Aug. 11, 1931. G. W. ELMEN 1,818,054

MAGNETIC MATERIAL

Original Filed Jan. 12, 1927

FIG. 1

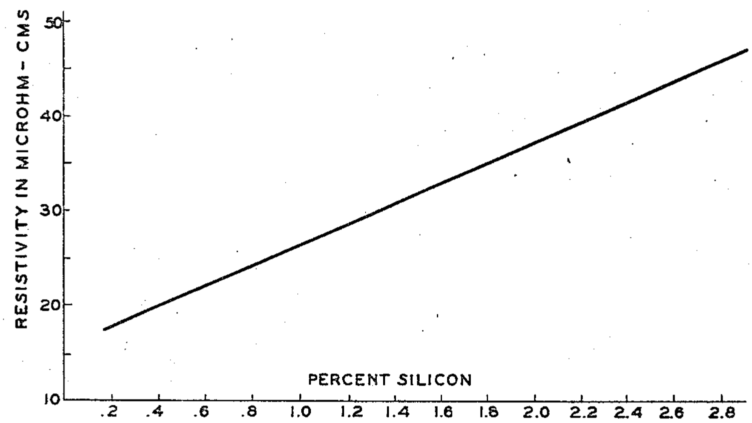



FIG. 2

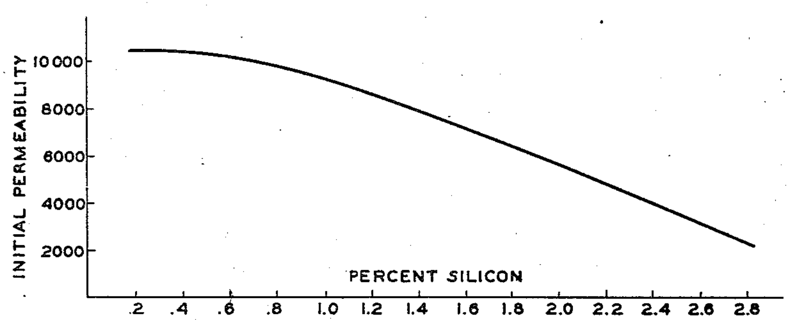
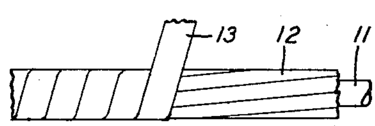



FIG. 3

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# UNITED STATES PATENT OFFICE

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## MAGNETIC MATERIAL

Original application filed January 12, 1927, Serial No. 160,569. Divided and this application filed June 20, 1930. Serial No. 462,558.

This application is a division of application Serial No. 160,569, filed January 12, 1927, which was a continuation in part of application Serial No. 48,188, filed August 5, 1925.

This invention relates to magnetic materials and electromagnetic systems. It has wide application and is especially useful where the magnetizing forces are small, as in signaling systems.

Among the important characteristics of the material of this invention are high permeability, especially at low magnetizing forces, and high resistivity with consequent low eddy current losses.

Magnetic materials have been variously employed in electrical systems for such purposes as the cores of loading coils, transformers, magnetic modulators and the like, for tractive electromagnets, dynamos, motors, telephone receivers, telegraph relays, etc. Magnetic materials have also been employed for the continuous loading of signaling conductors, but until recently their use has been limited to relatively short cables for telephone purposes. Heretofore, the magnetic materials generally used for these purposes have been soft iron and silicon steel. The principal possible rivals of iron are nickel and cobalt but they are far below iron in permeability at the magnetizing forces involved in such apparatus. With nickel and cobalt, in this respect, stands Heusler's alloy of aluminium, manganese, and copper. It has been found that a composition of about ⅔ nickel and ⅓ copper, when tested at low magnetizing forces, gives a permeability higher than that of iron alone. It will be seen that with the exception of aluminum, all these metals stand close together in their atomic weights and atomic numbers, and in this specification the five elements, manganese, iron, cobalt, nickel and copper, having the consecutive atomic numbers 25, 26, 27, 28 and 29, will be referred to as constituting the magnetic group of elements.

Recently, alloys comprising elements of the magnetic group and especially those consisting chiefly of nickel and iron, have been employed to great advantage particularly in connection with signaling systems and apparatus in which the magnetic forces involved seldom exceed .2 gauss. Such alloys and the method of producing them are disclosed in United States Patent No. 1,586,884, granted to G. W. Elmen, June 1, 1926, and in application Serial No. 48,188 referred to above.

That application discloses a composition comprising elements of the so-called magnetic group with the addition of a third element and having high permeability and resistivity, and small hysteresis and eddy current losses. Among the compositions mentioned is an alloy of nickel, iron and silicon.

The present invention relates to magnetic alloys consisting of at least two elements of the magnetic group combined in suitable proportions with silicon. These alloys, when subjected to a proper heat treatment and guarded against undue stresses and other disturbing causes, not only develop and retain an extremely high permeability at low magnetizing forces of the order of .2 gauss or less, but at the same time have a notably high resistivity and consequent low eddy current loss. Furthermore, they can be applied with advantage to the continuous loading of signaling conductors in such a manner as to obtain the full benefit of the above noted desirable properties.

In its preferred form the alloy of the present invention comprises nickel, iron and silicon properly proportioned and properly heat treated as described in the following detailed description in connection with the drawings in which:

Fig. 1 shows graphically the relation between the resistivity and the percentage of silicon in alloys comprising nickel, iron and silicon, the proportions of nickel and iron being approximately in the ratio of 78 to 22;

Fig. 2 shows graphically the general trend of the initial permeability with respect to the percentage of silicon of the same alloys; and

Fig. 3 shows a signaling conductor loaded with the magnetic material of this invention in the form of tape.

The curve of Fig. 1 shows that the resistivity of alloys containing as the basic constituents about 78% nickel and 22% iron may be increased by the addition of small amounts of silicon. The high resistivity of these alloys makes them particularly well adapted for use where low eddy current losses are desirable.

The curve of Fig. 2 shows the general trend of the initial permeability of this group of alloys with respect to the percentage of silicon. The samples upon which this curve is based were subjected to the double heat treatment hereinafter described. As shown by this curve, silicon in percentages up to about 1% has little effect on the initial permeability, while larger quantities tend to decrease the initial permeability. The high resistivity together with the relatively high initial permeability of these alloys renders them better than iron for use as a loading material for signaling conductors, and for other uses where the magnetizing forces are small and low eddy current losses are desirable, as in transformer and inductance coil cores.

The magnetization curves for this group of alloys generally follow the characteristics of the nickel-iron alloy containing 78½% nickel and 21½% iron as shown in application Serial No. 48,188 referred to above. The addition of silicon in increasing amounts causes the curve to rise less rapidly at the origin and reach a saturation point at a lower magnetizing force, although the effect is not very marked for percentages of silicon below about 1%. For example, for a sample alloy containing about 0.51% silicon it was found that the strengths of the magnetic fields for magnetizing forces of 0.05, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0 and 10.0 gauss were 1,850, 5,680, 6,720, 8,540, 9,350, 9,800, 10,250 and 10,400 gauss, respectively.

Although alloys of this group containing at least 70% nickel and preferably about 78% nickel have been found to give the highest permeability and to be preferable for many purposes, these characteristics are not limited to these particular percentages of nickel, since, by decreasing the quantity of nickel in the material, alloys having a higher resistivity may be obtained, although the initial permeability of such alloys is ordinarily decreased by the use of smaller quantities of nickel. Any quantity of nickel in the alloy greater than 25% to 30%, which will give a considerably higher initial permeability than iron, may be employed in iron-nickel-silicon compositions in accordance with this invention. For many purposes in which low eddy current loss is a prime requisite, as is the case for cores for loading coils and for loading material for signaling conductors, an alloy of a lower percentage of nickel, or a higher percentage of silicon, or both, may be found preferable to the alloys having higher initial permeability but lower resistivity.

In preparing magnetic materials according to this invention, nickel, iron and silicon in the desired proportions are fused together in an induction furnace and then poured into molds and formed or worked into the desired shape. For continuously loaded conductors a particularly suitable form for the alloy is that of a tape about .006 inch thick and about .125 inch in width.

In order to give the alloy the desired characteristic it is necessary to subject it to a process of heat treatment which will depend upon the composition of the alloy and upon the particular characteristics which it is desirable to produce in the material. An example of this heat treatment is the heating of the alloy to about 1100° C. and maintaining it at that temperature for a period of approximately one hour and subsequently cooling the material slowly. The rate of cooling and temperature to which the material is heated may be determined by experiment in each case, in order that those characteristics sought in the particular material may be produced to the desired degree. An average rate of cooling which has been found to be suitable is approximately 5° C. per minute. The temperature to which the material is heated may vary considerably from the above value. For materials containing higher percentages of silicon it may be desirable to heat the material to a somewhat higher temperature.

For alloys containing various percentages of silicon it has in general been found preferable to employ a modification of this heat treatment in which the alloy is reheated after the initial heat treatment, outlined above, to a temperature somewhat above its magnetic transition point. The material is then cooled to room temperature, past the magnetic transition point at a certain rate which should be determined for each alloy, but which is preferably faster than that employed in an anneal, but not so fast as to set up strains in the material due to uneven cooling throughout the body.

A modified form of heat treatment which may be desirable in some instances is to omit the reheating process and cool the material from the original annealing temperature in two steps; cooling to a point slightly above the magnetic transition point being carried on at one rate, and from that point to room temperature at a more rapid rate.

When the material is to be used for the continuous loading of signaling conductors, it is formed into a tape having substantially the dimensions stated above. This tape is produced by working the alloy into the form of a rod or bar by repeated steps of swaging and annealing. The bar is subsequently drawn down to the form of a wire of about No. 20 B. & S. gauge and then passed between rollers whereby it is flattened into tape of the proper thickness. This tape is then passed between cutting rolls or discs which trim its edges squarely at both sides and give the tape uniform width.

The loaded conductor shown in Fig. 3 comprises a stranded core consisting of a central cylindrical wire 11 enveloped by a plurality of surrounds 12 which are shaped to fit together closely to form a cylindrical annulus about the central wire. The magnetic material 13 in the form of tape is wrapped helically about the stranded core, as disclosed in U. S. Patent No. 1,586,887, granted to G. W. Elmen, June 1, 1926.

When it is desired to use a loading material in the form of a wire rather than a tape the drawing processes as outlined above are continued until the wire has the desired dimensions.

After the loading tape has been applied to the core, it is given its final heat treatment by drawing the assembled loaded conductor through a furnace, for example of the type described in U. S. Patent No. 1,586,884 referred to above. This is an electric furnace of the muffle type having a horizontal iron heating tube extending through the furnace and projecting a considerable distance beyond. The furnace is maintained at the optimum temperature for the particular composition of the alloy being employed. The length of the pass through the heating tube and the rate at which the conductor is moved are chosen so as to produce the most desirable magnetic characteristics in the loaded conductor. After cooling the conductor is insulated and formed into a cable in the usual manner.

It will be found that certain of these alloys are better suited for some particular uses than others, and that the characteristics of any alloy may be varied by the use of different heat treatments. No attempt has, therefore, been made to give an exhaustive analysis of the characteristics of each composition but merely to point out generally the characteristic advantages and uses of this group of alloys and some typical methods of producing the same, with the understanding and intention that other particular compositions and methods of production are comprised within the spirit and scope of the invention as described and claimed.

What is claimed is:

1. An iron-nickel alloy containing about 33% to 48% of nickel, 0.3% to 3% of silicon, and the remainder iron.

2. Articles of high initial permeability consisting of about 33% to 48% of nickel, 0.3% to 5% of silicon, and the remainder iron.

3. A magnetic material which comprises as an essential component a composition containing 33% to 48% of nickel, 0.3% to 5% of silicon and the remainder iron, such composition having high initial permeability and high specific resistance.

4. An alloy of nickel, iron and silicon, heat treated to develop therein high permeability for magnetizing forces of the order of 0.2 gauss and less, said alloy comprising 0.2% to 3% silicon, 33% to 50% nickel and the balance iron.

In witness whereof, I hereunto subscribe my name this 19th day of June, 1930.

GUSTAF W. ELMEN.