

March 19, 1929.

I. F. KINNARD

1,706,172

TEMPERATURE RESPONSIVE MAGNETIC MATERIAL

Filed Nov. 11, 1925

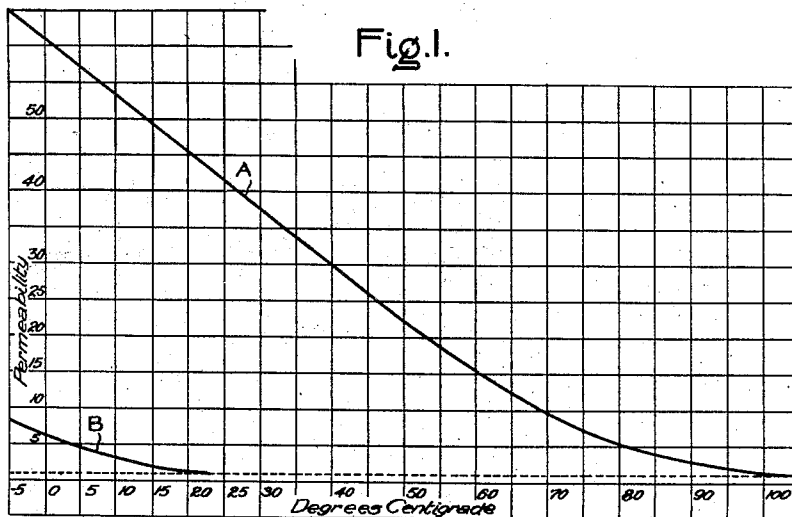


Fig. 2.

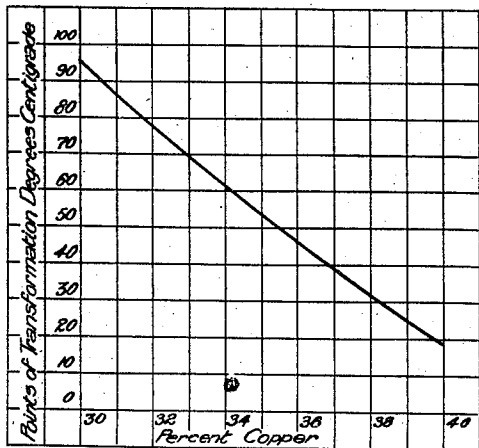


Fig. 3.

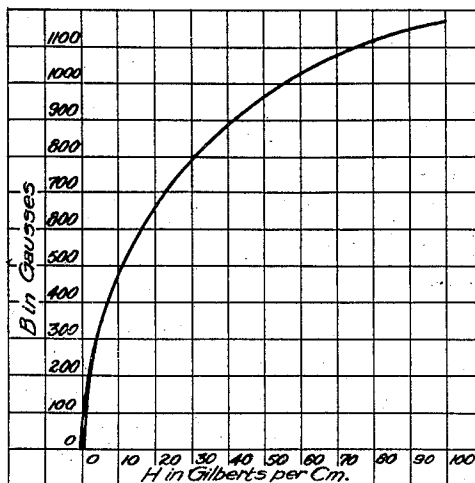
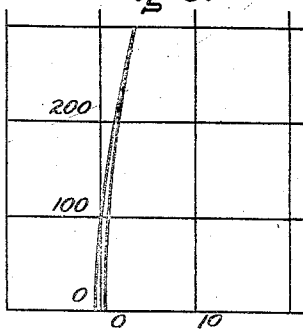


Fig. 3a



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Patented Mar. 19, 1929.

1,706,172

UNITED STATES PATENT OFFICE.

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TEMPERATURE-RESPONSIVE MAGNETIC MATERIAL.

Application filed November 11, 1925. Serial No. 68,462.

My invention relates to magnetic material and in particular to magnetic alloys having a substantially linear negative temperature coefficient of permeability between ordinary temperature limits. Such a material is useful in the construction of temperature responsive magnetic devices and for use in various electromagnetic devices to correct for temperature errors as described, for example, in my copending application Serial No. 711,023, filed May 5, 1924, assigned to the same assignee as the present invention, of which the present application is in part a continuation.

The features of my invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. For a better understanding of my invention the method of making the alloys in question, their composition and properties will now be explained and reference will be made to the accompanying drawing which shows in Fig. 1 temperature-permeability curves of material prepared in accordance with my invention. Fig. 2 is a curve showing how the transformation point of the material varies with the copper content; and Figs. 3 and 3^a give the results of hysteresis tests on the material.

I have discovered that certain copper-nickel alloys when properly prepared can be made to have, in addition to other desirable properties, a substantially linear negative temperature coefficient of permeability between ordinary temperature limits and that this characteristic may be controlled and varied by varying the composition of the alloy and the method of preparation.

Most magnetic material has more or less hysteresis loss. That is to say, the magnetism of the material lags behind the force producing the magnetism such that the magnetism for a given producing force will be less if the force is increasing than it would be if the force were decreasing. This property gives rise to the well known hysteresis loop characteristic of magnetic materials. It will be readily expected that a material having a negative temperature coefficient of permeability and having appreciable hysteresis loss would have different values of magnetism at a given temperature when placed in a constant magnetic field depending upon whether the material had been brought to the given temperature by a de-

crease or an increase in temperature. However, if such material had a very low or inappreciable hysteresis loss, it would be expected that it would always have the same magnetism under the above conditions irrespective of the direction of change in temperature. My investigations have shown the above theory to hold good. In order to utilize the negative temperature coefficient of permeability characteristic of a magnetic material to the best advantage, it is of course desirable that the permeability vary with the temperature and be independent of the direction of temperature change as otherwise the material would give different results at a given temperature, depending upon whether the temperature was increasing or decreasing. It is therefore desirable that such material have zero or negligible hysteresis and it is one of the objects of my invention to provide a material having these desirable properties.

I have found that the effect of adding a small amount of iron to certain copper-nickel alloys is to raise the point of magnetic transformation, which is the point where the permeability approaches unity or becomes equal to that of air. Thus I have found that the addition of about 2.3 per cent iron to an alloy of 70 per cent pure nickel and 30 per cent electrolytic copper, raises the transformation point about 45° C. Since most commercial nickels contain some iron along with other impurities, the transformation point may be raised by simply adding sufficient additional iron to bring the total percentage up to the value desired. It is possible to obtain desirable results at a low cost in this manner. An alloy containing approximately the percentages of copper, nickel and iron above specified when prepared as described hereinafter gives a permeability temperature curve as shown in curve A of Fig. 1. It will be noted that the curve is approximately straight between 0° and 100° C. and below about 70° C. corresponding to range of temperatures where the material will be ordinarily used, the curve is substantially straight. Another desirable feature of this material, as may be seen from the curve, is that it approaches unity permeability very gradually. The percentage of copper used also varies the point of transformation. Thus curve of Fig. 2 shows how the point of transforma-

tion varies with changes in the per cent of copper, the iron content being maintained constant at about 2.2 per cent and the nickel content varying inversely as the copper.

5 Curve B of Fig. 1 shows the characteristics of an alloy containing approximately 60 per cent nickel and 40 per cent copper. In this case the permeability becomes negligible at about 14° C.

10 The heat treatment given during the preparation of the alloys is very important if the desired characteristics and uniformity of product are to be obtained. To obtain an alloy having the characteristics given in
15 curve A of Fig. 1, I prefer to use the following method:

The following ingredients are melted in an Ajax high frequency induction furnace:

	Per cent.
20 Inco X nickel shot-----	68.2
Clean copper scrap (pure)-----	30.
Commercially pure iron-----	1.8

A chemical analysis of the Inco X nickel
25 shot shows the composition to be as follows:

	Per cent.
Nickel-----	98.6
Iron-----	.88
Copper-----	.18
30 Impurities (Si, C, etc.)-----	.34

Assuming that the copper and iron are pure, the theoretical composition of the alloy is as follows:

	Per cent.
35 Nickel-----	67.25
Copper-----	30.12
Iron-----	2.4
Impurities-----	0.23

40 A typical chemical analysis of the finished alloy is as follows:

	Per cent.
Nickel-----	67.35
Copper-----	30.17
45 Iron-----	2.08
Impurities-----	0.40

Some of the iron is evidently lost through oxidation. The impurities apparently have
50 no influence on the temperature permeability characteristics.

The alloy is heated to approximately 1650° C. before pouring. No additional stirring is necessary as the electromagnetic
55 forces acting on the molten metal in this type of furnace produce a stirring action sufficient to thoroughly mix the alloy. Preferably, immediately before pouring, 0.15% of magnesium wire is added to the
60 melt in order to deoxidize the alloy. This deoxidation apparently has little or no effect on the magnetic properties of the material, but it has the effect of making the alloy malleable, while without deoxidation it
65 would be brittle.

The alloy is cast in green sand molds and as soon as the castings have solidified, they are seized with tongs and plunged into cool water.

A test piece of standard size weighing 70 about 5 grams is cut from one of the castings of each melt and is tested by being placed on a permanent magnet which is suspended in a bath of hot water or oil. The test piece should be sufficiently magnetic at 90° C. 75 to be held by the magnet, and it should drop from the magnet by its own weight at some temperature less than 105° C. Material which fails to pass this test may be heat treated in order to obtain the correct re- 80 lease temperature. Material having a release temperature less than 90° C. may be corrected by annealing or by quenching from a temperature lower than the original quenching temperature. Material having a 85 release temperature higher than 105° C. may have its release point lowered by heating to 1050°-1100° C. and quenching in oil.

The same general procedure is followed in making other alloys having different release 90 points, the characteristics being varied as desired by varying the percentage composition of iron, copper and nickel as previously pointed out. When thus prepared the materials are malleable and have a negligible 95 hysteresis loss and very low retentivity. The curves of Fig. 3 give the results of hysteresis test of an alloy having the properties shown in curve A, Fig. 1. It will be noted that the hysteresis loss is so small that it can be hardly 100 detected on this curve. The lower part of the curve is enlarged in Fig. 3^a. This material has a specific resistance of about 49 microns per centimeter cube. Another unusual characteristic is its low retentivity 105 which is only about 8 per cent of the maximum induction.

The importance of uniform temperature treatment to obtain a uniform product cannot be overemphasized. For example I have 110 found that the alloy which gives the characteristics of curve A, Fig. 1, when prepared as previously described is very sensitive to heat treatment both before and after solidifying in the mold. If this same material is 115 poured in a graphite mold instead of a sand mold, the resulting material is practically non-magnetic at 20° C. If poured in a mold of zirconium silicate, it becomes substantially non-magnetic at 60° C. If this last 120 mentioned sample is then heated for two hours at 700° C. and cooled in air, its release point is raised to 98° C.

It will be seen therefore that in order to obtain uniformity in results it is necessary 125 to very carefully control the conditions under which the alloys are made as well as the percentage composition of the alloy. I believe the linear temperature-permeability relationship of these materials is due to the 130

non-homogeneous manner in which the copper is held in solution, which gives the effect of the summation of a large number of alloys, each having a different transformation point. They differ from Monel metal in this respect. Monel metal is a natural alloy of copper and nickel which has a negative temperature coefficient of permeability over a short range of temperature, but which does not have the desirable straight line characteristics shown in Fig. 1 and is not suitable for many purposes because its permeability drops very abruptly as it approaches zero.

It is believed that the desirable magnetic characteristics of the alloys which I have described and the manner in which the characteristics may be controlled to produce predetermined desirable results has escaped previous notice and that they are an important adjunct to engineering materials. Consequently I do not wish to limit my invention to any particular alloy or to any particular method of preparation but seek claims commensurate with the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An alloy containing between 60 and 80 per cent nickel and between 40 and 20 per cent copper and having substantially a linear negative temperature coefficient of permeability which gradually becomes less as the permeability of the material approaches that of air at some temperature between 10 and 110° C.

2. A malleable, magnetic alloy containing between 60 and 80 per cent nickel and between 40 and 20 per cent copper having a negligible hysteresis loss and having a substantial negative temperature coefficient of permeability which gradually becomes less as the permeability of the alloy approaches that of air.

3. A magnetic alloy containing between 60 and 80 per cent nickel, between 40 and 20 per cent copper, and approximately 2 per cent iron having a substantial and approximately a linear negative temperature coefficient of permeability between 0 and 100° C. and having a permeability which approximates that of air in the neighborhood of 100° C.

4. A malleable magnetic material containing between 60 and 80 per cent nickel, between 40 and 20 per cent copper, and approximately 2 per cent iron having a negligible hysteresis loss and having a substantial and approximately a linear negative temperature coefficient of permeability between

0 and 100° C. which gradually reduces to unity in the neighborhood of 100° C.

5. A heat treated cast magnetic alloy having a predetermined negative temperature coefficient of permeability formed by mixing approximately 68 parts of nickel, 30 parts of copper, and 2 parts of iron in the molten state, casting said alloy in a sand mold and quenching in water as soon as the alloy solidifies.

6. A magnetic material having a temperature permeability characteristic which approaches unity at about 100° C. and which increases substantially uniformly with decrease in temperature below about 100° C. over a wide range of temperature, consisting of a copper-nickel alloy containing between 40 and 20 per cent copper, between 60 and 80 per cent nickel, and a small amount of iron.

7. A cast material containing between 20 and 40 percent copper and between 60 and 80 percent nickel which is quenched from a temperature slightly below that at which the material solidifies and in which the permeability of the material approaches unity at some temperature point above 15° C. and increases substantially uniformly with a decrease in temperature from such point downward over a temperature range of at least 50° C.

8. A magnetic copper-nickel alloy containing between 60 and 80 per cent nickel and between 40 and 20 per cent copper, having a negligible hysteresis loss and having a substantial and approximately linear negative temperature coefficient of permeability over a temperature range in excess of 40 centigrade degrees.

9. A magnetic copper-nickel alloy having a negligible hysteresis loss and having a substantial and approximately linear negative temperature coefficient of permeability over a wide temperature range, the copper content of said alloy being between 20 and 40 per cent and being held in solution in a non-homogeneous manner.

10. A magnetic copper-nickel alloy containing a small percentage of iron having a negligible hysteresis loss and having a substantial and approximately linear negative temperature coefficient of permeability over a wide temperature range, the copper content of said alloy being between 20 and 40 per cent and being held in solution in a non-homogeneous manner.

In witness whereof, I have hereunto set my hand this ninth day of November, 1925.

ISAAC F. KINNARD.