

Patented Aug. 21, 1923.

1,465,547

## UNITED STATES PATENT OFFICE.

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### ELECTRIC RESISTANCE ELEMENT.

No Drawing.

Application filed December 6, 1921. Serial No. 520,248.

*To all whom it may concern:*

Be it known that I, FRANK L. DRIVER, JR., a citizen of the United States, residing at Newark, county of Essex, State of New Jersey, have invented a certain new and useful Improvement in Electric Resistance Elements, of which the following is a full, clear, and exact description.

My invention relates to electric resistance elements and has for its object to produce an electric resistance element formed of wire which will have, when in use, a longer life than those now available. It further has for its object to produce a drawn electric resistance element in which the formation of "hot spots" when in use is largely eliminated. It further has for its object to produce a drawn electric resistance element in which the coefficient of expansion of the surface when oxidized shall be substantially the same as the coefficient of expansion of the body of the element.

In the manufacture of wire for electric resistance elements for electrical heating and cooking devices there are two main matters to be considered. The first is the wire must have a high specific electrical resistance and the second is that the wire must have a long life and high resistance to oxidation at the operating temperature. There have been on the market for some years several nickel-chromium-iron and nickel-chromium resistance wires which combine comparatively high specific electrical resistance with comparatively long life under high temperatures. These alloys have given satisfaction to a limited extent, being the best known alloys for this purpose, but the electrical heating and cooking device manufacturers are demanding a wire for electrical resistances which will operate under more severe conditions than any wire heretofore attainable and at the same time continue to function properly over a greater number of operating hours. A great deal of effort has been put forth by me with the idea of finding some means of either increasing the life of the present alloys when used for this purpose or of discovering new alloys to take the places of the old alloys. This effort has been extended along the lines of research work which involved the alloying of various new metals with the nickel-chromium and nickel-chromium-iron alloys already used. In this work I have discov-

ered that the metal silicon has apparently been greatly under-rated as a means for improving the nickel-chromium and nickel-chromium-iron alloys for resistance wire. I have discovered that by the addition of silicon to such alloys their resistance to oxidation can be increased, that the formation of "hot spots" can be greatly reduced, if not eliminated, and that the coefficients of expansion of any oxidized surface formed thereon and the mass of the wire can be made substantially equal. All these features tend to prolong the life of the resistance element and result in a very superior article.

I have further discovered that it is commercially possible by the usual methods to manufacture drawn resistance elements of these alloys when silicon has been added thereto; that is, that the hammering of the ingot, the hot rolling of the rod, and the cold drawing of the wire is commercially possible.

I have found that very small amounts of silicon materially increase the specific electrical resistance of the nickel-chromium and nickel-chromium-iron alloys, and also materially increase their life under operating conditions. I have found that the most beneficial results are to be obtained when the silicon is from about .5 to 1.5 per cent. by weight in the alloy, although I have found that even smaller amounts of silicon increase the life of the wire. When a larger amount of silicon is used there is no apparent increase in resistance to oxidation. The difficulty of mechanically working the alloy and drawing into wire is, however, greatly increased, although it is possible to draw such wire when the amount of silicon is approximately 10 per cent.

One of the great advantages accruing from the use of silicon in accordance with my invention is that the wire when drawn and tested on a life testing machine at temperature ranging about 1000° C. shows an entire absence of "hot spots" in the wire. In wire heretofore used these "hot spots" appear very readily and contribute largely toward the breaking down of the wire, particularly when the wire is alternately heated to 1000° C. and cooled by putting it in and out of the circuit.

The failure of former resistance wires containing nickel and chromium is also largely

due to excessive scaling produced by alternate heating and cooling. When the wire is brought up to temperature an oxide forms on the surface of the wire which, if it has a coefficient of expansion materially different from the coefficient of expansion of the mass is dislodged during the cooling. The addition of the element silicon in accordance with my invention as one of the main constituents of the alloy has the effect of bringing the two coefficients of expansion into substantial equilibrium so that the oxide adheres very closely under all working conditions of temperature and renders the wire substantially immune from further oxidation and deterioration.

Among the wires containing nickel, chromium and iron which I have tested were those containing the following percentages of silicon:

.16  
.50  
1.20

These wires tested better than wires containing similar proportions of nickel, chromium and iron but no silicon in the ratio of two, three and six, showing that the increase in life was substantially in direct proportion to their silicon content.

By the addition of the element silicon the yield point and ultimate tensile strength of the wire is greatly increased, due to the fact that a denser and more homogenous metal results. This increased density and homogeneity results from the fact that any carbide in the mass during the solidifying of the molten metal into an ingot is held in molten condition until the alloy has substantially reached the solidifying or freezing stage, this being due to the fact that the freezing point of the alloy is lowered by the addition of the silicon. This, together with the formation of nickel silicides results in a more even distribution of any carbide formed and thus prevents segregation of such carbide. In the absence of means for preventing such segregation any carbide present solidifies or freezes out first during the cooling of the alloy, taking the form of long needle-shaped crystals segregated in groups located at intervals throughout the alloy. The presence of such crystals when they exist is much in evidence, since the carbides being harder than the solid solution of nickel-chromium or nickel-chromium-iron in which they are found, stand out in relief in any polished section of the alloy. This relief may be further accentuated by etching the polished surface with any proper etching re-agent. These crystals being of lower conductivity increase the resistivity of the wire at the point at which segregations occur. In consequence these points become more highly heated when a current is passed

through the wire, producing the "hot spots" which have been previously referred to.

As is well understood, efficient resistance wires containing nickel and chromium sometimes contain substantial amounts of iron and sometimes are free from iron. The iron when present is of advantage in reducing the cost of commercial manufacture. So far as the ultimate product is concerned, it is preferably omitted.

In both of these alloys when commercially manufactured some carbon is necessarily present. Where iron is not present carbon exists in the form of chromium carbide, probably  $\text{Cr}_3\text{C}_2$ . When iron is also present the carbon exists in the form of a complex iron-chromium carbide, probably  $\text{Cr}_3\text{C}_2 + \text{Fe}_3\text{C}$ . These carbides are soluble only to a limited extent in the solid state and it is of great importance to have the portions which are not in solution equally distributed throughout the mass, so as to make the mass as dense and homogeneous as possible and this result I accomplish by my addition of silicon.

The silicon forms with the nickel, silicides of nickel which remain in solid solution in the metal and there is no evidence from microscopic investigation that these silicides separate at all from the main body of the alloy on cooling. Their presence, however, appears to bring about a better distribution of the insoluble carbides of chromium or iron and chromium, which may be present, resulting in the absence of "hot spots" during the operation and the material prolongation of the life of the resistance element.

In order to embody my invention in connection with a commercial alloy composed of approximately 90 parts nickel and 10 parts chromium and carbon varying from .5 to 2 per cent, I preferably add to the mixture between 1 and 2 per cent of silicon by weight, although this may be varied from .5 to 10 per cent. When a portion of the nickel is replaced by iron such for instance as in an alloy containing nickel 60 per cent, iron 26 per cent, chromium 12 per cent, in which, in commercial manufacture, there would be carbon from .15 to 2 per cent, I make additions of silicon, namely, preferably between 1 and 2 per cent by weight, although the percentage may vary from .5 to 10 per cent, resulting in each case in an alloy which is dense and homogeneous, the carbides not being segregated but being distributed throughout the mass and the coefficient of expansion of any surface oxide which may be formed being substantially the same as the coefficient of expansion of the body of the mass.

As will be evident to those skilled in the art, my invention permits of various modifications without departing from the spirit

thereof or the scope of the appended claims.

What I claim is:

1. A drawn metallic resistance element for high temperature heating composed of a carbide containing alloy comprising nickel and chromium, the carbon content being at least two tenths per cent (0.20%) and producing free carbide, and a carbide distributing constituent, all free carbide being distributed with substantial uniformity throughout the mass.

2. A drawn metallic resistance element composed of a carbide containing alloy comprising nickel, chromium and silicon, the carbon content being at least 0.20 per cent, the silicon being sufficient to cause substantially all of any carbide in the alloy to be distributed with substantial uniformity throughout the mass.

3. A drawn metallic resistance element

composed of a carbide containing alloy comprising nickel, chromium and silicon the carbon content being at least 0.20 per cent, the silicon being between .5 per cent and 10 per cent by weight of the mass.

4. A drawn metallic resistance element composed of a carbide containing alloy comprising nickel, chromium and silicon the carbon content being at least 0.20 per cent, the silicon sufficient to cause the coefficient of the body of the element to be substantially equal to the coefficient of expansion of the surface when oxidized.

5. A drawn metallic resistance element composed of a carbide containing alloy comprising nickel, chromium and silicon, the carbon content being at least 0.20 per cent, the silicon being between 1 per cent and 2 per cent by weight of the mass.

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