Feb. 7, 1933. O. E. BUCKLEY 1,896,767

SIGNALING SYSTEM

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FIG. 1

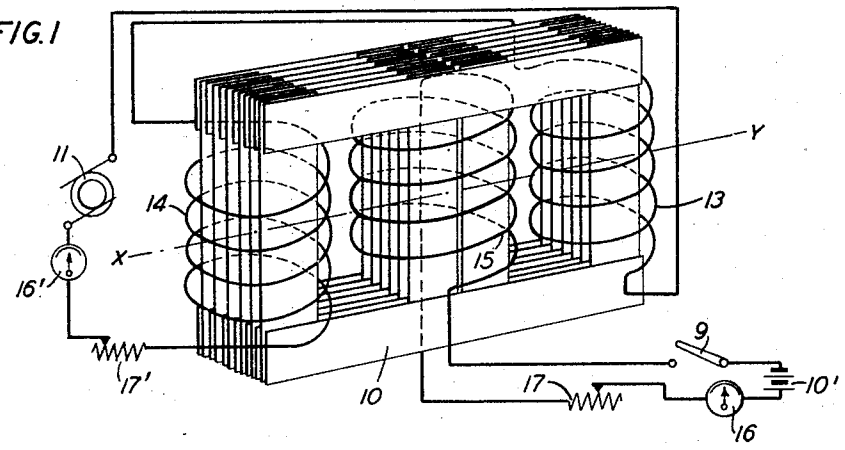

FIG. 2

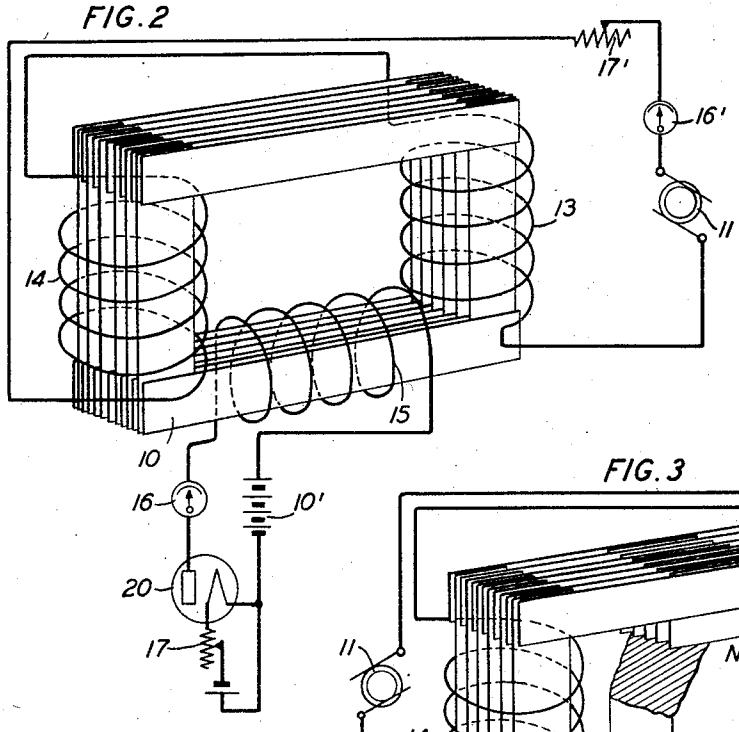

FIG. 3

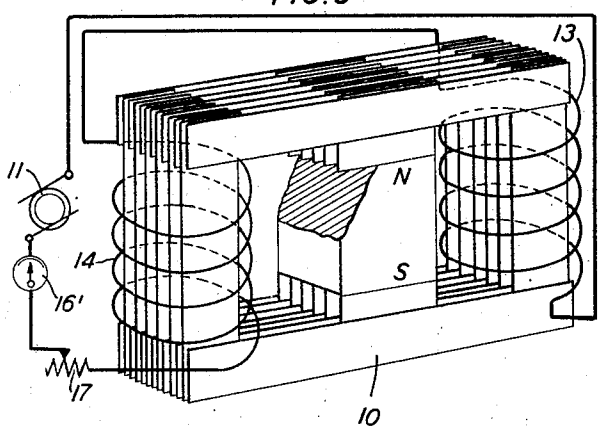

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FIG. 4

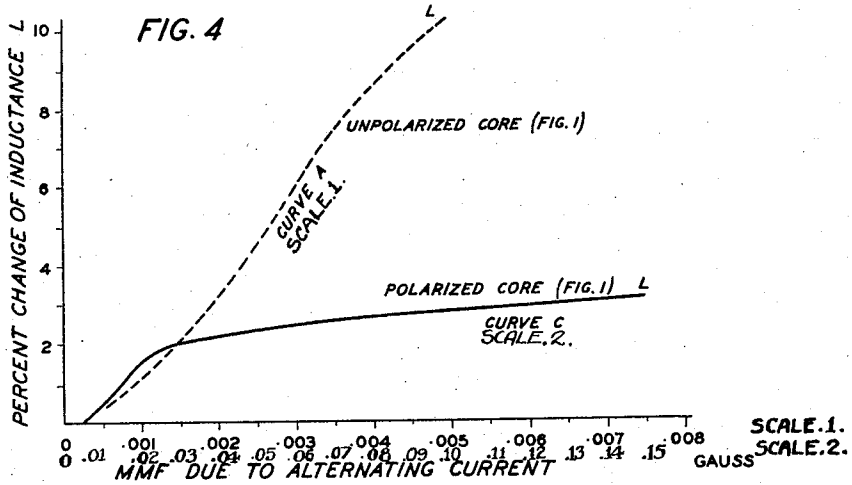


FIG. 4A

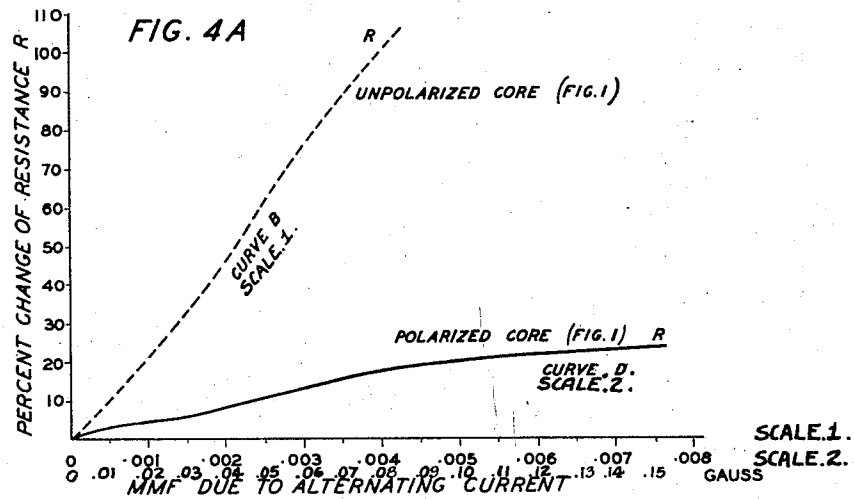
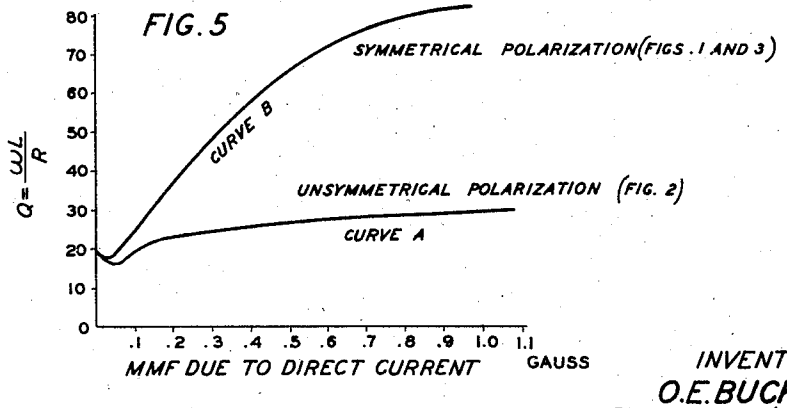


FIG. 5



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UNITED STATES PATENT OFFICE

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SIGNALING SYSTEM

Application filed June 29, 1931. Serial No. 547,689.

This invention relates to signaling systems and particularly to inductance and other coils employed in such systems.

An object of the invention is to reduce hysteretic losses in magnetic materials forming the cores of inductance and similar coils.

Another object of the invention is to reduce resistance losses in coils comprising cores of magnetic materials.

A further object of the invention is to so condition magnetic materials that they may be subjected to alternating and direct current fields encountered in signaling without suffering serious impairments of their efficiency.

A more specific object of the invention is to secure constancy in the inductance presented to alternating current by magnetic cores employed in signaling.

It has been found that there exists a need in signaling systems, particularly in telephone systems, for coils whose inductance and resistance do not vary with current amplitude. This applies particularly to carrier current loading coils and filter coils where the variations introduced by the non-linear magnetic characteristics of the core material introduce cross-talk and modulation difficulties between the different signaling channels. At present air core coils are used, since no known magnetic material has sufficiently constant permeability to prevent modulation effects.

A means which has frequently been proposed in the past to secure constancy of inductance for alternating current is to magnetize the core material with a steady magnetizing force much larger than and superposed on the alternating magnetizing force. The magnetic material is thus partly saturated with the result that the permeability over a small range of alternating magnetizing force is reduced and made more nearly constant, while at the same time the hysteresis loss is reduced.

In accordance with the principles of this invention, the objects stated above are attained by subjecting the magnetic material, when in use in a signaling system, and when it is consequently under the effect of an alternating or fluctuating magnetic field, to an additional unidirectional field. This unidirectional or steady magnetization may be accomplished, either by a direct current flowing through an additional winding provided on the core of magnetic material, or by a permanent magnet suitably disposed in proximity to the core. Furthermore, the steady magnetization may be applied, either symmetrically with respect to an axis intersecting the alternating current windings or dissymmetrically with respect to said axis. If use is made of a dissymmetrical magnetization, it is preferable to prevent the flow of alternating current in the direct current circuit because such current flow would cause: (1) alternating current losses in the direct current circuit; (2) variations of magnetic permeability and of inductance, which in accordance with the objects of this invention are to be reduced. It has been found that the insertion of a suitable device such as a two-electrode vacuum tube working at "filament saturation" into the direct current circuit creates an impedance sufficiently high to prevent the flow of appreciable alternating current therein and consequently the provision of such a device is an important feature of this invention.

Among the magnetic materials which have been found to be particularly suitable for the purposes of the present invention, compositions containing from about 30% to 78½% nickel and the balance iron are particularly adapted. These materials have a much lower hysteresis loss in relation to their permeability when nearly saturated than does iron or other relatively hard magnetic materials. They possess the further advantage of requiring only a very small magnetizing force to magnetize them nearly to saturation. Consequently, the steady magnetization may be accomplished by a permanent magnet suitably disposed. As a material for the permanent magnet, cobalt steel has been found to be suitable.

Specific embodiments of the present invention will now be described and a comparison will be made between four types of cores, to wit, unpolarized and polarized cores on the one hand; and symmetrically polarized

and dissymmetrically polarized cores on the other hand, with reference to the accompanying drawings, in which

Fig. 1 serves to illustrate both the unpolarized type and the symmetrically polarized type of core;

Fig. 2 shows a type of a dissymmetrically polarized core;

Fig. 3 shows a different embodiment of a symmetrically polarized core in which a magnet made of permanent magnet steel is used for supplying the steady symmetrical magnetization; and

Figs. 4, 4—A and 5 represent various curves to which reference will be made during the discussion below of the principles of operation of this invention.

Referring more particularly to Fig. 1, a transformer core 10 having the form shown and comprising about 70 laminations .006 inch (.152 millimeter) thickness in the outer members and 140 laminations in the inner member of a magnetic material containing about 78½% nickel, 1.7% chromium and the balance iron is provided with alternating current windings 13 and 14, respectively, and with a direct current winding 15 which latter is arranged symmetrically with respect to an axis x—y. A steady magnetizing current may be supplied to the coil 15 by the battery 10′. A source of alternating current 11 supplies alternating current of about 100 cycles per second to the windings 13 and 14. Measuring devices 16 and 16′ are provided for measuring the direct and alternating current magnetizing forces, respectively. Variable resistances 17 and 17′ serve for the purpose of varying the direct and alternating magnetizing forces, respectively. Windings 13 and 14 are connected in series and wound in the same direction. In this manner no alternating magneto-motive force is produced in the center limb of the magnet core since any flux caused by one of the windings and tending to flow through the center limb is opposed and neutralized by an opposing flux of the same magnitude caused by the other winding.

An unpolarized core structure is constituted by an arrangement such as the one shown in Fig. 1 in which the switch 9 in the direct current circuit is left open. By suitably adjusting and varying the resistance 17′, the core 10 of Fig. 1 was subjected to an alternating magnetizing force which was varied from .0003 gauss to .005 gauss, while the direct current circuit was open. The variations of the inductance L and of the resistance R of the alternating current circuit are graphically represented as functions of the varying magneto-motive force due to the variation of the alternating current in curves A and B of Figs. 4 and 4—A, respectively. For the small range of alternating current magnetization mentioned (.0003 to .005 gauss) the inductance L increased 11% and the resistance increased 135%. As a standard of comparison of the efficiency as inductance stabilizers of the various coil structures under different conditions of operation, the expression

$$\frac{\omega L}{R}=Q$$

will be used herein. In this expression ω equals $2\pi f$, where f is the frequency of the alternating current; L is the inductance and R is the resistance of the alternating current circuit. For high values of constancy of inductance the factor Q should also be high, and the higher Q the better the efficiency of the core as an inductance stabilizer. When the direct current circuit was open, the mathematical expression

$$Q=\frac{\omega L}{R}$$

varied between 24.9 and 9.9, when the magnetizing force was varied from .0003 to .005 gauss and the magnetic permeability of the material varied from 5930 to 6550.

The core was then treated by closing the direct current circuit and applying a direct magnetizing force of one gauss upon its center member; simultaneously, the alternating magnetizing force was varied for the considerable range of from .0004 to .15 gauss. As is shown by curves C and D of Figs. 4 and 4—A, for this large change of magnetization L and R increased only 2 and 5%, respectively. Similarly, if calculated and expressed in values of Q, this decreased from 74.5 but was stabilized at the considerable value of 31, as compared to the change from 24.9 to 9.9 in the previous case. The magnetic permeability varied from 840 to 865 over this range.

In order to determine the relative merits of symmetrically and dissymmetrically magnetized cores, investigations were carried out which will be described with particular reference to Fig. 2 in which those reference numerals which are identical with those of Fig. 1 indicate parts similar to those of Fig. 1. In this embodiment of the invention, however, in order to avoid alternating current losses in the direct current circuit and variations of inductance in the alternating current circuit, there is provided an element of high impedance, to wit, in the particular embodiment shown, a two-electrode tungsten filament vacuum tube 20 which is preferably adjusted to operate in a condition of voltage saturation, i. e., a condition such that the whole of the electron emission from the filament is utilized as the plate current, and consequently an increase of the plate voltage will no longer increase the number of electrons emitted per unit of time. In a practical embodiment of the dissymmetrically polarized core of this modification, the direct current magnetizing force was varied from zero

to about one gauss while the alternating current magnetization was kept at a constant value of about 0.005 gauss. For these increasing values of direct magnetization, Q increased from 20.1 to 29.8 only; see curve A of Fig. 5 and the permeability of the core material varied from 7020 to 788 when the direct current magnetizing force was varied from 0 to 1 gauss.

Next, the direct current magnetizing force of the symmetrically polarized core of Fig. 1 was varied between the same limits as in the case of the dissymmetrically polarized core, i. e., between 0 and about 1 gauss and the alternating magnetization was kept at the same constant value as in the previous test. The variation of Q is shown in curve B, Fig. 5. It is seen that Q increased from 20 to 82 as compared with an increase from 20.1 to 29.8 for curve A; this corresponds to a decrease in the magnetic permeability of from 7050 to 788 with increasing direct current magnetization.

In the embodiment of the invention represented by Fig. 3, a permanent steel bar magnet made of steel having a high coercivity was used to symmetrically polarize a core of magnetic material of the same composition as that mentioned above. The permanent magnet was placed in the center limb of the core in a manner to polarize the core in the same manner and direction as the direct current winding of Fig. 1. It produced a direct magnetizing force of .18 gauss. When the alternating current magnetizing force was changed from .0002 gauss to .0034 gauss, L increased 1.28% and R increased 24%. Q decreased from 41.7 but was stabilized at the rather high value of 28 for this range of magnetizing force. The permeability increased from 3220 to 3260 when the magnetizing force was changed from .0002 gauss to .0034 gauss.

It was thus ascertained that the magnetic stability during operation of inductance and other coils may be improved by the application of a polarizing field thereto, and that a higher value of magnetic stability may be obtained if the polarizing field is applied symmetrically with respect to an axis passing through the operating winding or windings and the center of gravity of the core.

While the methods of the present invention have been applied successfully in particular to signaling systems including cores of magnetic material containing about 78½% nickel, 1.7% chromium and the balance iron, the invention is not limited to the use of this particular material but magnetic materials of other compositions may also be benefited by this treatment.

What is claimed is:

1. A signaling system comprising a coil substantially free of modulation characteristics having a core of magnetic material, windings on said core carrying alternating or pulsating current for operating said system, said magnetic material possessing high permeability at low magnetizing forces, means for causing the impedance of said coil to said current to remain substantially constant, said means comprising instrumentalities for subjecting at least a portion of said core to a unidirectional magnetic field, said instrumentalities being independent of the winding carrying the alternating current.

2. System as defined in claim 1, characterized in this that the impedance stabilizing means comprises instrumentalities for applying a magnetic polarizing field which is symmetrical with respect to an axis passing through said winding carrying the alternating current and through the center of gravity of said core.

3. System as defined in claim 1, characterized in this that the impedance stabilizing means are located dissymmetrically with respect to an axis intersecting the winding and the center of gravity of the core.

4. System as defined in claim 1, characterized in this that the impedance stabilizing means comprises a permanent magnet suitably arranged to magnetize said core.

5. System as defined in claim 1, characterized in this that the impedance stabilizing means comprises a separate winding upon the core of magnetic material in addition to that carrying the alternating current, said winding being connected in series with a source of direct current and with an element having a high impedance, whereby the flow of alternating current in said direct current winding is minimized.

6. In a signaling system comprising a coil having a core of magnetic material and a winding traversed by the signaling currents, a circuit including a source of current for applying a unidirectional magnetizing field to said core, said circuit including a two-electrode space discharge device having a high impedance, whereby the signaling currents are prevented from flowing in the direct current circuit.

7. A driving source of alternating electromotive force, a load receiving current from said source and at the same frequencies, a regulating device connected between said source and said load, said device having a stabilized impedance to flow of said current, said regulating device comprising a winding associated with a core and means for steadily magnetizing the core to a nearly saturated condition such that the magnetic characteristic of said core is linear with respect to the variations in m. m. f. impressed in consequence of passage through said winding of said load current.

In witness whereof, I hereunto subscribe my name this 26th day of June 1931.

OLIVER E. BUCKLEY.