United States Patent Office 2,974,036 Patented Mar. 7, 1961

2,974,036

HIGH TEMPERATURE COBALT-BASE ALLOY

Rudolf H. Thielemann, Palo Alto, Calif., assignor to Sierra Metals Corporation, Chicago, Ill., a corporation of Delaware

No Drawing. Filed July 28, 1958, Ser. No. 751,136

7 Claims. (Cl. 75—171)

This invention relates to a cobalt base metal alloy which includes alloying metal additives which make the resulting alloy corrosion resistant and of great mechanical work strength at temperatures between about 1500° F. and about 2200 F.

Important features of the alloy of this invention are that it may be cast, is highly resistant to oxidation and other forms of corrosion, and possesses great mechanical strength at temperatures up to between about 1500° F. and about 2200° F. As a result, this alloy may be used as blades, vanes and other parts of high temperature gas turbine engines. Other important uses of the alloy of this invention are as exhaust valves and manifolds in internal combustion engines, heat exchangers, as linings for retorts and container vessels used in the chemical and metallurgical industries, and as an oxidation resistant coating material for metals and metal alloys such as columbium, tantalum, nickel base alloys, cobalt base alloys, etc., which possess high strength characteristics at elevated temperatures but whose resistance to oxidation at elevated temperatures, i.e., above about 1500° F., is inadequate. The alloy of this invention can also be utilized as high temperature, high strength, corrosion resistant tubing and sheet material, as a material for forming cutting blades useful for cutting molten glass and other hot corrosive materials, as a material for forming supporting members or holders for use in metallurgical testing apparatus, etc.

The prior art nickel and/or cobalt base metal alloys which have been used as blades, vanes, and other parts of high temperature gas turbine engines, have a maximum operating temperature of about 1500° F. For example, a common nickel-cobalt base metal alloy which incorporates molybdenum as a constituent is for all practical purposes non-utilizable as a structural member in a gas turbine engine if the metal temperature is above 1500° F. One reason for this temperature limit is that the oxidation resistance of such an alloy fails above 1500° F.

The alloy of this invention when used as a blade or vane in a high temperature gas turbine engine can be operated at markedly higher temperatures than was possible heretofore. The performance of gas turbine engines incorporating such blades or vanes is considerably improved, since at higher temperatures the total thrust of a gas turbine engine increases and the amount of fuel consumed per pound of thrust decreases.

The metal alloy of this invention is comprised, by weight, of the following constituents: from about 15 to about 30 percent of chromium; from about 5 to about 15 percent of tungsten; from about 0.5 to about 20 percent of tantalum; from about 0.01 to about 3 percent of zirconium; from about 0.1 to about 1.3 percent of carbon; and the balance essentially cobalt.

I have found that the high temperature corrosion resistant properties of the alloy of this invention are not affected if the alloy includes an amount of columbium

which is not more than one-half of the amount of tantalum in the alloy and, in any event, is no greater than 3 percent, by weight, of the alloy, and preferably not more than 2.0 percent, by weight, of the alloy.

It is important to note that in the past the metals tantalum and columbium have been considered to be equivalent for various purposes. This is not true in the case of the alloy of this invention. For example, if in the alloy of this invention, columbium is substituted for tantalum in the range of proportions specified, the resulting alloy does not possess the high temperature corrosion resistance characteristic of the alloy of this invention.

While molybdenum is not a primary constituent of the alloy of this invention, I have found that the properties of the alloy of this invention are not deleteriously affected if the alloy includes an amount of molybdenum which is not more than one-half of the amount of tungsten in the alloy and, in any event, is no greater than 3.5 percent, by weight, of the alloy.

I have also found that titanium may be tolerated in the alloy of this invention in an amount up to about 0.5 percent by weight of the total alloy, but in no event more than about 70 percent of the amount of zirconium in the alloy.

It has further been found that the inclusion of any one or more of the following ingredients: up to about 0.2 percent of boron, up to about 1.5 percent of silicon, and up to about 5 percent of nickel and/or iron may in certain formulations improve various metallurgical characteristics of the alloy. For example, the oxidation resistance of alloys of the invention may be somewhat improved by the addition of from about 0.1 to about 0.3 percent of silicon; and the strength characteristics of such alloys may be increased by the addition of from about 0.1 to about 0.15 percent of boron. Additional amounts of these ingredients may in some cases be tolerated in the alloy without deleterious effects.

It is to be noted that, if the boron content in the alloy of this invention exceeds about 0.2 percent, then the alloy of this invention becomes unsatisfactory, particularly in those applications where thermal shock requirements are important.

To achieve the optimum desired properties, it is preferred that the following impurities which may be in the alloy be held to the following limits by weight. The manganese content in the final alloy should not be greater than about 2 percent. The interstitial elements such as nitrogen, hydrogen, tin, lead, and the like should be kept as low as possible. In addition, not more than about 0.5 percent total of deoxidizers such as calcium, magnesium, and the like should be present in the final alloy.

A preferred range of proportions of constituents of the alloy of this invention which has especially high oxidation resistance and strength characteristics, at temperatures of 2000° F. and above, and which is particularly suitable for use as a vane material in a gas turbine, high temperature engine, is as follows: from about 16 to about 25 percent of chromium; from about 7.5 to about 12.5 percent of tungsten; from about 7 to about 11 percent of tantalum; from about .08 to about 0.5 percent of zirconium; from about 0.6 to about 1.0 percent of carbon; and the balance being essentially cobalt.

A second and somewhat more preferred range of proportions of constituents is as follows: from about 19 to about 23 percent of chromium; from about 7.5 to about 12.5 percent of tungsten; from about 8 to about 10 percent of tantalum; from about 0.1 to about 0.3 percent of zirconium; from about 0.7 to about 1.0 percent of carbon; and the balance being essentially cobalt.

A preferred range of proportions of constituents of

the alloy of this invention, which is particularly suitable for use as a high temperature corrosion resistant wrought material in the form of bars, sheets, etc., is as follows: from about 16 to about 25 percent of chromium; from about 7.5 to about 12.5 percent of tungsten, from about 7 to about 11 percent of tantalum;; from about .08 to about .5 percent of zirconium; from about 0.1 to about 0.5 percent of carbon; and the balance being essentially cobalt. The corrosion resistance of such wrought material may be further improved by the addition of any or all of the following constituents: up to about 1.5 percent of silicon; up to about 2.5 percent of nickel; and up to about 2.5 percent of iron. Also the strength characteristic of the wrought material may be improved by the addition of up to about 0.2 percent of boron. The preferred wrought material may also include up to about 3 percent of columbium.

Following are examples of the preparation and test results of the cobalt base metal alloy of this invention:

Example 1

A 5 pound alloy melt of a cobalt base metal alloy composition containing about 20 percent of chromium, about 11 percent of tungsten, about 1.5 percent of tantalum, about 1.5 percent of zirconium, about 0.4 percent of carbon, and the balance essentially cobalt, all percentages by weight, was prepared by melting the chromium and cobalt under a blanket of argon gas in a magnesia crucible, following which the tungsten, tantalum, zirconium, and carbon, in the form of graphite, were added. A cluster of 6 test bars were formed from the 5 pound melted alloy heated and cast by the usual investment casting technique under a blanket of argon gas. These bars were each 3 inches long and ¼ inch in diameter.

The test bars of this example had an elongation of 7 percent at room temperature under a tensile stress of 115,000 p.s.i.

The test bars of this example had a rupture life in exces of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 2

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 28 percent of chromium, about 5 percent of tungsten, about 1.5 percent of tantalum, about 1.5 percent of zirconium, about 0.4 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 5 percent at room temperature under a tensile stress of 98,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 3

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 11 percent of tungsten, about 4 percent of tantalum, about 1.5 percent of zirconium, about 0.4 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 7 percent at room temperature under a tensile stress of 115,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 4

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 11 percent of tungsten, about 0.5 percent of tantalum, about 3 percent of zirconium, about 0.7 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 7 percent at room temperature under a tensile stress of 115,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 5

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 18 percent of chromium, about 8.6 percent of tungsten, about 2.5 percent of tantalum, about 0.4 percent of zirconium, about 0.49 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 2.5 percent at room temperature under a tensile stress of 105,600 p.s.i.

The test bars of this example had a rupture life in excess of 397 hours under a load of 25,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 14,000 p.s.i. at a temperature of about 1800° F. in air.

Example 6

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 2.5 percent of tantalum, about 0.3 percent of zirconium, about 0.44 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 5 percent at room temperature under a tensile stress of 111,600 p.s.i.

The test bars of this example had a rupture life in excess of 386 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 19,000 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 100 hours under a load of 13,000 p.s.i. at a temperature of about 1800° F. in air.

Example 7

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 1.4 percent of tantalum, about 0.4 percent of zirconium, about 0.55 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 3.5 percent at room temperature under a tensile stress of 119,300 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 18,000 p.s.i. at a

temperature of about 1700° F. in air, and a rupture life in excess of about 100 hours under a load of 12,000 p.s.i. at a temperature of about 1800° F. in air.

Example 8

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 2.5 percent of tantalum, about 0.4 percent of zirconium, about 0.52 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 4.0 percent at room temperature under a tensile stress of 110,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 19,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of about 100 hours under a load of 13,000 p.s.i. at a temperature of 1800° F. in air.

Example 9

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 1 percent of tantalum, about 0.4 percent of zirconium, about 0.1 percent of titanium, about 0.52 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1, except under high vacuum conditions instead of a blanket of argon gas.

The test bars of this example had an elongation of 4.5 percent at room temperature under a tensile stress of 98,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 18,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 10,000 p.s.i. at a temperature of about 1800° F. in air.

Example 10

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.4 percent of zirconium, about 0.65 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 2.5 percent at room temperature under a tensile stress of 118,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 11

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.3 percent of zirconium, about 0.1 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 6 percent at room temperature under a tensile stress of 118,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 12

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.4 percent of zirconium, about 0.8 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The tests bars of this example had an elongation of 6.6 percent at room temperature under a tensile stress of 127,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 13

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 15 percent of chromium, about 15 percent of tungsten, about 13 percent of tantalum, about 0.01 percent of zirconium, about 0.65 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 10 percent at room temperature under a tensile stress of 124,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 14

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 12 percent of tantalum, about 1.0 percent of zirconium, about 0.5 percent of titanium, about 0.6 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1, except under high vacuum conditions instead of a blanket of argon gas.

The test bars of this example had an elongation of 9 percent at room temperature under a tensile stress of 127,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 15

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chro-

mium, about 10 percent of tungsten, about 20 percent of tantalum, about 3 percent of zirconium, about 0.85 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 6 percent at room temperature under a tensile stress of 118,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 16

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 28 percent of chromium, about 5 percent of tungsten, about 8 percent of tantalum, about 2.5 percent of zirconium, about 0.7 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 10 percent at room temperature under a tensile stress of 120,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 17

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 30 percent of chromium, about 5 percent of tungsten, about 5 percent of tantalum, about 0.4 percent of zirconium, about 0.5 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 7 percent at room temperature under a tensile stress of 110,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life in excess of 100 hours under a load of 20,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 100 hours under a load of 10,000 p.s.i. at a temperature of about 1800° F. in air.

Example 18

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 21.3 percent of chromium, about 9.7 percent of tungsten, about 2.7 percent of tantalum, about 0.4 percent of zirconium, about 0.45 percent of carbon, about 1.5 percent of silicon, about 0.28 percent of manganese, about 0.5 percent of nickel, about 0.5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 1, except under high vacuum conditions instead of a blanket of argon gas.

The test bars of this example had an elongation of about 2 percent at room temperature under a tensile stress of 113,000 p.s.i.

The test bars of this example had a rupture life in excess of 250 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air, a rupture life of about 329 hours under a load of 17,500 p.s.i. at a temperature of about 1700° F., and a rupture life in excess of 63 hours under a load of 10,000 p.s.i. at a temperature of about 1800° F. in air.

Example 19

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 21.5 percent of chromium, about 9.6 percent of tungsten, about 1.2 percent of tantalum, and 0.3 percent of zirconium, about 0.45 percent of carbon, about 0.4 percent of silicon, about 0.28 percent of manganese, about 1.5 percent of nickel, about 1.5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of about 3.3 percent at room temperature under a tensile stress of 118,000 p.s.i.

The test bars of this example had a rupture life in excess of 233 hours under a load of 18,000 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 154 hours under a load of 12,000 p.s.i. at a temperature of about 1800° F. in air.

Example 20

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 9 percent of tantalum, about 0.2 percent of zirconium, about 0.85 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of about 1.66 percent at room temperature under a tensile stress of 138,000 p.s.i.

The test bars of this example had a rupture life of about 48 hours under a load of 17,000 p.s.i. at a temperature of 1800° F. in air, and a rupture life of about 25 hours under a load of 8000 p.s.i. at a temperature of 2000° F. in air.

The oxidation penetration of the alloy of this example was determined in the usual fashion and found to be .04 mil per side per hour at a temperature of 2000° F. in moving air after 100 hours and .10 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 21

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 21.5 percent of chromium, about 9.7 percent of tungsten, about 10.6 percent of tantalum, about 0.5 percent of zirconium, about 0.75 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example has an elongation of 1.1 percent at room temperature under a tensile stress of 110,000 p.s.i.

The test bars of this example had a rupture life in excess of 59 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 22

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 21 percent of chromium, about 7.5 percent of tungsten, about 9 percent of tantalum, about 0.2 percent of zirconium, about 0.85 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18. Molybdenum in 3.5 percent amount was also present.

The test bars of this example had an elongation of .8

percent at room temperature under a tensile stress of 126,200 p.s.i.

The test bars of this example had a rupture life in excess of 30 hours under a load of 15,000 p.s.i. at a temperature of about 1800° F. in air.

Example 23

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 21 percent of chromium, about 9 percent of tungsten, about 9 percent of tantalum, about 0.2 percent of zirconium, about 0.85 percent of carbon, about 1.0 percent of molybdenum, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1 percent at room temperature under a tensile stress of 125,000 p.s.i.

The test bars of this example had a rupture life in excess of 51 hours under a load of 12,000 p.s.i. at a temperature of about 1800° F. in air.

Example 24

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 19 percent of chromium, about 7.7 percent of tungsten, about 6.7 percent of tantalum, about 0.05 percent of zirconium, about 0.88 percent of carbon, about 0.1 percent of silicon, about 0.05 percent of nickel, about 0.48 percent of iron, about 0.1 percent of manganese, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of about 3.3 percent at room temperature under a tensile stress of 142,800 p.s.i.

The test bars of this example had a rupture life in excess of 41 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 60 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air.

The oxidation penetration was .02 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 25

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.9 percent of carbon, about 0.3 percent of silicon, about 0.5 percent of manganese, about 0.4 percent of zirconium, about 0.13 percent of titanium, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 2.5 percent at room temperature under a tensile stress of 139,000 p.s.i.

The test bars of this example had a rupture life in excess of 51 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 137 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 26

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 7.5 percent of tungsten, about 7.5 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 142,000 p.s.i.

The test bars of this example had a rupture life in excess of 134 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 51 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 27

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 125,100 p.s.i.

The test bars of this example had a rupture life in excess of 262 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 56 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.08 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 28

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 20 percent of chromium, about 12.5 percent of tungsten, about 12.5 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 144,800 p.s.i.

The test bars of this example had a rupture life in excess of 129 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 84 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.12 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 29

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 2.5 percent at room temperature under a tensile stress of 135,900 p.s.i.

The test bars of this example had a rupture life in excess of 350 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 92 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

The oxidation penetration was nil after 100 hours at 2000° F. in moving air and was 0.005 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 30

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 18 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.83 percent at room temperature under a tensile stress of 131,200 p.s.i.

The test bars of this example had a rupture life in excess of 168 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 105 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 31

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 15 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.7 percent at room temperature under a tensile stress of 140,000 p.s.i.

The test bars of this example had a rupture life in excess of 156 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air, and a rupture life in excess of 67 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

The oxidation penetration was 0.005 mil per side per hour in moving air after 100 hours at 2000° F. and 0.08 mil per side per hour after 24 hours in moving air at 2100° F.

Example 32

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 15 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, about 5 percent of nickel, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 2.5 percent at room temperature under a tensile stress of 125,600 p.s.i.

The test bars of this example had a rupture life in excess of 166 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 68 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 33

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, about 5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 137,500 p.s.i.

The test bars of this example had a rupture life in excess of 59 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 49 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.03 mil per side per hour after 24 hours in moving air at 2100° F.

Example 34

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, about 5 percent of nickel, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 3.3 percent at room temperature under a tensile stress of 134,000 p.s.i.

The test bars of this example had a rupture life in excess of 56 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 37 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration of the alloy was 0.02 mil per side per hour after 24 hours in moving air at 2100° F.

Example 35

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 7.5 percent of tungsten, about 7.5 percent of tantalum, about 0.1 percent of zirconium, about 1 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 3.3 percent at room temperature under a tensile stress of 145,800 p.s.i.

The test bars of this example had a rupture life in excess of 178 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air and a rupture life in excess of 57 hours under a load of 17,000 p.s.i at a temperature of about 1800° F. in air. The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.05 mil per side per hour after 24 hours in moving air at 2100° F.

Example 36

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 10 percent of tantalum, about 0.1 percent of zirconium, about 1.3 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.7 percent at room temperature under a tensile stress of 145,500 p.s.i.

The test bars of this example had a rupture life in excess of 41 hours under a load of 17,000 p.s.i at a temperature of about 1800° F. in air. The oxidation penetration of the alloy was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and the same value after 24 hours in moving air at 2100° F.

Example 37

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 10 percent of tungsten, about 10 percent

of tantalum, about 0.1 percent of zirconium, about 0.2 percent of boron, about 0.85 percent of carbon, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 135,000 p.s.i.

The test bars of this example had a rupture life in excess of 50 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 38

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 12.5 percent of tungsten, about 7.5 percent of tantalum, about 0.1 percent of zirconium, about 0.84 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 144,900 p.s.i.

The test bars of this example had a rupture life in excess of 85 hours under a load of 17,000 p.s.i at a temperature of about 1800° F. in air. The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.08 mil per side per hour after 24 hours in moving air at 2100° F.

Example 39

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 7.5 percent of tungsten, about 12.5 percent of tantalum, about 0.1 percent of zirconium, about 0.86 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 149,800 p.s.i.

The test bars of this example had a rupture life in excess of 66 hours under a load of 17,000 p.s.i. at a temperature of about 180° F. in air. The oxidation penetration was nil after 100 hours in moving air at 2000° F. and was 0.15 mil per side per hour after 24 hours in moving air at 2100° F.

Example 40

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 8 percent of tungsten, about 8 percent of tantalum, about 3 percent of columbium, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.95 percent at room temperature under a tensile stress of 125,000 p.s.i.

The test bars of this example had a rupture life in excess of 62 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

Example 41

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 12.5 percent of tungsten, about 3 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 1 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 8.3 percent at room temperature under a tensile stress of 137,000 p.s.i.

The test bars of this example had a rupture life in excess of 22 hours under a load 17,000 p.s.i at a temperature of about 1800° F. in air. The oxidation penetration of the alloy was 0.015 mil per side per hour after 100 hours in moving air at 2000° F. and 0.065 mil per side per hour after 24 hours in moving air at 2100° F.

Example 42

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 12.5 percent of tungsten, about 3 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 1 percent of carbon, about 0.01 percent of boron, about 5 percent of nickel, and the balance essentialy cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 3.3 percent at room temperature under a tensile stress of 131,900 p.s.i.

The test bars of this example had a rupture life in excess of 41 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air. The oxidation penetration of the alloy was nil after 100 hours in moving air at 2000° F. and was 0.01 mil per side per hour after 24 hours at 2100° F.

Example 43

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 8 percent of tungsten, about 8 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 132,100 p.s.i.

The test bars of this example had a rupture life in excess of 277 hours under a load of 22,500 p.s.i. at a temperature of about 1700° F. in air, a rupture life in excess of 128 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air, and a rupture life in excess of 28 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.005 mil per side per hour after 100 hours in moving air at 2000° F. and 0.09 mil per side per hour after 24 hours at 2100° F. in moving air.

Example 44

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 8 percent of tungsten, about 8 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 0.74 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 103,800 p.s.i.

The test bars of this example had a rupture life in excess of 84 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air.

The oxidation penetration was 0.015 mil per side per

hour after 100 hours in moving air at 2000° F. and 0.02 mil per side per hour after 24 hours in moving air at 2100° F.

Example 45

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 8 percent of tungsten, about 8 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, about 2.5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 140,600 p.s.i.

The test bars of this example had a rupture life in excess of 84 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 31 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.01 mil per side per hour after 100 hours at 2000° F. in moving air and 0.085 mil per side per hour after 24 hours in moving air at 2100° F.

Example 46

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 22 percent of chromium, about 8 percent of tungsten, about 8 percent of tantalum, about 1 percent of columbium, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, about 5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 0.8 percent at room temperature under a tensile stress of 127,600 p.s.i.

The test bars of this example had a rupture life in excess of 33 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 19 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration after 100 hours in moving air at 2000° F. was nil and was 0.10 mil per side per hour after 24 hours in moving air at 2100° F.

Example 47

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 25 percent of chromium, about 10 percent of tungsten, about 5 percent of tantalum, about 2 percent of columbium, about 0.1 percent of zirconium, about 0.85 percent of carbon, about 0.01 percent of boron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 132,800 p.s.i.

The test bars of this example had a rupture life in excess of 41 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 38 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.01 mil per side per hour after 100 hours in moving air at 2000° F. and 0.08 mil per side per hour after 24 hours in moving air at 2100° F.

Example 48

A 5 pound alloy melt and test bars of the same dimensions as set forth in Example 1 of a cobalt base metal alloy composition containing about 25 percent of chromium, about 10 percent of tungsten, about 5 percent of tantalum, about 2 percent of columbium, about 0.85 percent of carbon, about 0.1 percent of zirconium, about 0.01 percent of boron, about 5 percent of iron, and the balance essentially cobalt, all percentages by weight, were prepared in the same manner as set forth in Example 18.

The test bars of this example had an elongation of 1.6 percent at room temperature under a tensile stress of 139,400 p.s.i.

The test bars of this example had a rupture life in excess of 53 hours under a load of 17,000 p.s.i. at a temperature of about 1800° F. in air and a rupture life in excess of 21 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.017 mil per side per hour after 100 hours in moving air at 2000° F. and 0.07 mil per side per hour after 24 hours in moving air at 2100° F.

The above detailed description has been given for clearness of understanding only. No unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. A metal alloy composed of, by weight, from about 15 to about 30 percent of chromium, from about 5 to about 15 percent of tungsten, from about 0.5 to about 20 percent of tantalum, from about 0.01 to about 3 percent of zirconium, from about 0.1 to about 1.3 percent of carbon, and the balance cobalt except for impurities and minor alloying constituents which do not substantially affect the properties of the basic alloy.

2. A metal alloy composed of, by weight, from about 16 to about 25 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 7 to about 11 percent of tantalum, from about 0.08 to about 0.5 percent of zirconium, from about 0.6 to about 1 percent of carbon, and the balance cobalt except for impurities and minor alloying constituents which do not substantially affect the properties of the basic alloy.

3. A metal alloy composed of, by weight, from about 19 to about 23 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 8 to about 10 percent of tantalum, from about 0.1 to about 0.3 percent of zirconium, from about 0.7 to about 1.0 percent of carbon, and the balance cobalt except for impurities and minor alloying constituents which do not substantially affect the properties of the basic alloy.

4. A metal alloy composed of, by weight, from about 16 to about 25 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 7 to about 11 percent of tantalum, from about 0.08 to about 0.5 percent of zirconium, from about 0.1 to about 0.5 percent of carbon, and the balance cobalt except for impurities and minor alloying constituents which do not substantially affect the properties of the basic alloy.

5. A metal alloy composed of, by weight, from about 16 to about 25 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 7 to about 11 percent of tantalum, from about 0.08 to about 0.5 percent of zirconium, from about 0.6 to about 1 percent of carbon, up to about 0.5 percent titanium but not more than 70 percent of the amount of zirconium, up to about 3 percent of columbium, up to about 1.5 percent of silicon, up to about 5 percent of iron, up to about 5 percent of nickel, up to about 0.2 percent of boron, up to about 3.5 percent of molybdenum, and the balance cobalt except for impurities which do not substantially affect the properties of the basic alloy.

6. A metal alloy composed of, by weight, from about 19 to about 23 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 8 to about 10 percent of tantalum, from about 0.1 to about 0.3 percent of zirconium, from about 0.7 to about 1.0 percent of carbon, up to about 0.5 percent titanium but

not more than 70 percent of the amount of zirconium, up to about 3 percent of columbium, up to about 1.5 percent of silicon, up to about 5 percent of iron, up to about 5 percent of nickel, up to about 0.2 percent of boron, up to about 3.5 percent of molybdenum, and the balance cobalt except for impurities which do not substantially affect the properties of the basic alloy.

7. A metal alloy composed of, by weight, from about 16 to about 25 percent of chromium, from about 7.5 to about 12.5 percent of tungsten, from about 7 to about 11 percent of tantalum, from about 0.08 to about 0.5 percent of zirconium, from about 0.1 to about 0.5 percent of carbon, up to about 0.5 percent titanium but not more than 70 percent of the amount of zirconium, up to about 3 percent of columbium, up to about 1.5 percent of silicon, up to about 5 percent of iron, up to about 5 percent of nickel, up to about 0.2 percent of boron, up to about 3.5 percent of molybdenum, and the

balance cobalt except for impurities which do not substantially affect the properties of the basic alloy.

References Cited in the file of this patent

UNITED STATES PATENTS

2,051,562	Lohr	Aug. 18, 1936
2,247,643	Rohn et al.	July 1, 1941
2,515,774	Johnson	July 18, 1950

FOREIGN PATENTS

443,821	Great Britain	Mar. 6, 1936
686,180	Great Britain	Jan. 21, 1953
542,813	Canada	June 25, 1957

OTHER REFERENCES

Materials and Methods, September 1953, Number 260, page 139.

UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,974,036 March 7, 1961

Rudolf H. Thielemann

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 39, for "exces" read -- excess --; column 5, line 71, for "0.1" read -- 1.0 --; column 8, line 58, for "has" read -- had --; column 13, line 47, for "180° F." read -- 1800° F. --.

Signed and sealed this 22nd day of August 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents