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PERMANENT MAGNET CONSISTING OF IRON, NICKEL, AND COPPER

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Fig. 1.

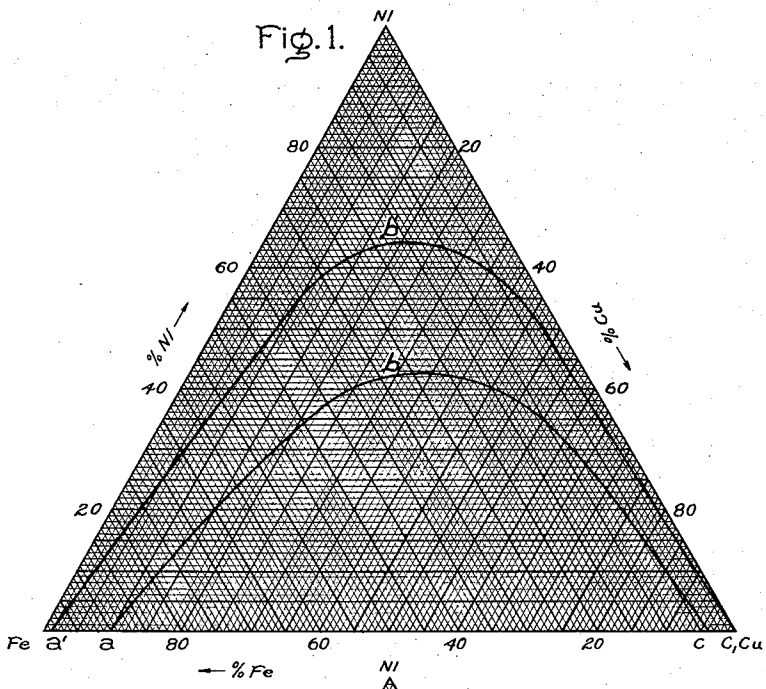
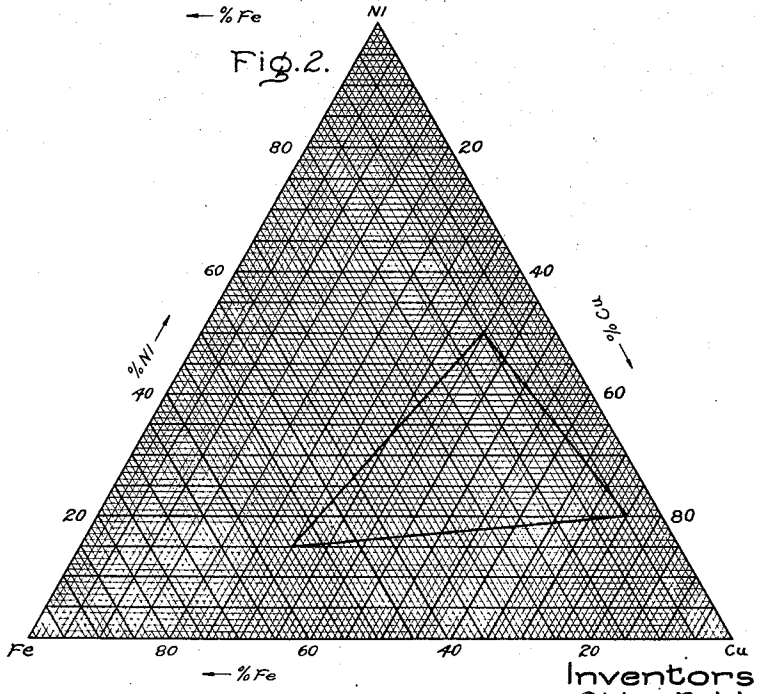


Fig. 2.



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PERMANENT MAGNET CONSISTING OF IRON, NICKEL, AND COPPER

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3 Claims. (Cl. 175—21)

In the fabrication of permanent magnets it is customary to use ferro-magnetic materials which possess as large as possible a coercive force and as large as possible a residual magnetism. The product of residual magnetism and coercive force is termed the coefficient of quality. A number of magnet steels are known, which have a high coefficient of quality, e. g. steels which consist of alloys of iron, carbon and a third alloy component. Chromium, tungsten and cobalt have proved particularly advantageous for use as a third component in such alloys. Besides alloys containing carbon, alloys substantially free from carbon, e. g. iron-nickel-aluminium alloys, are known, which have a high coefficient of quality. In all these steels the high coefficient of quality, or magnetic hardness is always associated with a great mechanical hardness, for which reason these alloys are practically incapable of being wrought in the magnetic hard condition. The production of the magnets must therefore essentially be undertaken by casting and, if desired, by subsequent grinding. This fact is very inconvenient since the design of a magnet must be restricted to those limits within which castings may be made.

According to the present invention these difficulties are overcome by so choosing the material and so treating it that a high magnetic hardness is present therein in a condition of the material in which a high mechanical hardness is not present or not yet present. For this purpose, iron-nickel-copper alloys capable of being precipitation hardened are used as the ingredients for permanent magnet alloys, which alloys are slowly cooled or else quenched and tempered in the cast or rolled condition in order to effect the precipitation.

Fig. 1 of the accompanying drawing shows diagrammatically various combinations of iron, nickel and copper which are heterogeneous at all temperatures below 1050° C. as well as those combinations of iron, nickel and copper which become heterogeneous by slow cooling. Fig. 2 is a diagram illustrating various combinations of iron, nickel and copper which give the highest permanent magnet values.

Alloys of iron, nickel and copper are known. The structure composition of such alloys is apparent from the graph of Fig. 1. While iron and nickel, also nickel and copper, dissolve in the solid condition in all proportions of mixture, i. e. they form mixed crystals, the iron-copper alloys harden over the best part of the alloy range into a mixture of two types of crystal. This mixture gap in the solid condition, as shown in Fig. 1, is closed by the addition of nickel, this being done with lower nickel contents for high temperatures than for low temperatures. Tests made show that, in respect of the electrical conductivity and the structure, at 1050° C. the lower range takes the course *a b c*, and that at a lower temperature—tests were made up to approx. 400° C.; below that the equilibrium adjustment is too sluggish—it is limited by *a' b' c'*. The alloys of the range *a b c a* are heterogeneous at all temperatures below 1050° C., which is hereafter treated as the quenching or homogenising temperature; the alloys lying between *a b c* and *a' b' c'* become heterogeneous by slow cooling. All alloys lying within *a' b' c' a'* show precipitation, according to the decrease of the solubility with a decreasing temperature, and therefore fall under the heading "alloys capable of being hardened by precipitation." This precipitation hardening in combination with cold working of iron-nickel alloys has led to the use of such materials for loading coils which have become known under the name of isoperms. Further it has been established in regard to the iron-nickel-copper alloys that they possess very high values of initial permeability so that they can be used to advantage as magnetically soft alloys.

It has been found that with certain iron-nickel-copper alloys, capable of being precipitation hardened, surprisingly high coercive forces can be obtained, such as are required and adequate for permanent magnet steels. This high coercive force may be obtained in the absence of any great mechanical hardness, which would render shaping impossible. These high values of the coercive force are obtained with the desired mechanical condition of the alloys by slowly cooling the alloys, cast or rolled, from a high temperature, or, in accordance with the known method for alloys capable of being hardened by precipitation, by quenching and tempering for the highest coercive force between 400 and 800 degrees C. According to examinations so far, the highest values are obtained in the partial range as limited in the ternary diagram, approximately by the triangle drawn into Fig. 2, with the following compositions as the corner points: 50% Ni/10% Fe/40% Cu/; 20% Ni/5% Fe/75% Cu; 15% Ni/55% Fe/30% Cu. For example, by slowly cooling from 1050° C. to 250–300° C. in the furnace during a total cooling time of 8 hours, with an alloy (1) 20% Fe/40% Ni/40% Cu, a coercive force of 155 oersteds was obtained; (2) 12.5% Fe/35% Ni/52.5% Cu, a coercive force

of 214 oersteds, (3) 10% Fe/30% Ni/60% Cu, a coercive force of 315 oersteds.

As shown, the coercive force exceeds that of the most highly alloyed cobalt magnet steels, and approaches that of the iron-nickel-aluminium alloys, which however, as mentioned above, are not mechanically capable of being wrought. Compared with these steels and alloys, the residual magnetism with equal coercive forces is indeed lower. The coefficient of quality, however, exceeds by far the usual commercial chromium and tungsten magnet steels. The coefficient of quality, for instance, in the above given alloy (1) amounted to 745×10^3. The high coercive force makes new alloys suitable above all for short compact magnets, e. g. in measuring implements. As the alloys may be forged and rolled, they can be used as permanent magnet steels in all manner of shapes. For instance, permanent magnets can be made in lamellated form, so that it is possible to employ permanent magnets instead of electromagnets at such places where this was not possible hitherto on account of eddy currents. This malleability is maintained after obtaining the magnetic hardness, as the precipitation causes only a slight mechanical hardening. Cold working can consequently be used for a further improvement of the magnetic qualities. For example in the alloy (1), as a result of cold rolling the coercive force rose from 155 oersteds to 177 oersteds, and the residual magnetism from 4800 gauss to 5600 gauss. The coefficient of quality increased consequently from 745×10^3 to 992×10^3 and thus exceeded the value of the low alloyed cobalt steels.

The permanent magnet alloys above described, besides having desirable magnetic properties, also have a high corrosion resistance. This advantage enables the alloys to be used without any exterior surface protection in all cases, where they are subjected to a possible corrosive influence. Formerly the normal magnet steels, which owing to their high iron content were easily subject to rust formation, had to be provided with a surface protection, e. g. they had to be tinned or lacquered, in order to prevent corrosion. This is, however, not necessary in the case of the alloys described above, as these contain in general only a small quantity of iron and have to all intents and purposes a Ni-Cu character. These alloys can, therefore, be used to advantage in measuring instruments, which are to be used in tropical countries, and in every kind of liquid measures.

By varying the heat treatment, deviating magnetic properties may also be obtained. The new alloys are, therefore, also employable if a magnetically soft or a practically non-magnetic material is required, or a material, the magnetic properties of which are without importance, but which possesses a high resistance to corrosion.

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

1. A precipitation hardened permanent magnet consisting of 5 to 55% iron, 15 to 50% nickel and 30 to 75% copper.

2. A permanent magnet consisting of iron, nickel and copper, the composition of the alloy being so selected that in the ternary graph it lies substantially within the triangle determined by the three corner points 50% nickel, 10% iron, 40% copper; 20% nickel, 5% iron, 75% copper; and 15% nickel, 55% iron, 30% copper.

3. A precipitation hardened permanent magnet consisting of iron, nickel and copper, the composition of the magnet being so selected that in the ternary graph it lies substantially within the triangle determined by the three corner points of 50% nickel, 10% iron, 40% copper; 20% nickel, 5% iron, 75% copper; and 15% nickel, 55% iron, 30% copper, said magnet having a coercive force of at least 155 oersteds and a residual magnetism of at least 4800 gauss.

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