

April 3, 1928.

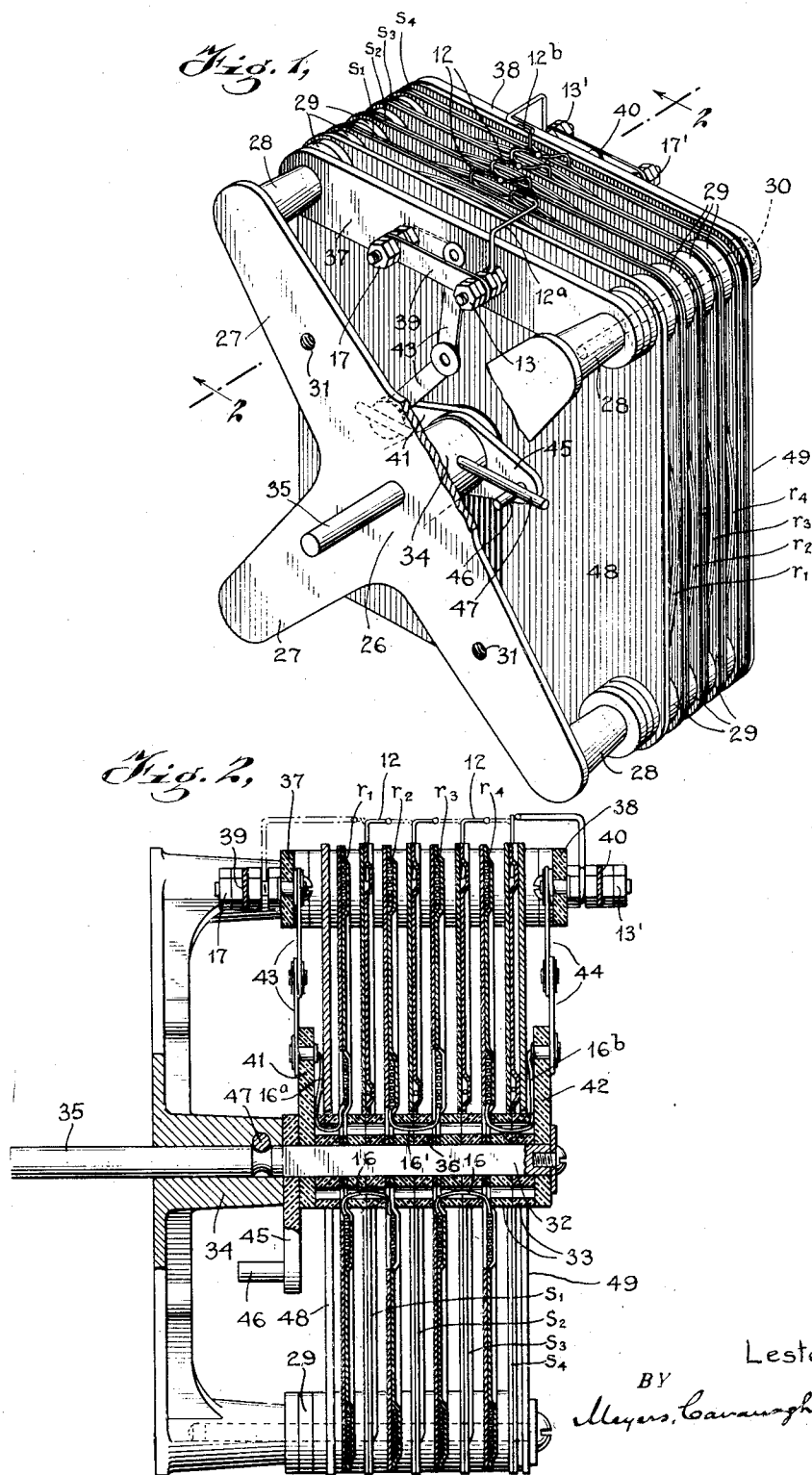
1,664,513

L. L. JONES

VARIOMETER

Filed Jan. 23, 1923

3 Sheets-Sheet 1



INVENTOR  
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1,664,513

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VARIOMETER

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*Fig. 3,*

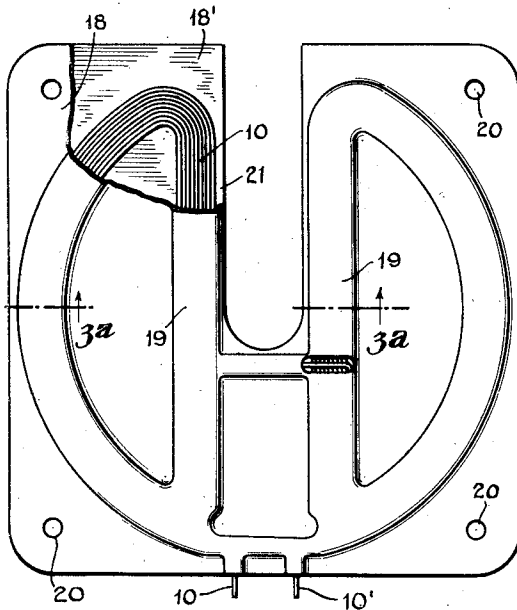


*Fig. 4,*

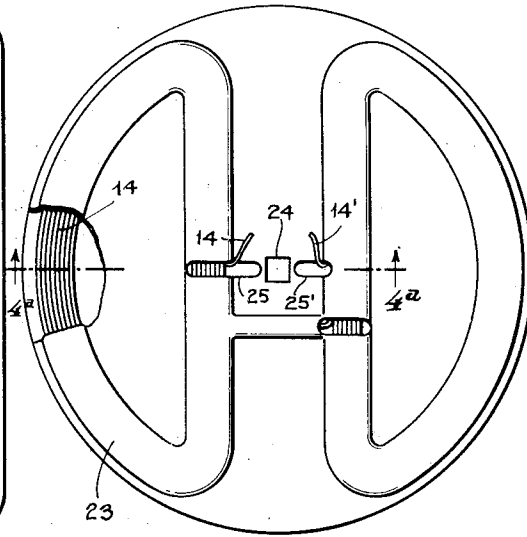


*Fig. 3a*

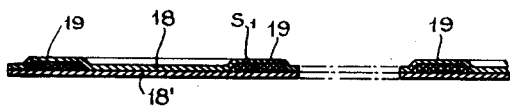


*Fig. 4a*

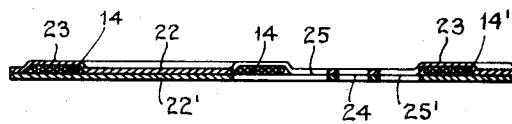


*Fig. 3b*

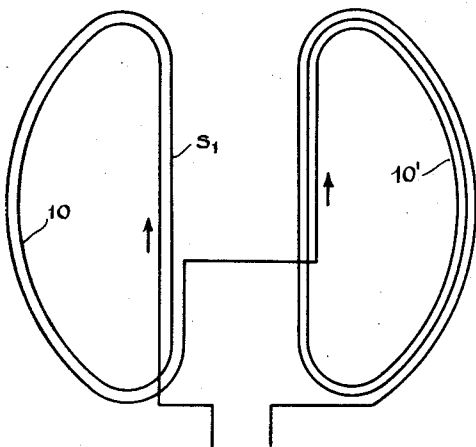
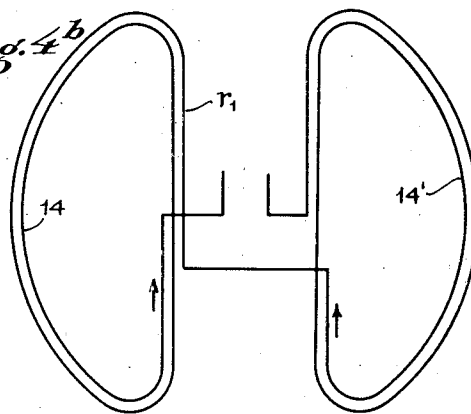


*Fig. 4b*



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3 Sheets-Sheet 3

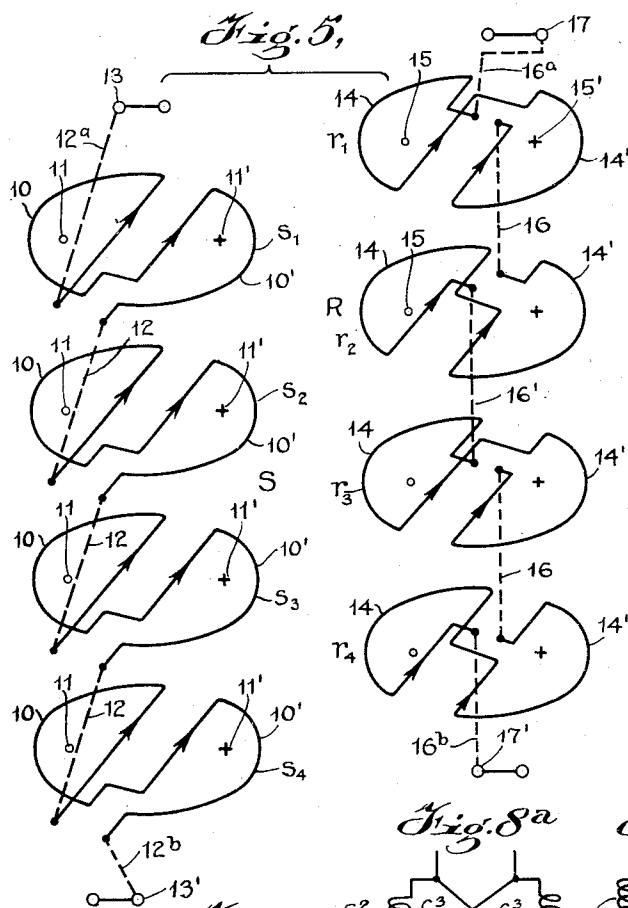
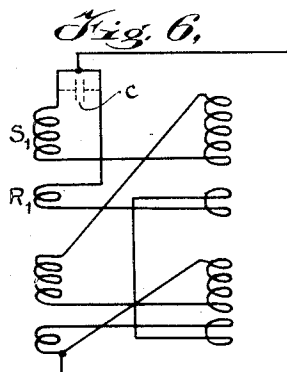
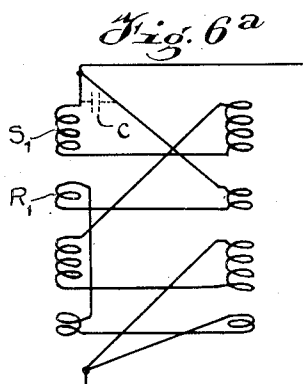
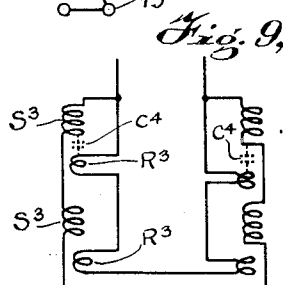
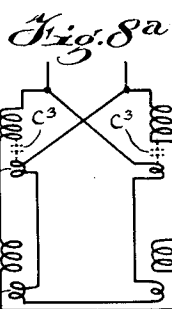
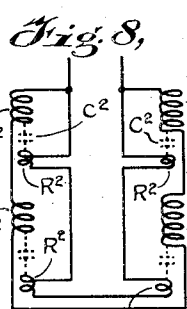
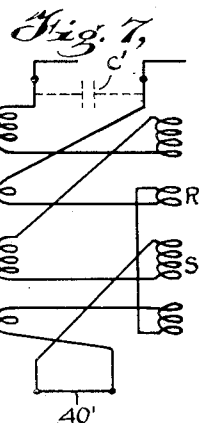
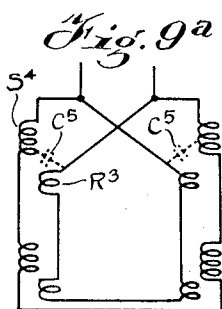
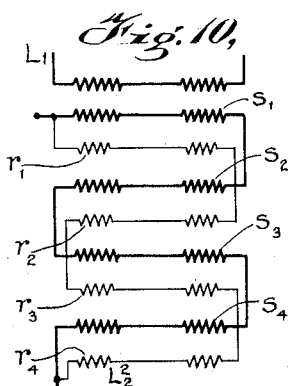
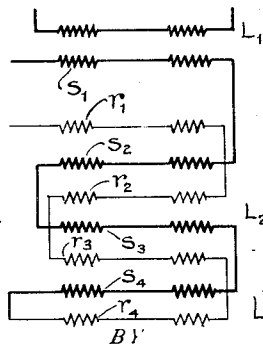


*Fig. 12.*

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## UNITED STATES PATENT OFFICE.

LESTER L. JONES, OF ORADELL, NEW JERSEY.

## VARIOMETER.

Application filed January 23, 1923. Serial No. 614,404.

This invention relates to variable inductances, and more particularly to variometers and variotransformers; and has special reference to the provision of variometers and variotransformers especially designed for employment in radio receiving and transmitting circuits.

As is well known, the employment of the standard ball and socket type of variometer in radio circuits is attended with many serious objections, among which are notably the relatively small inductance and wave length range of the same and the inter-magnetic-coupling between variometers used in the same radio set or between a variometer and a coil or loop antenna when such is used. When the ball and socket variometers are placed for example in the wing and grid circuits of regenerative sets, the objectionable inter-coupling which is due to the large external magnetic field produced by this type of variometer is very difficult of avoidance, since the space limitations in the set forbids of that distant spacing between variometers that is essential when coupling interference is desired to be prevented. When these variometers are made to produce a high inductance and large inductance range, the magnetic field produced is of a correspondingly high intensity, and magnetic coupling between the grid and wing circuits is undesirably intensified. Moreover, due to leakage and other factors, it is very difficult to obtain small inductance values and a straight line curve for the whole inductance range. To obviate these objections and to produce a variometer in which inter-magnetic-coupling may be substantially minimized if not eliminated, and in which large inductance and wave length ranges may be produced efficiently and without an intense or large external magnetic field is a prime desideratum of my present invention.

A further prime object of my present invention centers about the provision of a variometer having rotor and stator coils so constructed and inter-related as to permit the obtaining in a predetermined manner of a distributed capacitance of the coils such as to produce a variometer having any of a number of desired characteristics and uses. More specifically, the variometer of my invention comprises a rotor and a stator made up of sets of coils arranged in interleaving

alternation and having a construction which permits of selected interconnections between the coils to produce either

(a) A small distributed capacitance which does not vary substantially with the variation of inductance of the variometer so as to produce a variometer of high electrical efficiency, ideal for antenna tuning, or

(b) A distributed capacitance which is interrelated with the inductance such as to produce a large inductance and wave length range, or

(c) A distributed capacitance which may be made to vary with the variation in inductance and in the same direction so as to produce a combined variable condenser and inductance having a very large wave length range, or

(d) A distributed capacitance which may be made to vary with the variation in inductance in a direction opposite thereto for producing a variable time constant and constant frequency apparatus.

Still further and related principal objects of the invention comprehend the provision of a variotransformer having a primary and a variometer secondary, adapted especially for employment as a radio frequency transformer having a tunable secondary; and the further provision of such a variotransformer constructed to permit of choice of coupling variation between the primary and the secondary with a variation of the secondary inductance or with a variation in wave length. In inductively tuning the secondary of a radio frequency transformer, I have found that for the greatest efficiency combined with the maximum selectivity, the coupling between the primary and secondary should be varied with variation in the tuning of the secondary, and more particularly that the coupling should vary in the same direction with the wave length, so that for short waves the coupling should be loose, and for long waves the coupling should be tight. By means of the variometer and variotransformer of my present invention, these results may be desirably achieved.

To the accomplishment of the foregoing and such other objects as may hereinafter appear, my invention consists in the elements and their relation one to the other as hereinafter particularly described and sought to be defined in the claims; reference being

had to the accompanying drawings which show a preferred embodiment of my invention, and in which:

Fig. 1 is a perspective view of my variometer with parts broken away.

Fig. 2 is a vertical elevational view of the same taken in cross-section on the line 2—2, Fig. 1, showing the rotor turned 90°.

Figs. 3, 3<sup>a</sup> and 3<sup>b</sup> are views showing the construction of a stator element or unit,

Figs. 4, 4<sup>a</sup> and 4<sup>b</sup> are views showing collectively the construction of a rotor element or unit,

Fig. 5 depicts diagrammatically the arrangement between the stator and rotor coils and the interconnections of the windings thereof,

Figs. 6 and 6<sup>a</sup> show the connection of the rotor and stator in parallel,

Fig. 7 is a view showing the connection between the rotor and stator in series,

Figs. 8 and 8<sup>a</sup> are views showing a way of connecting the rotor and stator elements to provide a very large wave length range,

Figs. 9 and 9<sup>a</sup> are views showing a connection between the rotor and stator elements to provide a variable time constant and a constant frequency,

Fig. 10 is a view showing the application of the variometer as the tuned secondary of a transformer, and

Fig. 11 is another view showing diagrammatically a transformer having the variometer secondary.

Referring now more in detail to the drawings, the variometer constructionally comprises a rotor including a set of coils and a stator also including a set of coils, the coils of the stator set and the coils of the rotor set being arranged in interleaving alternating relation after the manner of the stator and rotor plates of a variable air condenser, and as shown diagrammatically in Fig. 5 of the drawings, the rotor R comprises the set or plurality of rotor coils  $r_1$ ,  $r_2$ ,  $r_3$ , and  $r_4$  arranged in alternation with the set or plurality of coils  $s_1$ ,  $s_2$ ,  $s_3$  and  $s_4$  of the stator S. The rotor and stator coils, as will be made clearer hereinafter, are arranged in closely spaced superposed relation, and are shown in Fig. 5 displaced laterally only for purposes of clarification and for facilitating the tracing of the circuits in the independent stator and rotor coils.

The stator coils are each wound so as to produce a winding in a single plane, the winding comprising two coil sections for producing magnetic fields in opposite directions, each of the coils to this end comprising the two coil sections 10 and 10' wound in opposite directions and presenting a double D formation, this being indicated by the arrows showing the momentary direction of flow of current in the windings to produce a field in the coil section 10 in one

direction as indicated by the circles 11 and a magnetic field in the coil section 10' in the opposite direction as indicated by the cross 11'. The stator coils are connected together so that their mutuals add, and to this end the oppositely positioned coil sections 10 and 10' are electrically connected by conductors 12 and the end coils are connected to the terminals 13 and 13' by means of the conductors 12<sup>a</sup> and 12<sup>b</sup> respectively. With this arrangement and interconnection, it will be seen that the magnetic flux threads up through the coil sections on one side and down through the coil sections on the other producing a magnetic field which is closed substantially within the confines or dimensions of the coils, thus minimizing any external magnetic field.

The rotor coils  $r_1$  to  $r_4$  are each similarly constructed, comprising two sections 14 and 14' producing a double D coil, the sections being wound in opposite directions as clearly indicated by the arrows in the figure to produce oppositely directed magnetic fluxes as shown by the circles 15 and the crosses 15'. These rotor coils are also interconnected so that the mutuals therebetween add, and to this end some of the coil sections 14' are connected by means of the conductors 16 and some of the coil sections 14 are connected by means of the conductor 16', the end coils being connected to the terminals 17 and 17' by means of the conductors 16<sup>a</sup> and 16<sup>b</sup> respectively. It will be noted that contradistinguished from the connections of the stator coils, adjacent in lieu of opposed rotor coil sections are connected, this so that the conductors 16 and 16' lie on one side or lie on a side of the axis of the rotor for a purpose as will appear clearer hereinafter. To obtain the desired direction of the fluxes with this interconnection, it will be noted that the coils  $r_2$  and  $r_4$  are inversed with respect to the coils  $r_1$  and  $r_3$ , the connection between the coil sections of the first set of coils being on one side of the rotor axis, and the connection between the coil sections of the other set being shown on the other side of the said axis. With this arrangement it will be also noted that the magnetic flux threads through all the rotor coil sections in a manner to minimize an external magnetic field.

Still referring to Fig. 5, the rotor coils are shown arranged in alternation with the stator coils, and when the same are superposed in the position shown in Fig. 5, the mutuals aid to produce a maximum inductance. With this construction it will be seen that as the rotor is rotated from the position shown to a position of 180° thereto, the mutuals will change from full aiding to full opposing, and in the latter position the fields of equal magnitude will oppose each other to produce a very small inductance value.

To accomplish this latter end, the rotor coils are preferably made equal in number to the stator coils, and are similarly wound to produce like physical dimensions.

For the purpose of permitting a very close spacing between the rotor and stator coils to produce a flat compact organization and to minimize any leakage so that a true straight line calibration curve is produced, the coils are wound and mounted to provide thin or shallow coil elements which may be described as disk or "pancake" units. Referring to Figs. 3, 3<sup>a</sup> and 3<sup>b</sup> of the drawings, I show the preferred construction of a stator coil unit, the unit preferably comprising the coil such as  $s_1$  (see Fig. 3<sup>b</sup>) providing the double D sections 10 and 10' each preferably of a plurality of convolutions, the coil being preferably though not necessarily assembled between two thin backing or mounting sheets 18 and 18' which are preferably made of an insulating material such as fibre, one of the sheets such for example as 18 being stamped or pressed to provide grooves or pockets 19 for receiving the convolutions of the coil sections as clearly indicated in Figs. 3 and 3<sup>a</sup> of the drawings. For assembling the coil units to form the stator, each stator element is provided at its corners with the orifices 20 for receiving means for securing the same in spaced relation as will be detailed hereinafter. Each stator unit is furthermore preferably cut away as at 21 to facilitate removal of a stator unit when desired without disassembling the rotor structure.

Now referring to Figs. 4, 4<sup>a</sup> and 4<sup>b</sup>, I show the preferred construction of a rotor unit, the rotor unit preferably comprising the rotor coil such as  $r_1$  provided with the sections 14 and 14' each preferably having a plurality of convolutions as shown in Fig. 4<sup>b</sup> assembled between the thin backing or mounting sheets 22 and 22' preferably of fibre, the fibre sheet 22 being preferably stamped or pressed to provide the grooves or pockets 23 receiving the coil formation as clearly shown in Figs. 4 and 4<sup>a</sup> of the drawings, the rotor unit thus presenting the flat and disk-shaped element clearly shown in the drawings. For assembling the rotor elements on the shaft, each rotor is provided with a square shaped central opening 24, and adjacent the opening 24 the mounting sheets are cut out as at 25 and 25' through which cut-out portions the leads of the coil sections 14 and 14' are threaded for connection to the adjacent rotor elements. With this construction of the stator and rotor elements, it will be seen that flat units are provided which may be assembled in very closely spaced relation to form the variometer structure.

Referring now to Figs. 1 and 2 of the drawings, in which is shown the assembled variometer, there is provided a front supporting frame which preferably comprises

the spider frame 26 provided with the spaced arms 27 four in number, each arm being provided with a short post 28 at an end thereof, and on these posts the stator units  $s_1$  to  $s_4$  are built up in stacked formation and are spaced from one another by the preferably fibre washers 29, the assembled units being held together and on the post 28 by means of the elongated securing screws 30 which thread through the apertures 20 of the stator units and through the washers and are threadedly received by tapped bores in the posts 28. The spider frame 26 provides means for attaching the variometer to a support such as a panel, and to this end some of the arms 27 of the spider may be suitably tapped as at 31 for receiving securing elements.

The rotor units  $r_1$  to  $r_4$  are stacked up in superposed relation on a rotor shaft 32 the shank of which is preferably square to receive the central square orifices 24 of the rotor units, the said units being held in spaced position on the shaft by the means of the preferably fibre washers 33 which are also provided with squared central apertures fitting the shank in the shaft 32. The shaft 32 is journaled in the spider frame 27, the said spider frame being to this end provided with an elongated central bearing 34 through which the shaft spindle 35 projects, the said spindle being adapted in the usual manner for receiving a dial. As hereinbefore mentioned, the rotor units are preferably connected by means of conductors such as 16 and 16' which lie on one side of the rotor shaft 32, and these conductors are threaded through perforations 36 provided in the washers 33.

For interconnecting the stator and rotor units, I preferably provide connecting terminals at opposite ends of the variometer, and for this purpose there are provided the insulating bars 37 and 38 held by the securing screws 30, the bar 37 being provided with the binding posts 13 and 17 which may be electrically connected together by means of the conducting strip 39, the bar 38 being provided with the binding posts 13' and 17' heretofore mentioned which may also be electrically connected by means of the conducting strip 40. The stator units which are connected as shown by the conductors 12 are connected to the opposite terminals 13 and 13' by means of the conductors 12<sup>a</sup> and 12<sup>b</sup> heretofore mentioned.

For connecting the rotor coils to the terminals, I preferably provide linkage mechanism which functions to mechanically as well as electrically interconnect the rotor and stator. To this end referring to Figs. 1 and 2, the shaft 32 is provided at its opposite ends with the crank arms 41 and 42 fixed to the shaft, the said crank arms being connected to the binding posts 17 and 17'

respectively by means of the linkage mechanism, the crank arm 41 being connected to the binding post 17 by the links 43 and the crank arm 42 being connected to the binding post 17' by means of the links 44, these links being made of a conducting material and serving to electrically connect the terminal conductors 16<sup>a</sup> and 16<sup>b</sup> of the rotor coils to the binding posts, the said conductors being electrically united to this end to the lower ends of the linkage mechanism.

As heretofore mentioned in connection with Fig. 5 of the drawings, the rotor is adapted to be rotated through an angle of 180° from maximum to minimum inductive position, and for the purpose of definitely locating the rotor at the maximum and minimum positions, I preferably provide limiting or stop means which may comprise a second crank arm 45 carried by the rotor shaft and provided with a stop pin 46 cooperating with the horizontally arranged stop rod 47 which is carried by the frame bearing 34, the cooperation between these parts being such that the pin 46 is stopped by the rod in positions 180° apart. For the purpose of protecting the stator and rotor coils I may also provide the opposite end plates 48 and 49 made of fiber and assembled with the stator units.

As heretofore mentioned, a principal object of the invention centers about the provision of a variometer having rotor and stator coils so constructed and inter-related as to permit the obtaining in a predetermined manner of a distributed capacitance of the coils such as to produce a variometer having any of a number of desired characteristics and uses, a few examples of which will now be given.

(a) The stator and rotor coils of the variometer shown in Figs. 1 and 2 may be connected either in parallel or in series, the connection shown in Figs. 1 and 2 being a parallel connection. This connection is diagrammatically illustrated in Figs. 6 and 6<sup>a</sup> of the drawings, Fig. 6 showing the stator and rotor coils in maximum inductance position and Fig. 6<sup>a</sup> showing the same in minimum inductance position, the stator coils being designated as S<sub>1</sub> and the rotor coils being designated as R<sub>1</sub>, with the interconnection between the rotor and stator coils and the sections thereof being that heretofore described. When the coils are thus connected in parallel, the front end of the rotor to front end of the stator, and rear end of the rotor to rear end of the stator, a variable inductance is provided with an extremely small distributed capacity diagrammatically represented by the condenser C, and with these connections this distributed capacity does not substantially vary with change of inductance, this connection having high electrical efficiency and being ideal

for antennæ tuning. It will be understood as hereinbefore described that the rotor and stator coils have a like number of convolutions to produce equal inductances, the representations shown in Figs. 6 and 6<sup>a</sup> being merely diagrammatic.

(b) When it is desired to connect the stator and rotor coils in series, the manner of connection shown in Fig. 7 of the drawings may be adopted, the stator coils S' and the rotor coils R' being connected together only at one end as by means of the conducting strip 40'. To effect this connection in the construction shown in Figs. 1 and 2, it is only necessary to disconnect the conducting strip 39 from one of the binding posts. With this series connection a very large inductance and wave length range may be obtained, the distributed capacity as represented by the condenser C' being somewhat greater than that for the parallel connection.

(c) The variometer of my invention is found adaptable for producing a combined variable condenser and inductance, the rotor and stator coils being so interconnectible as to provide a distributed capacity which may be varied with variation of the inductance. The coils may moreover be so connected that the distributed capacity may be made to vary either in the same or in the opposite direction with the inductance so that very large wave length ranges or variable time constant devices respectively may be obtained. The former arrangement is shown in Figs. 8 and 8<sup>a</sup> of the drawings, and referring to these figures it will be seen that when the stator coils S<sup>2</sup> are connected in series as shown with the rotor coils R<sup>2</sup> connected in series, and the rotor and stator coils interconnected in parallel, a distributed capacity which is designated as C<sup>2</sup> is obtained which varies from small values when the rotor is in a position of minimum inductance as shown in Fig. 8 to large values C<sup>2</sup> when the rotor is in maximum inductive position as shown in Fig. 8<sup>a</sup> of the drawings. With this construction, therefore, a minimum inductance is combined with a minimum capacitance and a maximum inductance with a maximum capacitance, the capacitance and inductance varying simultaneously in the same direction for providing a very large wave length range.

(d) For providing a constant frequency and variable time constant construction, the rotor and stator may be interconnected as shown in Figs. 9 and 9<sup>a</sup> of the drawings. The stator coils S<sub>2</sub> are connected in series and the rotor coils R<sub>2</sub> are also connected in series, the rotor and stator being assembled in parallel as shown, with the interconnection such that a minimum capacity designated as C<sup>4</sup> is provided when the rotor and stator coils assume the position of maximum inductance, that is, with the mutuals thereof

aiding. When the rotor  $R_3$  is moved to minimum inductance position as shown in Fig. 9<sup>a</sup>, the distributed capacity designated as  $C_5$  is at its maximum. With this arrangement it will be seen therefore that the inductance and capacitance may be made to vary in inverse ratio, and this may be so designed that the frequency ( $\omega = \sqrt{LC}$ ) is constant and the time constant ( $\frac{C}{L}$ ) is a variable.

As heretofore referred to, a further principal object of the invention relates to the provision of a variotransformer having a primary and a variometer secondary adapted especially for employment as a radio frequency transformer in which the secondary is tunable, and in which a coupling variation between the primary and the secondary may be obtained with a variation of the secondary inductance. This is accomplished by providing a primary which may comprise one or more flat stator coil units arranged adjacent a stator coil of a variometer having the alternating rotor and stator coils comprising the secondary of the transformer. This is shown in Fig. 10 of the drawings, the primary being designated as  $L_1$  and the secondary as  $L_2$ , the said secondary having the spaced stator coils  $s_1$  to  $s_4$  and the rotor coils  $r_1$  to  $r_4$ . The primary  $L_1$  is a stator coil which is preferably arranged adjacent the stator secondary coil  $s_1$  of low potential in the circuit, this so as to minimize capacity coupling.

This variometer transformer or variotransformer permits of a choice of coupling variation with variation of the secondary inductance or with variation in wave length, and such variation may be accomplished by changing the distance between the last stator of the variometer  $s_1$  and the rest of the variometer as shown for example in Fig. 11 of the drawings. If  $s_1$  is very far from the remainder coils of the variometer, then  $M$  is constant, and the coupling co-efficient (coupling co-efficient =  $\sqrt{\frac{M^2}{L_1 L_2}}$ ) varies as  $\sqrt{\frac{1}{L_2}}$ .

But if  $s_1$  is very close to the remainder coils of the variometer, then  $M$  varies as  $L_2$ , and the coupling co-efficient varies as  $\sqrt{L_2}$ . At intermediate spacings the variation is some function between  $\sqrt{\frac{1}{L_2}}$  and  $\sqrt{L_2}$  and may

be adjusted to remain practically constant or to increase or decrease as  $L_2$  is varied. In this way a coupling variation may be effectively obtained with facility by a variation of the secondary inductance. The arrangement wherein the coupling coefficient is made to increase with  $\sqrt{L_2}$  has been found especially useful in radio receiving sets in which the variotransformer is employed as a radio frequency transformer having an inductively tuned secondary. I

have found that with such an arrangement, I am enabled to obtain the greatest efficiency combined with the maximum selectivity, the coupling varying in the same direction with the wave length so that for the short waves the coupling is loose, and for the long waves the coupling is tight.

The manner of making and using my variometer and the numerous adaptations and functions thereof will in the main be apparent from the above detailed description thereof. With this variometer when employed as shown in Figs. 6 and 7 the wing and grid circuits of a receiving set may be made to tune almost degree for degree with each other at the point of maximum regeneration, a feature which greatly simplifies picking up weak signals. The distributed capacity may be so adjusted that maximum regeneration occurs with the grid and wing circuits in resonance when using an average small antenna. When the rotor and stator are connected in parallel a high electrical efficiency is obtained. The variometers may be placed side by side without inter-coupling, and therefore may be arranged compactly in a receiving set without interference. The connections between the rotor and stator may be changed at will to produce different inductance and wave length ranges to suit the conditions of service. Moreover, the supporting framework provided may if desired be grounded, thus holding the shaft and the framework of the variometer at ground potential interposing an effective shield between the operator's hand and the variometer, simplifying tuning. Other manifold advantages of my variometer will be evident to those skilled in the art, such for example as the advantage of using the variometer with a small magnetic field when using a receiver near a transmitting station, since the receiving coils do not of themselves act as small loop antennae, this feature being a further advantage when using loop antennae, because of the absence of coupling between the loop and variometer.

I am aware that it has hitherto been proposed to arrange coils in alternating relation in rotor and stator fashion, but as far as I am aware such coils are not constructed and inter-related as in the variometer of my invention to effect a small external magnetic field and the large inductance range which are characteristics of the present invention. While I have shown my device in the preferred form, it will be obvious that many changes and modifications may be made in the structure disclosed without departing from the spirit of the invention, defined in the following claims.

I claim:

1. A variable inductance comprising a stator formed of a set of flat coils each coil comprising oppositely wound coil sections

wound in a single plane, and a rotor also formed of a set of flat coils each coil comprising oppositely wound coil sections wound in a single plane, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

2. A variable inductance comprising a stator formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, and a rotor also formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation and interconnected to produce a distributed capacity therebetween.

3. A variable inductance and capacitance comprising a stator formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, and a rotor also formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation and interconnected to produce a distributed capacity therebetween variable when the rotor is turned to vary the inductance.

4. A variable inductance comprising a stator formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, and a rotor also formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation and interconnected to produce a distributed capacity therebetween variable in the same direction with the inductance variation when the rotor is turned whereby the frequency may be made to vary over a wide range.

5. A variable inductance comprising a stator formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions and wound in a single plane, and a rotor also formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions and also wound in a single plane, each of the stator coils and rotor coils being similar and of like inductance, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

6. A variotransformer having a primary and a secondary, the primary comprising a coil and the secondary comprising a stator formed of a set of coils each coil comprising oppositely wound coil sections and a rotor also formed of a set of coils each comprising

oppositely wound coil sections, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

7. A variotransformer having a primary and a secondary, the primary comprising a stator coil and the secondary comprising a stator formed of a set of coils each coil comprising oppositely wound coil sections and a rotor also formed of a set of coils equal in number to the stator coils and each comprising oppositely wound coil sections, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

8. A variotransformer having a primary and a secondary, the primary comprising a stator coil and the secondary comprising a stator formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions and a rotor also formed of a set of coils each coil comprising a plurality of coil sections for producing magnetic fields in opposite directions, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

9. A variotransformer having a primary and a secondary, the primary comprising a stator coil and the secondary comprising a stator formed of a set of coils each coil comprising oppositely wound coil sections and a rotor also formed of a set of coils each coil comprising oppositely wound coil sections, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

10. A variotransformer having a primary and a secondary, the primary comprising a stator coil and the secondary comprising a stator formed of a set of coils, each coil comprising oppositely wound coil sections, and a rotor also formed of a set of coils equal in number to the stator coils and each comprising oppositely wound coil sections, each coil of the stator having an inductance equal in magnitude to the inductance of each of the rotor coils, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation.

11. A variotransformer comprising a primary and a secondary coupled thereto, the secondary comprising a variable inductance and the coupling between the primary and the secondary being such as to produce a coupling coefficient which varies with variation of the inductance of the secondary.

12. A variotransformer comprising a primary and a secondary coupled thereto, the secondary comprising a variable inductance and the coupling between the primary and the secondary being such as to produce a variation in the coupling coefficient with and in the same direction as the variation in the inductance of the secondary.

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13. A variotransformer having a primary and a secondary coupled thereto, the primary comprising a stator coil and the secondary comprising a variable inductance including a stator formed of a set of coils each coil comprising oppositely wound coil sections, and a rotor also formed of a set of coils each coil comprising oppositely wound coil sections, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation, the coupling between the primary and secondary being such as to produce a variation in the coupling co-efficient with variation in the inductance of the secondary.

14. A variotransformer having a primary and a secondary coupled thereto, the secondary comprising a variable inductance including a stator formed of a set of coils each coil comprising oppositely wound coil sections, and a rotor also formed of a set of coils each coil comprising oppositely wound coil sections, the coils of the stator set and the coils of the rotor set being arranged in alternating interleaving relation, the coupling between the primary and the secondary being such as to produce a variation in the coupling coefficient with and in the same direction as the variation in the inductance of the secondary.

15. A variotransformer comprising a primary including a coil subdivided into opposite D-shaped sections and a secondary comprising stator and rotor coils arranged in alternation, each stator and rotor coil being also subdivided into opposite D-shaped sec-

tions, the said primary coil being arranged contiguous to a stator coil.

16. A variotransformer comprising a primary including a flat coil and a secondary comprising flat stator and rotor coils arranged in alternation, the said primary coil being arranged contiguous to a stator coil.

17. A variotransformer comprising a primary including a flat coil and a secondary comprising flat stator and rotor coils arranged in alternation, the said primary coil being arranged contiguous to a stator coil which is connected to a point of low potential.

18. A variotransformer comprising a primary including a flat coil and a secondary comprising stator and rotor coils arranged in alternation, one of the said stator coils being arranged a predetermined distance from the remainder of the stator and rotor coils, the said primary coil being arranged contiguous to the said movable stator coil.

19. A variotransformer comprising a primary including a flat coil and a secondary comprising stator and rotor coils arranged in alternation, one of the said stator coils being arranged a predetermined distance from the remainder of the stator and rotor coils, the said primary coil being arranged contiguous to the said movable stator coil, each of the primary and secondary coils comprising opposite D-shaped sections.

Signed at New York city in the county of New York and State of New York, this 17th day of January, A. D. 1923.

LESTER L. JONES.