June 10, 1930. L. W. McKEEHAN 1,762,730

HEAT TREATMENT OF MAGNETIC MATERIALS

Filed Oct. 30, 1926

Fig. 1.

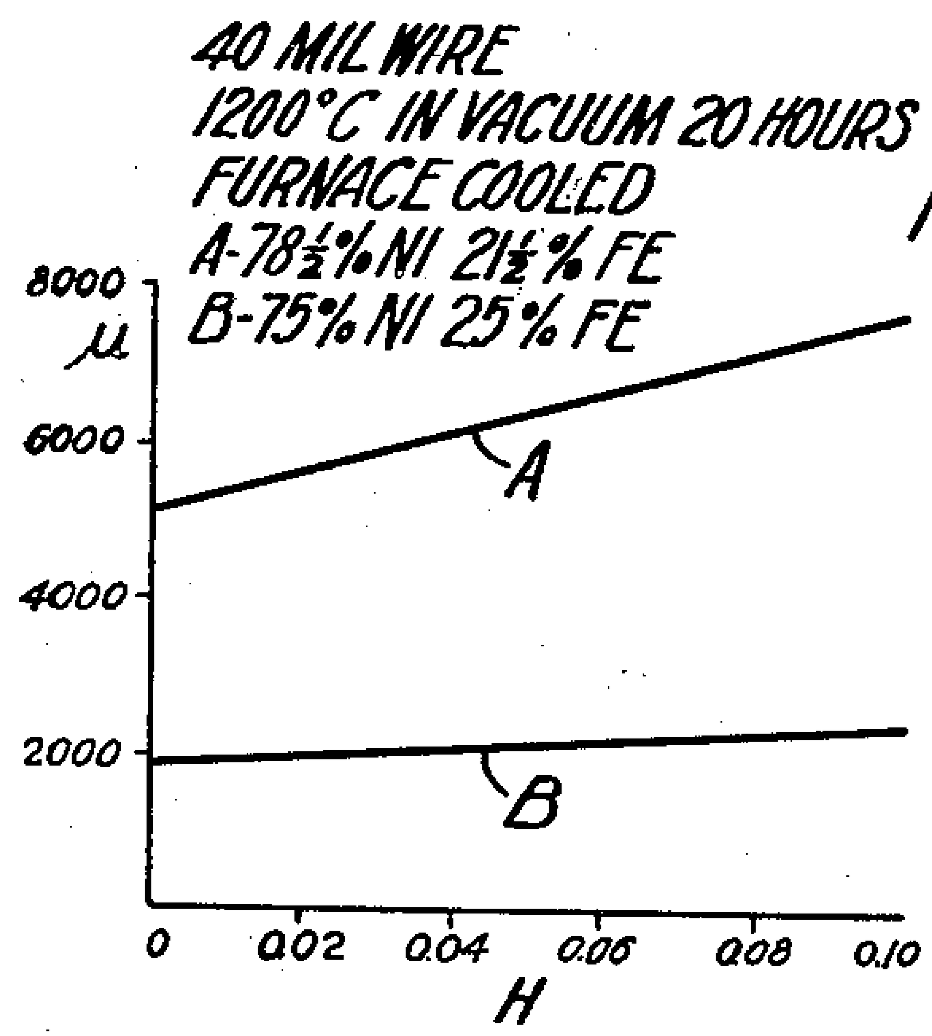


Fig. 2.

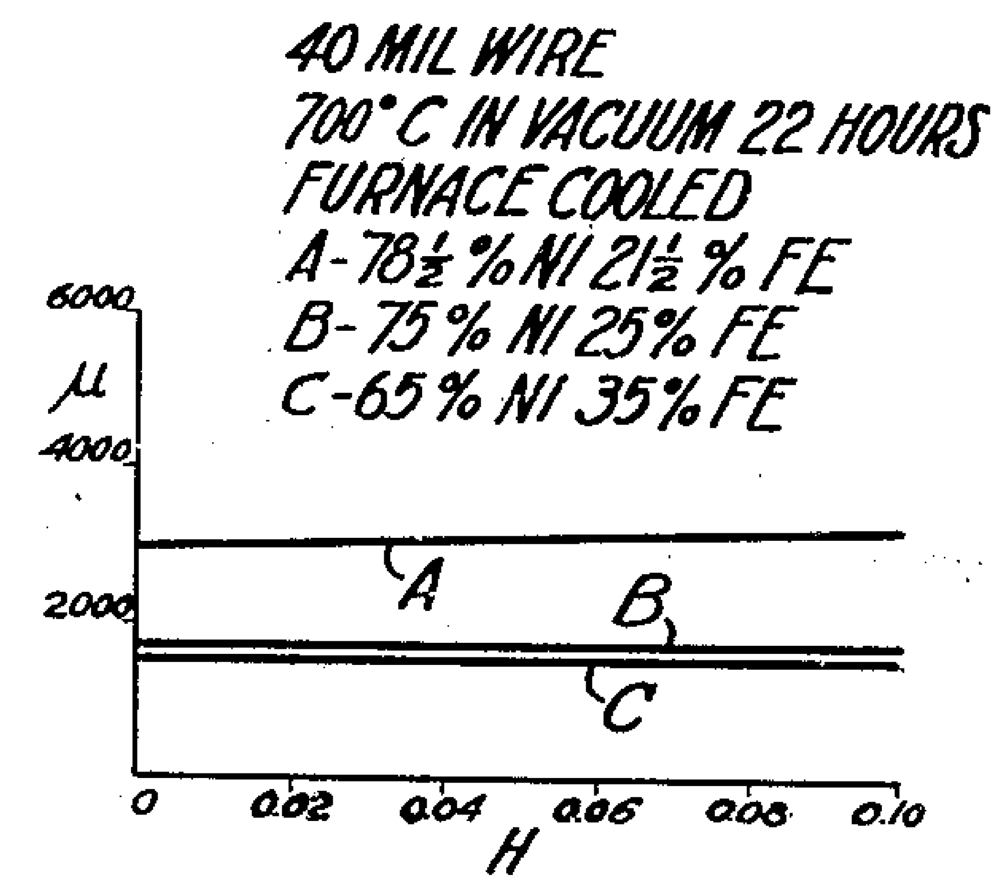


Fig. 3.

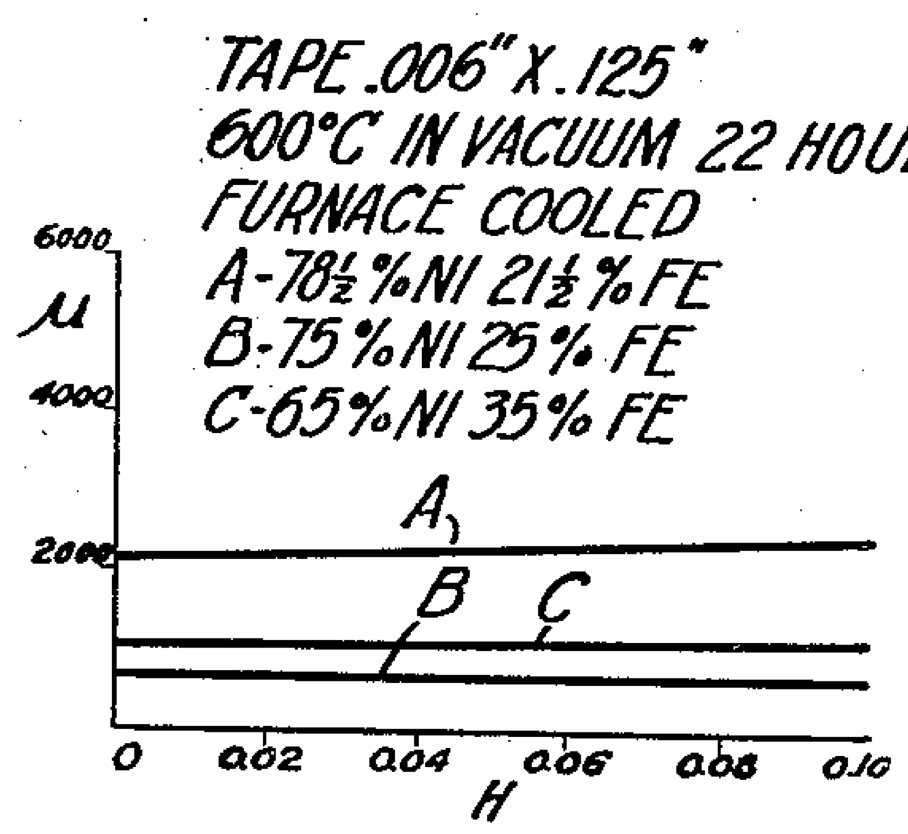


Fig. 5.

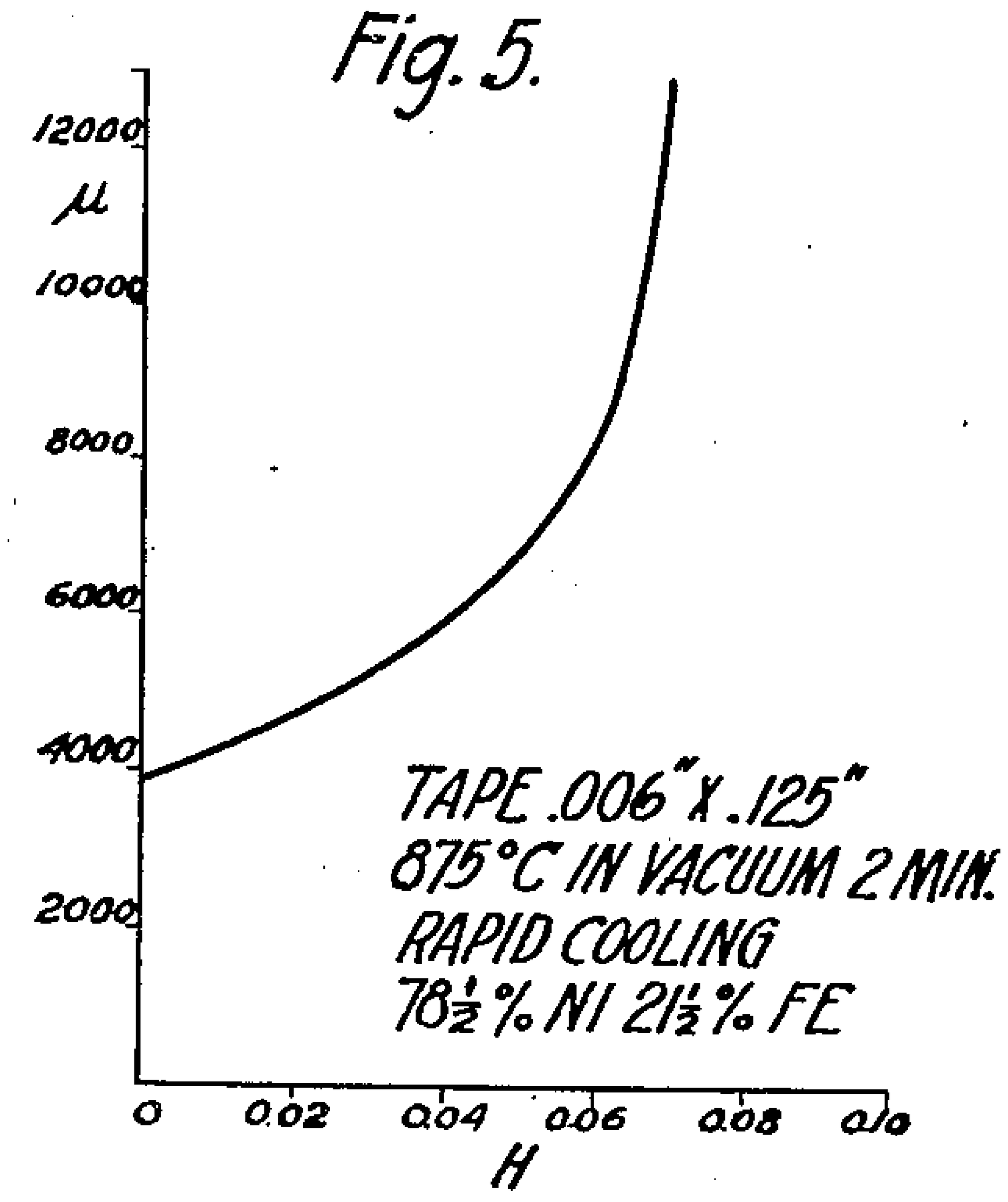


Fig. 6.

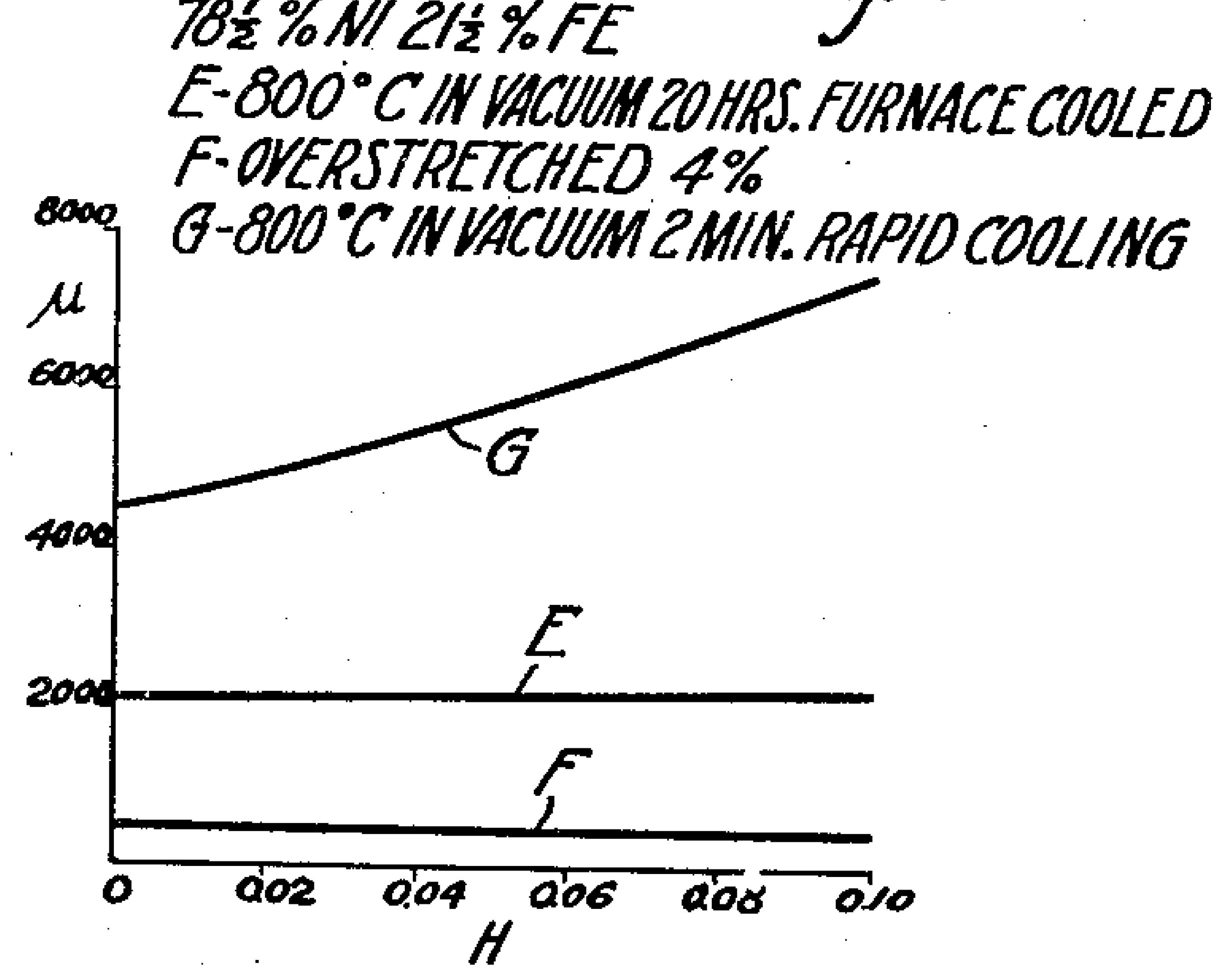
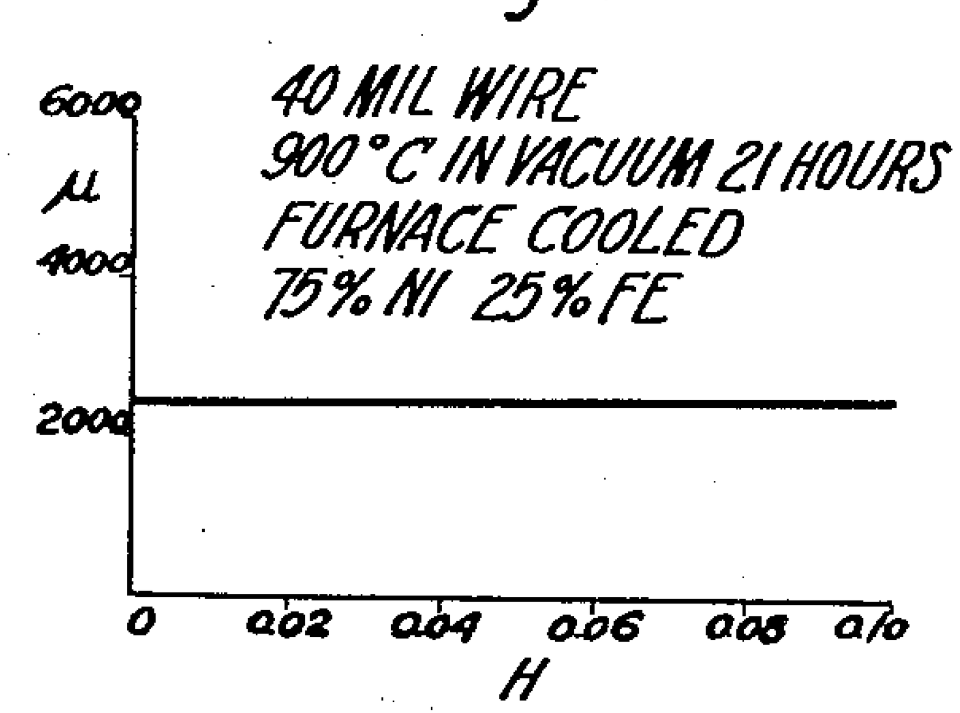


Fig. 4.



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Patented June 10, 1930 1,762,730

UNITED STATES PATENT OFFICE

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HEAT TREATMENT OF MAGNETIC MATERIALS

Application filed October 30, 1926. Serial No. 145,124.

This invention relates to magnetic materials, and particularly to producing desirable magnetic characteristics in nickel-iron alloys.

A feature of the invention resides in treating certain magnetic compositions, particularly nickel-iron alloys containing from 60% to 80% of nickel, to give them substantially constant permeability with accompanying low hysteresis loss at low magnetizing forces of the order employed in signaling.

Recent discoveries have taught that magnetic materials containing nickel and iron as the principal ingredients can be given very high permeability at low magnetizing forces and a low hysteresis loss as compared with iron. Examples of such materials and methods of heat-treating them to obtain the desired properties are disclosed in U. S. Patent No. 1,586,884 to G. W. Elmen, issued June 1, 1926.

The usual method of preparing nickel-iron compositions comprises casting the elements into an alloy, alternately working and annealing the alloy until the desired shape or form is obtained, and then heat-treating it in its final form. Many of the alloys containing nickel and iron are sensitive to strain, the permeability changing markedly when stress is applied. One reason for heat-treating the materials after they are in their final form is to remove unfavorable residual strains.

The heat treatment to which these materials are subjected depends largely upon the characteristics which are desired in the finished product. For example, one treatment which may be employed effectively to develop high permeability consists in heating the material to a temperature of about 1200° C. for about twenty hours in a vacuum furnace, and then allowing the material to cool down to room temperature with the furnace. Another treatment resulting in high permeability consists in heating the material to about 875° C., by passing an electric current through it for several minutes, then cutting off the current and allowing it to cool. The rate of cooling in the second case, of course, is much more rapid than in the first. Other methods of heat-treating the materials are also employed.

The present invention is concerned particularly with nickel-iron alloys containing from about 60% to 80% nickel. When alloys within this range are given the heat treatment hereinafter described, the permeability becomes substantially constant for magnetizing forces up to at least .1 gauss. These alloys, when treated according to the invention, exhibit a much higher initial permeability than iron as well as substantially constant permeability through the range of field strengths ordinarily employed in signaling circuits.

The characteristics of substantially constant permeability and accompanying low hysteresis loss which are exhibited by these alloys in the range of magnetizing forces from zero to about .1 gauss are important in telephone and telegraph circuits and other applications where uniformity of characteristics over the operating range is required. The resulting advantages of reduced energy dissipation and reduction of wave distortion will be apparent to those skilled in the signaling art.

In the drawing, Figs. 1 to 6 are curves illustrating the relation of permeability to magnetizing force for different nickel-iron alloys when subjected to different heat treatments, showing the greater constancy of permeability obtainable by means of this invention. In each case the magnetizing forces are plotted in c. g. s. units.

The magnetic alloys hereinafter considered are prepared by melting the constituents together in the desired proportions in an induction furnace. Good commercial grades of these materials are suitable. The molten metal is then cast into rods or bars which are subsequently rolled or drawn into any desired shape. For convenience in treating and testing samples of these alloys they are sometimes worked into 40 mil wire, or formed into a tape about .006 inch thick and .125 inch wide, the latter also being a form which has been employed for continuously loading signaling conductors.

The variations of permeability exhibited by two magnetic alloys, heat-treated according to one of the ordinary methods referred to above, are illustrated by the curves of Fig. 1 in which the ordinates represent permeability and the abscissæ represent magnetizing forces. These samples were in the form of 40 mil wire. The curve A designates an alloy containing approximately 78½% nickel and 21½% iron, and the curve B an alloy containing approximately 75% nickel and 25% iron. These alloys were annealed in a vacuum furnace at about 1200° C. for twenty hours, and were then allowed to cool slowly to room temperature with the furnace. The curves show that prolonged heating of the alloys at high temperatures, followed by very slow cooling, gives the alloys high permeability, and hence such treatment is advantageous where this characteristic is desired. It will be noted, however, that with this heat treatment the permeability rises when the alloys are subjected to increasing field strengths ranging from zero to .1 gauss. The rate of change in permeability with increasing field strengths varies for the different compositions, but the slope is fairly great in each case. Slopes of this magnitude are characteristic of ordinary heat treatments heretofore employed.

At a given magnetic induction and for the same permeability the hysteresis losses in alternating magnetic fields of the magnitude here considered are substantially proportional to the rate of variation of the permeability with increasing field strength. Reduction of the slope of curves of the sort shown in Fig. 1 is therefore an important advantage, provided that permeability is not too much depressed in attaining the result. As an example of an artifice which causes non-advantageous reduction of slope may be mentioned the introduction of airgaps into the magnetic circuit. Airgaps reduce permeability to an extent which leaves hysteresis losses at the same induction substantially unaffected by the simultaneous reduction in slope of the permeability vs. field strength curve.

The curves of Fig. 2 illustrate the greater constancy of permeability obtainable by means of the present invention. The curve A represents an alloy containing approximately 78½% nickel and 21½% iron, the curve B an alloy containing approximately 75% nickel and 25% iron, and the curve C an alloy containing approximately 65% nickel and 35% iron. These alloys, like those described in connection with Fig. 1, were in the form of 40 mil wire. The samples were annealed in a vacuum furnace at a temperature of about 700° C., for twenty-two hours, and were then allowed to cool slowly to room temperature with the furnace, the rate of cooling being slightly less than 10° C. per minute. The essential difference between this heat treatment and that described in connection with Fig. 1 resides in the temperature employed. It will be noted by comparing the curves A and B of Figs. 1 and 2 that greater constancy of permeability is obtained by employing the lower temperature. The curve A of Fig. 2 shows only a very slight increase in permeability over the range of magnetizing forces from zero up to .1 gauss, while the curves B and C show no change in permeability over this range.

It can be inferred from the data used in plotting these curves that at low field values the hysteresis losses in the material with 78½% nickel are less for the state shown in Fig. 2 by about 25 per cent and that the hysteresis losses in the material with 75% nickel are less by about 80%. Improvements of this order are typical.

The samples of magnetic alloys represented by the curves of Fig. 3 are the same in composition as those represented by the corresponding curves of Fig. 2, but are in the form of tape .006 inch thick and .125 inch wide. The heat treatment was also identical except that the temperature employed was 600° C., instead of 700° C., as in the previous case. The curves show that while the permeability of each of these alloys is lower than that obtained by employing higher temperatures, the permeability is remarkably constant over the range of magnetizing forces up to .1 gauss.

An alloy containing approximately 75% nickel and 25% iron maintained at 900° C. for about twenty-one hours and cooled slowly with the furnace also exhibited a high constant permeability as shown by the curve of Fig. 4. This sample was in the form of 40 mil wire. The best results have been obtained, according to the invention, with temperatures between about 600° C., and 900° C.

While the time of heating the alloys herein described was in the neighborhood of twenty hours, excellent results may be obtained with treatments as short as two hours, the optimum temperature and duration of the heating being determined by trial in each case. Heating the magnetic alloys at comparatively low temperatures for only a very short time, however, does not give them great constancy of permeability. Fig. 5 illustrates the sloping characteristic obtained by treating an alloy containing 78½% nickel and 21½% iron according to such method. This sample was in the form of tape .006 inch thick and .125 inch wide. The tape was heated to a temperature of 875° C., by passing an electric current through it, while in a vacuum, for two minutes. When the heating current was cut off the tape cooled rapidly to room temperature. This heat treatment gives the alloy a high initial permeability, but accentuates the rise in permeability with increasing field strengths.

It may be difficult in some cases to heat the magnetic materials for several hours after they are in their final form. It has been found, however, that the valuable properties conferred by long-continued heating at a relatively low temperature can be restored by a very short supplementary treatment when these properties are lost by over-strain in placing the heat-treated material where it is finally to be used. This is illustrated by the curves of Fig. 6, representing an alloy which is the same in form and composition as that represented by the curve of Fig. 5. The curve E represents an alloy containing approximately 78½% nickel and 21½% iron, maintained at a temperature of 800° C., for twenty hours and allowed to cool to room temperature with the furnace at a rate slightly less than 10° C. per minute. This curve shows the high and substantially constant characteristic obtained with this heat treatment which is within the scope of this invention. Following this treatment the tape was overstretched about 4%. The result is indicated by the curve F, showing that the permeability was greatly reduced. The overstretched tape was then reheated at a temperature of 800° C. by passing an electric current through it, while in a vacuum, for two minutes, this treatment restoring the material to its previous condition as illustrated by the curve E. When another sample of this same material not previously heat-treated in accordance with this invention was heated to 800° C., for two minutes, this being the heat-treatment according to a method referred to above, the permeability was higher but not nearly so constant, as illustrated by the curve G. Curve G is generally similar to the curve of Fig. 5.

Various changes in the method and compositions described above may be made without departing from the scope and spirit of the invention. For example, small percentages of chromium or other materials may be added to the alloys to increase their resistivity, or for other purposes, as is common practice in nickel-iron metallurgy.

What is claimed is:

1. The method of treating a magnetic material containing from 60% to 80% nickel and the balance chiefly iron to give it substantially constant permeability for all field strengths up to at least .1 gauss which comprises heating it to a maximum temperature between about 600° C and about 900° C. for at least two hours and cooling to approach room temperature at an average rate of about 10° C. per minute.

2. The method of treating a magnetic material containing from 60% to 80% nickel and the balance chiefly iron to give it substantially constant permeability for all field strengths up to at least .1 gauss which comprises heating it to a maximum temperature between 600° C. and 800° C. for at least two hours and cooling, to approach room temperature at an average rate of about 10° C. per minute.

3. The method of treating a magnetic material containing from 60% to 80% nickel and the balance chiefly iron to give it substantially constant permeability for all field strengths up to at least .1 gauss which comprises heating it to a temperature of about 700° C. for at least two hours and cooling to room temperature at an average rate of about 10° C. per minute.

4. A magnetic material comprising from 60% to 80% nickel and the remainder iron, having substantially constant permeability for all magnetic field strengths up to at least .1 gauss.

5. A magnetic material having substantially constant permeability for different magnetic field strengths up to at least .1 gauss, comprising from 60% to 80% nickel and the remainder chiefly iron and a small amount of non-magnetic material for increasing the resistivity, said amount being greater than that of an impurity.

6. A magnetic material comprising approximately 75% nickel and 25% iron, having substantially constant permeability for different magnetic field strengths up to at least .1 gauss.

7. A magnetic material comprising approximately 78½% nickel and 21½% iron, having substantially constant permeability for different magnetic field strengths up to at least .1 gauss.

8. A method in accordance with claim 1, further characterized in this that the material is worked into final shape for use, and that the constancy of permeability lost by the working is restored by reheating the material to a temperature of about 800° C. for a comparatively short time and cooling it to about room temperature at an average rate of about 10° C. per minute.

In witness whereof, I hereunto subscribe my name this 29th day of October A. D., 1926.

LOUIS W. McKEEHAN.