June 4, 1929. G. W. ELMEN 1,715,648

MAGNETIC MATERIAL

Filed June 28, 1928

FIG. 1.

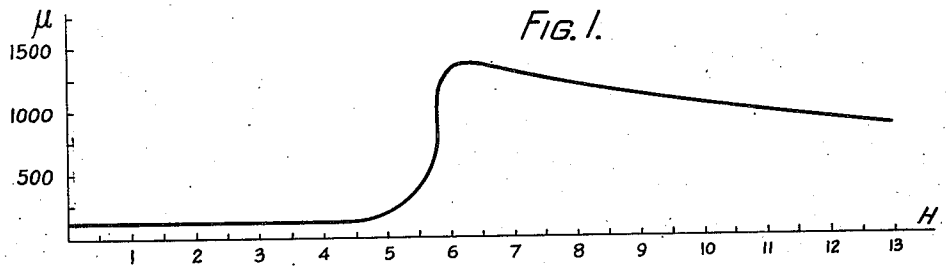


FIG. 2.

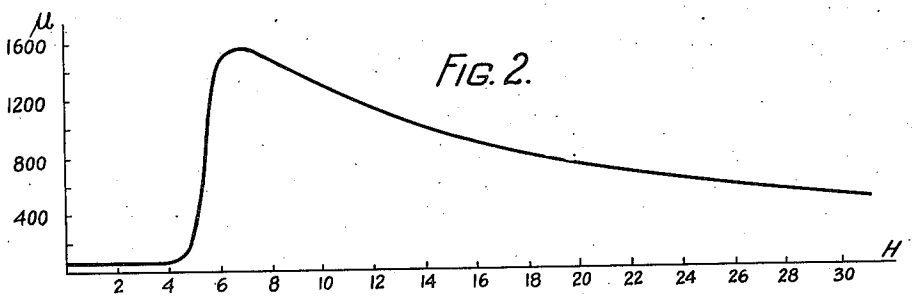


FIG. 4.

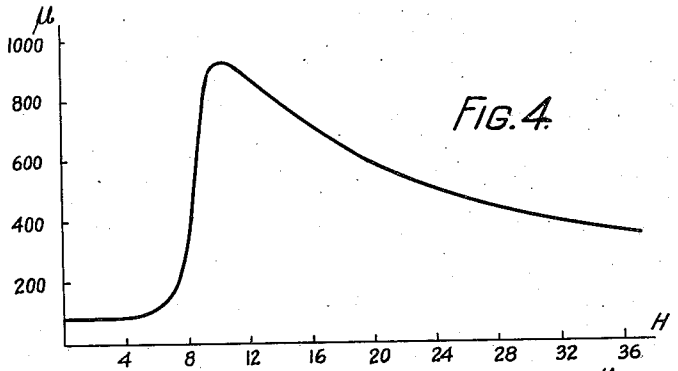


FIG. 3.

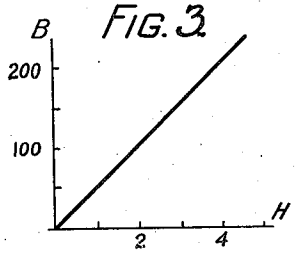


FIG. 6.

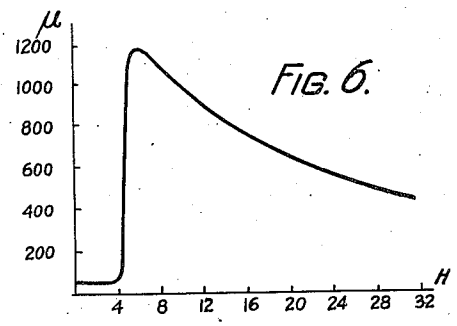
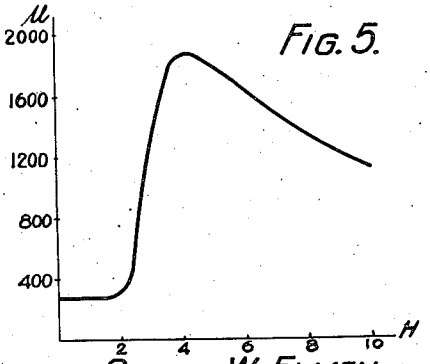


FIG. 5.



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UNITED STATES PATENT OFFICE.

GUSTAF W. ELMEN, OF LEONIA, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

MAGNETIC MATERIAL.

Application filed June 28, 1928. Serial No. 289,050.

The present invention relates to magnetic materials and to their application in electromagnetic systems. Materials in accordance with the present invention have a field of usefulness and are of special interest in those cases in which the impressed magnetizing forces are small such as in electric signaling systems. More particularly, the present invention relates to magnetic compositions having a relatively low hysteresis loss and a high degree of constancy of permeability for magnetizing forces up to several gauss.

In Elmen's applications Serial No. 119,622 and Serial No. 119,623, both filed June 30, 1926, there are described and claimed magnetic compositions of iron, nickel and cobalt which have been discovered to have, among other unusual properties, a very high degree of constancy of permeability over a wide range of magnetizing forces including the low range employed in loading signaling conductors.

The utility of such compositions may be increased, especially for applications where low eddy current loss is desirable, by increasing their resistivity, when this can be done without excessively or considerably impairing their other desirable properties. In Elmen application Serial No. 220,387, filed September 19, 1927 there are described and claimed several compositions having their resistivity increased and other properties improved or modified adversely to a slight extent only by the addition of moderate percentages of such elements as molydenum, chromium, tungsten, manganese, vanadium, tantalum, zirconium, copper and silicon.

Among such iron-nickel-cobalt compositions is noted a genus or variety in which the permeability remains constant or very nearly so for magnetizing forces as high as four gauss, more or less. These compositions, which in general are characterized also by a moderately low initial permeability and a cobalt content of more than 45 per cent (in most cases) of the entire iron-nickel-cobalt content, constitute a subject matter of the present invention. These compositions have a field of usefulness where constancy of permeability for considerable magnetizing forces is desired, for example, in loading coils for signaling conductors.

The resistivity of such high cobalt compositions may be increased by the addition of one or more of the fourth substances mentioned above in moderate amounts, and such compositions having increased resistivity constitute another feature of the present invention.

Titanium has been added to alloys of iron, nickel and cobalt of highly constant permeability to increase the resistivity and a further feature of the present invention comprises such alloys including titanium without limitation of their cobalt content to a high value.

In order to develop desirable properties in compositions such as claimed herein or to accentuate certain properties, particular heat treatments have been found to be desirable. These treatments differ for different compositions, and while the particular treatment best suited for a particular composition may be selected in accordance with the directions below, one heat treatment which was productive of satisfactory initial permeabilities, good constancies of permeability and small hysteresis losses, whenever used, will now be described.

The magnetic compositions, after having been prepared by melting the ingredients together in the proper proportions in an induction furnace, were allowed to cool and when at ordinary low temperature were placed in an annealing pot, and the pot and contents inserted in an electric resistance furnace adapted to have the temperature accurately regulated to any desired value. The pot was then heated to 1100° C., maintained at that temperature for about one hour and then cooled at such a rate that at each degree of cooling temperature the material was in a condition of equilibrium, that is, that no changes in its structure took place. For the various compositions described in this application, a suitable rate of cooling was found to consist in cooling within the furnace at approximately 200° C. per hour for the first hour, 100° C. for the next two hours, 66⅔° C. per hour for the next three hours, 50° C. for the next four hours and 40° C. per hour for the remainder of the time required to reach room temperature. This treatment will be referred to herein as heat treatment I.

Another suitable method consists in heating the materials to about 1100° C., cooling

to room temperature, reheating to about 435° C., maintaining them at that temperature for about 40 to 60 hours and then cooling them slowly at an average rate of about 50° C. per hour to room temperature. The most favorable length of time for which the material should be heated at about 435° C. varies somewhat for different compositions, but can readily be determined by a few tests.

The curve of Fig. 1 shows the measured variation of permeability with varying magnetizing force of a virgin alloy containing approximately 16 per cent iron, 30.5 per cent nickel, 50 per cent cobalt, 3.5 per cent molybdenum, and a trace of manganese, after having received heat treatment I.

This material exhibited an initial permeability of 113, which remained practically constant up to a magnetizing force of about 4 gauss. It had a resistivity of about 47.6 microhm-cms. and a hysteresis loss of 4490 ergs per cycle per cubic centimeter for a maximum induction of 7400 gauss.

Fig. 2 depicts the measured variation of permeability with a varying magnetizing force for a composition containing 20 per cent iron, 10 per cent nickel and 70 per cent cobalt given heat treatment I. The initial permeability was about 57 and remained constant up to magnetizing forces of over 4 gauss. One half a hysteresis curve of this particular composition is shown in Fig. 3; it is seen that the hysteresis loss was substantially zero up to the flux density of about 225 gauss.

The curve of Fig. 4 graphically shows the measured variation of permeability with varying magnetizing force for a composition containing 17 per cent iron, 26 per cent nickle, 55 percent cobalt and 2 per cent titanium after having received heat treatment I. The initial permeability, which was about 90 remained substantially constant with increasing magnetizing force up to about 5 gauss. The maximum permeability which occurred at about 10 gauss magnetizing force was 9200 and the resistivity about 30 microhm-cms. The hysteresis loss of this material was 7500 ergs per cubic centimeter per cycle for a maximum induction of 8000 gauss and its coercive force and remanence were 5.27 and 7720 gauss respectively for a maximum induction of 13000.

In Fig. 5 is shown the measured variation of permeability with increasing magnetizing force of a composition containing approximately 28 per cent iron, 45 per cent nickel, 26 per cent cobalt and 1 per cent titanium after being given heat treatment I. This composition had an initial permeability of about 345 which remained constant up to about 1.5 gauss. Its maximum permeability was about 1850 and its restivity 30 microhm-cms. Its hysteresis loss was 1795 ergs per cubic centimeter per cycle for a maximum induction of 7500 gauss. It had a coercive force of 1.17 and a remanence of 2735.

Fig. 6 shows the measured variation of permeability with increasing magnetizing force of a material containing approximately 20 per cent iron, 20 per cent nickle, 60 per cent cobalt and 0.3 per cent manganese, given heat treatment I. This material had an initial permeability of about 50 which remained constant up to a magnetizing force of about 4 gauss. Its maximum permeability which occurred at about 6 gauss was 1200. The material had a hysteresis loss of 7440 ergs per cubic cenetimeter percycle for a maximum induction of 16,000 gauss. Its coercive force was 2.60 gauss and its remanence 3,820 gauss for a maximum induction of 14,200 gauss.

In distinguishing between compositions having constancy of permeability for high flux densities combined with relatively high initial permeability and those of lower initial permeability constant to a higher magnetizing force the dividing line has been set at the point where cobalt constitutes about 45 per cent of the iron-nickel-cobalt content. This is based as nearly as possible upon physical differences in the compositions having over 45 per cent and those having less than 45 per cent cobalt. However, the dividing line is not an exact one and varies somewhat with the percentage of nickel. Thus with compositions of 10 per cent nickel and varying proportions of cobalt and iron a great change in properties takes place in passing from 30 per cent to 40 per cent cobalt. The flux density B, for H=50 increases from 7000 to over 16000 and the hysteresis loss for a loop B=5000 maximum decreases enormously as the cobalt content is increased from 30 to 40 per cent and the iron decreased from 50 per cent to 40 per cent. With compositions of 20 per cent nickel, however, corresponding but less striking changes occur as the cobalt content is increased through about 50 per cent. These facts are cited as evidence that a more or less distinct genus of heat treated magnetic iron-nickel-cobalt compositions comprises those having above about 45 per cent cobalt.

Although the present invention has been described with particular reference to but titanium and molybdenum as fourth elements in magnetic compositions containing cobalt in amounts of 45 per cent to 80 per cent of the iron-nickel-cobalt content, it is understood that equivalent fourth elements, particularly chromium, tungsten, manganese, vanadium, tantalum, zirconium, copper and silicon, mentioned in applicant's application Serial No. 220,387, filed September 19, 1927 may be used in amounts of 1 per cent to several per cent, either singly or in combination.

More specifically, any of the fourth ele-

ments mentioned may be substituted for the molybdenum or titanium content of the compositions hereinbefore described.

What is claimed is:

1. A magnetic composition composed chiefly of iron, nickel, and cobalt including 9 per cent or more of iron, 4 per cent or more of nickel, and cobalt, with or without the addition of a fourth substance to increase the resistivity or modify the other properties, characterized by a cobalt content greater than 45 per cent of the iron-nickel-cobalt content and not in excess of 80 per cent of the entire composition.

2. A magnetic material containing as essential constituents thereof nickel, cobalt and iron in which the cobalt content is greater than 45 per cent of the total nickel-cobalt-iron content and in which the three elements named constitute the major portion of the material.

3. A magnetic material containing as essential constituents thereof nickel, cobalt and iron in which the cobalt content is 46 per cent or more of the total nickel-cobalt-iron content and less than 85 per cent of the entire composition.

4. A magnetic material characterized by a negligible variation in permeability over a wide range of magnetizing forces comprising nickel more than 5 per cent, iron more than 9 per cent, and cobalt more than 45 per cent.

5. A magnetic composition comprising nickel approximately 30 per cent, cobalt approximately 50 per cent and the balance chiefly iron.

6. A magnetic composition comprising nickel approximately 30 per cent, cobalt approximately 50 per cent and the remainder composed chiefly of iron plus material selected to include material chiefly of the following elements, molybdenum, chromium, tungsten, manganese, vanadium, tantalum, zirconium, copper, silicon and titanium.

7. A magnetic composition containing as essential elements thereof nickel, cobalt, iron and titanium in which the cobalt content is greater than 40 per cent of the total nickel-cobalt-iron content.

8. A magnetic composition composed chiefly of iron, nickel and cobalt including at least 9 per cent of iron, at least 4 per cent of nickel, at least 5 per cent of cobalt and titanium to an extent greater than an incidental impurity and less than 10 per cent.

In witness whereof, I hereunto subscribe my name this 27th day of June, 1928.

GUTAF W. ELMEN.