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METAL ALLOY

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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 up to as high as 1800° F.

Important features of the alloy of this invention are that it may be cast, it is highly resistant to oxidation and other forms of corrosion at temperatures up to about 1800° F., and possesses great mechanical work strength at temperatures up to between about 1500° F. and about 1800° F. As a result, this alloy may be used in the fabrication of blades, vanes, and other parts for high temperature gas turbine engines. Other important uses of the alloy of this invention are in exhaust valves and manifolds in internal combustion engines, in heat exchangers and in linings for retorts and container vessels used in the chemical and metallurgical industries. It may also be utilized in high temperature, high strength, corrosion resistant tubing and sheet material.

The prior art nickel and/or cobalt base metal alloys which, for example, 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 temperature is above 1500° F. One reason for this temperature limitation is that the oxidation resistance of such an alloy fails when the alloy is raised to a temperature above 1500° F.

The alloy of this invention can be successfully used in blades or vanes in high temperature gas turbine engines, which engines can be operated at markedly higher temperatures than was possible heretofore due to the high temperature characteristics of the alloy. This results in improvements in the performance of gas turbine engines, 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 approximately: 15 to 30 percent of chromium; from 5 to 15 percent of tungsten; 0.5 to 5 percent of columbium; from 0.01 to 3 percent of zirconium; from 0.1 to 1.3 percent of carbon; and the balance being essentially cobalt.

Tantalum may be present in the alloy in an amount such that if the columbium is present in the alloy in an amount of more than 3 percent, then the combined amount of columbium and tantalum should be equal to or less than 20 percent by weight of the alloy; and if the columbium is present in the alloy in an amount equal to or less than 3 percent, then the tantalum in the alloy should never exceed twice the amount of columbium in the alloy.

Molybdenum may be tolerated in the alloy of this invention without deleteriously affecting the properties of the alloy provided that the amount of molybdenum in the alloy 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.

It has been further 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. Additional amounts of these ingredients may in some cases be tolerated in the alloy without deleterious effects.

If the boron content of the alloy exceeds about 0.2 percent, then the alloy of this invention becomes unsatisfactory, particularly in those applications where thermal shock requirements are important.

An alloy having the above composition is both resistant to oxidation and has high strength at elevated temperatures, considerably in excess of 1500° F., so as to be suitable for use in forming cast liners for retorts and container vessels used in the chemical and metallurgical industries, as well as other uses previously mentioned.

In order to assure that the optimum desired properties will be obtained in the alloy, it is preferred that the following impurities in the alloy be held to the following limits, by weight. The manganese content in the final alloy should be no more 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.

The following are examples of the proportions 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 25 percent of chromium; about 15 percent of tungsten; about 2 percent of columbium; about 0.75 percent of carbon; about 0.1 percent of zirconium; about 0.02 percent of boron; about 5 percent of iron; and the balance, substantially all cobalt, all by weight, was prepared by melting a chromium cobalt mix in a magnesia crucible under high vacuum conditions, following which the remaining constituents, including carbon in the form of graphite, were added. A cluster of 6 test bars were formed from the 5 pound melted alloy heated by the usual investment casting technique under high vacuum conditions. These bars were each 3 inches long and ¼ inch in diameter.

The test bars had an elongation of 1.66 percent at room temperature under a tensile stress of 138,200 p.s.i.

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

The oxidation penetration was measured in the conventional manner and was determined to be 0.04 mil per side per hour after 100 hours at 2000° F. in moving air, and 0.03 mil per side per hour after 24 hours at 2100° F. in moving 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 25 percent of chromium; about 15 percent of tungsten; about 0.1 percent of zirconium; about 2 percent of columbium; about 0.75 percent of carbon; about 0.02 percent of boron; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 0.84 percent at room temperature under a tensile stress of 122,000 p.s.i.

The test bars of this example had a rupture life in excess of 32 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 17 hours under a load of 8000 p.s.i. at a temperature of about 2000° F. in air.

The oxidation penetration was 0.19 mil per side per hour after 24 hours at 2100° F. in moving 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 1.5 percent of zirconium; about 0.5 percent of columbium; about 0.4 percent of carbon; and the balance, essentially cobalt, all 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 15 percent of chromium; about 15 percent of tungsten; about 1.5 percent of columbium; about 1.5 percent of zirconium; about 0.4 percent of carbon; and the balance, essentially cobalt, all 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 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 20 percent of chromium; about 11 percent of tungsten; about 0.5 percent of columbium; about 1.5 percent of zirconium; about 0.4 percent of carbon; and the balance, essentially cobalt, all 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 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 11 percent of tungsten; about 4 percent of columbium; about 0.2 percent of zirconium; about 0.1 percent of carbon; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 8 percent at room temperature under a tensile stress of 95,000 p.s.i.

The test bars of this example had 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 10,000 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 11 percent of tungsten; about 4 percent of columbium; about 0.2 percent of zirconium; about 0.3 percent of carbon; and the balance, essentially cobalt, all 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 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 11 percent of tungsten; about 4 percent of columbium; about 0.2 percent of zirconium; about 0.75 percent of carbon; and the balance, essentially cobalt, all 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 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 30 percent of chromium; about 5 percent of tungsten; about 1.5 percent of columbium; about 1.5 percent of zirconium; about 0.4 percent of carbon; and the balance, essentially cobalt, all 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 percent at room temperature under a tensile stress of 90,000 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 and 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.

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 10.5 percent of tungsten; about 1.5 percent of columbium; about 0.4 percent of zirconium; about 0.4 percent of carbon; and the balance, essentially cobalt, all 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 120 hours under a load of 25,000 p.s.i. at a temperature of about 1600° F. in air; a rupture life of 1157 hours under a load of 20,000 p.s.i. at a temperature of about 1600° F. in air; a rupture life of 795 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 13,000 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 0.75 percent of columbium; about 1.0 percent of tantalum; about 0.04 percent of zirconium; about 0.5 percent of carbon; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 4.5 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 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 14,000 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 0.75 percent of columbium; about 1.0 percent of tantalum; about 0.04 percent of zirconium; about 0.5 percent of carbon; about 3.5 percent of molybdenum; and the balance, essentially cobalt, all 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 100,000 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 12,000 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 20 percent of chromium; about 7.5 percent of tungsten; about 1.5 percent of columbium; about 0.5 percent of carbon; about 2.5 percent of tantalum; about 0.04 percent of zirconium; and the balance, essentially cobalt, all 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 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 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 7.5 percent of tungsten; about 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.04 percent of zirconium; about 0.50 percent of carbon; about 1 percent of molybdenum; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 8 percent at room temperature under a tensile stress of 105,600 p.s.i.

The test bars of this example had a rupture life of 100 hours under a load of 25,000 p.s.i. at a temperature of about 1600° 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 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 chromium; about 10 percent of tungsten; about 1 percent of columbium; about 0.48 percent of zirconium; about 0.5 percent of carbon; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 9 percent at room temperature under a tensile stress of 97,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 24,000 p.si. at a temperature of about 1600° F. in air; a rupture life in excess of 100 hours under a load of 17,000 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 12,000 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 20 percent of chromium; about 10 percent of tungsten; about 1 percent of columbium; about 0.48 percent of zirconium; about 0.5 percent of carbon; about 1.5 percent of silicon; and the balance, essentially cobalt, all 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 97,000 p.s.i.

The test bars of this example had a rupture life in excess of 100 hours under a load of 24,000 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 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 20 percent of chromium; about 10 percent of tungsten; about 1.5 percent of columbium; about 1 percent of zirconium; about 0.5 percent of carbon; and the balance, essentially cobalt, all 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 percent at room temperature under a tensile stress of 117,000 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 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 20 percent of chromium; about 10 percent of tungsten; about 1 percent of columbium; about 1 percent of zirconium; about 0.5 percent of carbon; about 0.2 percent of boron; and the balance, essentially cobalt, all 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 percent at room temperature under a tensile stress of 117,000 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 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 20 percent of chromium; about 7.5 percent of tungsten; about 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.5 percent of zirconium; about 0.5 percent of carbon; about 0.1 percent of boron; and the balance, essentially cobalt, all 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 percent at room temperature under a tensile stress of 97,000 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 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 20 percent of chromium; about 10 percent of tungsten; about 1.5 percent of columbium; about 2.0 percent of zirconium; about 0.5 percent of carbon; and the balance, essentially cobalt, all 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 percent at room temperature under a tensile stress of 119,000 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 1800° F. in 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 20 percent of chromium; about 10 percent of tungsten; about 1.5 percent of columbium; about 2 percent of zirconium; about 0.5 percent of carbon; about 0.2 percent of silicon; about 2.5 percent of nickel; about 2.5 percent of iron; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 6.5 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 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 20 percent of chromium; about 10 percent of tungsten; about 5 percent of columbium; about 0.01 percent of zirconium; about 0.65 percent of carbon; about 2.5 percent of iron; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 1 percent at room temperature under a tensile stress of 108,000 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 13,500 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 20 percent of chromium; about 10 percent of tungsten; about 3.1 percent of columbium; about 6.2 percent of tantalum; about 0.5 percent of zirconium; about 1.3 percent of carbon and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars of this example had an elongation of 0.6 percent at room temperature under a tensile stress of 147,000 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 15,00 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 20 percent of chromium; about 7.5 percent of tungsten; about 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.5 percent of zirconium; about 0.6 percent of carbon; and the balance, essentially cobalt, all 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 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 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 7.5 percent of tungsten; about 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.5 percent of zirconium; about 0.8 percent of carbon; about 1.0 percent of nickel; and the balance, essentially cobalt, all 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 122,000 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 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 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.5 percent of zirconium; about 1.0 percent of carbon; and the balance, essentially cobalt, all by weight, were prepared in the same manner as set forth in Example 1.

The test bars had an elongation of 2.5 percent at a 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 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 7.5 percent of tungsten; about 1.5 percent of columbium; about 2.5 percent of tantalum; about 0.5 percent of zirconium; about 1.3 percent of carbon; about 5 percent of nickel; and the balance, essentially cobalt, all 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 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.

The above detailed description of this invention 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 consisting essentially 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 5 percent of columbium; 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.

2. A metal alloy consisting essentially 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 5 percent of columbium, tantalum in an amount such that if the columbium is present in the alloy in an amount of more than 3 percent then the combined amount of columbium and tantalum in the alloy is equal to or less than 20 percent of the alloy; and if the columbium is in an amount equal to or less than 3 percent, then the tantalum should not exceed twice the amount of columbium in the alloy; 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.

3. A metal alloy consisting essentially of by weight: from about 15 to about 30 percent of chromium, from about 5 to about 15 percent of tungsten; up to about 0.2 percent of boron; from about 0.5 to about 5 percent of columbium; 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.

4. A metal alloy consisting essentially of by weight: from about 15 to about 30 percent of chromium; from about 5 to about 15 percent of tungsten; up to about 0.2 percent of boron; from about 0.5 to about 5 percent of columbium; tantalum in an amount such that if the columbium is present in the alloy in an amount of more than 3 percent then the combined amount of columbium and tantalum in the alloy is less than or equal to 20 percent of the alloy; and if the columbium is in an amount of equal to or less than 3 percent, the tantalum should not exceed twice the amount of columbium in the alloy; up to 3.5 percent of molybdenum, but not more than about 50 percent of the amount of tungsten in the alloy; 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.

5. A metal alloy consisting essentially 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 5 percent of columbium; tantalum in an amount such that if the columbium is present in the alloy in an amount of more than 3 percent then the combined amount of columbium and tantalum in the alloy is less than or equal to 20 percent of the alloy; and if the columbium is in an amount of equal to or less than 3 percent, the tantalum should not exceed twice the amount of columbium in the alloy; from about 0.01 to about 3 percent of zirconium; from about 0.1 to about 1.3 percent of carbon; up to about 1.5 percent of silicon; up to about 5 percent of nickel; up to about 5 percent of iron; and the balance cobalt.

6. A metal alloy consisting essentially of by weight: from about 15 to about 30 percent of chromium; from about 5 to about 15 percent of tungsten; up to about 0.2 percent of boron; from about 0.5 to about 5 percent of columbium; tantalum in an amount such that if the columbium is present in the alloy in an amount of more than 3 percent then the combined amount of columbium and tantalum in the alloy is less than or equal to 20 percent of the alloy; and if the columbium is in an amount of equal to or less than 3 percent, the tantalum should not exceed twice the amount of columbium in the alloy; up to 3.5 percent of molybdenum, but not more than about 50 percent of the amount of tungsten in the alloy; from about 0.01 to about 3 percent of zirconium; from about 0.1 to about 1.3 percent of carbon; up to about 1.5 percent of silicon; up to about 5 percent of nickel; up to about 5 percent of iron; and the balance cobalt.

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