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NONMAGNETIC IRON-NICKEL-COPPER ALLOY

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This invention relates to nickel steels and more particularly to a copper-bearing nickel steel which is characterized by the properties of inhibition or resistance to corrosion, and low magnetic permeability.

It is an object to provide such nonmagnetic compositions having corrosion-resisting properties which are also capable of being cast into tough, dense castings, or into sound, malleable ingots capable of being 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, 12–30%, copper, 1–20%, carbon, .01–2%, the balance substantially iron. The nickel should be equal to or greater than 1.5 times the copper content. Carbon, in the case of compositions in which the ratio of the nickel content to the nickel plus iron contents is less than .27, is defined as follows:

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

in which C is the minimum percentage of carbon desired, N the percentage of nickel, and F the percentage of iron. Silicon, manganese, and other elements commonly used to aid in securing sound, malleable ingots may be present. It will be observed, of course, that the ratio of

$$\frac{N}{N+F}$$

must not be greater than .270 otherwise the above equation will give a negative value.

Alloys lying within this range of compositions having a ratio of nickel to nickel plus iron contents less than .30 are substantially non-magnetic, respond very feebly if at all to a magnet and are adapted to many uses in the electrical industry which the more expensive copper alloys now fill. It is necessary to provide carbon exceeding the limit specified in the preceding paragraph in order to retain the alloys in the non-magnetic condition. With insufficient carbon they become strongly magnetic.

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 nonoxidizing acids and in various salt solutions.

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, is of material service.

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.

It is apparent from this that the higher carbon content alloys have a wider range of nickel-copper contents which are non-magnetic than the lower carbon content alloys, and while on the other hand increasing the carbon content increases the hardness, and that while a higher copper content gives greater corrosive resistance, it lessens the workability. For a particular application the best composition therefore depends upon the extent to which these opposing tendencies must be balanced.

As a particular example the alloy containing 25.5% nickel, 4.5% copper, .6% manganese and .07% carbon may be cited. This has a ratio of nickel to nickel plus iron of .27 and from the definition of composition given above should be non-magnetic without the aid of much carbon. It was in fact wholly non-magnetic even after annealing. It had excellent casting properties; ingots made from it forged perfectly to slabs which cold-rolled readily to thin, non-magnetic strip. The alloy had a Brinell hardness of 130, could be machined without difficulty by drilling, sawing and cutting in the lathe; it responded readily to welding with either the oxyacetylene flame or electric arc, as well as to resistance or spot welding; it accepted solders and brazes readily and is in fact 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.

These alloys have a high electrical resistivity and are suitable for use in electrical devices in which the operating temperature does not exceed 500° C.

It will now be seen that there has been provided a group of alloy compositions comprising iron, nickel, copper and carbon which are characterized by the properties of low rates of corrosion, particularly an atmospheric exposure, and ready workability (in the lower ranges of copper content) which are at the same time substantially nonmagnetic.

It will be observed that the present invention provides an alloy comprising copper about 1% to about 20%, nickel not exceeding about 22% and extending to about 12%, carbon exceeding about 0.4% and being under 2.0%, and the remainder consisting principally of iron which is not only non-magnetic but which is also of substantially uniform softness.

What I claim is:—

1. A nonmagnetic alloy comprising copper about 1% to about 20%, nickel not exceeding about 22% and extending to about 12%, carbon exceeding about 0.4% and being under about 2.0%, and the remainder consisting principally of iron whereby an alloy is produced which is nonmagnetic and which is of substantially uniform softness.

2. A nonmagnetic alloy comprising copper about 1% to about 20%, nickel not exceeding about 22% and extending to about 12%, carbon about 0.5%, and the remainder consisting principally of iron whereby an alloy is produced which is nonmagnetic and which is of substantially uniform softness.

In testimony whereof I have hereunto set my hand.

NORMAN B. PILLING.