March 6, 1951 F. H. GUSDORF ET AL 2,544,152

HIGH-FREQUENCY COIL SYSTEM

Filed April 12, 1946

Fig. 1.

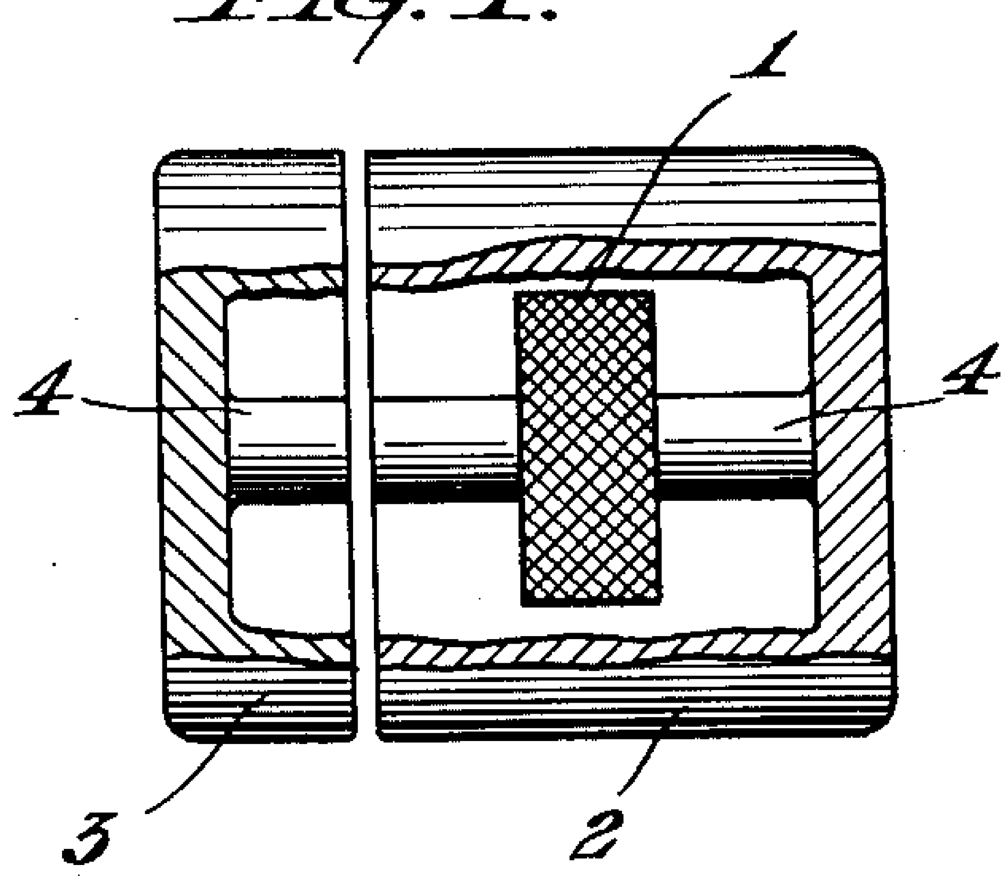


Fig. 2.

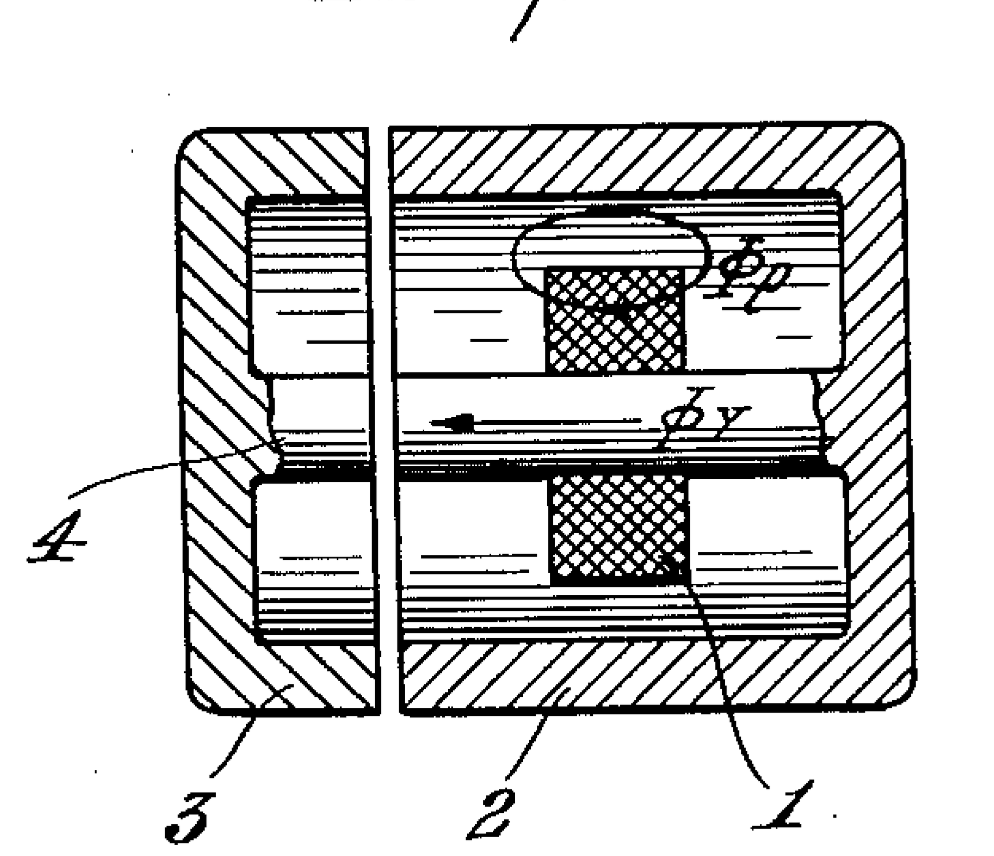


Fig. 3.

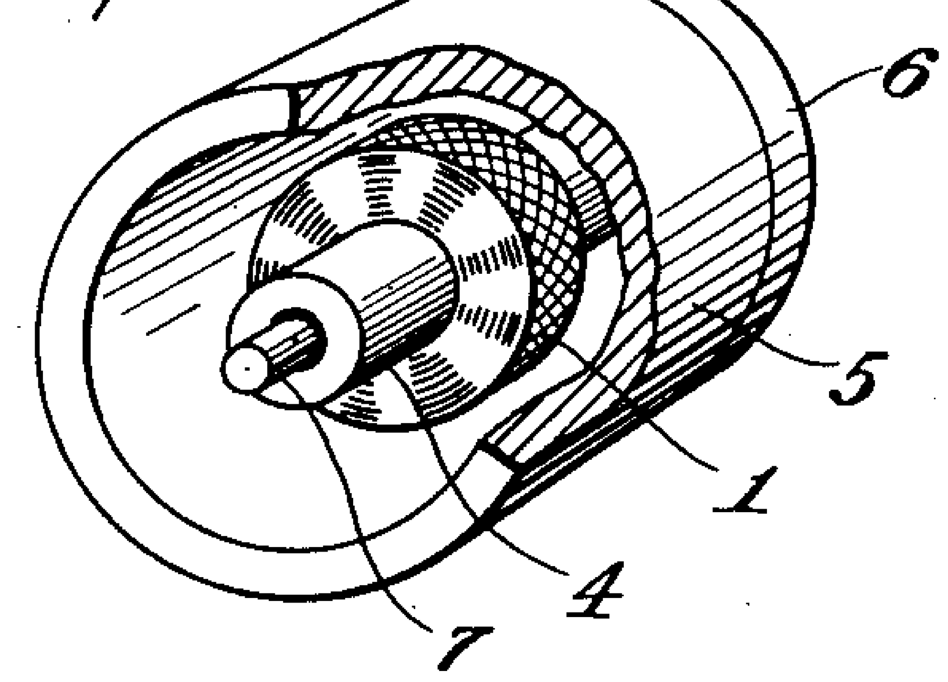


Fig. 4.

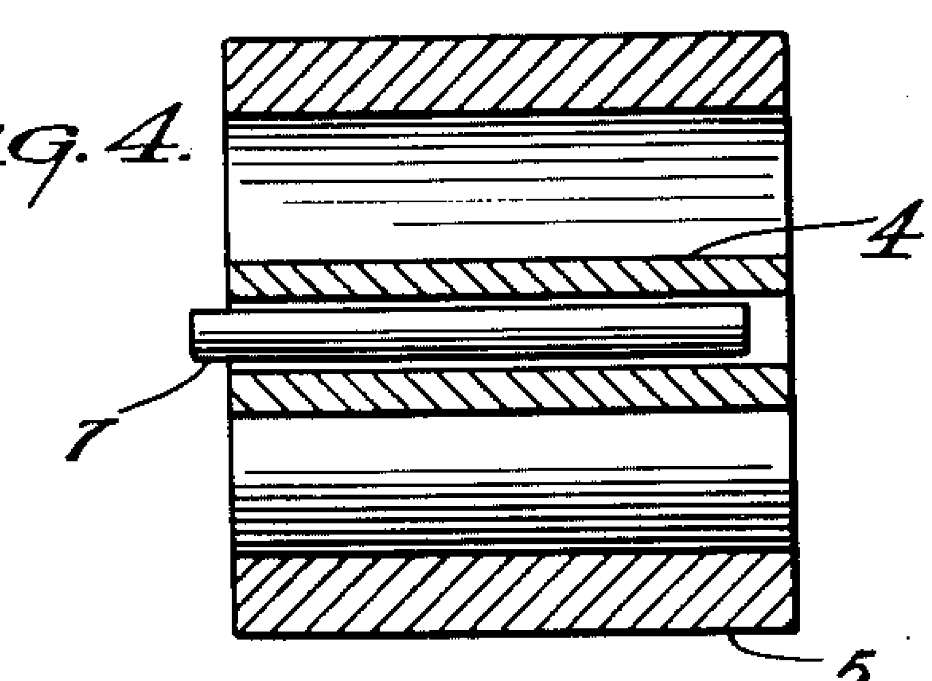


Fig. 5.

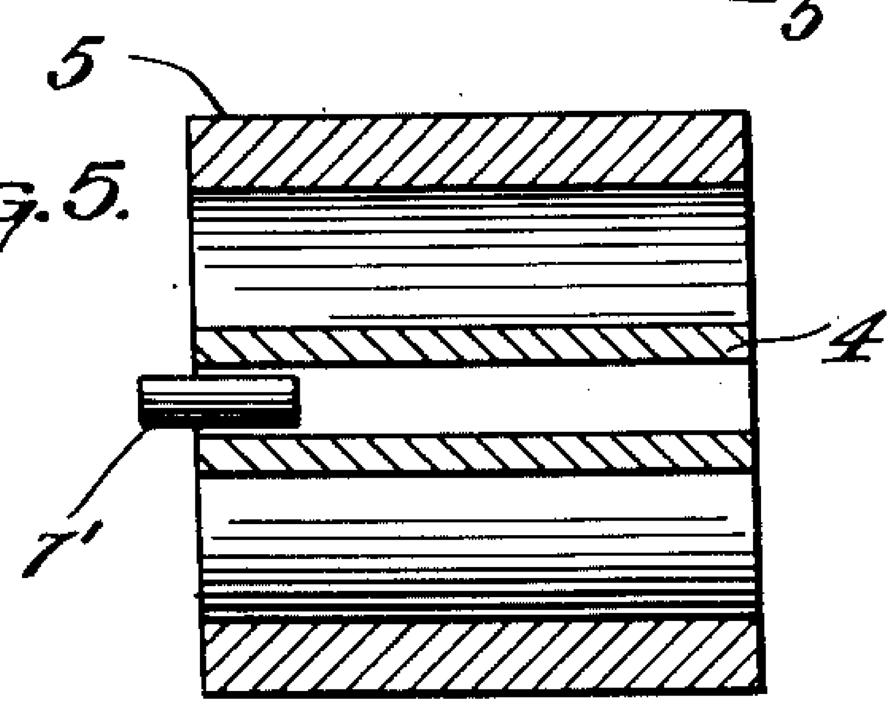
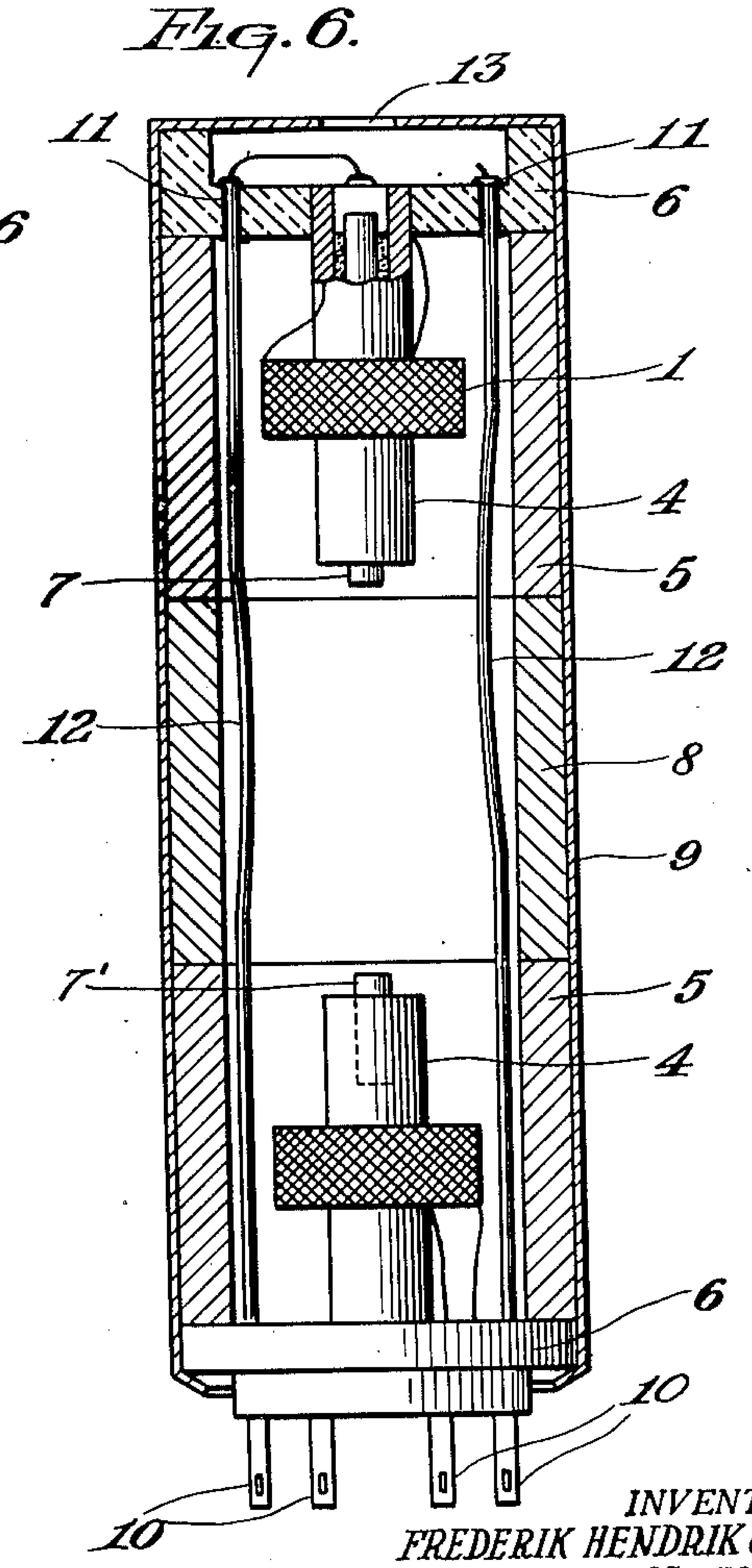


Fig. 6.



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HIGH-FREQUENCY COIL SYSTEM

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7 Claims. (Cl. 171—242)

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This invention relates to a high-frequency coil system comprising a core and a shell of high-frequency iron. High-frequency iron, hereinafter also briefly referred to as iron, is understood to mean those ferromagnetic materials which yield low losses even in the case of a very high frequency.

The choice of the shape of the core and the shell, which jointly form the magnetic circuit entails some difficulty. The magnetic field has generally to fulfill the requirement of exhibiting but low leakage in order that coupling to conductors adjacent the system may not be a source of trouble. On the other hand it is often necessary that such coupling should be established to another system. The majority of the well-known constructions only fulfill one of the two requirements.

In addition, the circuit should be so constructed that the inductance of the coil is accurately re-adjustable to a small extent and due regard should be had to the following factors. The quality of a coil system depends on the ratio between the inductance and the losses occurring in the system. Even in the case of variations of the inductance, the quality should be constant in connection with the matching between the system on the one hand and the apparatus, for example a wireless receiver to which the system is to be matched, on the other hand. The losses consist of the copper losses in the winding and the iron losses in the magnetic circuit. It has heretofore been proposed to control the inductance by providing an air gap of variable width in the magnetic circuit. This method of controlling firstly has the disadvantage of operating very coarsely due to the fact that a small variation of the width of the air gap brings about a heavy decrease or increase of the reluctance of the circuit. In addition, this method of varying the reluctance of the circuits generally has the effect of greatly altering the iron losses, particularly if the air gap is formed at an area, such as in the core of the coil, where the density of the lines of force is high, since the more the iron is saturated the more heavily the losses increase. In this case, the requirement of a constant quality of the coil is not satisfied. The same fault occurs in that form of coil system, in which an iron core is slipped more or less into the winding. In addition, the quantity of iron contained in the field is not constant.

The construction according to the invention secures in a simple manner a high frequency coil system which has a leakage field of low intensity

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and which in addition, permits of obtaining in a simple manner a highly satisfactory control of the inductance which has not the aforesaid disadvantages and which in addition has several other advantages which will become apparent hereinafter.

According to the invention, the high-frequency coil system comprises a rod-like core and a shell formed in the shape of a tube open on either side and surrounding the core axially. In this form, the field which extends through the air is practically wholly concentrated between the ends of the core and the shell. With this system it is, however, not difficult to secure a small coupling to a further system. The core and the shell may be relatively supported by providing the core with a flanged body of non-magnetic and electrically non-conductive material, the flange being secured to the shell. The shell is preferably of the same length as the core.

A satisfactory control of the inductance of this system is obtainable by making the core hollow and by introducing a plunger of high-frequency iron into the cavity in such manner that part of the plunger projects from the core. This part is preferably small compared with the part contained in the cavity. The length of the plunger may also be chosen to be small compared with the length of the core. In these cases, a shifting of the plunger results only in the deformation of the field in so far as it is contained in the air, whereas the field in so far as it extends through the core is substantially constant. In addition, in the two latter cases, when carrying out the control, a variation of the quantity of iron contained in the core practically does not occur so that a change of the iron losses is practically entirely avoided here. Frequently, a high-frequency coil system has to be coupled to a second system. The high-frequency transformers thus formed are often used in intermediate-frequency amplifiers. For the obtainment of a satisfactory high-frequency transformer that satisfies most practical requirements, two or more coil systems according to the invention may be axially disposed opposite each other. This generally brings about the problem of securing definite degree of coupling between the coil systems. It has heretofore been proposed to arrange two coils axially at both ends in a cylindrical member and for the control of the degree of coupling between the two coils to provide the said member with a slit in such manner that the field is partly driven out between the coils (vide French specification 872,004). This construction has the disadvantage that the extent to which readjustment of the degree of coupling is possible, is comparatively low. In addition, the construction is less simple, since the coils have to be introduced and secured in place successively in the cylindrical member and this involves a series of widely divergent manipulations.

The construction of the aforesaid transformer becomes very simple if bodies provided with flanges are fastened to the cores of the coil systems, said bodies supporting the shells associated with the cores and if these shells have arranged between them a piece of tubing of non-magnetic and electrically non-conductive material. In this construction the problem of securing a definite degree of coupling between the coil systems is thus reduced to a purely mechanical problem. The degree of coupling depends almost exclusively on the length of the pieces of tubing that keep the shells separated. It is, of course, readily possible to manufacture these pieces of tubing with such a degree of accuracy that the degree of coupling becomes sufficiently reproducible. The flanged bodies, the shells and the pieces of tubing may be assembled by means of a cylindrical member which surrounds them and which screens the coils from external fields in a manner known per se. All of the flanged bodies, the shells and the pieces of tubing are preferably given an identical external diameter. Thus a set of component members are obtained, which can readily be piled up and slid into a bushing. Mounting becomes particularly simple if the bodies provided with flanges, the shells and the pieces of tubing are joined by means of an adhesive. A combination is thus obtained upon which, even before it is slid into a cylindrical member, provisional measurements can be undertaken. As an alternative, the bodies, the shells and the pieces of tubing may be assembled by means of a couple of wire-like condensers, whose ends are connected to the bodies.

In order that the invention may be clearly understood and readily carried into effect, it will now be explained more fully with reference to the accompanying drawing, in which one embodiment is illustrated and in which

Figures 1 and 2 are an elevation and a sectional view of an example of a well-known coil system partly cut.

Figure 3 is a perspective view of a coil system according to the invention.

Figures 4 and 5 are two sectional views of coils systems in which styles of different length are used.

Figure 6 is sectional view of a transformer built up from two high-frequency coil systems according to the invention.

The high-frequency coil system shown in Figure 1 comprises a coil or winding 1 and a magnetic circuit which consists of two parts 2 and 3. These parts are made from high-frequency iron, for example a moulding of very finely powdered iron and a binder. Each of these parts has the shape of a pot comprising a core 4 standing centrally on the bottom. These two parts are separated by an air gap, whose width is variable in a manner not shown. It is obvious that a small variation of the air gap widely influences the reluctance, so that the control mechanism must satisfy high accuracy requirements. It is also evident from this figure that the field in so far as it extends outside the magnetic circuit is formed in such manner that it is difficult to couple it to a further coil system.

A satisfactory solution is provided by the construction shown in Figure 3; this high-frequency coil system comprises a winding 1 arranged on a core 4 which is axially surrounded by a shell 5. As before the core and the shell are made of high-frequency iron. They are relatively supported due to the fact that a body provided with a flange is arranged on the core, the shell being secured to the flange. This body is made of non-magnetic and electrically non-conductive material, for example of synthetic resin. In some cases, it may be integral with a ground plate or chassis of the set in which the coil system is housed. In addition this body may contain contacts for example, soldering lugs, to which the ends of the winding are fastened.

In this form of magnetic circuit it is on the one hand readily possible to establish a small coupling to a further coil system, whilst on the other hand the leakage field is of low intensity. The shell may be made about as long as the core. It is found that very favourable ratios are thus obtained between the quality, the adjusting possibility and the degree of coupling.

In order to control the inductance the core 4 is made hollow and a plunger made of high-frequency iron 7 is slidably arranged in this cavity; it may be secured in place in the cavity for example by cementing; it may also be threaded and shifted by rotation. The advantages of this construction become apparent from the following. In the present high-frequency coil systems may be distinguished a magnetic flux which passes, at least in part, through iron and a flux which passes entirely through air; in Figure 2 these fluxes are designated ϕ_y and ϕ_l. The losses occurring in the system consist of copper and iron losses, the latter being due to the first-mentioned flux. They depend in the field strength and on the quantity of iron contained in the field. Thus, if control of the inducance is used by which this flux varies, the quality of the coil changes as well and as already stated herein before, this must be avoided. The same disadvantages accrue to the control in which a so called sliding core can be slid into a winding to a greater or less extent. In this case both the flux and the quantity of iron traversed by the flux vary. In contradistinction to this, the losses do not vary, if the flux passing through air varies. Now, the position of the plunger is such that the part internal of the core is very slightly charged magnetically, so that this part hardly yields any losses. Even in the part projecting from the core only slight losses occur; on shifting the plunger only the field contained between the core and the shell becomes slightly deformed.

In the use of this control plunger the iron losses change to an even less extent if one of the constructions shown in Figure 4 or 5 is used.

In the construction shown in Figure 4 that part of the plunger 7 which projects from the core is small compared with the part that is internal of the cavity of the core.

In the construction shown in Figure 5 the entire control plunger 7' is short compared with the length of the core. It is obvious that in these constructions a slight displacement of the plunger practically does not alter the quantity of iron traversed by the flux.

In the high-frequency transformer shown in Figure 6 two coil systems of this kind are arranged axially opposite one another. As in the other constructions the cores 4 have arranged on them flanged bodies for example of synthetic resin. The shells 5 are supported relatively to each other by a piece of tubing 8 inserted between them. The flanged bodies, the shells 5 and the piece of tubing 8 have an identical external diameter, so that they can readily be piled up and slid into a bushing 9 which screens the transformer from external fields and which gives support to the various components. The lower body 6 is provided with several soldering lugs 10 to which, on one side, the ends of the windings 1 and, on the other side, the leading-in wires may be attached. The upper body 6 is also provided with several contacts 11 formed in the shape of flange bushings to which the ends of the upper winding may be connected preliminarily.

Before the assembling of the high-frequency transformer it should be possible to undertake some provisional measurements prior to the arrangement of the tube 9. For this purpose the various components must be attached to one another preliminarily. This may be effected, for example, by stretching a couple of wire-like condensers 12 in between a couple of soldering lugs 10 and the contacts 11. These condensers may subsequently be connected to the windings in such manner that they jointly with the latter form a tuned circuit. As an alternative the bodies 4, the shells 5 and the pieces of tubing 8 may be fixed together preliminarily by means of an adhesive.

The degree of coupling between the two coil systems depends almost exclusively on the length of the piece of tubing 8 which is moulded, for example, from synthetic resin.

In order to permit of controlling the inductance of each coil system separate control plungers 7 and 7′ are again provided in the cores 4. It is found that during the control of the inductance, the degree of coupling remains substantially unchanged. These control plungers may be readjusted even subsequent to the provision of the tube 9 which for this purpose has an aperture 13 formed in it at the top. The lower plunger 7′ may be shifted through an aperture in the body 6.

The coil system and the high-frequency transformer according to the invention are highly suited for manufacture in a very small size. The length of the transformer may be 50 mms. and the diameter 16 mms.

What we claim is:

1. A variable inductor comprising a tubular shell of magnetic material and having an open end, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, a coil disposed within said shell and surrounding said core, and a plunger of magnetic material slidably received within said core and projecting partly therefrom at the open end of said shell, whereby the reluctance of the air gap between said shell and said core may be adjusted by varying the extent of projection of said plunger.

2. A variable inductor comprising a tubular shell of magnetic material and having an open end, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, a coil disposed within said shell and surrounding said core solely in the vicinity of the central portion thereof, and a plunger of magnetic material slidably received within said core and projecting partly therefrom at the open end of said shell, the length of said plunger being small relative to the length of said core and having a size at which for any extent of projection

from said core said plunger is without said coil, whereby the reluctance of the air gap between said shell and said core may be adjusted by varying the extent of projection of said plunger.

3. A variable inductor comprising a tubular shell of magnetic material and having an open end, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, the length of said core being substantially the same as the length of said shell, a coil disposed within said shell and surrounding said core solely in the vicinity of the central portion of said core, and a plunger of magnetic material slidably received within said core and projecting partly therefrom at the open end of said shell, the length of said plunger being small relative to the length of said core and having a size at which for any extent of projection from said core said plunger is without said coil, whereby the reluctance of the air gap between said shell and said plunger may be adjusted by varying the extent of projection of said plunger.

4. A variable inductor comprising a tubular shell of magnetic material and having an open end, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, the length of said core being substantially the same as the length of said shell, a coil disposed within said shell and surrounding said core solely in the vicinity of the central portion of said core, and a plunger of magnetic material slidably received with said core and projecting partly therefrom at the open end of said shell, the length of said plunger being at least substantially the same as said core.

5. A variable inductor comprising a cylindrical shell of magnetic material, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, the length of said core being substantially the same as the length of said shell, a non-magnetic disc-shaped member enclosing one end of said shell and supporting said core therein, a coil disposed within said shell and surrounding said core solely in the vicinity of the central portion thereof, and a plunger of magnetic material slidably received within said core and projecting partly therefrom at the open end of said shell, the length of said plunger being at least substantially equal to the length of said core.

6. A transformer comprising a pair of variable inductors each including a tubular shell of magnetic material and having an open end, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, a coil disposed within said shell and surrounding said core and a plunger of magnetic material slidably received within said core and projecting partly therefrom at the open end of said shell, and a tubular non-magnetic spacer having substantially the same diameter as said shell, the shells of said inductors being secured at their open ends to opposing ends of said spacer.

7. A transformer comprising a pair of variable inductors each including a cylindrical shell of magnetic material, a hollow core of magnetic material coaxially positioned within said shell and spaced therefrom, the length of said core being substantially the same as the length of said shell, a non-magnetic disc-shaped member enclosing one end of said shell and supporting said core therein, a coil disposed within said shell and surrounding a portion of said core remote from the open end of said shell and a plunger of magnetic material slidably received within

said core and projecting partly therefrom at said open end of said shell, the length of said plunger being small relative to said core and having a size at which for any extent of projection from said core said plunger is without said coil, and a cylindrical spacer having the same diameter as said shell, the shells of said inductors being secured at their open ends to opposing ends of said spacer.

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