May 5, 1931. H. F. PORTER 1,803,353

MAGNETIC ALLOY

Filed Jan. 20, 1927

Fig. 7.

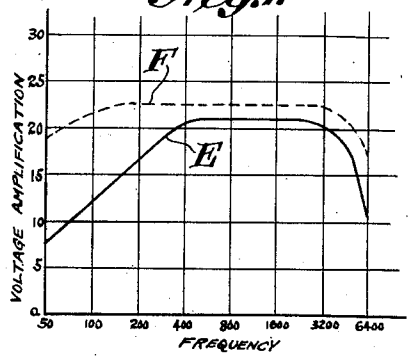


Fig. 3.

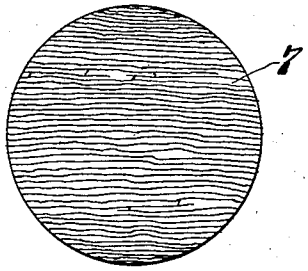


Fig. 4.

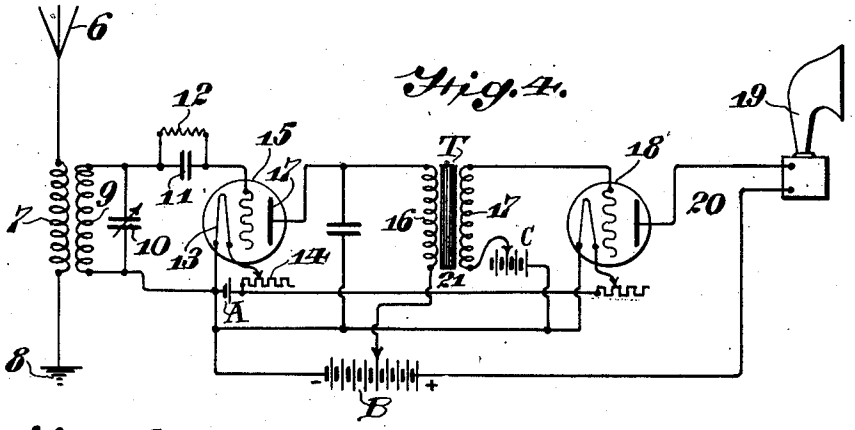


Fig. 6.

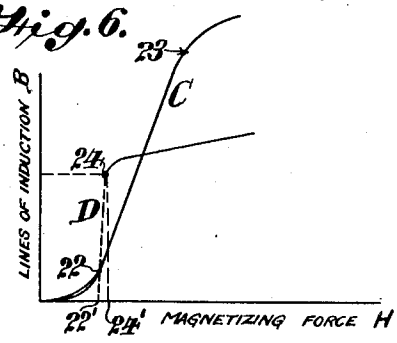


Fig. 1.

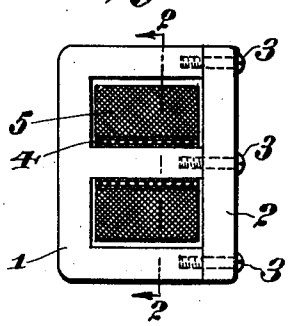


Fig. 2.

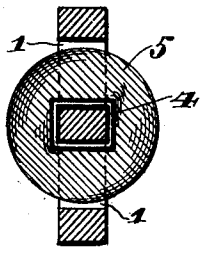
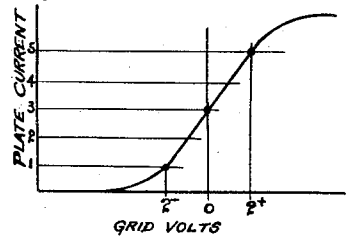


Fig. 5.



INVENTOR.
Harry F. Porter
BY Cornelius D. Ehret
His ATTORNEY.

Patented May 5, 1931 1,803,353

UNITED STATES PATENT OFFICE

HARRY F. PORTER, OF TRENTON, NEW JERSEY

MAGNETIC ALLOY

Application filed January 20, 1927. Serial No. 162,245.

My invention relates to magnetic alloys.

The known magnetic elements and alloys are not suited to meet the widely varying and exacting requirements of different types of electro-magnetic apparatus especially those in which high permeability and low hysteresis losses are desired throughout a range extending from very low induction to fairly high densities and more particularly in those cases in which a high and substantially constant rate of change of permeability is desired when an alternating flux is superimposed on a relatively large biasing magneto-motive force.

For an explanation of my invention, reference is made to the accompanying drawing in which

Fig. 1 is an elevational view, partly in section, of a transformer having a solid core.

Fig. 2 is a sectional view taken on line 2—2 of Fig. 1.

Fig. 3 is a reproduction of a microscopic photograph of the cross-section of a metal strip or lamination made according to my invention.

Fig. 4 is a schematic wiring diagram of a radio receiving circuit.

Figs. 5 to 7 are various characteristics curves involved in the explanation of the invention.

In my researches, I have found that a magnetic alloy may be made of copper, nickel and iron within the limits of

	Per cent
Copper	3–10
Nickel	35–55
Iron	35–55

which in certain fields of application is electrically and magnetically superior to known magnetizable substances and possesses the additional mechanical advantage of being easily worked, as is hereinafter more fully described.

The preferred method of making this ternary alloy consists of placing a quantity of manganese or manganese and magnesium in the bottom of the silica or quartz crucible of an induction furnace and superimposing upon it the proper proportion of copper. In lieu of this arrangement, an alloy (*b*) of copper and manganese, or of copper and magnesium, or of copper, manganese and magnesium, is employed. In any case, the iron and nickel, preferably in the form of sheets alternately arranged, are placed above the copper mixture or (*b*) alloy so that the latter, which melts first, in effect forms a solvent in which the iron and nickel dissolve. The downward movement of these melting metals and the currents induced by the primary winding of the furnace cause a stirring action which results in a uniform mixture of the metals throughout the entire mass.

To obtain the desired magnetic properties of the alloy, the total carbon content should not exceed .1 of 1% by weight of the alloy, and should be preferably below .05%. In making the alloy the nickel should contain but little carbon, less than .005%. Electrolytic nickel may be used. Manganese one-half of 1% insures removal of sulphur from the nickel and also de-oxidizes it. The iron should be of high purity, containing from but .01% to .03% carbon. The copper, which may be of the usual commercial varieties, is of high oxygen content and refines from the iron the small traces of carbon that may be present. By arranging the materials in the furnace as described, the melting and refining operations proceed simultaneously. The alloy should be poured soon after the entire mass has become molten; otherwise gases are formed which produce porous bars or castings.

For the combination of 46½% nickel, 46½% iron and the balance of copper, except for small amounts of manganese, magnesium and traces of the usual impurities, the melting point of the alloy is about 1300° centigrade and the time of melting a charge depends, of course, upon the amount of material, and other variables.

The alloy may be cast in various shapes, by the use of cast iron or sand moulds and thereafter machined. After all of the mechanical operations have been performed, the casting are annealed in a reducing or neutral atmosphere, free from all traces of carbon,

sulphur or oxygen, at temperatures ranging from 900° to 1200° centigrade, the time of holding and temperature being dependent on the thickness of the piece and also the desired magnetic characteristics. The metal before annealing is, to all practical purposes, non-magnetic.

The castings may be annealed in air if the precaution is taken to cover them with some substance such as iron borings, to remove impurities from the furnace gases before they come in contact with the casting. Further, during the cooling down in the open air, a partial vacuum is produced, sucking in air, which, except for the presence of the filter, as of iron borings, would oxidize the castings. As a matter of fact, the results produced by surrounding the casting with iron filings and annealing in air are fully as satisfactory as those produced by annealing in an atmosphere of hydrogen, which is considerably more expensive than the iron filing anneal. The hydrogen anneal is very commonly used for highly sensitive magnetic metals, or alloys having no copper in their composition. In general, the higher the temperature at which the annealing is performed within the range given, the less the time required to attain the desired objective.

The magnetic characteristics of the alloy are such that when a casting of the metal is used as a core or other magnetic element in electro-magnetic devices and the like, as transformers, alternating current relays, its performance compares favorably with a laminated core of the usual known magnetic alloys, as silicon-steel. The simplicity of assembly and construction of such devices resulting from the use of cast members of my alloy is illustrated by Fig. 1 which discloses an audio-frequency transformer, used to couple the successive stages of an audio-frequency amplifier having a core consisting of merely two castings. The middle leg of the E shape casting 1 receives the primary 4 of relatively few turns of wire upon which is wound the secondary 5 of a relatively large number of turns of finer wire. The magnetic circuits are completed by the yoke member 2, also a casting fastened to the main member, as by screws 3, passing through the yoke and threaded into the leg members of the E core.

Instead of casting the metal in molds substantially of the shape and size of the finished product it may be poured in flat slabs similar to the practice employed with non-ferrous metals prior to rolling. The bars or slabs are very malleable, and may be either hot or cold rolled, preferably cold rolled so as to reduce to a minimum the absorption of carbon, oxygen or sulphur during the rolling, inasmuch as any of these impurities are detrimental to the final desired magnetic qualities of the alloy. It is almost impossible to safeguard against this "poisoning" of the metal during the much more involved and expensive hot rolling process which is employed with the known magnetic substances. The cold rolling also effects a change in the internal structure of the alloy such that an examination under the microscope of a cross-section of the cold rolled metal reveals a series of minute, finely separated laminæ as shown in Fig. 3. This undoubtedly is explanatory of the low, eddy current losses of the alloy when cold rolled in the form of strips since each lamination or strip is in itself a plurality of thinner laminations. A similar condition results to a lesser degree if a casting of the material is subjected to a slight rolling consisting of a few passes.

After all mechanical operations have been completed, the strips are annealed as previously described. The tendency of light strips to stick together during the annealing process, if stacked and subjected to temperatures in excess of 925° C. may be minimized by giving the strips a light surface oxidation prior to annealing. When annealed in a reducing atmosphere, the material assumes a high lustre and when air annealed takes on an oxide coating desirable for transformer or other construction in which a core is built of a pile of laminations.

The alloy may also be poured in round ingots, which are readily drawn into a wire which in turn may be drawn down to the finest sizes. After annealing, the wire may be insulated and employed in circuits, as radio frequency circuits, wherein high permeability and low losses at feeble inductions are desirable. If cold drawn, the rod or wire is striated, and is, in effect, a bundle of very fine, substantially parallel wires or rods.

The magnetic properties of the alloy render it particularly useful in electro-magnetic devices involved in the transmission of currents of sound frequency, such as for example audio-transformers and impedances, having a magnetic member or members subjected to an alternating flux whose frequency may vary from 10 to 10,000 cycles per second, superimposed upon a relatively large biasing magneto-motive force.

Referring to Fig. 6, the curves C and D represent the general shape of the permeability curves of an ordinary magnetic alloy, as silicon steel, and of my copper-nickel-iron alloy, respectively. The steepness of the linear part of the curve D, that is, the portion of curve between 22 and 24, which may be mathematically expressed as the first derivative of the permeability or B/H curve or dB/dH is greater than the slope of the corresponding part of the curve C between the points 22 and 23. Therefore, for values of magnetizing forces H between 22′ and 24′ the rate of change of induction in the nickel-iron-copper alloy is much greater than in ordinary mag-

netizable alloy and is substantially a constant. As the curve D from its origin to point *a* is nonlinear and has a low dB/dH, a biasing magneto motive force having a value of H corresponding to 22′ is imposed upon the alloy which then becomes uniformly sensitive to further changes of magnetizing force within the range 22′—24′.

While this characteristic of the alloy makes it peculiarly adapted for use in all electromagnetic devices in which a relatively small alternating flux is imposed on a biasing magneto motive force, further description will be limited, for the purpose of illustration, to its use as the core member of an audio-frequency transformer having its primary in the output or plate circuit of a thermionic valve, particularly of a valve forming a part of a radio receiving set. For the sake of brevity in the description and claims, the term transformer is used in its generic sense and includes transformers whose windings are conductively or inductively coupled.

Referring to Fig. 4, 6 represents an antenna or equivalent absorption structure connected to one terminal of the primary 7 of a radio frequency transformer whose other terminal is connected to the ground or its equivalent 8. Placed in inductive relation to the coil 7 is the secondary 9 tuned by the variable condenser 10 and having its terminals connected to one common connection of the grid condenser 11 and grid leak 12 and to filament 13 of a thermionic valve. The temperature of the filament or cathode is regulated by a variable resistance or rheostat 14 connected in series with the cathode and the battery "A". The control electrode or grid 15 is connected to the other common terminal of the grid leak and grid condenser.

One terminal of the primary 16 of the transformer T is connected to the plate or anode 17 of the thermionic tube and the other terminal is connected to an intermediate positive electrode of the battery "B". The plate or anode circuit is completed by a conductor from the negative electrode of the "B" battery to the filament circuit and by the electronic discharge from the heated cathode to the plate. The terminals of the secondary 17 of the transformer are connected respectively to the grid 18 of a second thermionic valve and to the negative terminal of a variable, biasing or "C" battery. If an auto-transformer is used, a blocking condenser and a grid-leak will be employed in the control circuit of the second valve as is well understood. The anode circuit of the second valve or tube includes a sound reproducing device 19 as a loud-speaker connected to the plate 20 and to the positive terminal of the "B" battery.

Referring to Fig. 5, it will be seen that when the grid is at zero potential, there is a current of 3 milliamperes flowing in the plate circuit which subjects the core 21 of the transformer T to a definite magneto motive force. From −2 to plus 2 volts, the linearity of the curve is pronounced and is such that the change of plate current is substantially proportional to the grid volts applied. For detection or rectification, the valve would operate on the linear portion of the curve which it should be understood is not necessarily an actual curve but only representative for the purposes of explanation.

Knowing the current, by measurement, values through which the plate current passes due to measured variations of potential of the grid, it is necessary to employ a number of turns for the primary 16 of the transformer such that only the linear portion of the permeability curve of the core is utilized, for example, from 22 to 23 of curve C if of silicon steel or from 22 to 24 of curve D if of my copper-nickel-iron alloy.

Having so designed the transformer that the core is always magnetized within the range of linearity, the material having the steepest permeability curve, that is, the greatest "rate of change of induction", or mathematically expressed, the largest dB/dH, is desirable as will appear.

Delivery of energy from the thermionic valve to the transformer is efficient and effective for frequencies for which the primary impedance of the transformer is greater, at least 300%, than the impedance of the tube, a property determined by its construction. The primary impedance of the transformer may be expressed by the formula

$$Z=2\pi fL$$

Z=primary impedance
f=frequency of alternating component in cycles per second
L=inductance of primary to alternating component in cycles per second

As the inductance L is determined by the change of number of lines of magnetic induction for a unit change of current in the winding and the rate at which the lines of induction increase or decrease simultaneously with current changes depends upon the dB/dH of the medium in which they are produced, that is, the transformer laminations in this instance, it appears that for a given number of turns, the primary impedance is directly proportional to the dB/dH characteristic of the core material for a given frequency, and the higher the dB/dH characteristic, the lower is the frequency for which the primary impedance exceeds by a proper percentage the tube impedance. Therefore any improvement in the dB/dH coefficient of the magnetizable material of the transformer is manifested by a greater over-all amplification and a general improvement in tone quality or timbre because of the relatively greater amplification of low frequency tones which are weakest when amplified by a transformer of ordinary construction and proportions.

By using my ternary alloy, a very high primary inductive reactance impedance can be

obtained with a relatively small number of primary turns so that it is possible to have an efficient, high impedance transformer without an excessively large number of secondary turns. It is noted that when high ratio transformers having a core of ordinary transformer iron, a primary of proper impedance, and a secondary of a large number of turns, are used, the higher frequencies are slighted due to the by-passing effect of the large distributed capacity of the secondary winding. If the number of secondary turns is reduced to avoid this effect, the amplification of the entire range is proportionately decreased. The amplification curve E of a transformer using ordinary transformer iron falls off rather rapidly at each end. If the transformer is of the high impedance type and of generous proportions to secure better amplification at the lower frequencies, the curve drops off more sharply at the high frequencies, as explained, and vice versa. In other words, the curve E may be shifted somewhat along the horizontal axis but its shape remains substantially the same so that its tone range is not increased but merely displaced along the frequency scale. When a core of my copper-nickel-iron alloy is employed, the amplification curve F of the transformer is not only generally higher but is also lifted at both ends as compared to curve E so that the effective tone range of the transformer is greatly increased, an important factor when the faithful reproduction of tones is desired.

Other and varied uses of the alloy are suggested by its characteristics. As it is highly permeable and productive of but low losses at very low induction, it is adapted for use in current transformers, for measuring instruments as ammeters, wattmeters and watt hour meters, and as pole tips, armatures or other parts of devices as loud-speakers. Its high permeability at fairly high densities makes its use desirable in potential transformers for use with volt-meters, wattmeters, watt hour meters, and the like. In ignition apparatus, in auto-horns, or in vibrators generally, the low retentivity of the alloy recommends its use. It may be used as the magnetic vane of alternating current devices as indicating instruments, where low hysteresis losses are desirable.

What I claim as my invention is:

1. A magnetic alloy comprising copper 3% to 10%, nickel 35% to 55% and iron 35% to 55%.

2. A magnetizable lamination having low eddy current losses comprising a cold rolled strip of alloy of copper, iron and nickel.

3. An electro-magnetic device comprising coil structure, and core structure therefor of a magnetic alloy comprising copper 3% to 10%, nickel 35% to 55% and iron 35% to 55%.

4. An electro-magnetic device comprising coil structure traversed by current having alternating and direct current components, and core structure therefor of a magnectic alloy comprising copper 3% to 10%, nickel 35% to 55% and iron 35% to 55%, and of solid cross-section.

5. A transformer having a secondary winding and a primary winding traversed by current whose direct current component is large relative to the alternating current component, and core structure therefor of a magnetic alloy comprising copper 3% to 10%, nickel 35% to 55% and iron 35% to 55%.

6. A transformer having a secondary winding and a primary winding traversed by current whose direct current component is large relative to the alternating current component, and core structure therefor of solid cross-section and of a magnetic alloy comprising copper 3% to 10%, nickel 35% to 55% and iron 35% to 55%.

7. A magnetic alloy comprising commercial copper 3% to 10%, nickel 35% to 55% and iron 35% to 55% containing carbon less than .03%.

8. An electro-magnetic device comprising a winding traversed by current having alternating and direct current components of which the direct current component is large relative to the alternating current component, and core structure of high initial permeability, unsaturated by said direct current component, composed of a magnetic alloy comprising copper 3% to 10%, nickel 35% to 55%, and iron 35% to 55%.

9. A transformer having a winding traversed by current having alternating and direct current components of which the direct current component is large relative to the alternating current component, and core structure therefor having high initial permeability, unsaturated by said relatively large direct current component, composed of an alloy comprising copper 3% to 10%, nickel 35% to 55%, and iron 35% to 55%.

10. An audio-frequency transformer having a primary winding traversed by a current having a sound-representing component and a direct current component relatively large with respect to said sound-representing current, and core structure therefor, unsaturated by said relatively large direct current component, composed of an alloy comprising copper 3% to 10%, nickel 35% to 55%, and iron 35% to 55%.

HARRY F. PORTER.