy. Vitreous enamels fusing at about 800° C. may be applied to the work hardened or precipitation hardened alloy without softening, or enamels or glazes can also be applied during the heating to a temperature above 950° C. for solution heat treatment.

Although special reference is made in the foregoing specification and in the appended claims to tantalum-bearing alloys, it is of course apparent from what has been said above that columbium is an equivalent of tantalum in alloys according to the invention, and that consequently I contemplate the substitution of columbium for all or a part of the tantalum, if circumstances should make such substitution desirable.

Throughout the foregoing specification and in the appended claims percentages are given by weight.

I claim:

1. A precipitation hardenable alloy comprising about 20% to 50% nickel, about 1% to 1.75% tantalum, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

2. A precipitation hardenable alloy comprising about 10% to 50% nickel, tantalum in an amount between about 0.1% and 5%, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

3. A precipitation hardenable alloy comprising about 15% to 35% nickel, tantalum in an amount between 0.4% and 3%, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight

of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

4. A precipitation hardenable alloy comprising about 10% to 50% nickel, tantalum in an amount between about 0.1% and 5%, about 0.1% to 2% silicon, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

5. A precipitation hardenable alloy comprising about 10% to 50% nickel, tantalum in an amount between about 0.1% and 5%, about 0.1% to 1% aluminum, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

6. A precipitation hardenable alloy composed of about 30% nickel, about 1.75% tantalum, and the balance substantially all copper.

7. A precipitation hardenable alloy composed of about 30% nickel, about 1.75% tantalum, about 0.5% aluminum, and the balance substantially all copper.

8. A precipitation hardenable alloy composed of about 30% nickel, about 1.75% tantalum, about 0.75% silicon, and the balance substantially all copper.

9. A precipitation hardenable alloy comprising about 10% to 50% nickel, at least one metal of the group consisting of tantalum and columbium in an amount between about 0.1% and 5%, and the balance of the alloy being chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the combined percentage of tantalum and columbium being sufficient in relation to the amount of nickel so that the numerical value of said combined percentage falls on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the combined amount of tantalum plus columbium in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

10. A precipitation hardenable alloy comprising copper, nickel and at least one metal of the group consisting of tantalum and columbium in proportions within the following ranges:

	Per cent
Nickel	10 to 50
Tantalum, columbium	0.1 to 5
Copper	45 to 89.9

the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the combined percentage of tantalum and columbium being sufficient in relation to the amount of nickel so that the numerical value of said combined percentage falls on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the combined amount of tantalum plus columbium in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable.

11. A cupronickel containing about 0.1% to 0.8% of columbium.

12. A precipitation hardened alloy comprising about 10% to 50% nickel, tantalum in an amount between 0.1% and 5%, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, and characterized in that a significant proportion of the tantalum is present in the alloy in the form of a precipitated phase.

13. A precipitation hardened alloy comprising about 10% to 50% nickel, columbium in an amount between 0.1% and 5% and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the percentage of columbium being sufficient in relation to the amount of nickel so that the numerical value of such percentage falls on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, and characterized in that a significant proportion of columbium is present in the alloy in the form of a precipitated phase.

14. A cold worked precipitation hardenable alloy comprising about 10% to 50% nickel, tantalum in an amount between 0.1% and 5%, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the amount of tantalum present in the alloy in relation to the amount of nickel therein being sufficient to fall on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby

the amount of tantalum in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable, said cold worked alloy being characterized in that it does not become appreciably softened by prolonged heating at temperatures up to about 800° C.

15. A cold worked precipitation hardenable alloy comprising about 10% to 50% nickel, columbium in an amount between 0.1% and 5%, and the balance chiefly copper, the combined amounts of copper plus nickel constituting at least about 80% by weight of the alloy, and the percentage of columbium being sufficient in relation to the amount of nickel so that the numerical value of such percentage falls on the tantalum-rich side of the 800° C. isothermal line of Fig. 1 of the drawings forming part of the accompanying specification, whereby the amount of columbium in relation to the amount of nickel is sufficient to render the alloy precipitation hardenable, said cold worked alloy being characterized in that it does not become appreciably softened by prolonged heating at temperatures up to about 800° C.

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