March 31, 1953 K. SPITZ 2,633,420

ALLOY IRONS AND STEELS

Filed Oct. 21, 1949 2 SHEETS—SHEET 1

FIG. 1

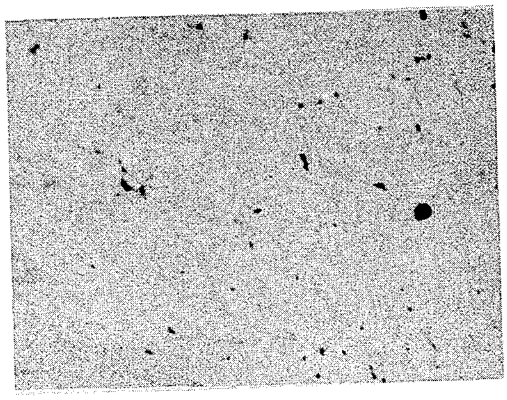
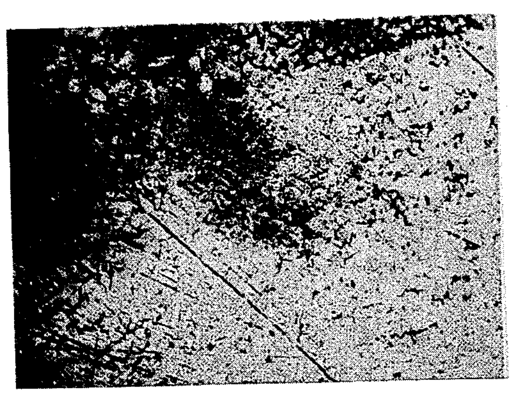


FIG. 2

FIG. 3



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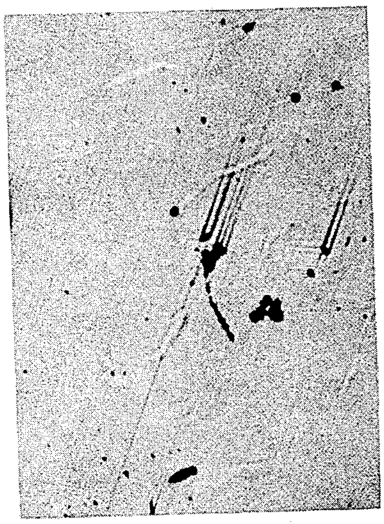


FIG. 4

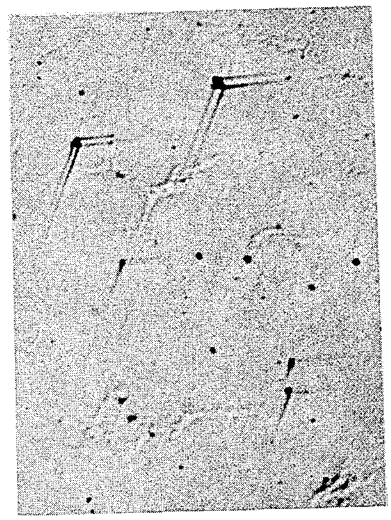
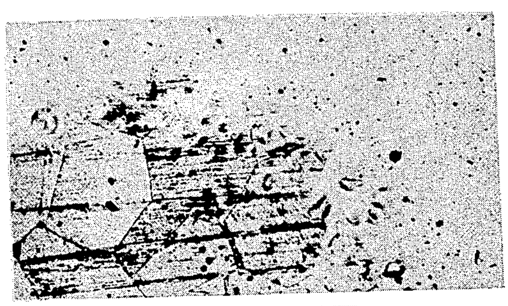


FIG. 5

STAINLESS STEEL 18:8



ALLOY № 123

FIG. 6

0.75 CARBON STEEL

ALLOY № 134

FIG. 7

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ALLOY IRONS AND STEELS

Karl Spitz, Cleveland, Ohio

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10 Claims. (Cl. 75—125)

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This invention relates to alloy irons and steels, as indicated, and more specifically to austenitic alloy irons and steels having a high degree of resistance to chemical corrosion generally and to acid corrosion in particular, and having, additionally, improved physical properties.

I have experimented extensively with alloy compositions and am very familiar with the attributes and physical characteristics of the various high alloy and low alloy steels which have hitherto been developed and which have received widespread use in the specific fields to which they are adapted. Such steels are exemplified by the well known austenitic chromium-nickel stainless steels, particulary 18% chromium, 8% nickel stainless steel, and also by the high nickel-molybdenum "Hastelloy" group, as for example, "Hastelloy B" which contains about 65% nickel, 30% molybdenum and 5% iron.

It is noteworthy that although strenuous efforts have been directed toward the development of corrosion resistant steels, little success has been achieved in developing alloy steels which have any sustained resistance to the action of acids, even under moderate conditions of temperature. Needless to say, such existing alloys are even less effective under high temperature conditions or when exposed to corrosive products of combustion such as prevail in the operation of jet engines and gas turbines.

The alloy irons and steels which I have invented are primarily noteworthy for their high degree of resistance to chemical corrosion which is a very potent and troublesome factor in the food processing and chemical industries, including the petroleum refining industry. They are likewise very resistant to high temperature corrosion such as occurs in the aforementioned jet engines and gas turbines.

Thus, it is a primary object of my invention to provide a new group of alloy irons and steels characterized by their outstanding ability to withstand chemical corrosion.

Another object of my invention is to provide alloy steels of the character described, which will have a significant resistance to the corrosive action of aqua regia, and thus will lie, insofar as corrosion resistance is concerned, intermediate platinum and the most effective alloys presently known, such as the "Hastelloy" group.

Still another object of my invention is to provide a group of corrosion-resistant alloy irons and steels having improved physical properties

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such as high tensile strengths and yield points whereby to obtain improved strength to weight ratios.

A further object of my invention is to provide corrosion-resistant alloy irons and steels having certain desirable and improved electrical and magnetic characteristics, particularly when formed as wires or filaments.

Still another object of my invention is to provide corrosion-resistant alloys of the character described, which are adaptable to a large variety of uses in that their physical characteristics can be varied; certain of the alloys being, for example, readily machinable and workable, and certain others, for example, being hard and wear-resistant.

Other objects and advantages of my invention will be apparent during the course of the following description.

For a graphic understanding of the characteristics and properties of the alloy irons and steels which I have invented, reference may be had to the accompanying drawings forming part of this application, in which,

Fig. 1 is a photomicrograph showing the structure of my alloy No. 123 as etched with aqua regia.

Fig. 2 is a photomicrograph of the same magnification as Fig. 1, showing the structure of stainless steel 18:8 as etched with aqua regia.

Fig. 3 is a photomicrograph of the same magnification as Fig. 1, showing the structure of "Hastelloy B" as etched with aqua regia.

Fig. 4 is a photomicrograph showing the structure of my alloy No. 132 as etched with picric acid.

Fig. 5 is a photomicrograph showing the structure of my alloy No. 134 as etched with picric acid.

Fig. 6 is a photomicrograph showing the structure in cross-section of a weldlayer of my alloy No. 123 as bonded to stainless steel 18:8 and etched with aqua regia.

Fig. 7 is a photomicrograph showing the structure in cross-section of a weldlayer of my alloy No. 134 as bonded to a high carbon (.75%) steel and etched with picric acid.

The alloys of my invention contain at least 50% iron, no more than 1.70% carbon and four major alloying constituents or elements, namely, chromium, nickel, copper and molybdenum, each being present in an amount not less than 3.60%, and preferably not less than 6.00%, the sum total of said alloying constituents being no more than 50% of the alloy composition. I have further found that the desired characteristics toward which my invention is directed, are generally obtainable without having any of said major alloying elements present in an amount in excess of about 20.00%.

In Table I, below, I disclose the composition of eleven specific alloys coming within the broad range of my invention, the characteristic of these alloys being their excellent corrosion resistance, although it will be understood that certain of said alloys may have said property in a greater or lesser degree than other of said alloys, as will more fully appear hereinafter. Each alloy, in addition to its corrosion resistance, is characterized by a particular physical, electrical, or chemical property which is considered desirable for adapting the alloy to a specific use or application, these characteristics resulting from changes in the proportions of the constituent elements, as will appear more fully hereinafter.

cause corrosion, the oxidizing influences perhaps being neutralized or inhibited by the reducing influences.

As a practical matter, it is, of course, very desirable that the aggregate total of the major alloying constituents be kept as low as possible, consistent with the degree of corrosion resistance which is the object of the invention, as the alloying elements are relatively expensive and therefore greatly influence the end cost of the alloy compositions. A compromise must also be effected between the desire for optimum corrosion resistance on the one hand, and the necessity of providing alloy compositions having other desired characteristics, such as workability, ductility and strength, on the other hand.

The alloy steels listed in Table I are to some extent representative of the various compromises which can be effected in the compositions while still maintaining the desired degree of corrosion-resistance.

TABLE I

Percentage composition

Alloy No.	Cr	Ni	Cu	Mo	Ti	C	Si	P	Mn	Fe
121	8.90	5.45	12.86	8.60	------	0.11	0.16	0.03	0.27	Remainder.
123	9.11	14.30	6.00	8.40	------	0.13	0.33	0.02	0.11	Do.
123a	12.60	18.20	7.70	10.80	------	0.11	0.25	0.02	0.12	Do.
125	10.86	4.85	15.37	6.00	------	0.12	0.72	0.02	0.08	Do.
129	11.00	4.55	13.00	7.20	------	0.10	0.79	0.22	0.18	Do.
132	12.12	14.00	5.42	6.60	------	0.12	0.48	0.02	0.16	Do.
134	5.64	14.00	6.00	13.80	------	0.12	0.39	0.02	0.12	Do.
162	16.37	14.72	3.91	3.63	------	0.13	0.05	0.04	0.26	Do.
200	15.25	15.30	5.47	6.23	------	0.11	0.10	0.02	0.24	Do.
201	10.50	12.10	4.17	5.46	------	0.12	0.08	0.02	0.29	Do.
208	13.60	13.62	4.93	5.74	0.45	0.12	0.09	0.02	0.26	Do.

It will be noted that the carbon range of my alloy compositions is that which is usually found in ordinary steel, the carbon being preferably less than 1% of the total composition. It is to be understood that my alloys can contain and usually will contain such incidental ingredients as are customarily present in ordinary steels, such ingredients including, for example, silicon, phosphorus, manganese and sulfur in small amount. Although in the foregoing Table I, I have separately stated the percentages of such ingredients which are present in the listed alloys, I wish it to be understood that whenever such ingredients are not separately stated, I intend the terms "iron" and "substantially all iron" to embrace not only pure iron, but also iron containing the aforementioned incidental ingredients in amounts up to the maximum amounts usually found in steel.

The combination of chromium and nickel in the alloys influences the ability of the alloys to resist oxidizing corrosion such as results from oxidizing atmospheres or oxidizing chemicals including oxidizing acids. The combined alloy group of chromium, nickel, copper and molybdenum shows resistance not only to oxidizing corrosion, but also to reduction corrosion such as results from reducing chemicals, including reducing acids.

This attribute or characteristic of my alloys is their primary feature and results as aforementioned in their improved resistance to combined oxidizing-reducing influences such as are effected by aqua regia.

It appears that to obtain optimum corrosion resistance, a certain balance in the proportions of the individual major alloying constituents must be obtained irrespective of the combined total or aggregate of the alloying constituents. This balance seems to effect a corresponding equilibrium in the electro-chemical forces which

It is noteworthy that the chromium content of the listed alloys lies below 17% and in some instances lies below 10%, such as in alloys Nos. 121, 123 and 134, whereas it has heretofore been accepted that no significant corrosion resistant characteristics could be obtained in austenitic chromium-nickel steels which did not contain in excess of 10% chromium, as evidenced by the chromium content of the well known stainless steels 18:8, 25:12, etc.

Despite this restriction in the chromium content, it is aparent from an inspection of Figs. 1, 2 and 3 of the drawings, that alloy No. 123 which has a chromium content of 9.11% and a combined Cr-Ni content of under 23.50%, resists the action of aqua regia much better than the 18:8 stainless or "Hastelloy B."

I have found alloy No. 123 to have about the best corrosion-resistance of the listed alloys, followed closely however by alloy No. 134 and alloy No. 121.

In Fig. 6 a direct comparison is possible between 18:8 stainless steel and a weldlayer of alloy No. 123 as etched by immersion in aqua regia. It will be evident that the resistance of the stainless steel is quite poor whereas alloy No. 123 shows little evidence of attack. It is noteworthy that the structure of alloy No. 123 is that of a one phase alloy.

Figs. 5 and 7 show the action of picric acid on alloy No. 134 and, as is evident from Fig. 7, the high carbon steel is strongly attacked by the acid whereas the acid has little effect on the weldlayer of alloy No. 134.

As shown in Fig. 4, even my alloy No. 132 which ranks as a low corrosion-resistant member of the group, has excellent resistance to the picric etch. The alloy has been subjected, without failure, to the standard Strauss corrosion test which is used for testing stainless steels.

All of the listed alloys are austenitic, have high tensile strengths and yield points, and can be cast.

Table II below shows the results of tests I have conducted on various of the alloys with regard to tensile strength and reduction of area, in the cast condition.

TABLE II

Alloy No.	Tensile Strength (1,000 p. s. i.)	Per cent R. A.
121	101	19
123	91	26
125	100	28
129	96	6
132	86	38
134	91	16
162	85	53
200	90	22
208	86	38

Generally speaking, the high strength alloys, such as Nos. 121 and 125 have a relatively high molybdenum-copper content, whereas the more ductile alloys such as Nos. 162 and 208 have a relatively greater chromium-nickel content.

Since copper has a hardening effect on the alloys, which is aided by increases in the carbon, silicon and phosphorus content, alloys Nos. 125 and 129, especially when modified by an increased carbon content, are usable mainly "as cast" for wear-resistant and heat-resistant purposes. Their high copper content also increases their electrical conductivity and makes them suitable for use in the electrical industry.

Generally speaking, those alloys in which carbon does not exceed 0.3%, silicon does not exceed 0.5%, phosphorus does not exceed 0.05%, and manganese does not exceed 1.0%, are most suitable for wrought applications.

On the other hand, those alloys in which carbon is up to 1.7%, or silicon is up to 1.2%, or phosphorus is up to 0.5%, or manganese is up to 1.5%, are mainly suitable for cast applications.

As the chromium and nickel content influence the ductility of the alloys, as heretofore stated, all of the listed alloys, with the exception of Nos. 125 and 129, can be wrought, including forging and coldworking.

It is to be emphasized that all of my alloys are austenitic even after coldworking and that no intergranular corrosion occurs in the higher carbon alloys such as occurs in stainless steels when the carbon content exceeds about 0.10%.

In addition to alloys Nos. 125 and 129, alloy No. 121, due to its high copper content, is also suitable for electrical applications in the cast and forged condition.

Other of the alloys are capable of being drawn into fine wire which is austenitic and non-magnetic and therefore has applications in the electrical field, especially in the field of electronics. Alloys Nos. 132 and 200 are particularly suitable for this purpose.

I have successfully drawn alloy No. 132 into a fine wire of .004 diameter which had a tensile strength of about 300,000 p. s. i. and had a 15% greater electrical conductivity than like wire formed of 18:8 stainless steel. As heretofore stated, the wire is entirely austenitic and non-magnetic.

The fact that, in general, a high degree of corrosion-resistance denotes a correspondingly high degree of heat resistance, is evidenced by the fact that annealed wire formed of alloy No. 132 has about 30% greater tensile strength than like wire similarly treated and formed of 18:8 stainless steel.

The influence of changes in the total amount of major alloying elements present in a particular alloy composition, is indicated by tests I have conducted using alloy No. 132 as a basis.

Alloy No. 132, which contains a total of 38.14% of the major alloying elements, was tested for hardness and gave a Rockwell B reading of 72.

By increasing each major alloying element of alloy No. 132 proportionately to a total alloy content of 42.25%, alloy No. 200 was obtained which has a Rockwell B hardness of 87 and increased tensile strength.

By porportionately decreasing the total alloy content of alloy No. 132 to 32.23%, alloy No. 201 was obtained which showed a hardness of 70 Rockwell B and corresponding lower tensile strength.

All of my alloys are work hardenable and when so treated reach hardness values of about Rockwell C 32.

All of my alloys can be welded or brazed by conventional methods.

All of the alloys, but particularly alloys Nos. 123, 123*a*, and 134, are suitable for use as filler metal in welding.

The alloys have demonstrated excellent creep resistance properties as well as a high degree of toughness as evidenced by notched-bar impact tests.

The foregoing description of the properties of my alloys indicates that they have numerous applications wherever corrosion resistance, high strength, and non-magnetic qualities are factors, especially where a combination of these properties is required.

In addition to the uses heretofore mentioned, my alloys may be used for such diverse purposes as springs, non-absorbable metallic sutures for surgery, marine equipment and devices, including roller bearings, architectural ornamentation, and components of valves, pumps and the like.

I have also found that my alloys have good tonal qualities which would permit of their use as bells, particularly in marine service.

The alloys are non-sparking and therefore are usable for tools utilized in mining operations and the like.

The alloys are also suitable for cladding applications and also appear to have application in low temperature fields of use.

It is to be understood that the particular alloy compositions herein listed are exemplary and illustrative of desirable alloy compositions, and that slight changes may be made in the proportions of the alloys without departing from the spirit of the invention as defined in the subjoined claims.

Having thus described my invention, I claim:

1. A ferrous alloy composed of more than 6.0% but not more than 20% each of chromium, nickel, copper and molybdenum, the sum total of said elements being less than 50%, and the remainder being substantially all iron.

2. A corrosion-resistant ferrous alloy of the following composition: chromium about 9.11%, nickel about 14.30%, copper about 6.0%, molybdenum about 8.40%, and the remainder substantially all iron.

3. A corrosion-resistant ferrous alloy of the

following composition: chromium about 5.64%, nickel about 14.0%, copper about 6.0%, molybdenum about 13.8% and the remainder substantially all iron.

4. A corrosion-resistant ferrous alloy of the following composition: chromium about 10.86%, nickel about 4.85%, copper about 15.37%, molybdenum about 6%, and the remainder substantially all iron.

5. A corrosion-resistant ferrous alloy of the following composition: chromium about 15.25%, nickel about 15.30%, copper about 5.47%, molybdenum about 6.23%, and the remainder substantially all iron.

6. A corrosion-resistant ferrous alloy of the following composition: chromium about 12.60%, nickel about 18.20%, copper about 7.70%, molybdenum about 10.80%, and the remainder substantially all iron.

7. A ferrous alloy composed of chromium, nickel, copper and molybdenum, each of said elements being present in an amount greater than 6% and less than 32% of the composition, the sum total of said elements being less than 50% of the composition, and the remainder being substantially all iron.

8. A steel alloy composed of chromium, nickel, copper and molybdenum, each of said elements being present in an amount greater than 6% and less than 32% of the composition, the sum total of said elements being less than 50% of the composition, carbon from about 0.01% to

about 1.70%, and the remainder substantially all iron.

9. An austenitic corrosion-resistant ferrous alloy characterized by its superior resistance to oxidation-reduction environments as exemplified by aqua regia, composed of more than 3.6% and less than 10% chromium, more than 6% and not more than 20% nickel, more than 6% and not more than 20% copper, more than 6% and not more than 20% molybdenum, the sum total of said elements being less than 50%, and the remainder being substantially all iron.

10. A corrosion-resistant alloy steel containing at least 3.6% chromium, at least 3.6% nickel, at least 5.3% copper, at least 6% molybdenum, the sum total of said elements being less than 50% of the composition, and the remainder being substantially all iron.

KARL SPITZ.

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