June 4, 1929. G. W. ELMEN 1,715,542

ELECTRICAL COILS AND SYSTEM EMPLOYING SUCH COILS

Filed Sept. 19, 1927

FIG. 1.

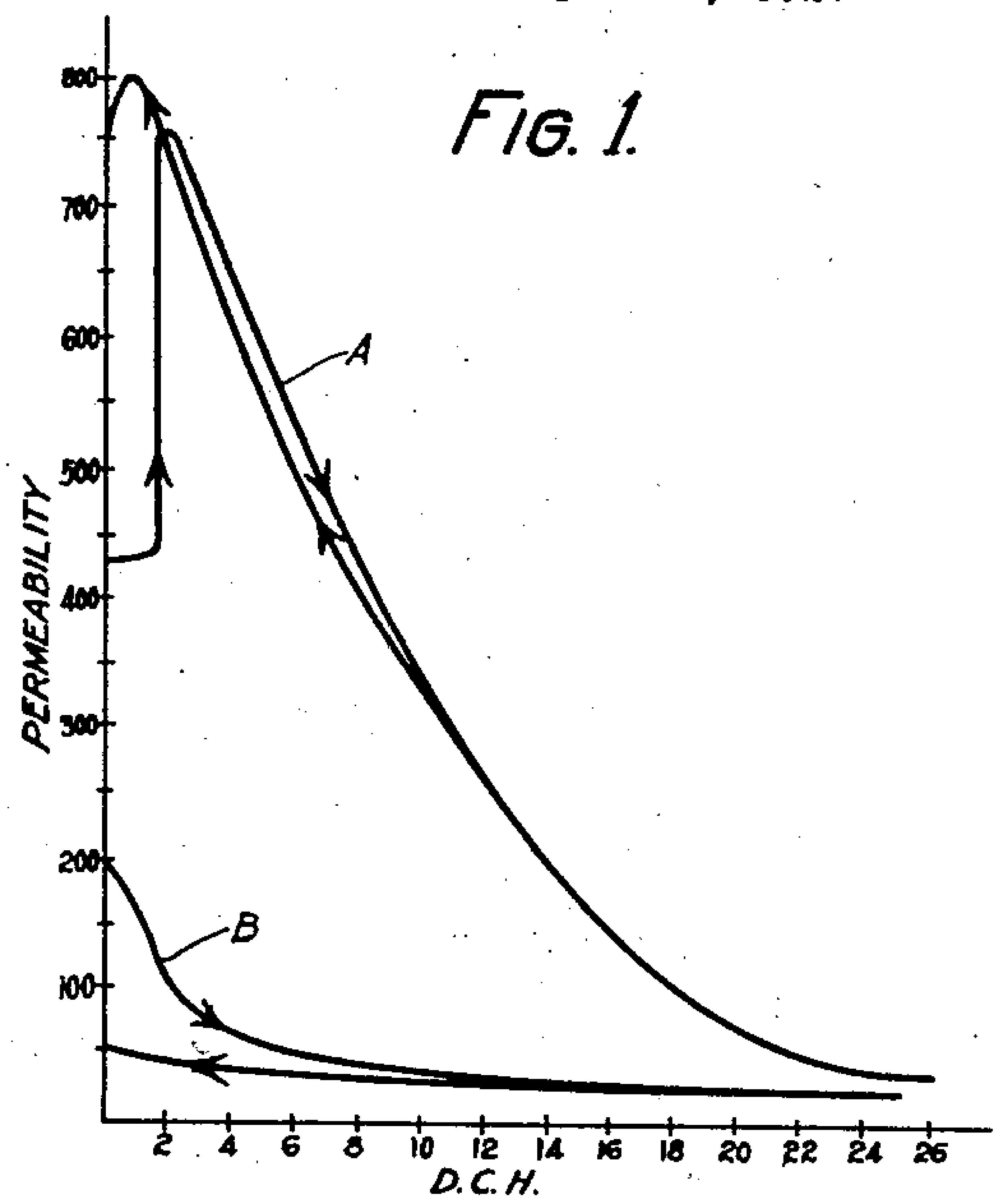


FIG. 2.

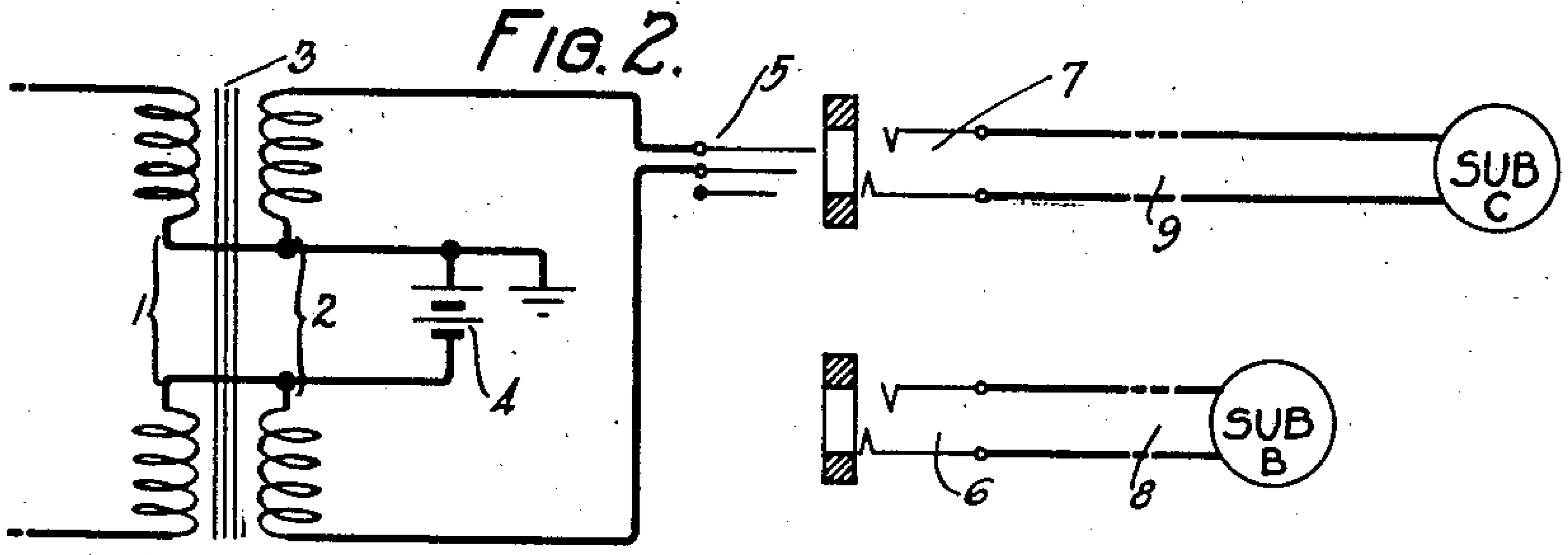
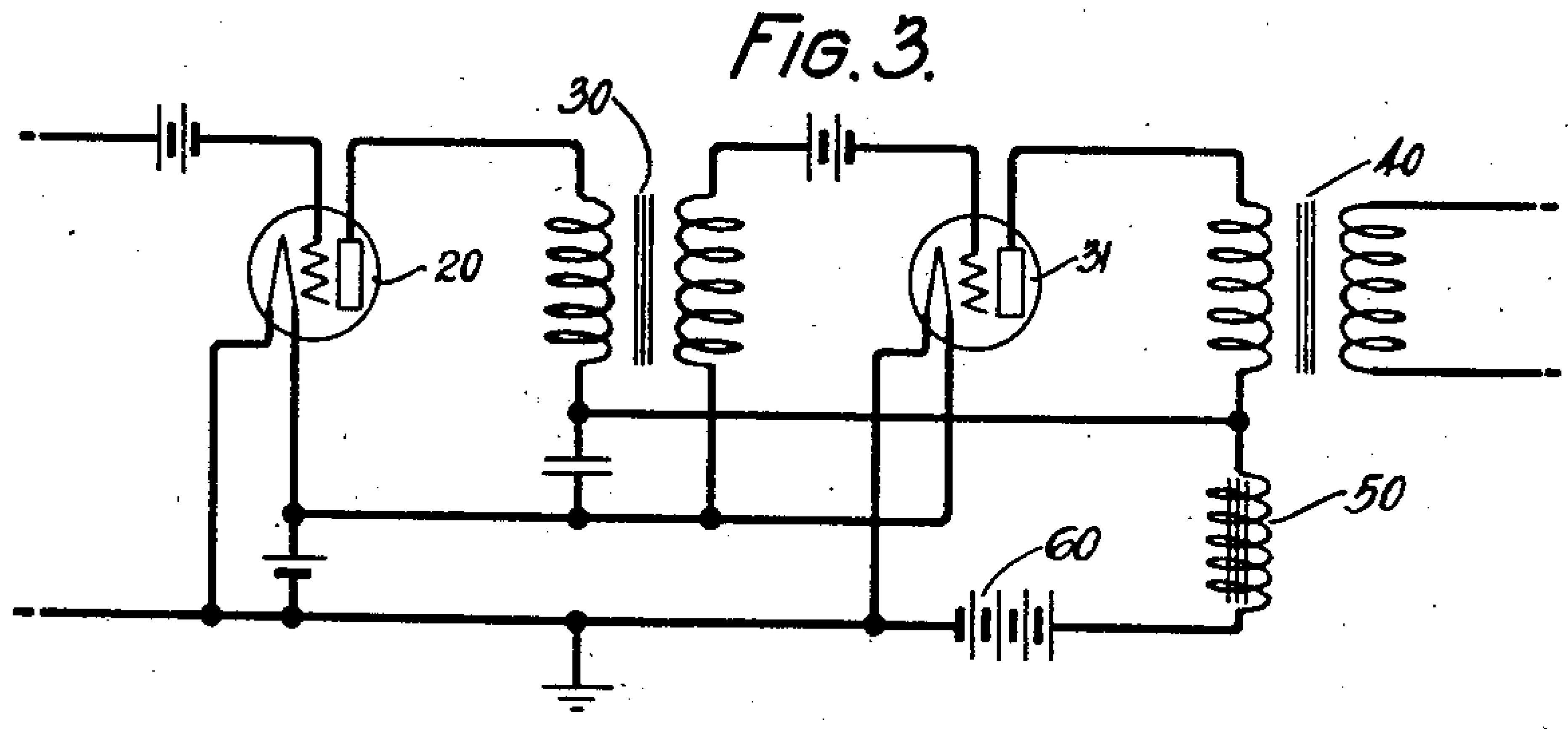


FIG. 3.



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UNITED STATES PATENT OFFICE.

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ELECTRICAL COILS AND SYSTEM EMPLOYING SUCH COILS.

Application filed September 19, 1927. Serial No. 220,388.

The present invention relates to improvements in inductance coils, especially current supply and audio frequency transformers and to systems employing such transformers.

An object of the invention is to stabilize the inductance of magnetic coils such as current supply transformers, retardation coils, and radio transformers used in speech amplifiers.

Another object is to provide that coils such as telephone repeating coils and radio transformers will not become reduced in efficiency by the magnetic saturation of the core, but will on the contrary be made more effective by such saturation.

A further object is to improve telephone transmission by compensating for the difference in attenuation of long and short lines so that subscribers connected to the central exchange by means of a long line will receive a volume of speech more nearly approximating the volume received by a subscriber connected with the same central exchange by means of a short line.

The above objects are carried into effect by employing coils, or in the specific case, current transformers having cores of alloys which have their incremental permeability to low magnetizing forces increased when subjected to a large unidirectional magnetizing force and after its application to and removal from the core. This is in contra-distinction to prior coils in which the incremental permeability of the core is decreased by the application to and removal from the core of a large magnetizing force.

The term "incremental permeability" is used in this specification as defining the ratio of the induction increment to the magnetic force increment for any position on a magnetization curve, where these increments may be of any magnitude, but the magnetic force increment must be in the reverse direction from the immediately preceding change. See "Properties and testing of magnetic materials" by T. Spooner, 1927, page 11.

Among the alloys serving the above mentioned purposes we may mention one consisting of approximately 45% nickel, 25% cobalt and 30% iron with a small amount of manganese added to improve the forgeability.

When properly heat treated such a magnetic composition may have, by way of example, an initial permeability of 430 which remains constant up to H=1.4. When magnetized from H=1.4 to H=1.9 the incremental permeability increases to about 700. As the magnetizing force is increased the incremental permeability gradually decreases to 80 at H=26. Upon decreasing the magnetizing force the incremental permeability gradually increases to about 700 at H=1.9. Instead of decreasing further, the permeability actually increases to a higher value, i. e. about 800, and then falls slightly as the magnetizing current is reduced to zero, so that the initial permeability is about 750. The important point is that the application and removal of a large uni-directional magnetizing force increases the incremental and initial permeabilities of the material instead of decreasing it, as in the case with well known and commonly used materials such as Armco iron.

The present application is in part a continuation of application Serial No. 119,622, filed June 30, 1926.

It has been found that a large class of alloys of cobalt, nickel and iron, with or without other ingredients, exhibit the property of increased permeability at small magnetizations circuiting or to any other cause of large uni-directional magnetizing force. The invention comprises broadly the application of any magnetic material exhibiting this property to such purposes as cores of current supply transformers, audio frequency transformers, retardation coils, or any coil or transformer which might become subjected to short-circuiting or to any other cause of large currents.

In applicant's copending applications, Serial No. 119,622, filed June 30, 1926, and Serial No. 220,387, filed September 19, 1927, there are disclosed and claimed various magnetic compositions containing nickel, cobalt, and iron with or without a fourth element such as molybdenum or chromium for increasing the resistivity and lessening the eddy current losses. A particular composition containing such a fourth element is one comprising approximately 50% Ni, 25% Co, 21½% Fe and 3½% Mo. This composition exhibits satisfactory properties. Compositions characterized by an incremental permeability variation such as that of the particular compositions mentioned therein may be employed with great advantage as cores for inductance and other coils in accordance with the present invention. In general magnetic compositions containing cobalt between 5 and 80%, nickel between 20 and 81%, and iron between 9 and

50%, with or without the addition of up to about 8% of a fourth element to increase the resistivity, exhibit to some extent properties suitable for the purposes herein described. The best compositions are those having a content of the several elements somewhat within the extremes of the ranges cited. The compositions of nickel content from about 40 to 75% exhibit, in general, the higher values of initial and maximum permeability.

For telephone work it is desirable that the increased initial and incremental permeability be stable. Experiments indicate that the alloys of the present invention possess these properties. This is a factor enhancing the utility of alloys of the type just described in current supply coils for telephone systems.

Typical examples of modes of practicing the invention and apparatus employed in connection therewith will be described in greater detail in connection with the accompanying drawings, in which;

Fig. 1 represents the variation of permeability with increasing direct current magnetizing forces of a sample material of the present invention, as compared with Armco iron, a small alternating current being superimposed in each case;

Fig. 2 depicts a portion of the apparatus at a telephone central office, namely, a current supply coil in a connecting cord circuit having a core made of a magnetic material in accordance with the invention, in conjunction with telephone lines of different lengths; and

Fig. 3 shows a portion of an audio frequency transformer including cores of the material described herein.

Curve A of Fig. 1 depicts the permeability variation of an alloy containing approximately 45% Ni, 30% Fe, 23% Co and .5% Mn when an alternating magnetizing force of .00207 gauss is impressed upon a variable uni-directional magnetizing force. The initial permeability was about 430. As the uni-directional magnetizing force was increased from 0 to 1.7 the permeability remained substantially constant, but at a magnetizing force between 1.7 and 1.9, the permeability increased suddenly to over 700, and with further increase of the magnetizing force diminished steadily until at about 26 gauss the permeability was about 40. Removal of the uni-directional magnetizing force, however, caused the permeability variation graph to almost coincide, in part, with the curve traced during the application of the magnetizing force, but at H=1.9 magnetizing force the permeability did not begin to fall off rapidly but actually increased and reached a value of 750 at 0 magnetizing force.

Curve B represents the variations of permeability with increasing direct current magnetizing forces for Armco iron when an alternating current of .00532 amperes is superimposed upon the circuit. The initial permeability of this material is seen to be about 200. As the uni-directional magnetizing force increases, the permeability diminishes rapidly for the first 3 gauss, and then less rapidly as the magnetizing forces are further increased. The removal of the magnetizing force does not tend to restore the permeability to its primary state, but on the contrary, at zero magnetizing force the permeability is only about 50.

We shall now consider Fig. 2 in conjunction with the permeability variations discussed in Fig. 1. In Fig. 2 we have an arrangement comprising current supply repeating coil A having primary winding 1, secondary winding 2 and core 3, and battery 4. By means of plug 5 and jacks 6 and 7 the current supply coil may be connected either to line 8 or line 9. Line 8 is assumed to have a length of 5 miles and line 9 a length of 20 miles. B indicates a subscriber's station at the end of line 8 and C a subscriber's station at the end of line 9. When the shorter line 8 is being used for telephone service a direct current traverses the circuit constituted by the battery 4, the current supply coil A and line 8. Assume that the parts are so proportioned that this direct current establishes a direct current field of 24 c. g. s. units, superimposed upon the alternating current which is set up by the fluctuating signaling current, and which in Fig. 2 is assumed to have a value of .00207 c. g. s. units. In this case inspection of Fig. 2 shows that the permeability of the current supply coil is about 50. Assume now that line 9 is connected for telephone service to current supply coil A. Since the length of this line is 20 miles, it offers a considerable resistance to the flow of the direct current supplied by battery 4. The intensity of this direct current, therefore, will be decidedly lower, as will also be that of the magnetic field set up in the core 3 by this current. Suppose that the magnetizing force produced by the direct current is 4 gauss. Inspection of Fig. 2 shows that the permeability of the material for the magnetizing force due to the voice currents is approximately 600 in this case. The cases which we have assumed are quite in accordance with practical conditions.

With installations of this type used at the present time the maximum direct current which will pass through the windings of the battery supply coil will produce a direct current magnetizing force of about 26 gauss. A material which is in common use in these cores is Armco iron. After the application of a magnetizing force of 26 gauss the permeability of the Armco iron is reduced from an initial value of about 200 in the virgin material to about 50 after the field has been applied and removed. This is a rather low permeability for the functions which these cores have to perform. By comparison with the incremental permeability of 600 of the alloy herein described the advantage of their use as current supply coil cores will be easily appreciated.

Fig. 3 shows, as a further example of practicing the present invention, a portion of an audio-frequency amplifier. Detector 20 is designed for detecting received radio signaling waves, transforming them into electrical waves of audible frequency and applying them to the input connections of transformer 30. Transformer 30 steps up the voltage of the signal waves and impresses it upon vacuum tube amplifier 31, which in turn, after further amplification, impresses the waves upon the input circuit of transformer 40. A choke coil 50 is inserted into the circuit between the primary windings, transformers 30 and 40 and battery 60. The cores of transformers 30 and 40 and coil 50 are composed of material in accordance with the present invention. Assume now that for any reason, such as a temporary short circuit, the direct current passing through the windings of transformers 30 and 40, or coil 50, or both, is considerably increased. This large current will set up a correspondingly high unidirectional field in the core material of the transformers 30 and 40 and of the choke coil 50. If the core material is Armco iron or a similar composition, the permeability after the cessation of the excessive current will be decreased from a value around 200 to a value around 50. If, however, material in acocrdance with this invention is employed for forming the cores of the coils, in addition to the advantage of considerably higher permeability to start with (around 450 or more), the large current actually raises the permeability of the material after the removal of the current.

In order to produce the magnetic properties desirable and useful for the application of the materials of the present invention for the purposes intended the material must be properly heat-treated after all the mechanical work incident to its manufacture has been completed. The magnetic properties of any particular composition of the alloy are largely dependent upon this heat treatment and especially upon the rate of cooling. For the composition containing approximately 45% Ni, 25% Co and 30% Fe, a treatment which was conducive of good results consisted in heating material to about 1100° C. for approximately one hour and then cooling it slowly during several hours from that annealing temperature to room temperature. A treatment comprising reheating the slowly cooled material to about 600° C. and then cooling it fairly rapidly has produced results still better than those illustrated by Fig. 1. The incremental permeability rose from an initial value of about 800 in the virgin material to about 1400 after the application of a uni-directional magnetizing force of 25 gauss when such a double heat treatment was employed. More general rules concerning heat treatments and descriptions of other specific alloys suitable for present purposes are disclosed in the applications mentioned above.

Satisfactory results were obtained for a composition containing approximately 50% Ni, 25% Co, 21½% Fe and 3½% Mo by pot-annealing the alloy at about 1100° C. for about one hour and then cooling it slowly in the furnace down to room temperature.

What is claimed is:

1. A coil having a core characterized by incremental permeability at low magnetizing forces greater after being subjected to a large direct magnetizing force than prior thereto.

2. A transformer having a core of incremental permeability higher at small or moderate magnetizing forces after being subjected to a large D. C. magnetizing force than before the application of said direct magnetizing force.

3. A current supply transformer comprising a core composed of magnetic material comprising cobalt between 5% and 80%, nickel between 20% and 81% and iron between 9% and 50%.

4. A coil in accordance with claim 3 with an additional element to increase the resistivity between a small value and about 8%.

5. A coil having a core of nickel between 40% and 75%, cobalt between 15% and 50%, iron between 15% and 40%.

6. A coil having a core composed of magnetic material comprising as essential elements approximately 45% nickel, 25% cobalt and 30% iron.

7. A current supply repeating coil comprising a primary winding, a secondary winding and a core, said core being characterized by incremental permeability for voice currents greater when subjected to a large direct magnetizing force than when subjected to a smaller direct magnetizing force.

In witness whereof, I hereunto subscribe my name this 17th day of September, A. D., 1927.

GUSTAF W. ELMEN.