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2,857,266

HIGH TEMPERATURE RESISTANT ALLOYS

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6 Claims. (Cl. 75-124)

This invention relates generally to the art of ferrous alloys and is particularly concerned with such alloys which are less expensive than, but are equal, or superior to, prior alloys, particularly in such respects as resistance to corrosive gases at high temperatures, strength and resistance to deformation at high temperatures, length of life and rate of creep.

For a long time a demand has existed for alloys of improved physical properties at high temperatures. Probably the best and most extensively used alloys for high temperature work are those containing a large percentage of nickel and chrome in various commercially used compositions and listed under many names and designations. Some of these alloy combinations have been standardized by the Alloy Casting Institute as HH (chrome 24%-nickel 12%), HT (chrome 15%-nickel 35%), HU (chrome 18%-nickel 38%), HW (chrome 12%-nickel 60%), HX (chrome 18%-nickel 66%). These compositions are not all of the compositions used, but are considered to be the best of the regular temperature resistant alloys and are widely used. These alloys, as they are now commercially used, are not suitable for the increasing temperature requirements and physical property demands, which have become more exacting in the past few years. As a result, numerous workers in the art have tried to improve the properties of these alloys. These efforts increased the cost of the alloy by reason of the high price and limited supply of nickel but the physical properties of the alloys did not satisfactorily meet the new demands.

The present invention aims to provide a new alloy which is equal or, superior, to the best present-day alloy in physical properties for use at high temperatures in corrosive gases and which does not contain the increased percentages of nickel. These objects are attained by a new combination of elements which cooperate in a new way and have new properties and results superior to the commercial base alloys of 25% chrome-35% nickel.

Articles embodying this invention and requiring properties which it provides include parts of heating furnaces, such as radiant tubes, and weight-carrying parts such as shafts, rolls, rails, beams, and the like, and parts exposed to high temperature corrosive gases traveling at high velocities, such as blades of engines and gas turbines and valves of internal combustion engines.

The basic composition of alloys embodying the present invention include from about .45% to about .55% of carbon, from about 23% to about 27% of chromium and from about 34% to about 37% of nickel.

Alloys which embody the present invention have the following compositions:

	Percent
Carbon.....	Between about .45 and about .55.
Chromium.....	Between about 23 to about 27.
Nickel.....	Between about 34 and about 37.
Molybdenum.....	Between about 1 and about 2.
Silicon.....	Between about 1 and about 2.5.
Manganese.....	Between about 1 and about 4.
Aluminum.....	Between about .05 and about .40.
Nitrogen.....	Between about .15 and about .40.
Boron.....	Between about .001 and about .04.

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the remainder being iron with the usual amounts of impurities including not more than .04% of phosphorous and .04% of sulphur.

Other alloys within the foregoing broad range and embodying the invention have a composition substantially as follows:

	Percent
Carbon.....	Between about .47 and about .50.
Chromium.....	Between about 23.60 and about 25.80.
10 Nickel.....	Between about 35.08 and about 36.03.
Molybdenum.....	Between about 1.11 and about 1.77.
Silicon.....	Between about 1.19 and about 2.08.
Manganese.....	Between about 1.00 and about 1.19.
Aluminum.....	Between about .05 and about .40.
15 Nitrogen.....	Between about .15 and about .40.
Boron.....	Between about .001 and about .03.

with the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

20 A preferred composition consists of:

	Percent
Carbon.....	About .50.
Chromium.....	About 24.5.
Nickel.....	About 35.
25 Molybdenum.....	About 1.25.
Silicon.....	About 1.50.
Manganese.....	About 1.4.
Aluminum.....	About .25.
Nitrogen.....	About .27.
30 Boron.....	About .002.

with the remainder being iron and including not more than about .04% of each of phosphorous and sulphur.

35 The above-described preferred alloy has physical properties determined at the various temperatures indicated in the following table:

Temp., ° F.	100 Hrs. Rupture Strength, p. s. i.	Creep Rate, 1%— 10,000 Hrs.p.s.i.	Design Strength, p.s.i.	Short Time, High Temp. Strength, p. s. i.	Elong- ation in 2", Per- cent	Red. of Area, Per- cent
1,800.....	5,500	2,700	1,390	23,000	14.0	19.2
1,900.....	4,050	1,760	870	18,500	23.0	50.0
2,000.....	3,100	1,020	590	12,800	41.5	60.3
2,100.....	2,800	560	280	10,800	35.0	66.3
2,200.....	1,150	320	160	7,500	42.5	59.0
2,300.....	260	145	70	6,700	29.0	47.7

40 The air oxidation resistance 2200° F. of the foregoing alloys is less than .015 inch per year.

45 The physical properties of the alloys in the two different composition ranges above stated are closely comparable to those just given in the foregoing table. It is to be understood that many different alloys embodying the present invention may be made within the limits of the foregoing broad composition ranges. In general it may be said that the invention is embodied, at least to an appreciable extent, in each alloy which contains the elements of that broad range in any percentage within their respective specified ranges. As illustrative of this statement the following examples are given:

The composition of one such alloy was as follows:

	Percent
Carbon.....	.43
65 Chromium.....	23.5
Nickel.....	35
Molybdenum.....	1.26
Silicon.....	1.14
Manganese.....	1.0
70 Boron.....	.017
Aluminum.....	.14
Nitrogen.....	.178

with the remainder being iron and including not more than about .04% of each of phosphorous and sulphur. Test specimens of this alloy gave a stress rupture time of over 400 hours under a load of 4000 pounds and a temperature of 1800° F. and that test is not yet completed. The creep rate, design strength, tensile strength, elongation and reduction of area were closely comparable to those given above for the preferred alloy.

Another alloy had the following composition:

	Percent
Carbon	.55
Chromium	26.6
Nickel	36.4
Molybdenum	1.72
Silicon	1.7
Manganese	1.06
Aluminum	.13
Nitrogen	.189
Boron	.0012

with the remainder being iron and including not more than about .04% of each of phosphorous and sulphur. The short time, high temperature property of this alloy was 7000 pounds per square inch at 2200° F.

While the methods of determining the above values are well known to those skilled in the art, a brief explanation of some of them may be in order. The tensile strength, elongation and reduction of area figures were taken after standard test specimens had been heated for a short time at the indicated temperatures. The 100-hour rupture strength is the tensile force required to break a standard test specimen after it has been applied for 100 hours at the specified temperatures. The creep rate was determined by subjecting standard test specimens at the specified temperatures to the indicated tensile forces for 1000 hours with a resultant increase of 1% in length and applying Lawson's formula to get the creep for 10,000 hours. The design strength in the foregoing table is one-half of the force applied in the creep test.

Consideration of the foregoing compositions embodying the present invention discloses important distinctions over the prior art and the surprising consequences thereof. The nickel range in the newly compounded alloy is considerably lower than in the other alloys which have been made to meet the requirements for temperature ranges of 2200° F.-2300° F., but with the heavy loads specified as shown in the list of physical properties. This new alloy of the stated range contains 1% to 2% of molybdenum which has been found to be quite beneficial in alloys of the basic composition and is absent in alloys which have been made previously to meet this rigid specification. The silicon and manganese contents are both higher in the alloys embodying the present invention than in the standard prior alloys. It is believed that the molybdenum, silicon and manganese cooperate with the nickel and chromium to produce enhanced resistance to corrosion and thus permit the foregoing reduction in the nickel content of prior alloys.

An important feature of the present invention is the presence of the aluminum, nitrogen and boron in the ranges stated. It is believed that the nitrogen and boron cooperate with the basic composition, when in the austenitic temperature range, to prevent grain growth and hence to enhance the strength of articles composed of the alloy when subjected to high temperatures. It is also believed that the aluminum cooperates with part of the nitrogen to form aluminum nitride, thereby retaining the nitrogen in the composition for cooperation with the boron and that the aluminum also cooperates with the chromium and silicon in producing a tenacious coating on the surface of the metal which protects the alloy from corrosion at high temperatures. It is believed that the aluminum and nitrogen are largely responsible for the greatly increased resistance to oxidation at high temperatures which has been indicated above.

Alloys embodying the present invention may be made either from virgin metal or from scrap metal. A convenient way to make these alloys is to select scrap metal of the chrome-nickel types, for example, alloy scrap containing 15% chromium, 35% nickel or 25% chromium and 20% nickel, most of the remainder being iron, and to proportion scrap of the different compositions to obtain the chromium nickel content desired as specified above. The percentages of iron, chromium, nickel, molybdenum, manganese and silicon, as well as carbon, may be proportioned and brought within the desired range or to the desired percentages by adding material containing one or more of these metals in amounts sufficient to bring the total percentage of each in the mixture to the desired amount.

The nitrogen is conveniently added in the form of a high nitrogen bearing ferro-chrome alloy. The aluminum is best added as such in a container which can be submerged in the molten metal below the slag so as to prevent loss of aluminum by oxidation. The boron may be added to the molten metal in the form of ferro-boron or nitride-boron for the boron content is 15%-18%.

Having thus described this invention in such full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains to make and use the same, and having set forth the best mode contemplated of carrying out this invention, I state that the subject-matter which I regard as being my invention is particularly pointed out and distinctly claimed in what is claimed, it being understood that equivalents or modifications of, or substitutions for, parts of the above specifically described embodiment of the invention may be made without departing from the scope of the invention as set forth in what is claimed.

What is claimed is:

1. A nickel chrome iron alloy having a tensile strength above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about 200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to about 70 pounds per square inch at 2200° F. for 1000 hours, and consisting essentially of between about .45% and about .55% of carbon, between about 23% and about 27% of chromium, between about 34% and about 37% of nickel, between about 1% and about 2% of molybdenum, between about 1% and about 2.5% of silicon, between about 1% and about 4% of manganese, between about .05% and about .40% of aluminum, between about .15% and about .40% of nitrogen, between about .001% and about .04% of boron, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

2. A nickel chrome iron alloy having a tensile strength above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about 200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to a tensile stress of about 70 pounds per square inch at 2200° F. for 1000 hours, and consisting essentially of between about .47% and about .50% of carbon, between about 23.60% and about 25.80% of chromium, between about 35.08% and about 36.03% of nickel, between about 1.11% and about 1.77% of molybdenum, between about 1.19% and about 2.08% of silicon, between about 1% and about 1.19 of manganese, between about .05% and about .40% of aluminum, between about .15% and about .40% of nitrogen, between about .001% and about .03% of boron, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

3. A nickel chrome iron alloy having a tensile strength of above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about

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200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to a tensile stress of about 70 pounds per square inch at 2200° F. for 1000 hours, and consisting essentially of about .50% of carbon, about 24.5% of chromium, about 35% of nickel, about 1.25% of molybdenum, about 1.50% of silicon, about 1.4% of manganese, about .25% of aluminum, about .27% of nitrogen and about .002% of boron with the remainder being iron and including not more than about .04% of each of phosphorous and sulphur.

4. A nickel chrome iron alloy having a tensile strength above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about 200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to a tensile stress of about 70 pounds per square inch at 2200° F. for 1000 hours, and consisting essentially of between about .45% and about .55% of carbon, between about 23% and about 27% of chromium, between about 34% and about 37% of nickel, about 1.25% of molybdenum, about 1.50% of silicon, about 1.4% of manganese, between about .05% and about .40% of aluminum, between about .15% and about .40% of nitrogen and between about .001% and about .04% of boron with the remainder being iron and including not more than about .04% of each of phosphorous and sulphur.

5. A nickel chrome iron alloy having a tensile strength

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above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about 200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to about 145 pounds per square inch at 2200° F. for 10,000 hours, and consisting essentially of about 43% of carbon, about 23.5% of chromium, about 35% of nickel, about 1.26% of molybdenum, about 1.14% of silicon, about 1% of manganese, about .14% of aluminum, about .78% of nitrogen, about .017% of boron, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

6. A nickel chrome iron alloy having a tensile strength above about 6000 pounds per square inch at 2300° F., an air oxygen resistance of less than about .015 inch per year at 2200° F., a rupture strength of above about 200 pounds per square inch in 100 hours at 2300° F., a creep rate of less than about 1% when subjected to about 145 pounds per square inch at 2200° F. for 10,000 hours, and consisting essentially of between about .55% of carbon, about 26.6% of chromium, about 36.4% of nickel, about 1.72% of molybdenum, about 1.7% of silicon, about 1.06% of manganese, about .13% of aluminum, about .189% of nitrogen, about .0012% of boron, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

No references cited.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,857,266

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

Column 6, line 7, claim 5, for "about 43% of carbon" read -- about .43% of carbon --.

Signed and sealed this 8th day of March 1960.

(SEAL)

Attest:

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