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ALLOY OF HIGH SURFACE STABILITY COMPRISING NICKEL AND SILICON

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Our invention relates to an alloy containing principally iron, nickel, silicon and carbon, which is resistant to formation of scale at high temperatures, as when subjected to flame or hot gases or used as electrical heating elements, and is resistant to the action of acids, such as hydrochloric and sulfuric acid. Alloys in accordance with our invention are well adapted for a large number of uses, as, for example, a few of the many uses are valves for internal combustion engines, blades for steam and gas turbines, carburizing boxes, furnace muffles, covers for pyrometer couples, lead pots, acid containing vessels, apparatus to be used in contact with acids other than nitric acid, electrical heating elements, etc.

The addition of silicon to iron gives increased stable surface properties roughly proportionate to the quantity of silicon added, but as the quantity of silicon alloyed with iron is increased, brittleness is increased. We have found that when nickel is incorporated with iron and silicon, the proportion of silicon can be very considerably increased and a corresponding highly stable surface material obtained, and at the same time the brittlenesses which would result without the nickel is avoided or at least very substantially reduced.

We have found that in general in order to get tough material, that is, material which can be bent to some extent without breaking, the silicon that can be carried increases as the nickel is increased, up to about 20% of nickel, that from about 20% to 40% of nickel there is little change in the proportion of silicon that can be used, and above about 40% of nickel the proportion of silicon can no longer be increased and in fact to get desirably tough material silicon should be decreased somewhat as the nickel is increased.

We have found that with any given proportion of nickel, the higher the silicon content which can be carried therewith, the greater is the temperature which may be withstood without substantial oxidation or scaling.

For valves of internal combustion engines, one good example of material in accordance with the present invention contains: nickel about 5%, silicon about 2%, and carbon about .30% with the principal portion of the remainder iron; and another good material for this purpose contains: nickel about 10%, silicon about 2% and carbon about .30%. Chromium about 2–3% is of advantage for valve material and may be used, for example, in valve steel of the compositions above referred to.

For such purposes as carburizing boxes, lead pots, and the like, a material which gives long life at temperatures up to about 1800° F. may contain about 20% to 30% of nickel, and about 7% to 8.5% of silicon. A typical example of such material is: nickel 22%, silicon 8.5%, carbon .3%, and the principal portion of the remainder iron.

The above typical analysis material for carburizing boxes will stand temperatures up to about 1800° F. which is about 150° to 200° higher than the temperature at which most of the carburizing work is done. This material is tough and should be used in the cast condition. It can be heated to temperatures substantially in excess of 2200° F. before becoming plastic, but at this high temperature it is not highly resistant to scaling.

For withstanding very high temperatures, say up to about 2300° F. the nickel content should be increased and the iron and silicon reduced. For example 90% nickel, 5% silicon and 5% iron may be used and such material does not become plastic until it reaches about 2375° F., and shows very little scaling at or towards such high temperatures. We have found that some small percentage of iron, say about 2% to 5% of iron, appears to be necessary when the nickel is high approaching 90% or over, for the nickel

and silicon to melt together and go into the alloy combination. Use of such high nickel content is, of course, quite expensive and unless the temperatures to be withstood are excessively high, about 20% to 30% of nickel with about 7% to 8.5% of silicon is preferably used.

Where the conditions are such that mechanical strength is of relatively decreased importance and brittleness is not an important objection the silicon content may be increased while the nickel content is relatively low, as for example an alloy containing: nickel 15%, silicon 16%, carbon .2% and the principal proportion of the remainder iron withstands temperatures up to about 2000° F. for long periods without appreciable oxidation and is adapted for use as protecting tubes for pyrometers and for other uses and articles of manufacture which are not subjected to severe strains or required to carry heavy loads.

The beneficial effects of the nickel and silicon combination are not secured to an appreciable extent when the nickel is below about 5% and the silicon below about 2%. When the temperatures to be withstood are relatively low, the alloy can be composed of the various constituents of substantially the lower limits set forth herein. Where low nickel is employed and the maximum silicon is alloyed therewith, the resulting alloy is not tough and has a tendency towards brittleness. The maximum operating temperatures with a low nickel-higher silicon alloy can be much higher than the maximum operating temperatures with the same nickel content and a lower silicon content within the scope of our invention. With such lower silicon content the alloy is extremely tough and can be readily formed mechanically either by hot or cold working, preferably hot working. For material which is to be mechanically worked, as for example, to be used in the rolled condition, it is desirable not to have the nickel lower than about 5% nor higher than 90% and the silicon is preferably kept not higher than 16%, with either the minimum or maximum nickel content.

The silicon with either the minimum or maximum nickel should not be lower than about 2%. The carbon of the alloy is preferably kept low and may vary from about .05% to about 1.5%. The specific examples given herein are of low carbon content within commercial practice. The material, generally speaking, has greater ductility and greater workability with the lower carbon. For cast material it is not of such importance that the carbon be low, but for commercial reasons the carbon is preferably kept low in the cast material. If the carbon is kept very low, for example below .20%, this increases the cost of the alloy because of the substantially carbon free components required to be melted up in its manufacture. Mild or commercial steel or about .35% carbon is preferably used for melting purposes; the silicon used as an alloy addition is preferably in the form of ferrous silicon, which is substantially carbon free, and the nickel used in the alloy can be commercially obtained carbon free. There is, therefore, no tendency to pick up carbon from the use of lower priced nickel or silicon and to get the carbon as high as 1.5%, for example, which may be done if desired, requires the making of carbon additions in the furnace with resulting increase in the cost of manufacture. For the reasons stated the lower the carbon below about .15%, the greater are the costs and the difficulties in commerical production and above about .50% carbon there is no decrease and there may be increase in the melting cost due to higher carbon in the straight nickel-silicon-iron-carbon alloy. If other ferro-alloys are added containing substantial proportions of carbon, the production of material with higher carbon lowers the cost.

Various other materials may be added to the alloy, but the amount of silicon has to be reduced to compensate for such additions if a tough material is desired. It is not an advantage from the point of view of economy to add various other alloying materials, as the silicon content of the alloy is one of its cheapest components and should not be replaced if first cost is of importance.

Chromium from about 2% to 15% may be added, but when the chromium is as high as 7% a hardening effect is noted which diminishes the quantity of silicon that can be used, so that it becomes undesirable to add more than this amount of chromium, particularly where strength is a requisite, since it adds to the cost unnecessarily and tends to increase brittleness of the alloy. As the chromium is increased there is a corresponding increase in the stable surface character of the material, that is to say, resistance to rusting, staining and the like agents and to the action of nitric acid. A very good stain resisting steel is obtained with the addition to the alloy as above described of about 6% of chromium.

In casting alloys of nickel-silicon-iron with low carbon, there is a very high shrinking in the metal, particularly if the temperatures of casting are carried high, producing shrinkage cracks in the finished castings. Therefore, it is desirable, in commercial work, to add an additional alloying material to cut down this initial shrinkage during casting and we have found that a low percentage of chromium is particularly good for this purpose. Any other alloying material which will accomplish the same end could be used in the place of chromium; low percentages of manganese such as 2% to 3%, for example, serves equally well without any detriment to the properties of the alloy.

Where chromium is employed, we have found a good example for carburizing box work and articles of this character which have to be case hardened, nickel about 22%, silicon about 7%, chromium from 1.5% up to about 7%, carbon about .3%, and the principal proportion of the remainder iron.

Copper may be added to the alloy with the advantage that its addition does not require the reduction of the silicon to obtain material which is tough, and additions of from about .5% to about 10% of copper may be made to advantage, giving the material increased life and resistance to oxidation, scaling, corrosion, erosion, and the like.

Manganese may be added in varying quantities from that naturally present in steel, say .15% to 1%, up to as high as about 6%. While it tends to embrittle the alloy and to reduce the amount of silicon which can be used, very good material can nevertheless be made with manganese up to about 3%.

Aluminum may be used in this alloy combination to replace part of the silicon but no material advantage as regards the resistance to scaling will be obtained and the cost will be very much increased as will the melting difficulties. For the purpose of electrical resistance elements it may, however, be added with advantage.

Zirconium can be added to the alloy composition but it does not seem to convey any addition to the valuable properties of the alloy. It increases melting difficulties and has a tendency to produce unsoundness, particularly where the pouring temperature of the metal is high.

The higher melting point elements such as cobalt, tungsten, molybdenum, uranium and the like tend to detract from the toughness required for uses such as carburizing boxes, but these elements or combinations thereof, such for example as a combination of cobalt and molybdenum may be used to replace corresponding amounts of nickel or silicon or both in proportions not to exceed a total of about 3% without substantial adverse effect upon the hot oxidation properties.

For electrical heating elements silicon from about 2% to about 10% can be employed, and nickel from about 5% to about 90%. With the nickel about 90%, the silicon should not be more than 5% to 8%, since it is desirable that from 2% to 5% of iron should be present in order that the nickel and silicon may go into combination. The carbon should be under 1%.

If the material is to be rolled or rolled and drawn into wire, the silicon should preferably not be more than about 5%, but with cast electrical heating elements and the like silicon up to about 10% may be used.

The electrical resistivity of this alloy increases in general with increase in the amount of nickel and silicon employed, but depends more directly upon the amount of silicon than upon the amount of nickel, and electrical resistivity of about 80 to 90 microhms per cubic centimeter can easily be obtained at about the middle of the range given above.

The following table gives some typical examples of desirable analysis readily rolled into rods:

Chemical composition				Electrical resistance microhms per cu. cm.
C	Si	Ni	Fe	
0.08	4.45	60.10	The remainder	75.5
0.10	4.52	48.74	The remainder	82.8
0.13	4.56	39.40	The remainder	92.5

Where the electrical heating elements do not require to be rolled, higher silicon can be used, and considerably higher electrical resistivity can be obtained.

Other elements can be added, substantially as in the case where the alloys are used for carburizing boxes and similar articles subjected to heat from exterior sources, with the exception that copper cannot be used for electrical heating elements in quantities greater than about 1%.

The nickel-silicon alloy has the quality of resistance to acids particularly sulfuric acid, both concentrated and dilute, hydrochloric acid and the like, but does not resist action of nitric acid to any considerable degree.

For acid resistant materials, carbon may be present up to about 1.5% for cast articles. Also carbon not to exceed about .5% is preferably used for acid resistant articles to be subjected to rolling or other mechanical working treatment. The lower limit for silicon for such materials is about 5% and the upper limit about 12%. The lower limit of nickel is about 10% and the upper limit about 90%, as before.

One analysis well suited for acid resistant material was as follows: carbon .1%, silicon 7%, nickel 22%, and the principal part of the remainder iron. This alloy is strong and tough in the cast state and is suitable to be made into various forms and articles, such as containers for acid, and is adapted for various articles required for use in contact with acid materials.

It is to be understood that the examples herein given are for the purpose of affording an understanding of our invention and not for limitation of the invention, the scope of the invention being as set forth in the following claims by which our invention is defined.

We claim:

1. An alloy for resisting acid corrosion and oxidation at high temperatures, containing nickel in an amount greater than 20% and less than 60%, silicon in an amount greater than 3% and less than 9%, and the balance principally of iron.

2. An article resistant to corrosion and to

hot oxidation made from alloy containing as essential constituents nickel 8% to 60%, silicon 2% to 10%, carbon under 1%, the remainder being substantially entirely of iron.

3. An article resistant to corrosion and to hot oxidation made from alloy containing as essential constituents nickel 8% to 40%, silicon 2% to 10%, carbon under 1%, the remainder being substantially entirely of iron.

4. An article resistant to corrosion and to hot oxidation made from alloy containing as essential constituents nickel 20% to 40%, silicon 2% to 10%, carbon under 1%, the remainder being substantially entirely of iron.

5. An article resistant to corrosion and to hot oxidation made from alloy containing as essential constituents nickel 20% to 30%, silicon 2% to 8.5%, carbon under .6%, the remainder being substantially entirely of iron.

6. An article to be exposed to high heat and corrosive agents and which is resistant thereto, made from alloy containing nickel or cobalt in an amount greater than 20% and less than 60%, silicon in an amount greater than 3% and less than 9%, and the balance substantially entirely of iron.

In testimony that we claim the foregoing, we have signed our names hereto.

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CERTIFICATE OF CORRECTION.

Patent No. 1,759,477. **Granted May 20, 1930, to**

PERCY A. E. ARMSTRONG ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 4, for the words "case hardened" read "cast"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 24th day of June, A. D. 1930.

M. J. Moore,
Acting Commissioner of Patents.

(Seal)