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TUNGSTEN-BASE ALLOYS
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This invention pertains to tungsten-base alloys and means and methods for improving the mechanical properties of same.
It is an object of this invention to improve the mechanical properties of sintered tungsten compacts alloyed with nickel and copper.
Another object is to improve mechanical properties of sintered tungsten-base compacts alloyed with nickel and iron.
Still another object is to effect a selective improvement on those compacts exhibiting lowest values of elongation and tensile strength.
Yet another object of this invention is to increase the elongation and tensile strength of the aforementioned

sists in heating the alloy to a temperature of 500-1200° C. in a neutral or slightly reducing atmosphere, and then quenching it abruptly.
For a sintered compact comprised of 75-99% tungsten, balance nickel and copper, the indicated treatment consists of heating the sintered compact to a temperature of 500-1200° C. in a neutral or slightly reducing atmosphere for one-half to twelve hours, quenching rapidly, and then reheating to 350-600° C. in a neutral or slightly reducing atmosphere for one-half to twelve hours and quenching.
Iron-bearing and copper-bearing tungsten-nickel sintered compacts were made using ASTM (American Society for Testing Materials) and MPA (Metal Powder Assn.) standards. The ASTM bar was made by machining a sintered compact to a reduced diameter of 1/4 in. with a 2 in. test length. The MPA test bar was made by using an MPA die with a reduced area of 0.200" x 0.255" and a test length of 1 in. It will be noted that the ASTM test bar is approximately 10% greater in area than the MPA bar and the corresponding difference in mechanical properties is shown in Table I.

TABLE I

Standard Test Bar	Composition*	Sintered Only		Sintered and Heat-Treated		
		Tensile Strength, p.s.i.	Elongation Percent	Tensile Strength, p.s.i.	Elongation, Percent	Heat Treat
MPA-----	A-----	118,000	7	132,000	15	a
MPA-----	B-----	106,000	4-6	125,000	15-25	b
ASTM-----	B-----	95,000	3	138,000	16.5	b

*Composition "A"=95% W+3.5% Ni+1.5% Cu. Composition "B"=90% W+7% Ni+3% Fe.
Heat Treat "a"=Heat at 1,200° C. 1/2 hr., water quench; reheat to 450° C. 6 hrs., water quench.
Heat Treat "b"=Heat at 1,000° C. 4 hrs. and water quench.

alloys approximately proportionately to the cross-section of the alloy.
Other objects of this invention will become apparent as this invention is explained in detail.
Sintered compacts may be prepared by blending metallic oxides, reducing to a metallic state, compacting in a powder press, and sintering in a reducing atmosphere. Sintered compacts made with about 75% or more tungsten, balance nickel and copper, or nickel and iron, exhibit low ductility in general and even lower ductility for thicker cross-sections. As a consequence, such alloys cannot be swaged, spun, headed or rolled except to a very limited degree, thus reducing the field of potential applications of such sintered compacts.
It has been found that a specific heat-treatment may be applied to the iron-bearing and copper-bearing nickel-tungsten compositions, that has the effect of greatly increasing the elongation and appreciably increasing the tensile strength. Furthermore, the percentage increase is greater for thick sections than for thin section, thus tending to produce parts of relatively uniform properties despite a non-uniform cross-section.
An effective heat treatment for a sintered compact comprised of 75-99% tungsten, balance nickel and iron, con-

Comparing the MPA and ASTM test bars as sintered, it is seen that the MPA bar is about 10% stronger and 40% more ductile than the ASTM bar, attributable to the difference in cross-section of the two bars.
The effect of heat treatment b on the ASTM bar is an increase in tensile strength of 45% and an increase in elongation of 450%. Note that these values are greater than obtained with the MPA bar which has a tensile strength of 106,000 p.s.i. and elongation of 4-6% as sintered and a tensile strength of 125,000 p.s.i. and an elongation of 15-25% after the stipulated heat treatment b. This corresponds to an improvement of 18% in tensile strength and 300% in elongation and illustrates quite well that the trend of the stipulated heat treatment is more effective on sintered compacts of lower tensile strength and elongation than on sintered compacts closer to the ultimate values. This effect tends to produce a more uniform product after such heat treatment.
Another composition referred to in Table I as Composition A and comprised of 95% tungsten, 3.5% nickel, and 1.5% copper was made into an MPA test bar and exhibited a tensile strength of 118,000 p.s.i. and elongation of 7% after sintering and a tensile strength of 132,000 p.s.i. and elongation of 15% after heat treat-

ment *a*, thus proving the validity of the heat treatment stipulated.

As the elongation is on the order of 15%, the sintered compacts, so treated, are capable of being rolled swaged, spun, headed and formed, thus being applicable to many products where reliable, economical attachment is required and where maximum tensile strength is indicated.

Now that the invention has been revealed completely, the following claims are made:

1. In a process for heat-treating an alloy consisting of 75-99% tungsten, balance nickel and copper, the steps of heating the alloy to a temperature of 500-1200° C. in a neutral atmosphere, quenching rapidly, reheating to a temperature of 350-600° C. in a substantially neutral atmosphere for one-half to twelve hours and quenching, to increase elongation and tensile strength.

2. An alloy comprised of about 95% tungsten, 3.5% nickel, balance copper having a grain structure and inner granular composition for providing an elongation of substantially about 15% and tensile strength of substantially about 132,000 p.s.i.

3. A process for heat-treating an article of manufacture having a non-uniform cross-section and consisting of 75-99% tungsten, balance nickel and copper, the steps of heating said article uniformly to a temperature of 500-1200° C. in a slightly reducing atmosphere, quenching rapidly, reheating to a temperature of 350-600° C.

in a neutral atmosphere for one-half to twelve hours and quenching, thereby increasing the elongation and tensile strength of said article uniformly throughout said non-uniform cross-section.

4. An article of manufacturing having a non-uniform cross-section and consisting of about 3.5% nickel, about 1.5% copper, and about 95% tungsten sintered and heat-treated to obtain a tensile strength of substantially about 132,000 p.s.i. and elongation of substantially about 15%, said tensile strength and elongation being uniform throughout said non-uniform cross-section.

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