United States Patent [19]

Baxter

[11] **3,800,631**

[45] **Apr. 2, 1974**

---

[54] **FE AL CR Y CO ALLOY**

[75] Inventor: **Walter G. Baxter,** San Jose, Calif.

[73] Assignee: **General Electric Company,** New York, N.Y.

[22] Filed: **May 11, 1972**

[21] Appl. No.: **252,204**

[52] **U.S. Cl.** .... **75/124,** 75/126 G
[51] **Int. Cl.** **C22c 37/10,** C22c 39/14
[58] **Field of Search** .... 75/126 G, 126 H, 124

[56] **References Cited**

UNITED STATES PATENTS

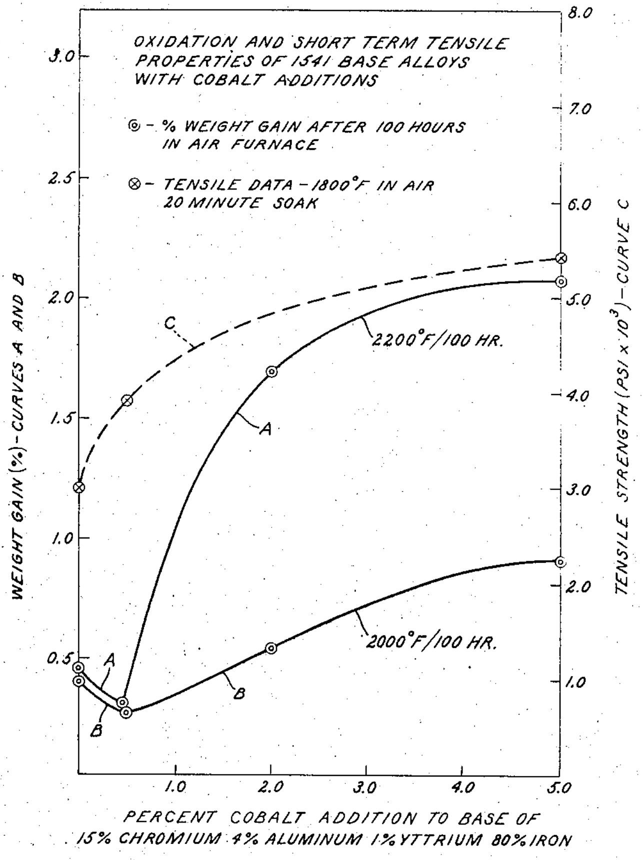
2,286,660	7/1942	Von Kantzow	75/124
3,170,112	2/1965	Bungardt	75/126 H
3,298,826	1/1967	Wukusick	75/124
3,591,365	7/1971	Ohmachi	75/124

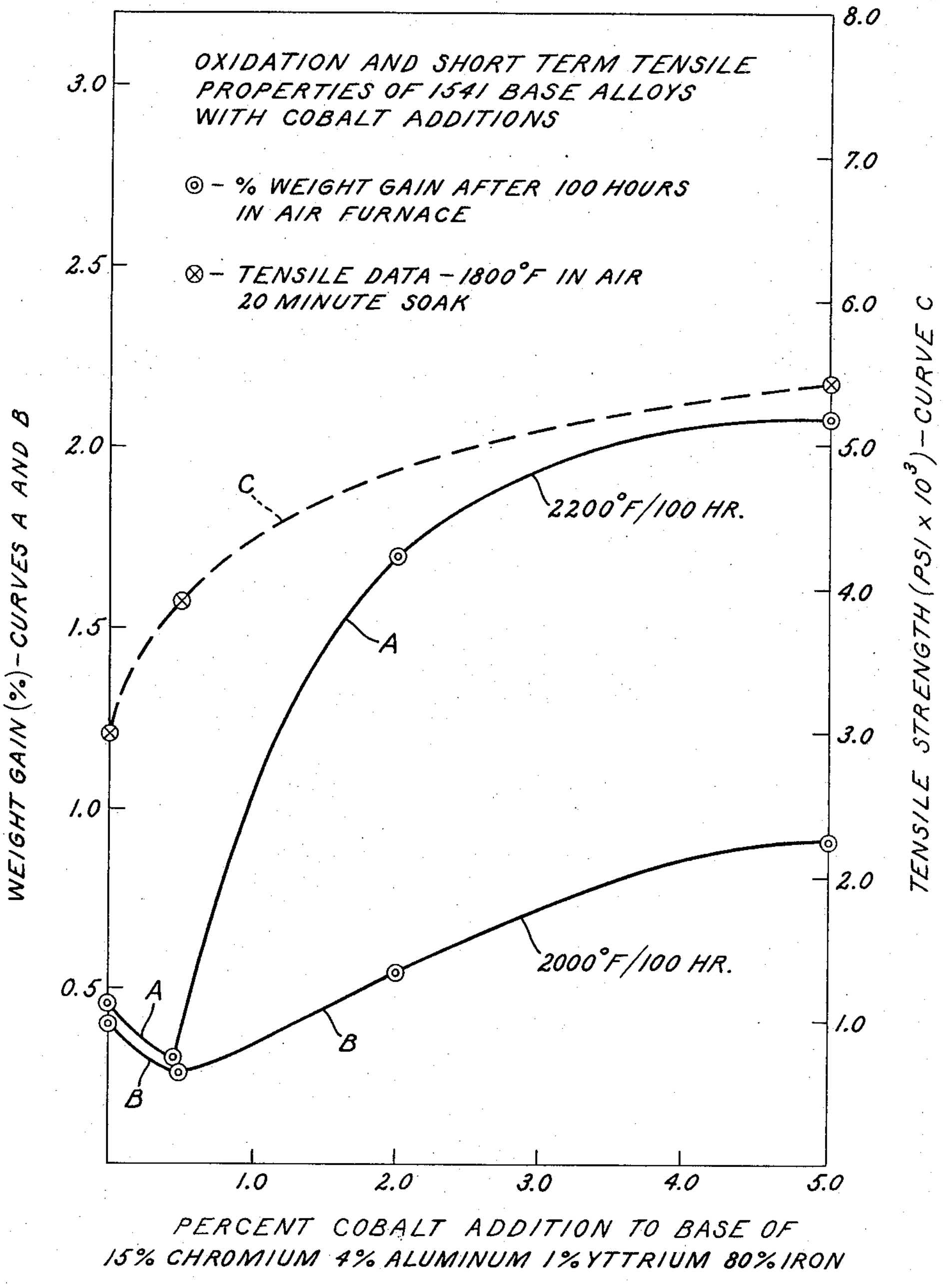
Primary Examiner—Hyland Bizot
Attorney, Agent, or Firm—Allen E. Amgott

[57] **ABSTRACT**

Addition of approximately 0.5 weight percent of Co to prior art's Fe-Al-Cr-Y alloy reduces oxidation rate in air at 2,000°F to approximately one-fourth or less, and at 2,200°F to approximately two-thirds, of same alloy without Co, while producing improved tensile strength. Useful, inter alia, for automotive anti-pollution thermal exhaust reactor.

2 Claims, 1 Drawing Figure




OXIDATION AND SHORT TERM TENSILE PROPERTIES OF 1541 BASE ALLOYS WITH COBALT ADDITIONS
⊚ - % WEIGHT GAIN AFTER 100 HOURS IN AIR FURNACE
⊗ - TENSILE DATA - 1800°F IN AIR 20 MINUTE SOAK
WEIGHT GAIN (%) - CURVES A AND B
TENSILE STRENGTH (PSI x 10³) - CURVE C
3.0
2.5
2.0
1.5
1.0
0.5
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
C
A
B
A
B
2200°F/100 HR.
2000°F/100 HR.
1.0
2.0
3.0
4.0
5.0
PERCENT COBALT ADDITION TO BASE OF 15% CHROMIUM 4% ALUMINUM 1% YTTRIUM 80% IRON

FE AL CR Y CO ALLOY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to the field of oxidation-resistant ferrous alloys, and more particularly to the class of these comprising aluminum and chromium.

2. Description of the Prior Art

The addition of chromium to iron, with or without nickel, to produce so-called stainless alloys is very old, but this stainless quality ordinarily appears only at relatively moderate temperatures, while the temperatures of interest in the present application are primarily of the order of 2,000°F, but may extend to 2,200°F. Pure chromium is subject to attack at high temperatures by both oxygen and nitrogen; the addition of 0.2 to 2.5 percent (by weight, as are all the percentages herein given) of yttrium is claimed to protect chromium to above 1,700°F. Iron plus 35 to 50 percent chromium is brittle and hot short; but the addition of 0.5 to 3 percent yttrium and 0.5 to 1 percent palladium produces an oxidation-resistant alloy which may be rolled first hot and then cold to sheet. Similarly, iron plus 25 to 35 percent chromium, 0.5 to 5 percent yttrium and 0.1 to 1 percent is oxidation resistant, as is iron plus 20 to 95 percent chromium and 0.5 to 5 percent yttrium. Iron plus 20 to 95 percent chromium, 0.5 to 4 percent aluminum and 0.5 to 3 percent yttrium is oxidation resistant and cold rolls readily; with 5 percent aluminum it is brittle and is hot short. Iron plus 20 to 35 percent chromium, 0.5 to 1.5 percent yttrium and 0.005 to 0.015 percent calcium is reported to be superior in oxidation resistance to above 2,000°F and to have good workability. For use in nuclear reactors an alloy is desired which will not become brittle by hardening at high temperatures; an alloy of iron plus 0 to 15 percent chromium, 0.5 to 12 percent aluminum, and 0.1 to 3.0 percent yttrium is markedly free from this as compared with 25 percent chromium, 4 percent aluminum, and 1 percent yttrium; the preferred alloy is of iron plus 15 percent chromium, 4 percent aluminum, and 1 percent yttrium.

The uses for high-temperature resistant alloys are so numerous that it is not possible to select any one as superior to another for all applications; economic considerations, including the different costs of fabricating differently workable alloys, and the economic value of greater life in a more expensive part as compared with shorter life in a less expensive part, determine ultimate superiority for a given application.

SUMMARY OF THE INVENTION

My invention is an alloy in which cobalt is added to an alloy of iron, chromium, aluminum, and yttrium, with a resulting improvement in resistance to corrosion at high temperature and an improvement in tensile strength. While, as has been indicated, there are a variety of uses for high-temperature resistant alloys whose major constituents are widely and economically available, a particular present need which the alloy of my invention is adapted to fill is for the structure of exhaust reactors for internal combustion engines for which current interest in reducing atmospheric pollution foretells a substantial demand.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE represents the oxidation rate at two different temperatures, and the tensile strength, of alloys of interest to this application having varying proportions of cobalt.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The basic prior art composition which serves as a basis for my improvement is an alloy of nominal weight composition 15 percent chromium, 4 percent aluminum, 1 percent yttrium, remainder iron, known by abbreviation of these percentages as "1541" alloy. This is known to have good resistance to oxidation by atmospheric air at high temperatures, and good tensile strength. I have found that adding cobalt to this prior art alloy produces an improvement in oxidation resistance and in tensile strength. The single FIGURE shows, against abscissas of weight percent of cobalt in the basic prior art alloy described above, the weight gain, in percent, of 0.030 inch thick strip when heated in air at 2,200°F. for 100 hours (upper solid curve, A) and at 2,000°F. for 100 hours (lower solid curve, B) as indicated by the left axis of ordinates; and the tensile strength of these alloys at 1,800°F. in air in kilopounds per square inch (C and right axis of ordinates). Data points are indicated.

The preferred manner of making these alloys is melting in vacuo with induction heating in charges of about 10 to 30 pounds, which produce an ingot about three and three-quarters inches in diameter and five inches long. This is hot extruded at 1,800°F. as 1 inch round bar. The bar is then forged flat, and hot rolled at 1,800°F. to about 0.060 inches thickness. This strip is then cold rolled with intermittent air annealing at 1,800°F. to 0.030 inch thick sheet. Photomicrographs of metallographic sections of samples of these alloys appear to indicate that it is preferable, in a composition which permits doing so, to add the yttrium and cobalt in the form of a master alloy of two parts yttrium and one part cobalt. This practice is believed to stabilize the oxidation-resistant oxide film formed by aluminum and yttrium, and to inhibit oxide "stringer" penetration through grain boundaries.

It will be observed that the weight gain (which is a measure of the oxidation rate) fall to a minimum for about 0.5 percent cobalt content, and then rises again. The tensile strength is increased by cobalt addition. As may be seen from the lower solid curve, for 2,000°F. for 100 hours, an addition of 2.0 percent of cobalt raises the weight gain (and hence the oxidation rate) to about what is obtained without cobalt addition — that is, for the original prior art alloy. On the other hand, it may be seen from curves A and B that some improvement, although not an optimum, may be expected from 0.25 percent cobalt. These limits represent reasonable bounds of the range of my invention which is productive of obviously useful results. Within the range, 0.4 to 1.0 percent cobalt is to be preferred. As the skilled metallurgist is aware, conventional art methods for making alloys do not produce exact compositions, and I have found by analysis that alloys in this class showed chromium from 15.0 to 15.4 percent for a nominal 15.0 percent content, and aluminum from 4.4 to 4.9 percent for a target composition of 4.0 percent; references to the basic alloy must be understood to include such variations as normal in the art.

Numerical data represented by the curves of the drawing are:

Percent Cobalt in 1541 Alloy	Tensile Strength 1800°F. in P.S.I.	Percent Weight Gain in 100 Hours Exposure to Atmosphere at Temperature 2,000°F.	2,200°F.
0	3,000	0.481	0.455
0.4	3,950		
0.5	0.278	0.305	
2	0.544	1.71	
5	0.914	2.09	

I claim:

1. An alloy consisting essentially by weight of 15 percent chromium, 4 percent aluminum, 1 percent yttrium, cobalt from 0.25 to 1.5 percent and the remainder iron.

2. The alloy claimed in claim **1** in which the cobalt content is from 0.4 to 1.0 percent.

* * * * *