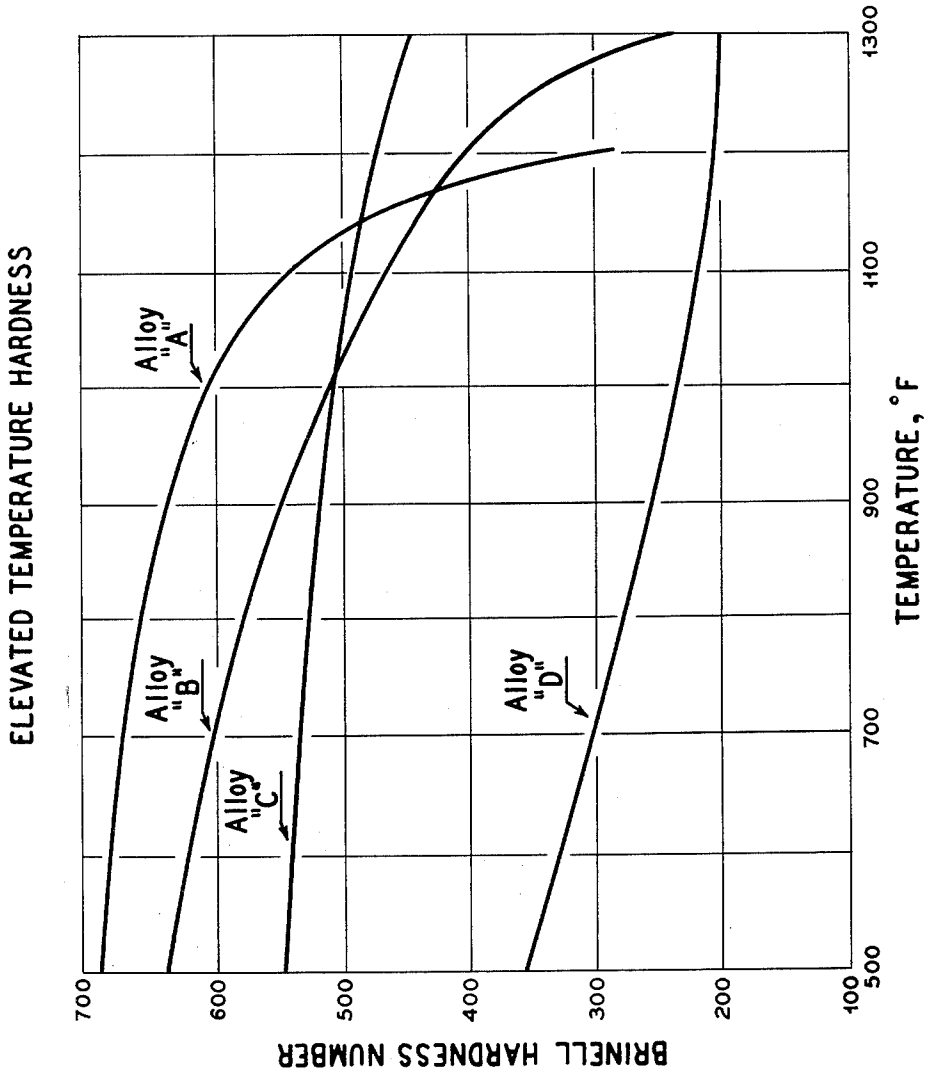
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IRON-BASE ALLOY

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IRON-BASE ALLOY

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This invention relates to an iron-base alloy for use in applications requiring wear resistance at moderately high temperatures.

The special property of resistance to wear and abrasion is required in machine and structural components subjected to the continual rubbing action of other moving parts. Very often the actual operation of a machine and also the accuracy of its performance requires a minimum of dimension-changing wear in the machine parts. Bearings, valves, guides, and other parts in steam and gas turbines, power equipment, process reactors, nuclear reactors, etc., must all be dependable in this regard. Because of the need for wear resistance in many such applications, alloys have been developed which especially exhibit this property.

Of special importance is the need for wear-resistant alloys suitable for use in the so-called "tempering range" of temperatures—from 800° F. to 1100° F. While many ordinary iron-base materials have sufficient hardness at room temperature, they do not retain enough hardness at temperatures above 800° F. The "superalloys" are generally designed for use at temperatures much higher than 1100° F. and so there exists a gap which is filled only in part by the moderate temperatures wear-resistant alloys, many of which have a cobalt-base or employ large amounts of tungsten, chromium or manganese. These alloys are generally characterized by high cost and high strategic element content. In Table I the compositions in percents by weight are given for several moderate temperature wear-resistant alloys.

TABLE I

Wear-Resistant Alloys

	Alloy B	Alloy C	Alloy D
Cr	4	30	22
Fe	Balance	2.5 max.	Balance
C	0.75	2.0	0.53
Si	0.30	0.5 max.	1.0 max.
Co		Balance	
Mo		0.8 max.	
V	1	4	
B		1.2	
W	18	18.5	
Ni		3.5	4
Mn	0.20	0.25 max.	9
N			0.4

Alloy B is an iron-base alloy with tungsten as the principal hardening agent. Alloy C is a cobalt-base alloy possessing high hardness and wear resistance at temperatures above 1500° F. Alloy D is a high manganese iron-base alloy possessing good wear resistance at temperatures up to 1600° F.

The high temperature hardness of these alloys is shown graphically in the drawing. It is to noted that wear resistance in an alloy is generally related to the hardness of the alloy.

Another class of excellent alloys is represented by U.S. Patent 1,729,154 which shows wear-resistant alloys containing from 13 to 40 percent molybdenum or tungsten,

5 to 20 percent chromium, 14 to 75 percent iron, 0.5 to 3 percent vanadium, 0.3 to 2 percent silicon, 4 to 20 percent nickel or cobalt, 0.5 to 4 percent manganese, and 0.85 to 3.5 percent carbon. Alloys based on this composition have excellent high temperature hardness but, for the reasons explained below, are not suitable for the purpose of this invention.

The above-mentioned alloys, in addition to their high cost and strategic element content, are not suitable for one very important use, that in nuclear reactors and related equipment, because of their high content of undesirable elements. As a result of bombardment by neutrons in a nuclear reactor, many materials become radioactive and are thereupon dangerous to handle, maintain, or repair. In the selection of materials for use in nuclear reactors, those materials are preferred which do not become radioactive at all, or for which the radioactivity is weak, without gamma radiation, or of a short half life. "Half life" is a measure of the activity of a radioactive substance and a material having a short half life is less dangerous than a material emitting the same radiation but having a longer half life. The elements nickel, boron, tungsten, cobalt, and manganese are such elements having comparatively long half lives and emitting dangerous radiation when exposed to neutron bombardment. The element cobalt is particularly dangerous in this regard. Neutron bombardment of cobalt forms cobalt^{60} having an induced radioactivity of high energy gamma radiation and having the extremely long half life of 5.3 years. It follows, therefore, that a wear-resistant alloy suitable for use in atomic energy applications should contain a minimum amount of such elements and, in particular, an absolute minimum of cobalt.

It is unfortunate that the elements tungsten, nickel, manganese, and especially cobalt are the commonly used hardeners in wear-resistant alloys, including the prior art alloys listed above and the alloys of the U.S. patent given above.

Furthermore since a nuclear reactor operates as a result of the absorption by a fuel nucleus of a neutron with the break down by fission of the then unstable nucleus yielding heat, it is essential that the neutrons in the system be conserved for such nuclear interactions. Structural materials which tend to absorb neutrons are generally to be avoided in the construction of a nuclear reactor.

It is the primary object of this invention, therefore, to provide a wear-resistant alloy for use at temperatures up to about 1100° F., which alloy has properties making it suitable for use in atomic energy applications.

It is another object of this invention to provide a wear-resistant alloy for general wear-resistant applications at temperatures up to about 1100° F. which alloy contains a minimum of strategic materials.

Other aims and advantages of this invention will be apparent from the following description and the appended claims.

In accordance with these objects an alloy is provided consisting essentially by weight of from 12 to 20 percent chromium, from 12 to 20 percent molybdenum, from 2 to 3.5 percent carbon, from 0.5 to 1.5 percent by weight silicon, up to a maximum of 3.5 percent in the aggregate of nickel and cobalt, up to a maximum of 0.5 percent manganese, up to 2.5 percent vanadium, and the balance substantially all iron and incidental impurities.

In the drawing the elevated temperature hardness data for this alloy, designated Alloy A, is shown graphically

along with similar data for some of the prior art alloys described before.

Chromium is present in the alloy to impart corrosion resistance and oxidation resistance and is preferably held at from 15.5 to 18.5 percent by weight. Molybdenum is the principal agent for promoting hot hardness and strength and is preferably contained in the alloy in an amount between 14.5 and 17.5 percent by weight.

Carbon is essential for the formation of carbides and is preferably contained in amounts from 2.85 to 3.25 percent by weight.

Silicon contents improve the fluidity of the alloy and its castability and weldability. Silicon contents are preferred in the range of from 0.50 to 1.3 percent by weight.

Impurities associated with iron-base alloys may be present in an amount up to about 5 percent by weight. Nickel and cobalt may be present up to 3.5 percent by weight in the aggregate in the broad alloy composition but should be limited in the preferred composition to less than 1.0 percent cobalt and less than 1.75 percent nickel. Manganese is a residual element of the usual metallurgical processes and may be present up to 0.5 percent but should be kept as low as possible. The presence of other impurities, such as columbium, tantalum, boron, manganese, sulphur, phosphorous, etc., should be kept as low as possible.

The essential constituents of this alloy, chromium, molybdenum, carbon, silicon, and iron have satisfactory nuclear properties allowing the use of the alloy in atomic energy applications. These elements have either relatively short half lives or are used in small safe amounts. Additionally these elements have a small cross section for neutron absorption. The neutron absorption cross sections, as measured in barns, for these elements are as follows: chromium—2.9; molybdenum—2.4; carbon—0.0045; silicon—0.13; iron—2.4 The neutron absorption cross sections of the above-mentioned long half life elements are much higher; tungsten—19; cobalt—37; manganese—13; boron—750; nickel—4.5.

In this regard it is to be noted that vanadium with a neutron cross section of 5.1 barns may be present in an amount up to 2.5 percent by weight when the alloy is used for general wear resistance applications. Where radiation problems are highly critical the amount of vanadium should be limited to less than 0.25 percent. At room temperatures the presence of vanadium in the alloy does not appreciably contribute to hardness. For high temperature use the alloy may contain about 2 percent vanadium.

Despite the absence from this alloy of the commonly used hardeners, tungsten, cobalt, etc., the alloy possesses excellent hot hardness and wear resistance. As seen in the drawing, the alloy of this invention, Alloy A, surpasses in hardness the prior art Alloys B, C, and D in the important temperature range of 800° F. to 1100° F. While there are wear resistant alloys of the same general hardness as this alloy as represented by the above-identified U.S. patent, they contain objectionable amounts of cobalt. It is an unexpected improvement over the prior art that higher hardnesses than those of Alloys B, C, and D can be achieved without the inclusion of cobalt or tungsten in the alloy. The hardness of the alloy without the presence of tungsten, cobalt, manganese, or nickel is due to a high alloy matrix with a fine carbide structure. The absence of cobalt in the alloy allows for its use in nuclear reactors and provides a material having a low strategic element content.

A preferred composition of the alloy consists essentially by weight of about 17 percent chromium, about 16 percent molybdenum, about 3 percent carbon, about 0.80 percent silicon, less than 0.2 percent cobalt, about 2 percent vanadium, and the balance substantially all iron.

As an example of the practice of the invention several heats of the alloy were prepared as shown in Table 2.

TABLE 2

Alloy A Compositions

	Heat No. 1	Heat No. 2	Heat No. 3	Heat No. 4	Heat No. 5
Cr	16.79	16.69	17.14	17.62	17.60
Fe	Bal.	Bal.	Bal.	Bal.	Bal.
C	2.94	2.75	2.96	2.98	2.78
Si	0.68	0.76	0.86	0.73	0.58
Co	<0.2	<0.2	<0.2	<0.2	<0.2
Mn	0.22	0.18	0.12	0.10	0.14
V	2.12	1.91	2.11	2.07	1.91
Mo	15.94	15.05	16.06	15.56	16.06
P	0.001	0.004	0.009	0.008	
S	0.016	0.017	0.017	0.010	
Ni	0.48				0.45

The average room temperature properties of the alloy are shown in Table 3.

TABLE 3

Mechanical Properties

Ultimate tensile strength, p.s.i.	78,900
Percent elongation in one inch	1.0
Percent reduction of area	2.0

The test specimens of Table 3 were given a heat treatment consisting of one hour at 1950° F., followed by an air cooling, and a tempering at 375° F. for one hour. However such heat treatments are generally not required to develop the hardness of the alloy as is seen in the data of Table 4.

TABLE 4

Hardness and Impact Strength After Heat Treatment

Heat Treatment	Hardness Rockwell C	Unnotched Charpy Impact Strength, Ft.-Lb.
I—1 hr. at 1,950° F., air cool, temper 1 hr. at 375° F	66-68	5-6
II—1 hr. at 1,950° F., air cool, temper 2 hrs. at 900° F	63-70	4-7
III—1 hr. at 2,025° F., air cool, temper 1 hr. at 375° F	66-67	5-7
IV—1 hr. at 2,050° F., air cool, temper 1 hr. at 900° F	65-66	5-7
As-Cast—no heat treatment	65-66	5-7

The results of the tests shown in Table 4 indicate that heat treatment does not materially affect the hardness properties of the alloy; however, a heat treatment consisting of 1 to 4 hours at 375° F. to 1100° F. may be used to relieve casting or welding stresses.

The alloy may be prepared by standard metallurgical methods. It is generally cast into desired shapes. The alloy may also be prepared as welding rods or powder.

The alloy has excellent welding properties. Table 5 shows the results of various welding tests to produce welding deposits and weldments. The observed characteristics were determined by evaluating the ease of application, porosity, and general appearance of the weld deposit. The hardness of the welded deposit averages Rockwell C 61–64. One of the outstanding welding characteristics of the alloy is the excellent wettability during welding and fusion hard facing operations. There is no segregation of compounds or elements during casting or welding.

TABLE 5

Welding Characteristics

	Wettability	General Characteristics
Alloy A	Excellent	Very good.
Alloy B	Poor	Poor.
Alloy C	Good	Very good.
Alloy D	Good	Very good.

The alloy also possesses a relatively high resistance to corrosion and oxidation.

What is claimed is:

1. A wear-resistant alloy consisting essentially by weight of from 15.5 to 18.5 percent chromium, from 14.5 to 17.5 percent molybdenum, from 2 to 3.5 percent carbon, from 0.5 to 1.5 percent silicon, up to a maximum of 3.5 percent in the aggregate of nickel and cobalt, up to a maximum of 0.5 percent manganese, about 2 percent vanadium, and the balance substantially all iron and incidental impurities.

2. A wear-resistant alloy consisting essentially by weight of from 15.5 to 18.5 percent chromium, from 14.5 to 17.5 percent molybdenum, from 2 to 3.5 percent carbon, from 0.5 to 1.5 percent silicon, up to a maximum of 1.0 percent cobalt, up to a maximum of 1.75 percent nickel, up to a maximum of 0.5 percent manganese, about 2 percent vanadium, and the balance substantially all iron and incidental impurities.

3. A wear-resistant alloy consisting essentially by weight of from 15.5 to 18.5 percent chromium, from 14.5 to 17.5 percent molybdenum, from 2.8 to 3.25 percent carbon, from 0.5 to 1.5 percent silicon, up to a maximum of 1.0 percent cobalt, up to a maximum of 1.75 percent nickel, up to a maximum of 0.5 percent manganese, about 2 percent vanadium, and the balance substantially all iron and incidental impurities.

4. A wear-resistant alloy consisting essentially of about 17 percent chromium, about 16 percent molybdenum, about 3 percent carbon, about 0.80 percent silicon, less than 1.0 percent cobalt, about 2 percent vanadium, and the balance substantially all iron and incidental impurities.

5. A wear-resistant alloy consisting essentially of about 17 percent chromium, about 16 percent molybdenum, about 3 percent carbon, about 0.80 percent silicon, less than 0.2 percent cobalt, about 2 percent vanadium, and the balance substantially all iron and incidental impurities.

References Cited in the file of this patent

UNITED STATES PATENTS

2,051,358	Zublin	Aug. 18, 1936
2,099,509	Blessing	Nov. 16, 1937