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NORMAN B. PILLING, OF ELIZABETH, NEW JERSEY, ASSIGNOR TO THE INTERNATIONAL NICKEL COMPANY, INC., A CORPORATION OF DELAWARE

IRON-NICKEL-COPPER ALLOY

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This invention relates to ferrous nickel alloys and more particularly to iron-nickel-copper alloys which are characterized by the property of resistance to corrosion.

An object of this invention is to provide an alloy of this type resistant to corrosion by atmospheric and other agencies and which is capable of being readily worked and adapted for a wide variety of uses.

These and other desired objects and advantages of the invention will be described in the following specification, certain preferred combinations being given by way of illustration, but since the underlying principles apply to a wide range of proportions of iron, nickel and copper, it is not intended to be restricted to the particular ones shown, except as such restrictions are clearly imposed by the appended claims.

As is well known, iron, and iron containing as much as several percent of alloyed elements, is extremely subject to corrosion by atmospheric agencies,—a coating of hydrated iron oxide, commonly known as rust, forming under the combined influence of moisture, oxygen and other gases usually present in the atmosphere. Such a coating of rust is loose, flaky and porous, and is not protective but may even accelerate further corrosion by its screening action, setting up the well-known electrolytic oxygen concentration cells. The addition of large amounts of nickel to iron lessens the rate of such corrosion but does not change in any substantial way the nature of the rust coating formed. Even iron-nickel alloys containing 80% of nickel will rust on exposure to moist air containing traces of sulphurous gases. The rust coating thus formed is thin but flaky, readily splitting off from the surface, or spalling, and corrosion proceeds at a slow rate but unchecked. With intermediate contents of nickel, as 30% or 50%, the flaky, non-protective type of rust coating forms, with corrosion rates about proportional to the iron content.

I have found that the addition of copper to iron-nickel alloys has a marked effect on the physical structure of the corrosion product formed on atmospheric exposure, whereby the pronounced flaking properties and porosity are eliminated and a tight, dense, highly adherent coating results, such that further corrosion is greatly retarded or practically stopped. The result of this is that articles made from alloys lying within the range of compositions described below show an excellent durability when continuously exposed to corrosion in natural atmospheres, even those contaminated by smoke or other industrial gases. The presence of copper, with its attendant change in adherence of the natural corrosion product, is to be considered not merely a permissible replacement of an equal amount of nickel, but as allowing a very substantial reduction in the total non-ferrous content to obtain an equivalent degree of atmospheric corrosion resistance. As concrete examples, an exposure test conducted in the open air for a period of several years showed that an iron-nickel-copper alloy containing 25% nickel, 5% copper, was equal in durability to an iron-nickel alloy containing 50% nickel; again, an iron-nickel-copper alloy containing 50% nickel, 9% copper, was the equivalent of an iron-nickel alloy containing 80% nickel. These examples show the economy which the addition of copper to iron-nickel alloys permits.

The alloys of the present invention comprise compositions containing the following elements in substantially the proportions enumerated, viz: nickel, 12–79%; copper, 1–32%; iron, 20–87%; and carbon, .01–2%. The nickel should be equal to or greater than one and one-half times the copper content. In practice the nickel content should not be less than 1.85 times the copper content to insure homogeneity of the alloy. Carbon, in the case of compositions in which the ratio of nickel content to the nickel plus iron content is less than .27, is defined as follows:

$$C - 6\left(.27 - \frac{N}{N+F}\right).$$

Where C equals the minimum percentage of carbon present, N equals the percentage of nickel, and F equals the percentage of iron. Silicon, manganese and other elements commonly used to aid in securing sound, malleable ingots may be present.

The alloys comprised within the above ranges are soft, that is, have a Brinell hardness number not greater than 175 and all have the common property of resistance to corrosion. Their resistance to atmospheric corrosion has been described above. To other forms of corrosion, I have found the addition of copper to iron-nickel alloys to be an advantage, owing to the lowered solution potential resulting. This improvement has been noted in many dilute non-oxidizing acids and in various salt solutions.

As an example of this, the iron-nickel alloy with 38% nickel has a corrosion rate in 5% aerated sulphuric acid of 860 milligrams per square decimeter per day; the substitution of 5% of copper for an equal amount of nickel lowered this rate to 550 milligrams. Again, the iron-nickel alloy with 65% nickel has a similar corrosion rate of 660 milligrams, and the addition to this alloy of 8% copper (displacing iron) lowered the corrosion rate to 340 milligrams.

In general, the hardness and strength properties do not vary to any substantial amount in going from one extreme of composition to another, but the corrosion resistance does, and alloys lying in the higher ranges of iron contents will have a much lower resistance to corrosion than those lying within the low iron ranges; there is no sudden change in order of magnitude, but a gradual, continuous, increasing degree of corrosion resistance as the nickel content or the copper content is increased. On the other hand, certain properties do change greatly within these limits, requiring a restriction of composition to gain certain ends. The hot malleability is largely a matter of copper content, and alloys containing more than 12% of copper are forgeable and otherwise workable only with much difficulty. Although showing a high degree of resistance to corrosion, they are of value chiefly in the form of castings. When articles shaped by working are required, it is preferable to have the copper content less than 12%, and when the highest degree of malleability and ductility is required, I limit the copper content to 6%. The process for improving the malleability of nickel alloys disclosed in my co-pending application, Serial Number 223,233, filed September 30, 1927 is of material service.

Some of these alloys are non-magnetic, and these are defined as having the ratio of the nickel content to the nickel plus iron content less than .30, and in which the minimum carbon content is regulated in accordance with the rule made in an earlier paragraph. This group combines physical softness, moderate strength, ductility, malleability, and a considerable degree of corrosion resistance, with a substantially non-magnetic condition. When the nickel-iron ratio is more than .30, the alloys are normally magnetic at room temperature and display magnetic critical points at higher temperatures analogous to the reversible iron-nickel alloys.

Some of these alloys have low coefficients of thermal expansion in addition to the other characteristics of the main group. These are those alloys having copper ranging from 1–12%, with the ratio of the nickel content to the nickel plus iron contents greater than .30 and less than .42. In general nature, these resemble the corresponding nickel-iron alloys. Copper increases the expansivity for a given nickel ratio, but a coefficient of .000003 per °C., coupled with improved corrosion resistance, may be had.

The effect of variations in nickel, copper and iron content have already been discussed. The carbon content may range from .01% to 2%, depending upon the use to which the alloy is to be put.

While excellent malleable alloys have been produced containing .03% carbon, a considerably higher content may be tolerated in the malleable grades. In general, increasing the carbon content increases the hardness of the alloy and also diminishes somewhat its cold workability. It is usually preferable to limit the carbon content to .30%; at .50% the precipitation of graphite begins, which tends to diminish ductility; alloys intended to be malleable should contain less than 1%, but castings may contain up to 2% carbon.

A high carbon content does not materially affect the corrosion resistance. While high carbon alloys are restricted to castings, it is possible with ordinary precautions to obtain castings with as little as .1% carbon.

These alloys, particularly with nickel contents from 25% to 35%, have a high electrical resistivity and are suitable for use in electrical devices in which the operating temperature does not exceed 500° C.

As a specific example of the properties common to the whole group, the alloy containing 29% nickel, 7% copper, .17% carbon, .8% manganese, is typical. This, in the hot rolled condition, has a proportional limit of 30,000 psi, an ultimate strength of 80,000 psi, an elongation of 44%, and a reduction of area of 68%. This alloy may be forged, hot rolled, cold rolled, cold drawn, machined without difficulty by drilling, sawing and cutting in the lathe; it responds readily to welding with either the oxyacetylene flame or the electric arc, as well as to resistance or spot welding; it accepts solders and brazes readily; and is, in general, suited for use as an engineering alloy. Exposed to clean, salty, and smoky air, thin sheets have formed a tight, rusty surface coating but remain in good physical condition under conditions in which so-called copper-bearing steel has failed by corrosion.

While a considerable variation in combination of corrosion resistance with other particular physical properties is possible, for general use as a cheap, easily worked and easily formed alloy to withstand corrosion, particularly by atmospheric agents, I prefer the range of 25–40% nickel, 4–6% copper, .01–.30% carbon, the balance substantially iron. A particular alloy containing 34% nickel, 6% copper, .2% carbon, is a good example suitable for use in exposed sheet metal work, as roofing, ventilators, stacks, cornices, skylight trim, etc., as well as heavier forms, such as in outdoor hardware.

It will now be appreciated that there has been provided an improved group of alloys comprising an iron-nickel base to which has been added copper in amounts ranging from 1% to 32%, the resulting products being distinguished by ready workability, ease of manufacture, and, under certain atmospheric conditions, characterized by the property of forming a tightly adherent corroded surface which appears to minimize or otherwise inhibit the propagation of the rust coating. In addition, the alloys of the present invention are characterized by the fact that, when exposed to dilute non-oxidizing acids, such as dilute sulphuric acid, they are relatively unattacked, and, when exposed to fresh-water sprays or the like, retain their original bright surface.

It will be observed that the present invention provides an iron-nickel-copper alloy containing approximately 26% to approximately 74% iron, approximately 25% to approximately 60% nickel, approximately 1% to approximately 12% copper, and carbon exceeding approximately 0.25% up to about 2%, whereby an alloy is produced which is wholly free from hard nodules and which has a substantially uniform softness.

It will also be noted that the present invention provides an iron-nickel-copper alloy comprising approximately 26% to approximately 74% iron, approximately 25% to approximately 60% nickel, approximately 1% to approximately 25% copper, nickel content being not less than 1.85 times the copper content to insure homogeneity of the alloy and carbon exceeding approximately 0.25% and extending up to about 2.0%, whereby an alloy is produced which is wholly free from hard nodules and which has a substantially uniform softness.

What I claim is:—

1. An alloy composed substantially of 26% to approximately 74% iron, approximately 25% to approximately 60% nickel, approximately 1% to approximately 26% copper, the nickel content being not less than 1.85 times the copper content to insure homogeneity, and carbon exceeding .40% and being under 2.0%, whereby an alloy is produced which is of substantially uniform softness.

2. An alloy composed substantially of 25% to approximately 60% nickel, approximately 1% to approximately 12% copper, approximately 28% to approximately 74% iron, and carbon exceeding .40% and being under 2.0%, whereby an alloy is produced which is of substantially uniform softness.

3. An alloy composed substantially of 25% to approximately 40% nickel, approximately 1% to approximately 12% copper, approximately 48% to approximately 74% iron, and carbon exceeding .40% and being under 2.0% whereby an alloy is produced which is of substantially uniform softness.

4. Castings composed substantially of 26% to approximately 74% iron, approximately 25% to approximately 60% nickel, approximately 1% to approximately 26% copper, the nickel content being not less than 1.85 times the copper content to insure homogeneity, and carbon exceeding .60% and being under 2.0% whereby an alloy is produced which is of substantially uniform softness.

In testimony whereof I have hereunto set my hand.

NORMAN B. PILLING.