

Feb. 8, 1938.

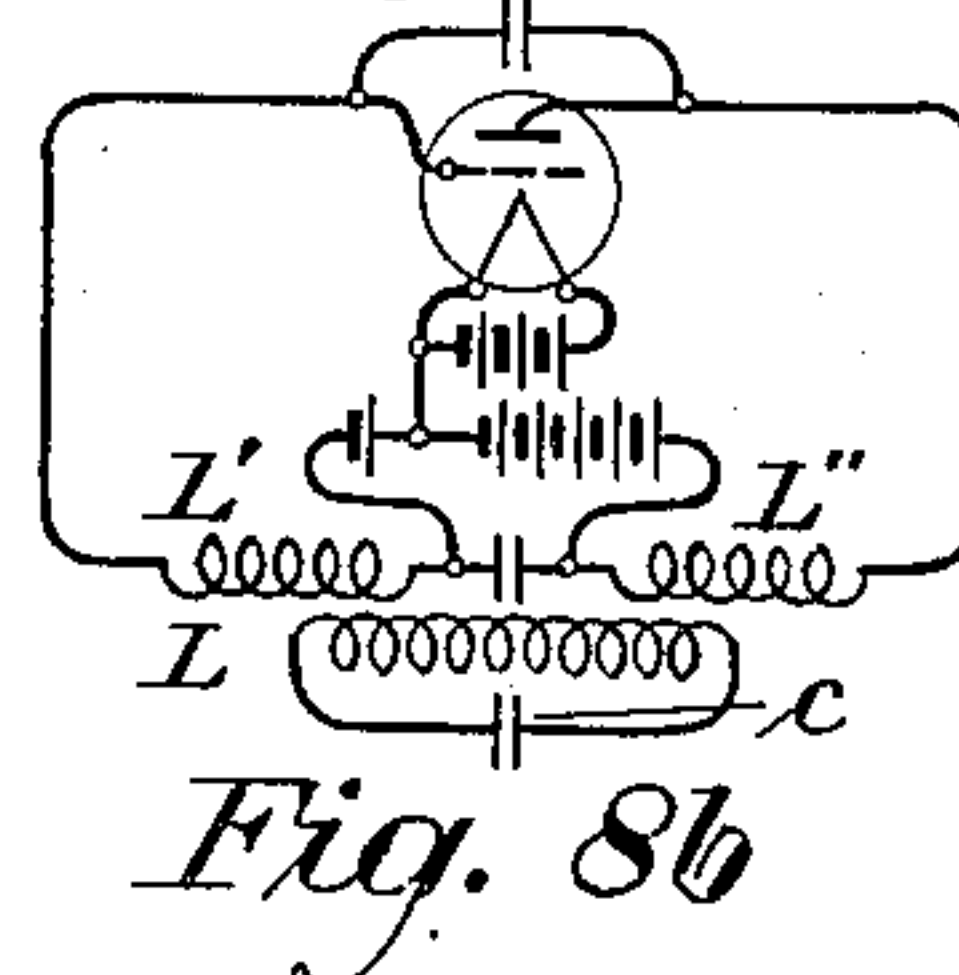
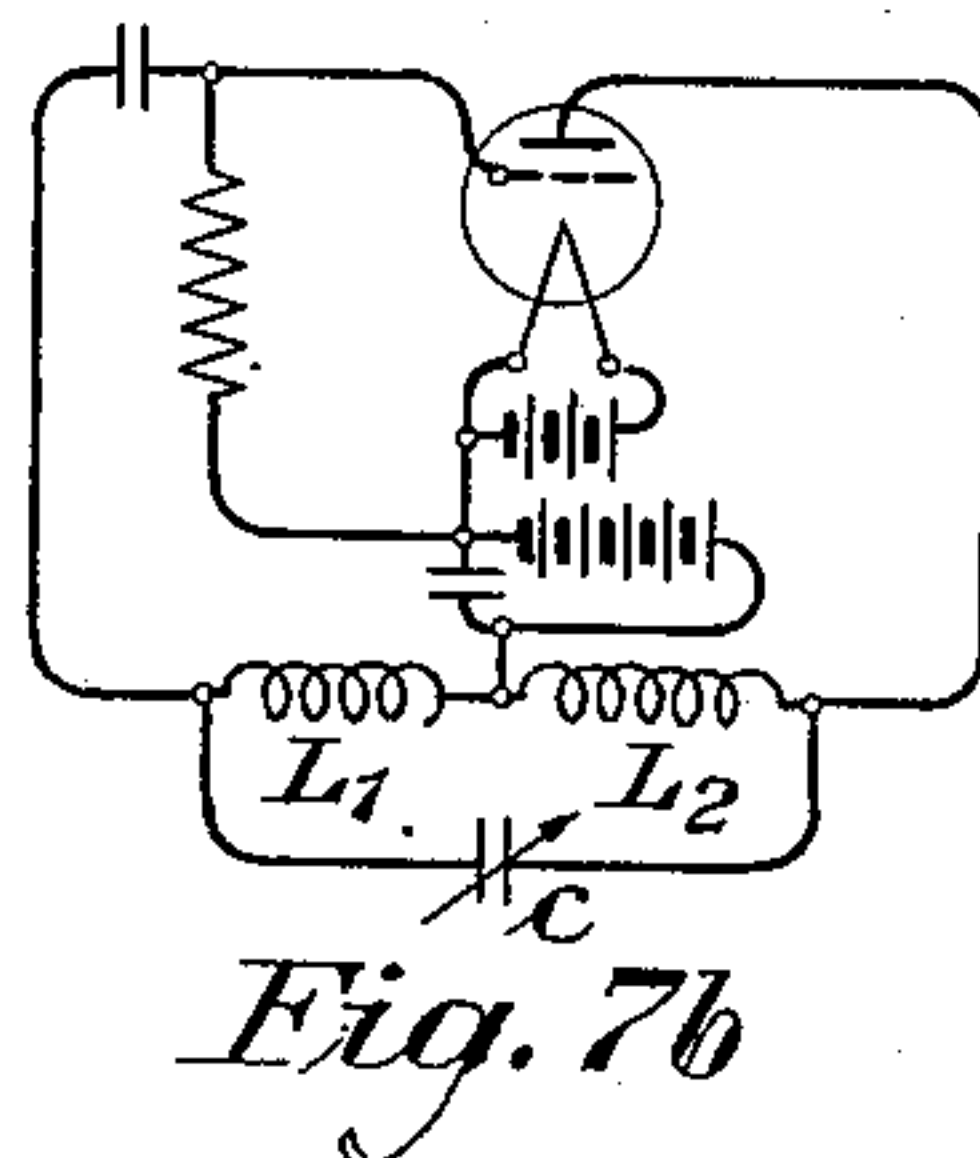
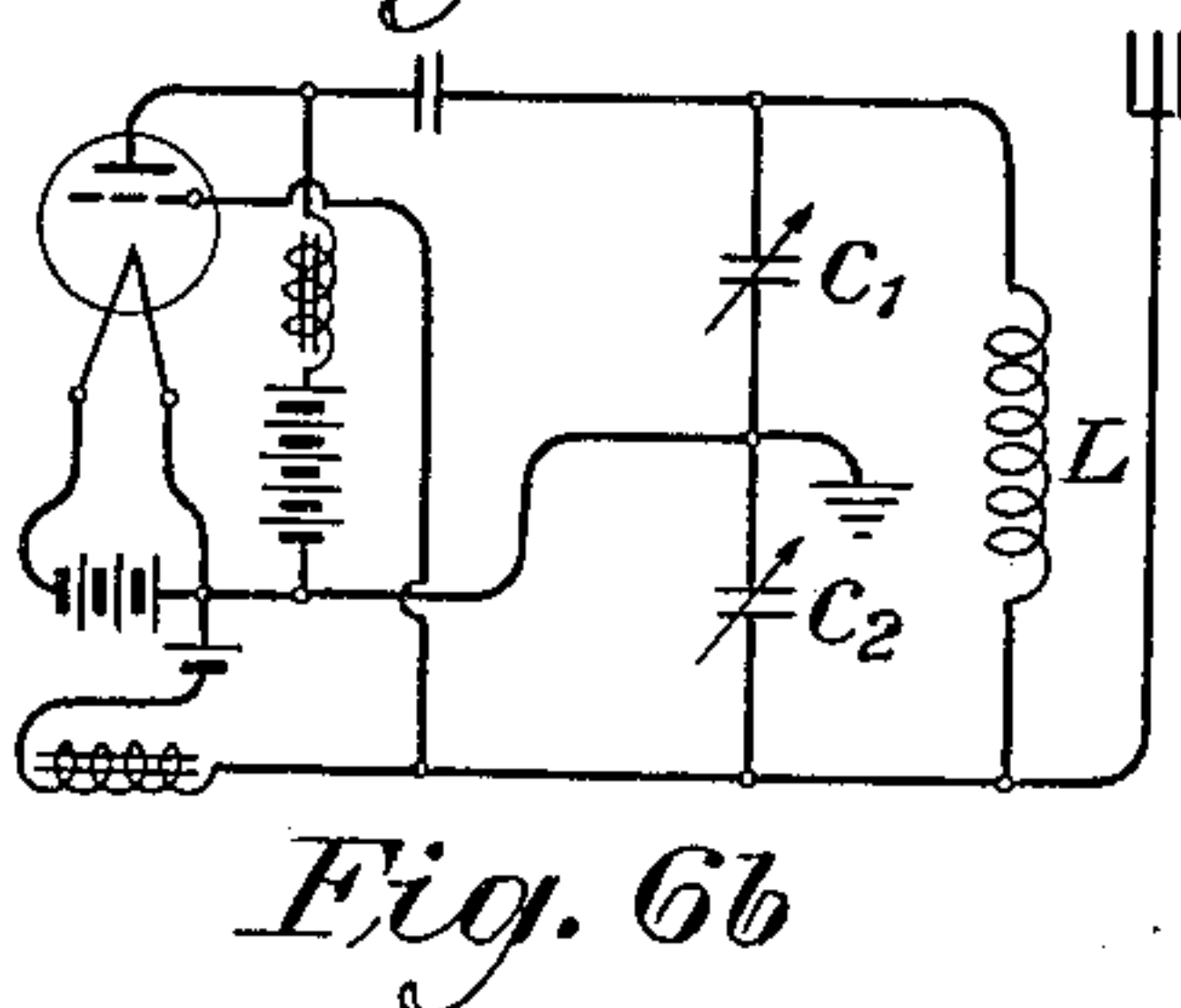
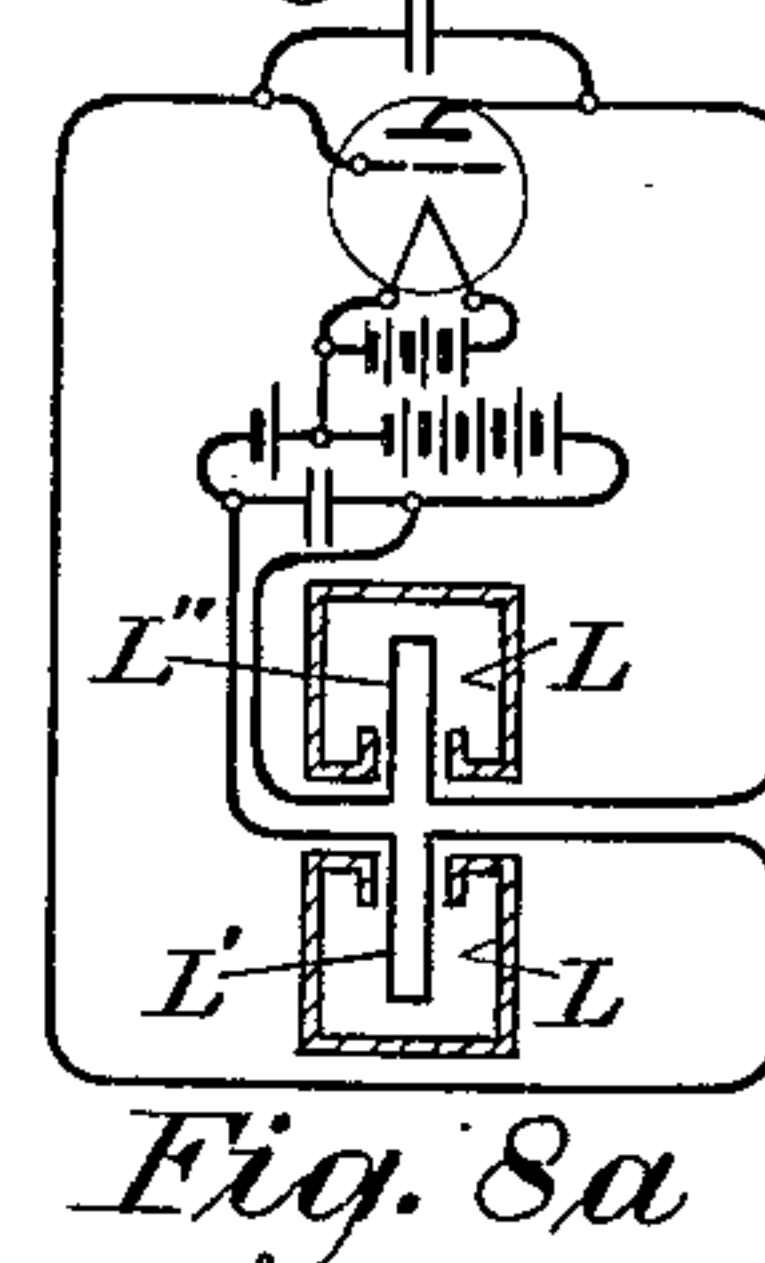
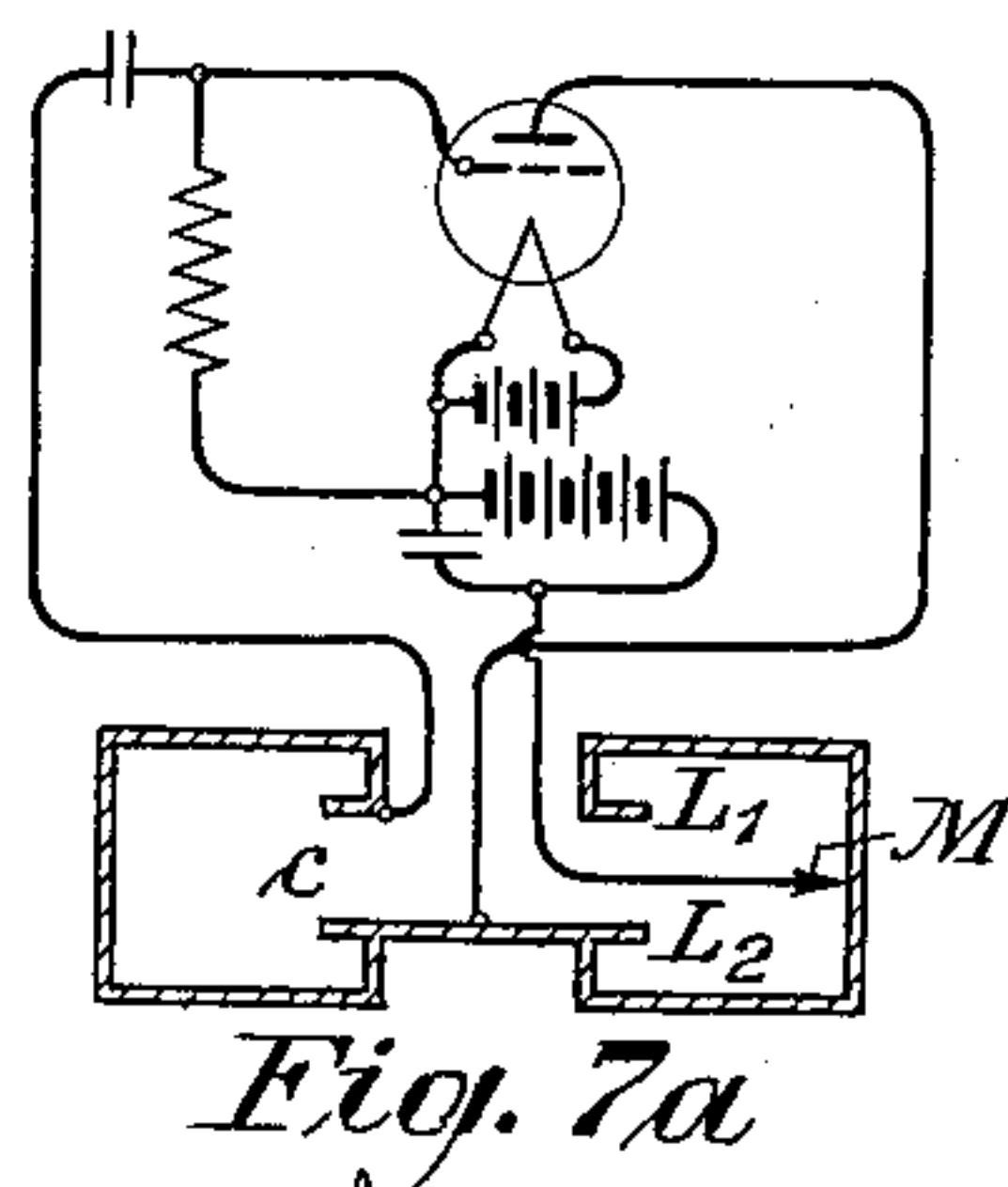
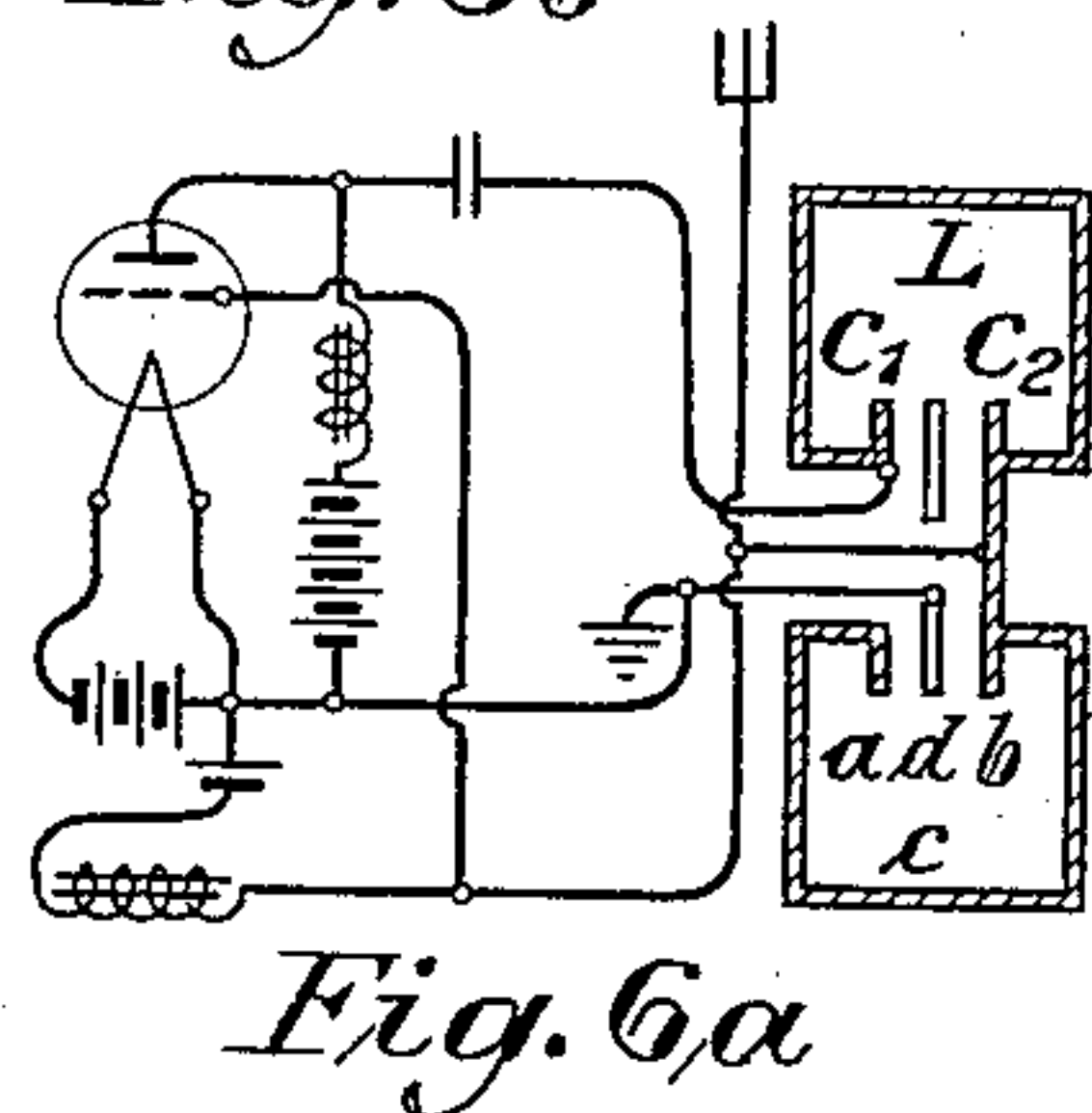
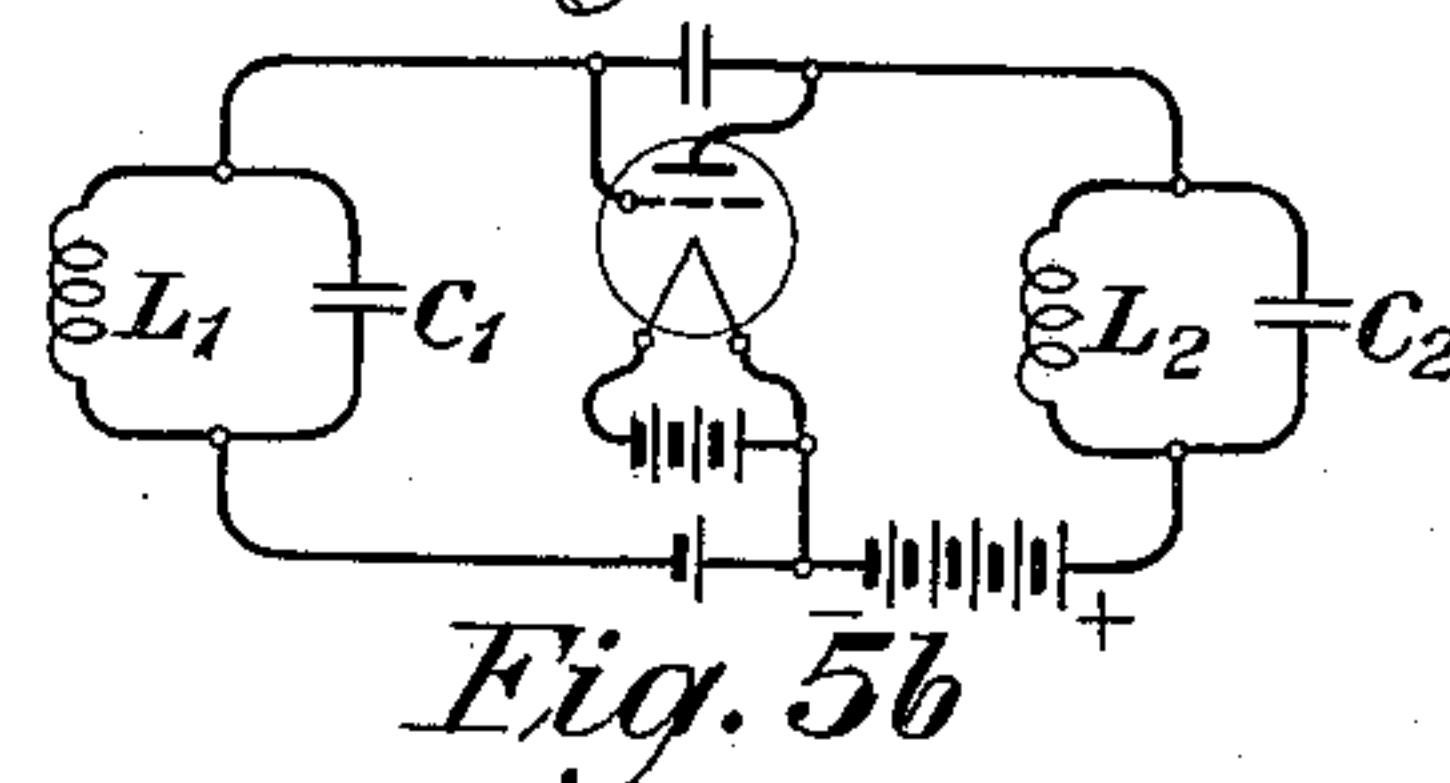
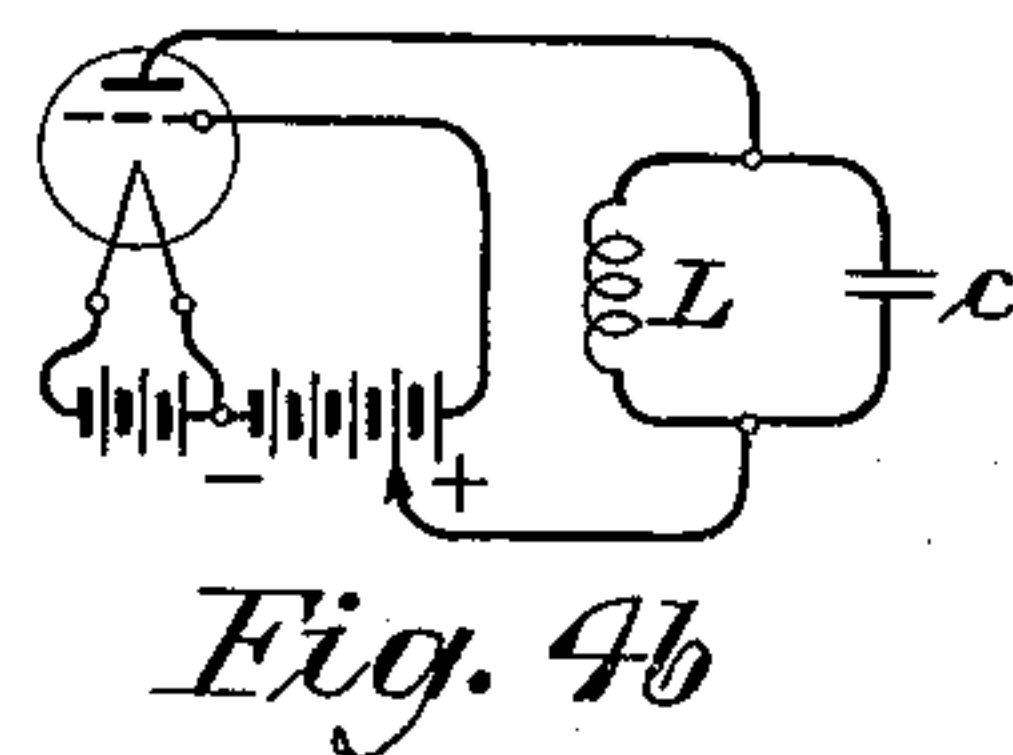
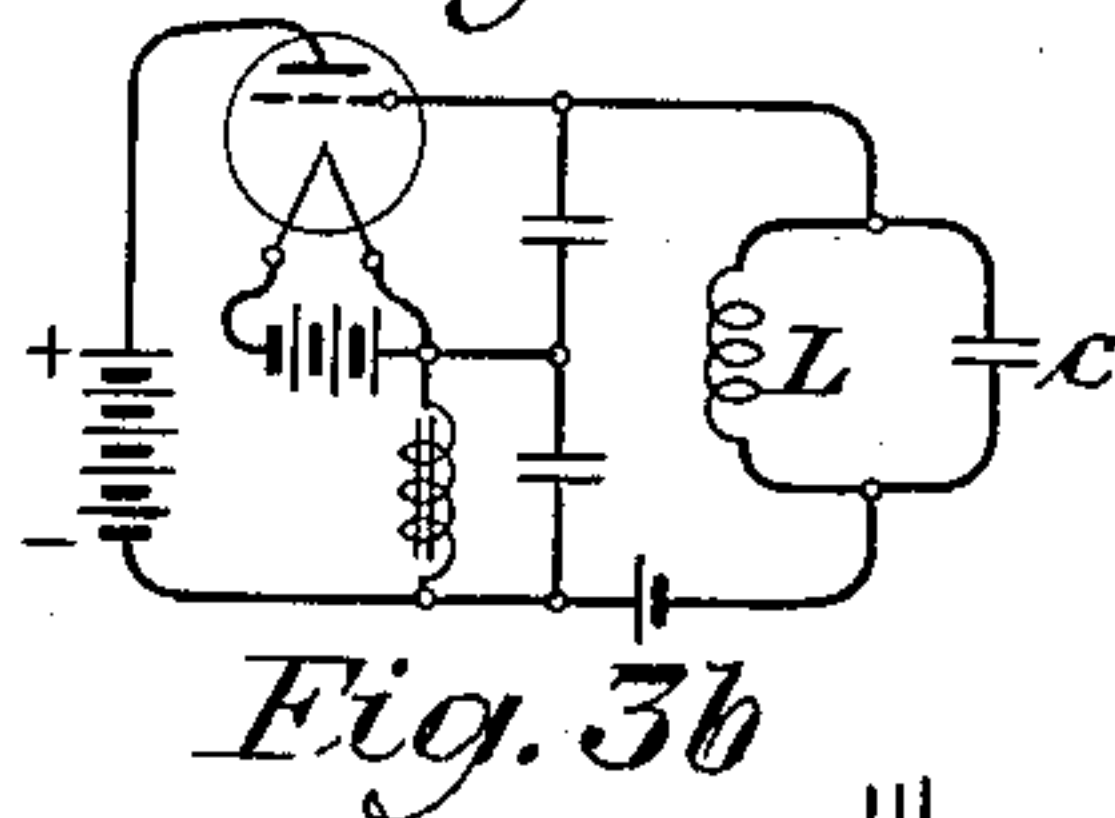
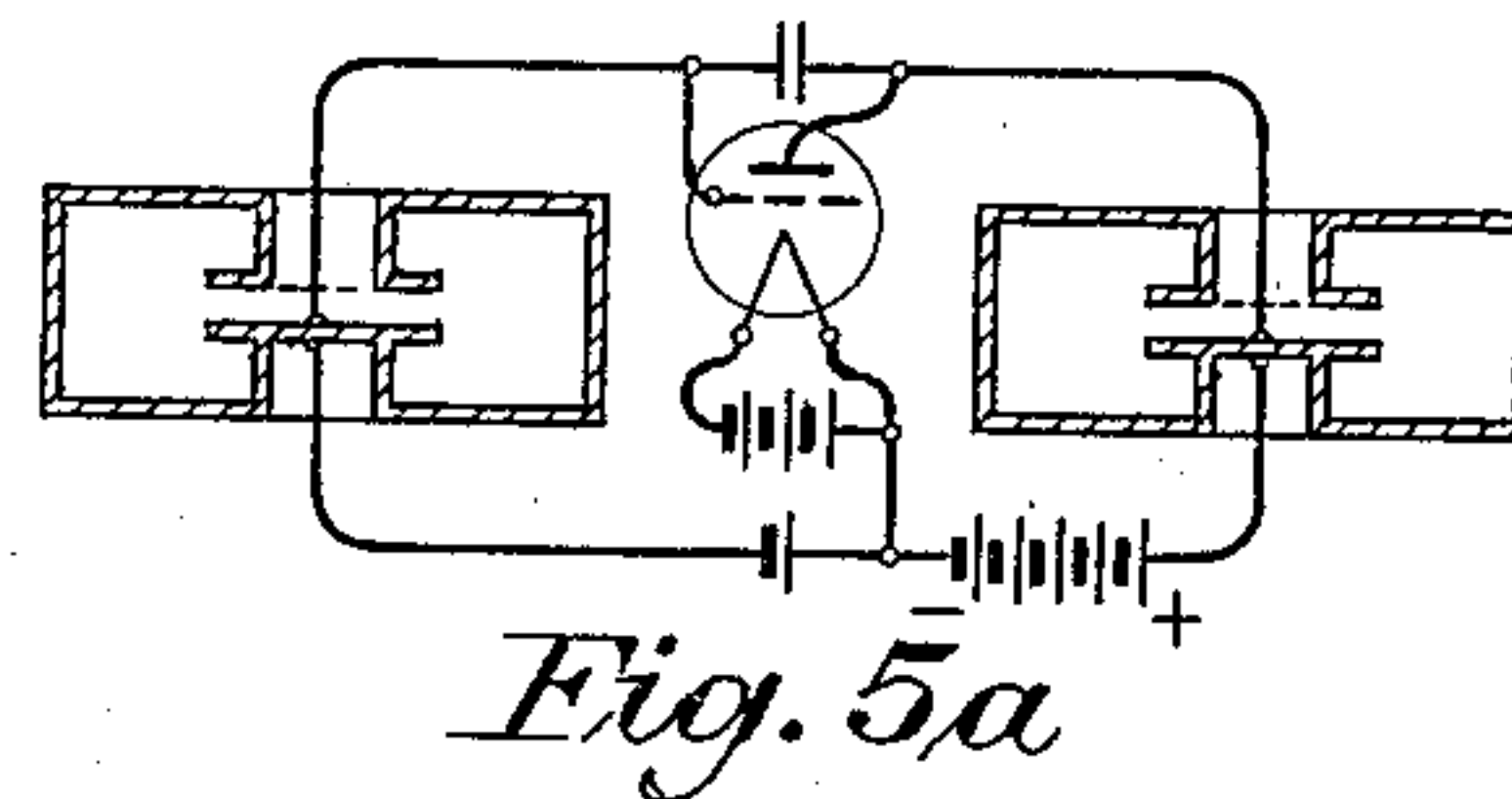
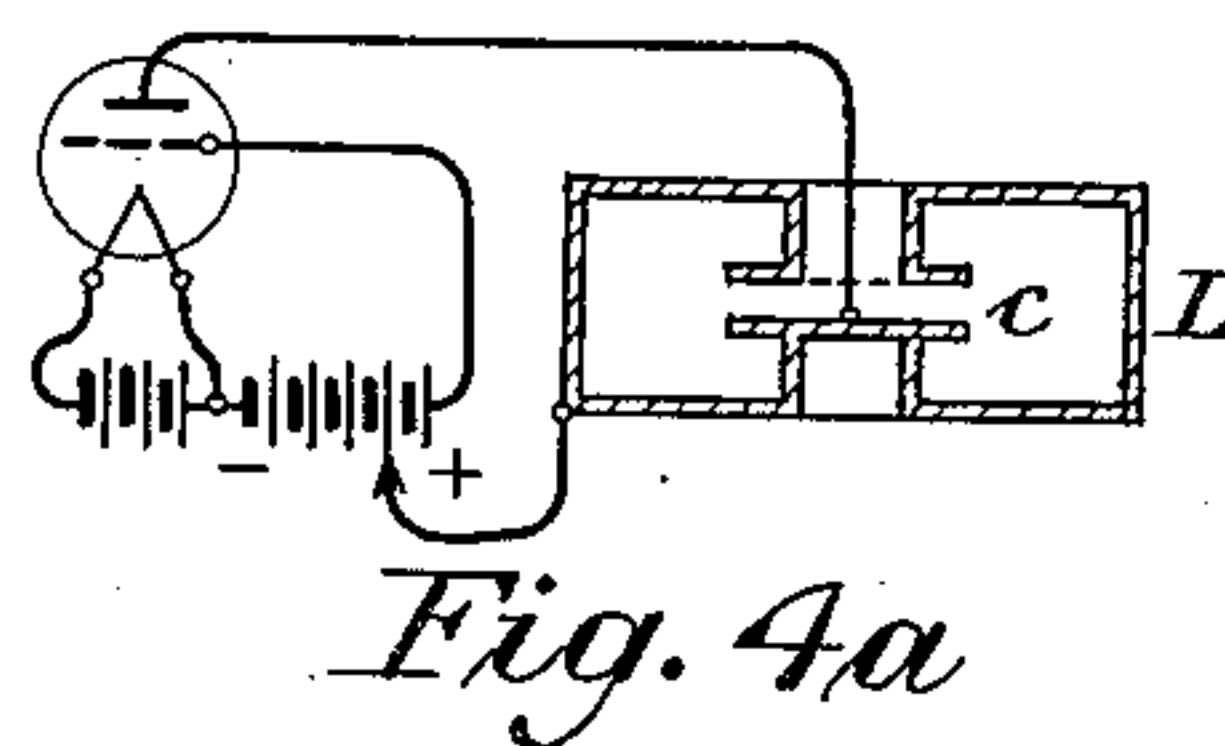
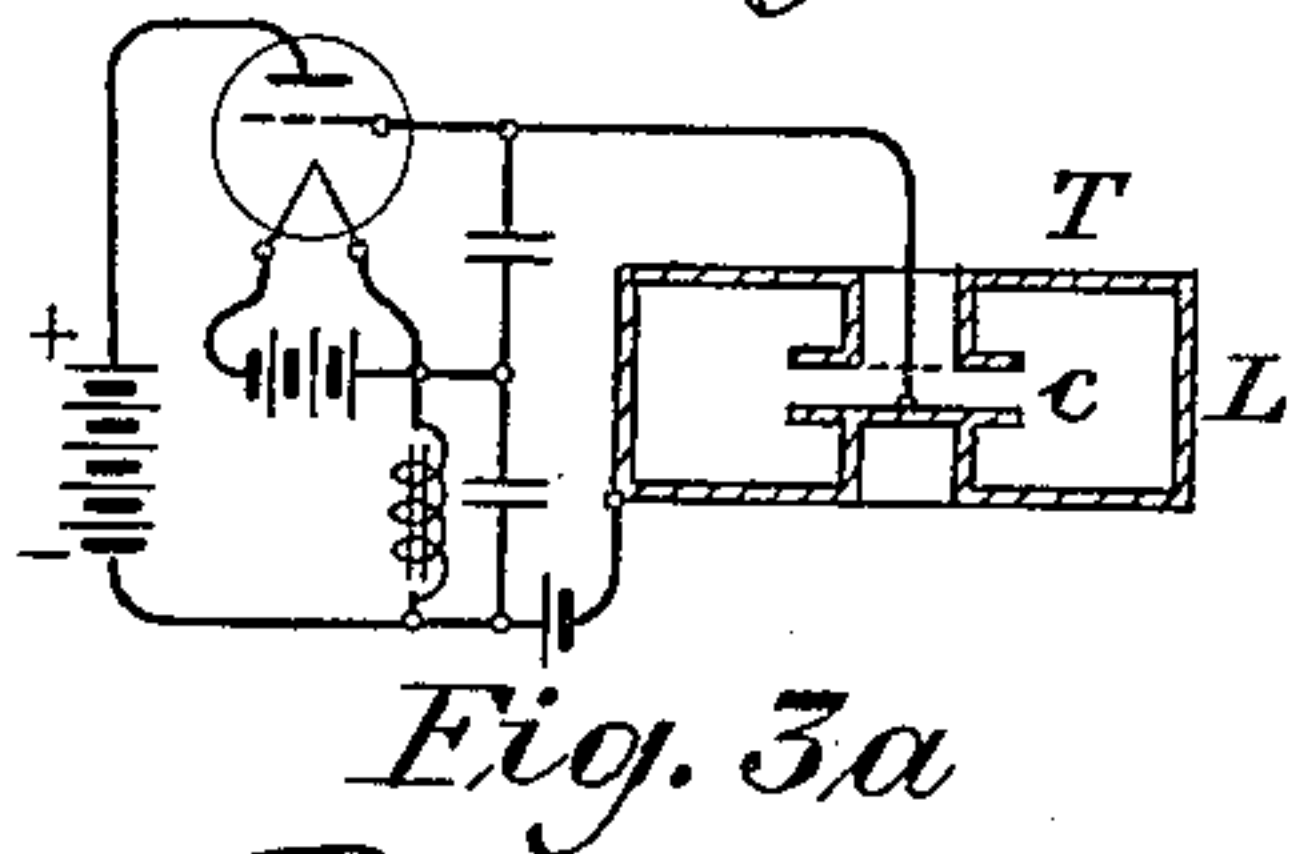
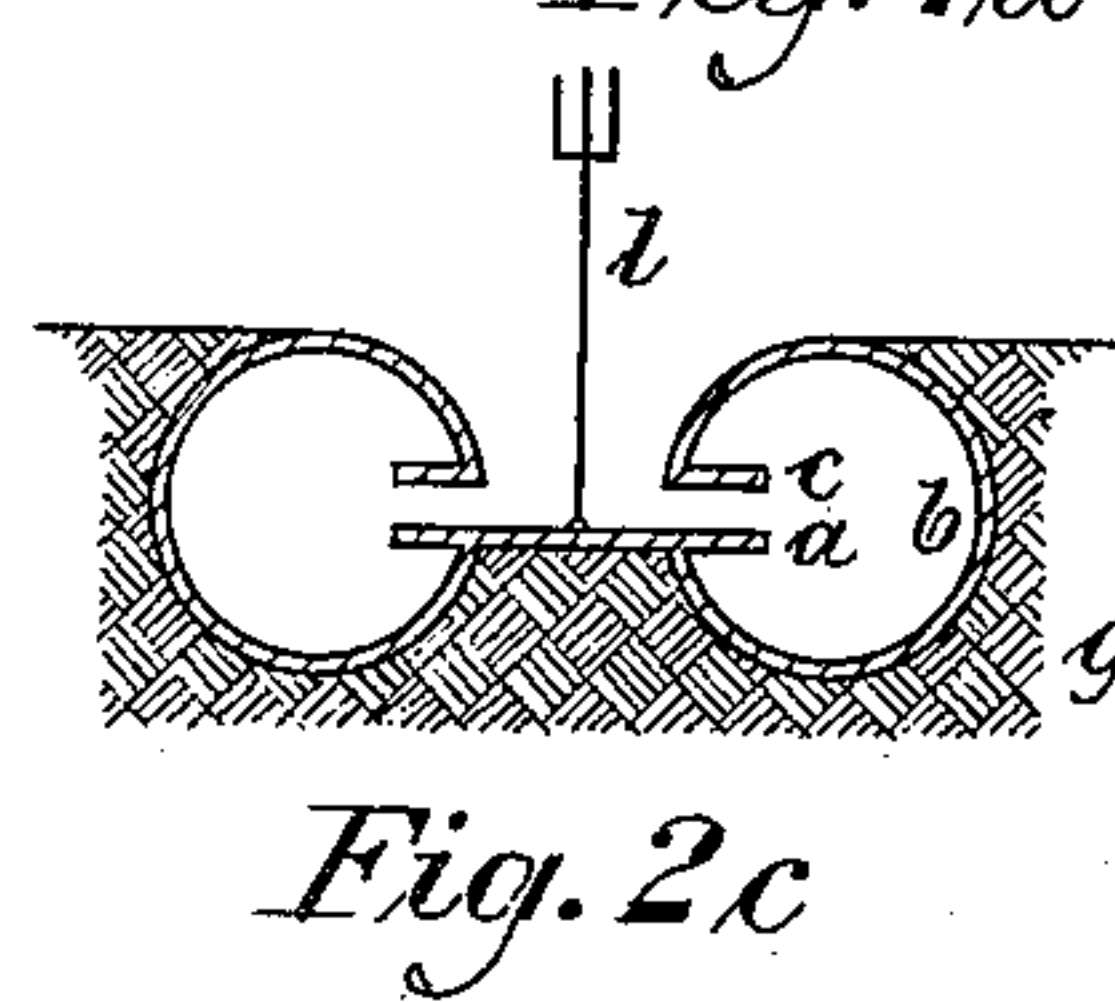
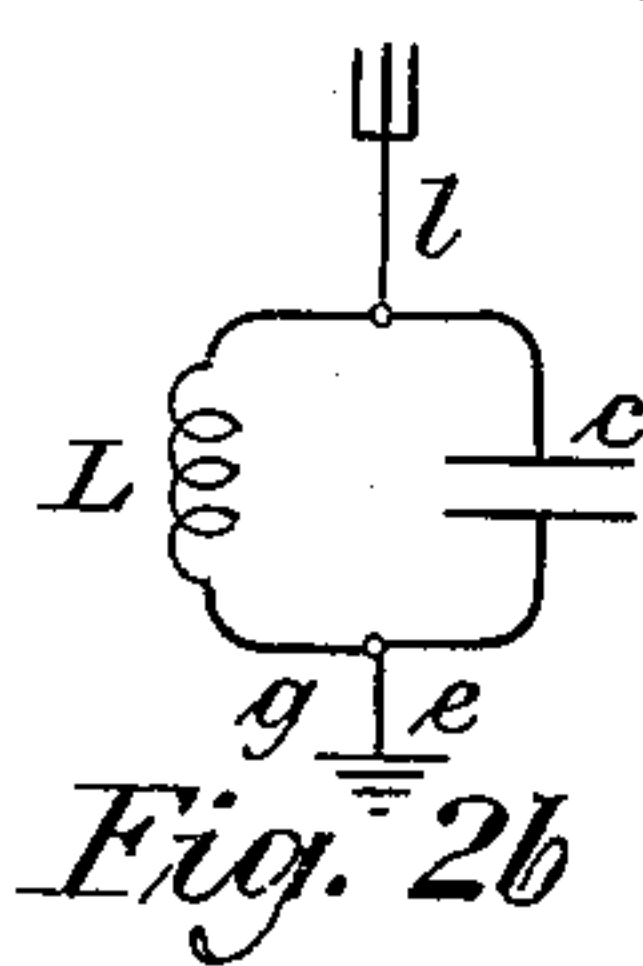
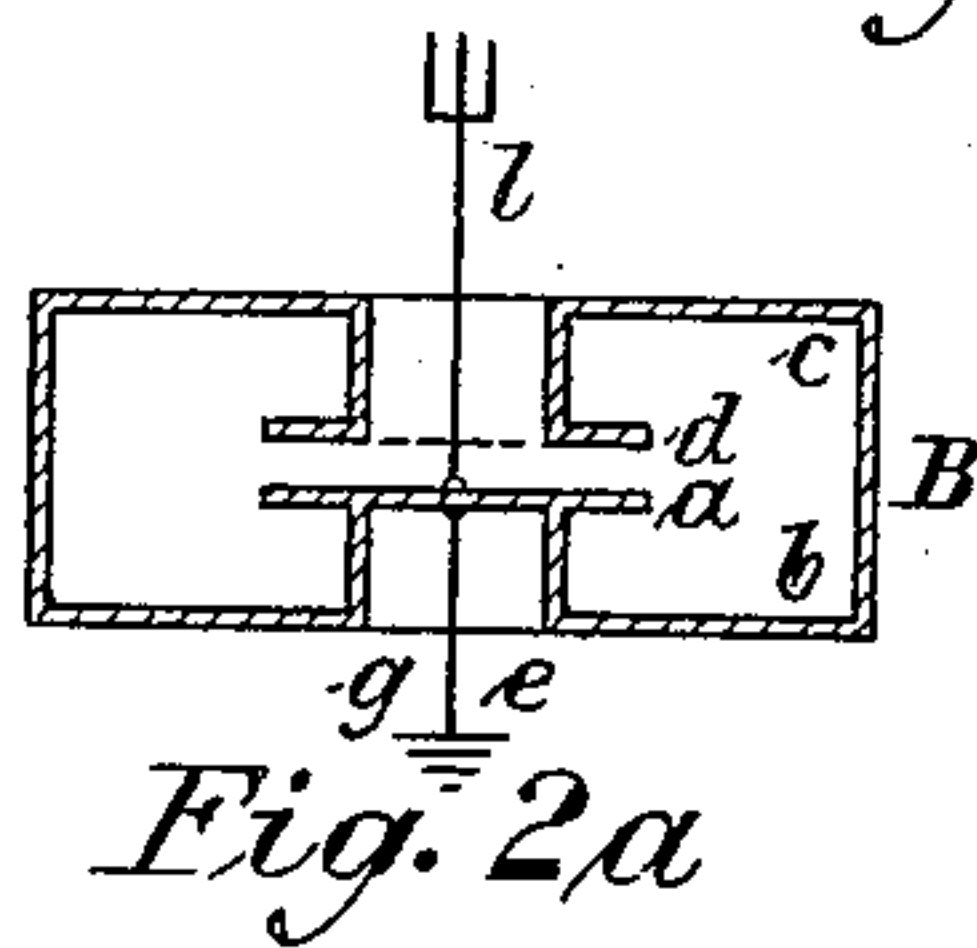
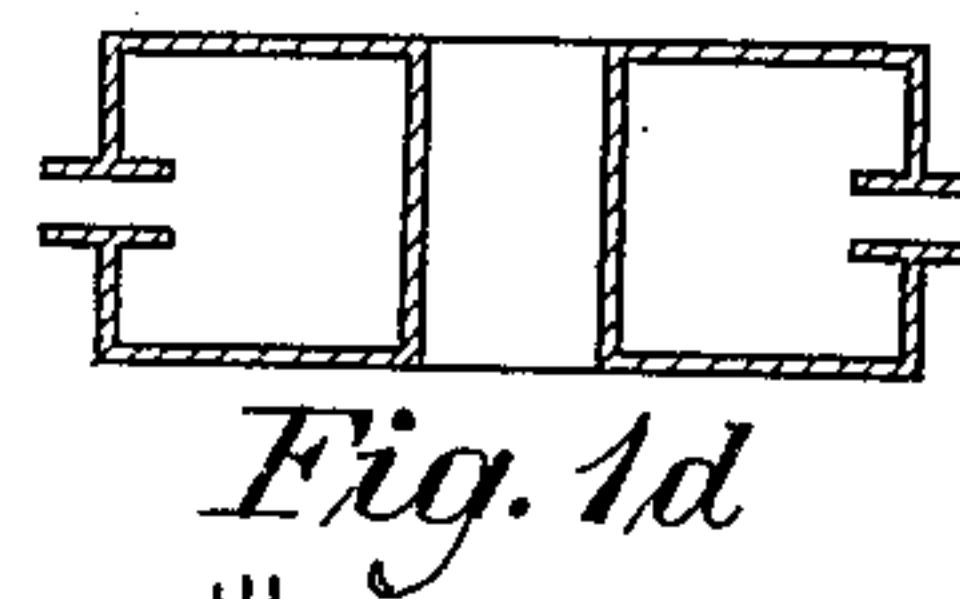
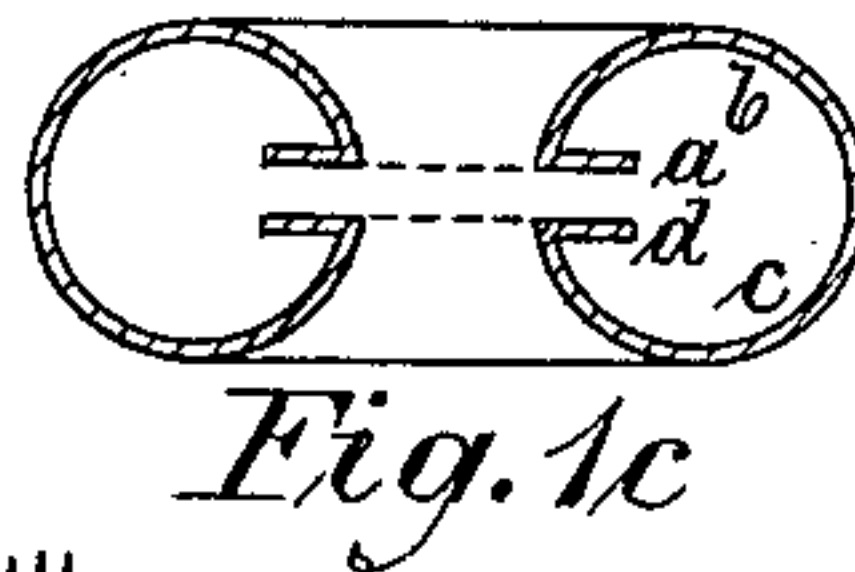
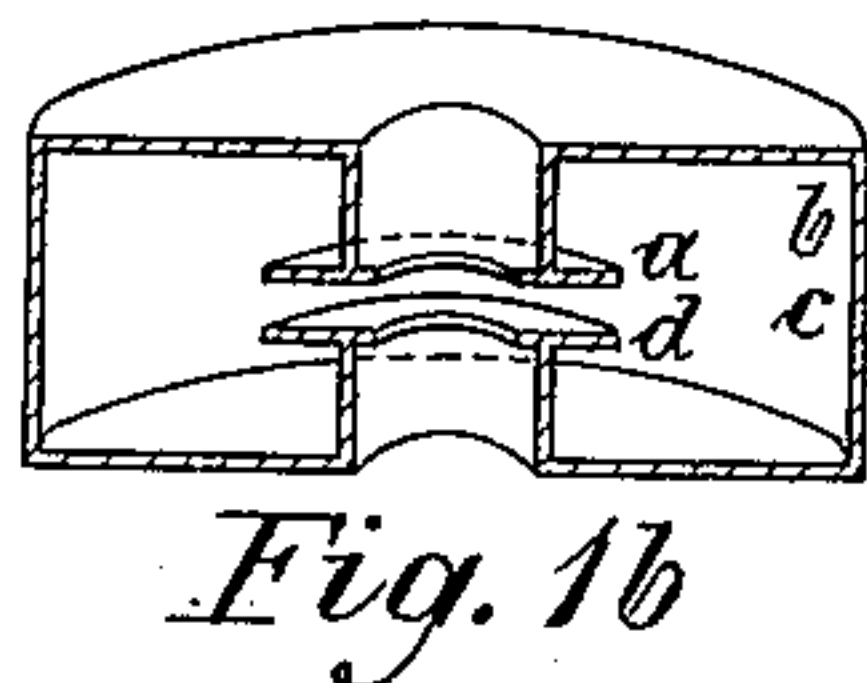
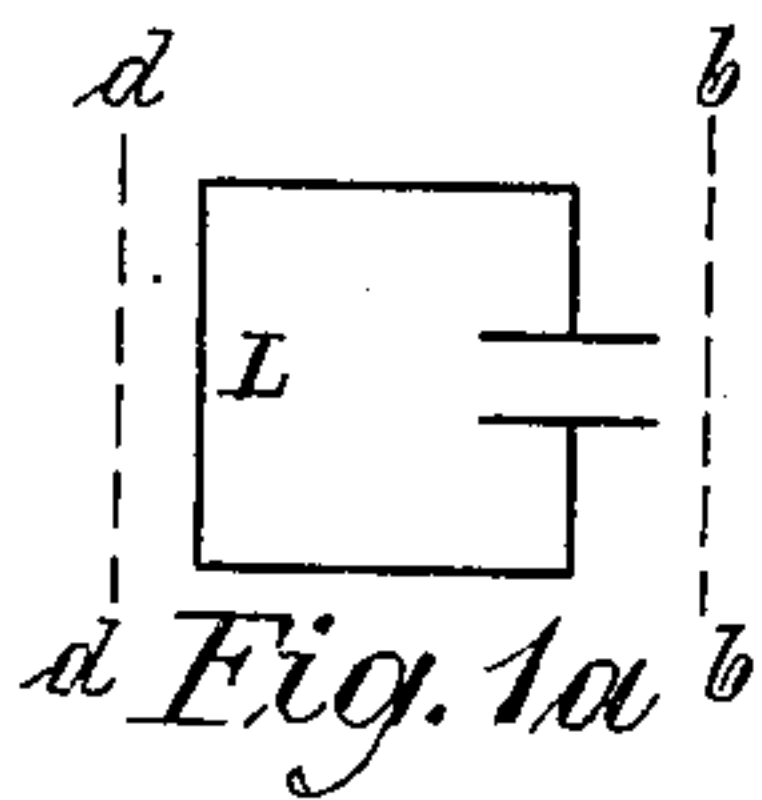
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2,107,387

VACUUM TUBE WITH TANK CIRCUITS

Filed June 12, 1936

3 Sheets-Sheet 1



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2,107,387

VACUUM TUBE WITH TANK CIRCUITS

Filed June 12, 1936

3 Sheets-Sheet 2

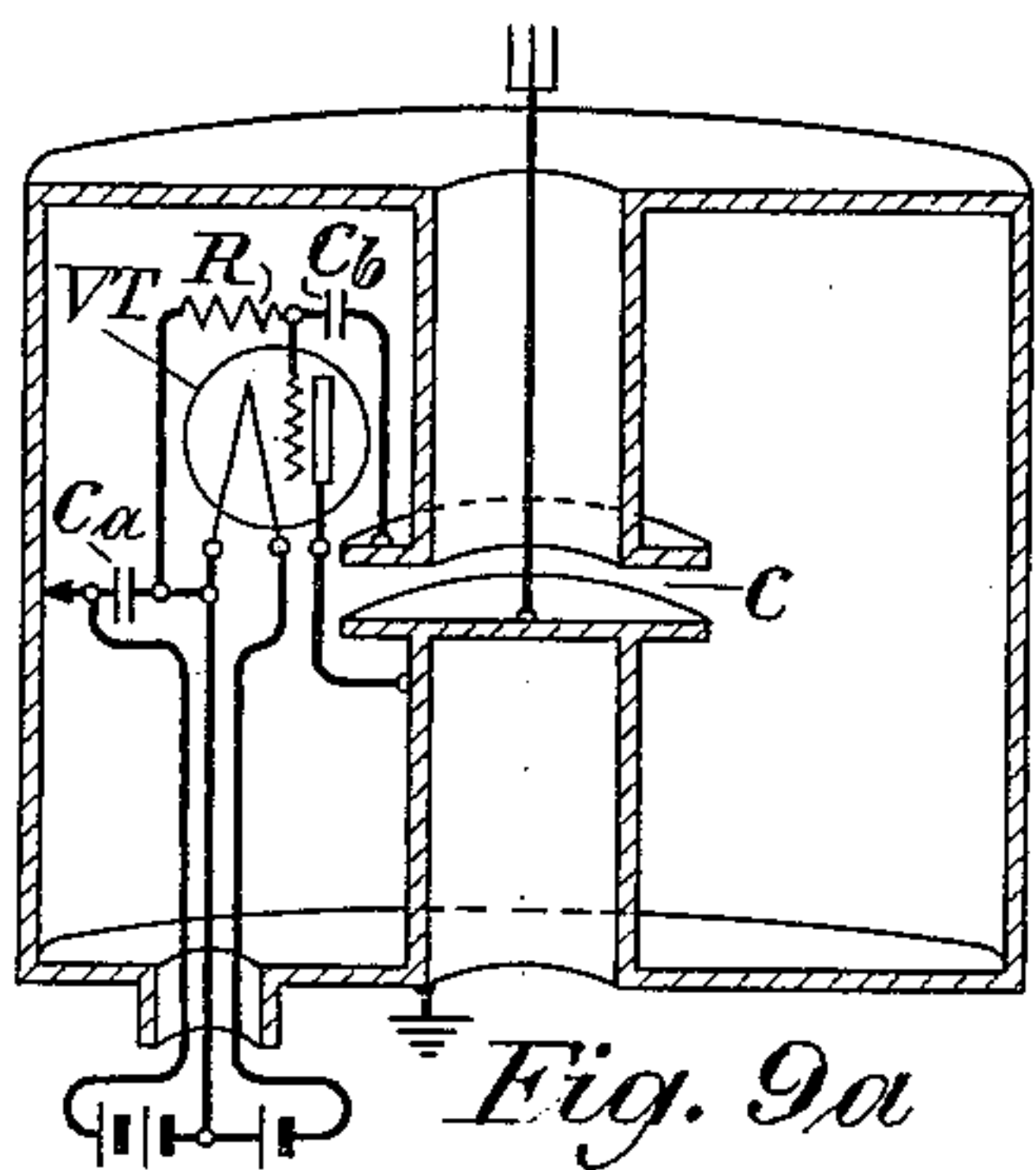


Fig. 9a

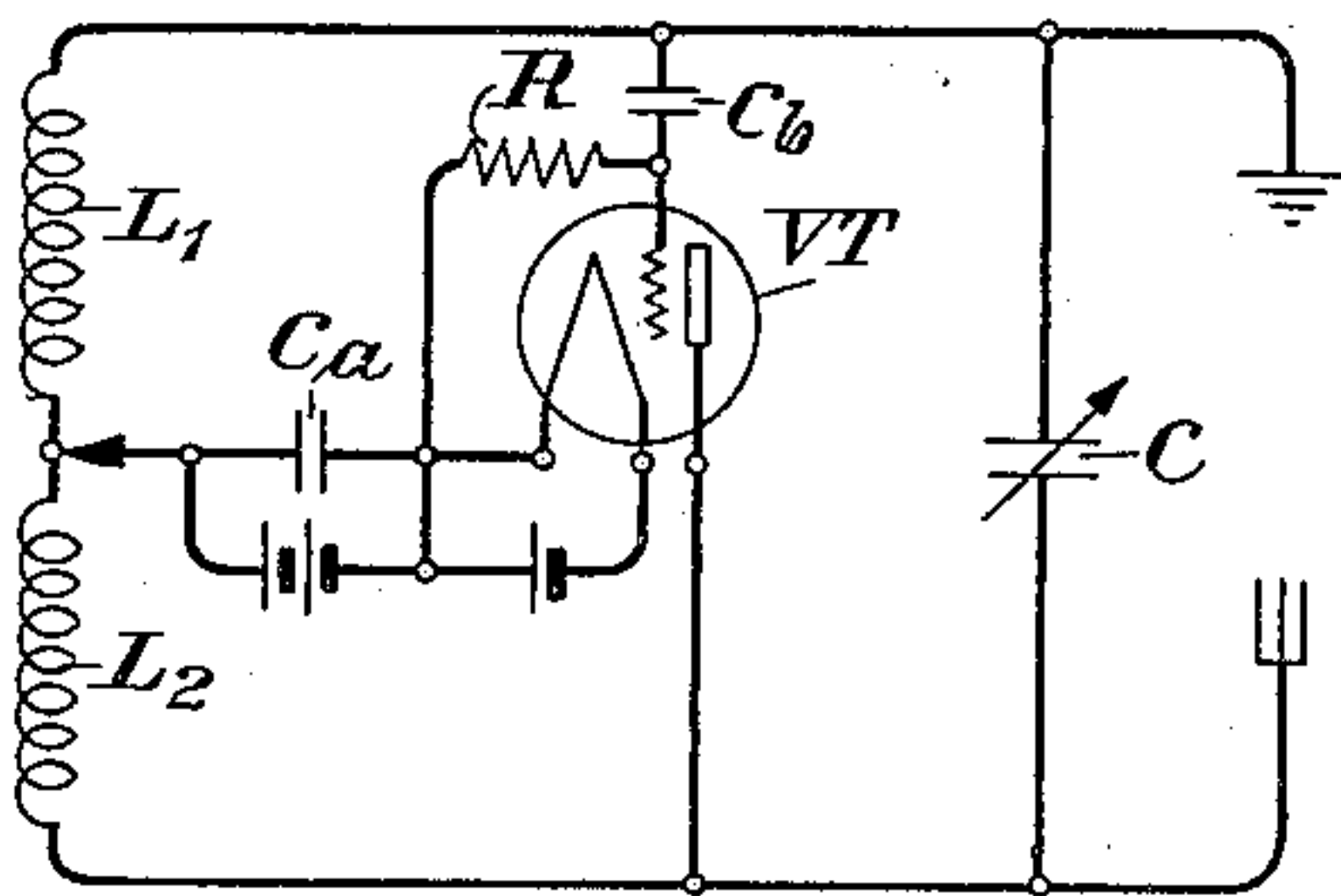


Fig. 9b

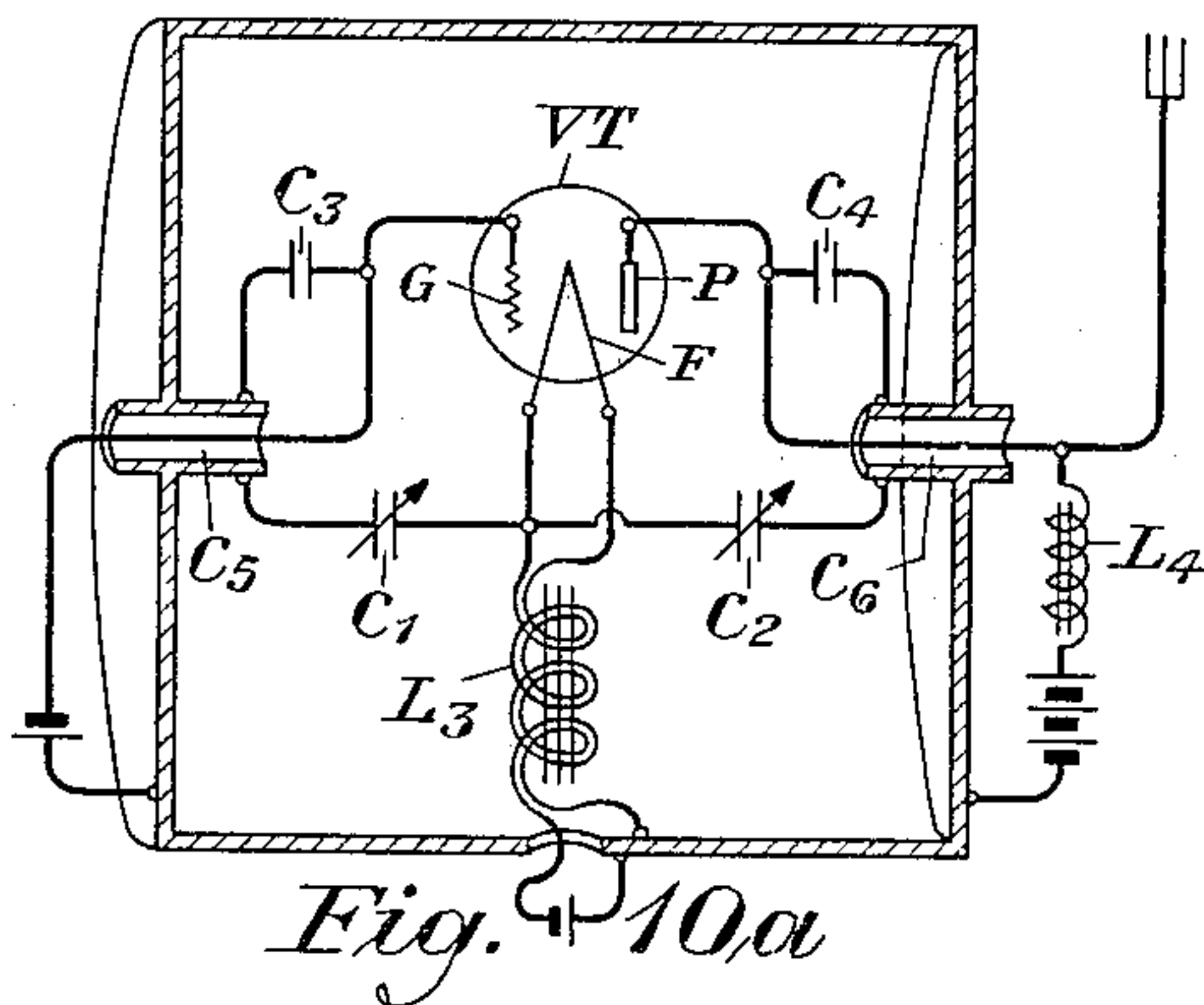


Fig. 10a

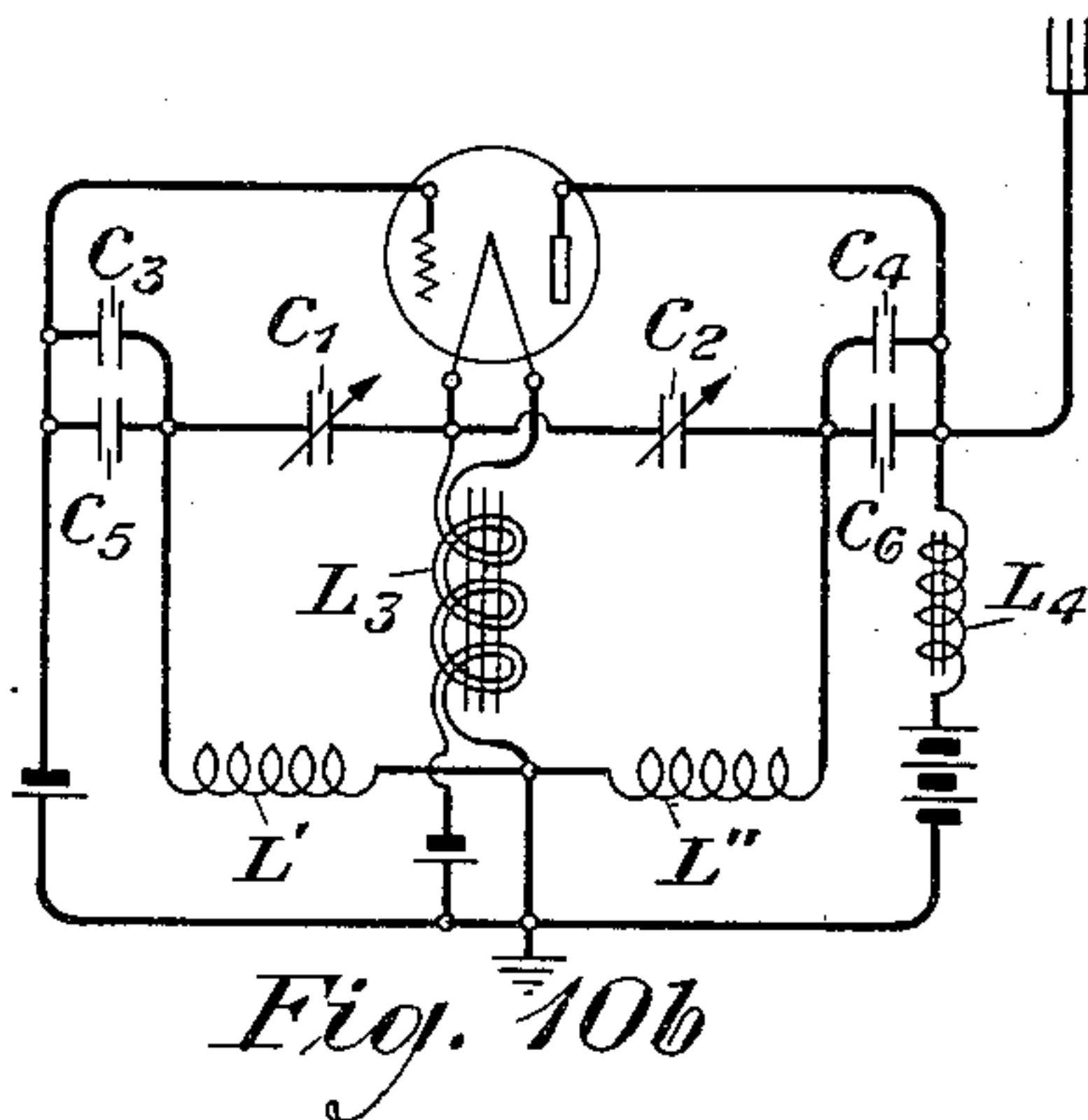


Fig. 10b

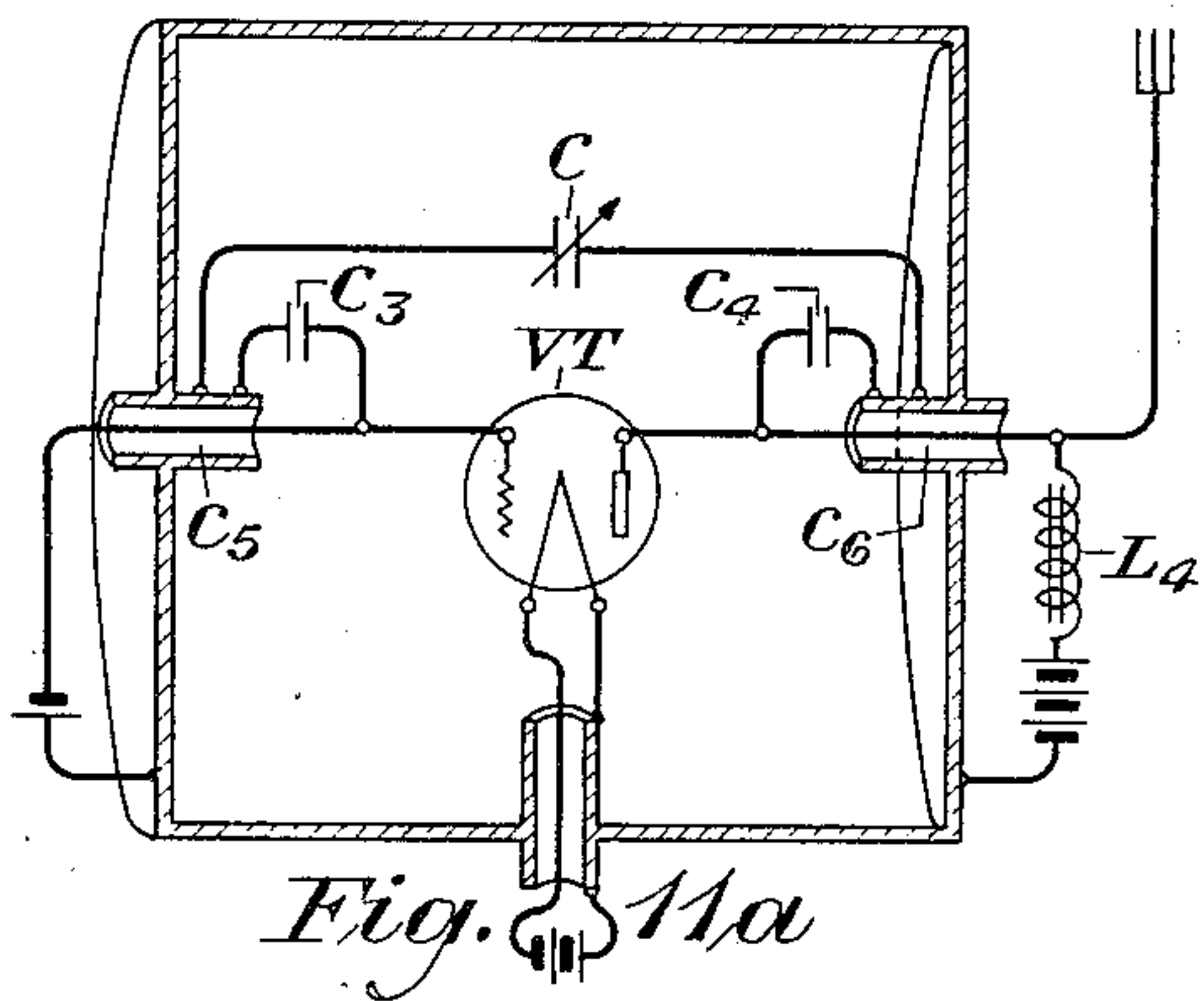


Fig. 11a

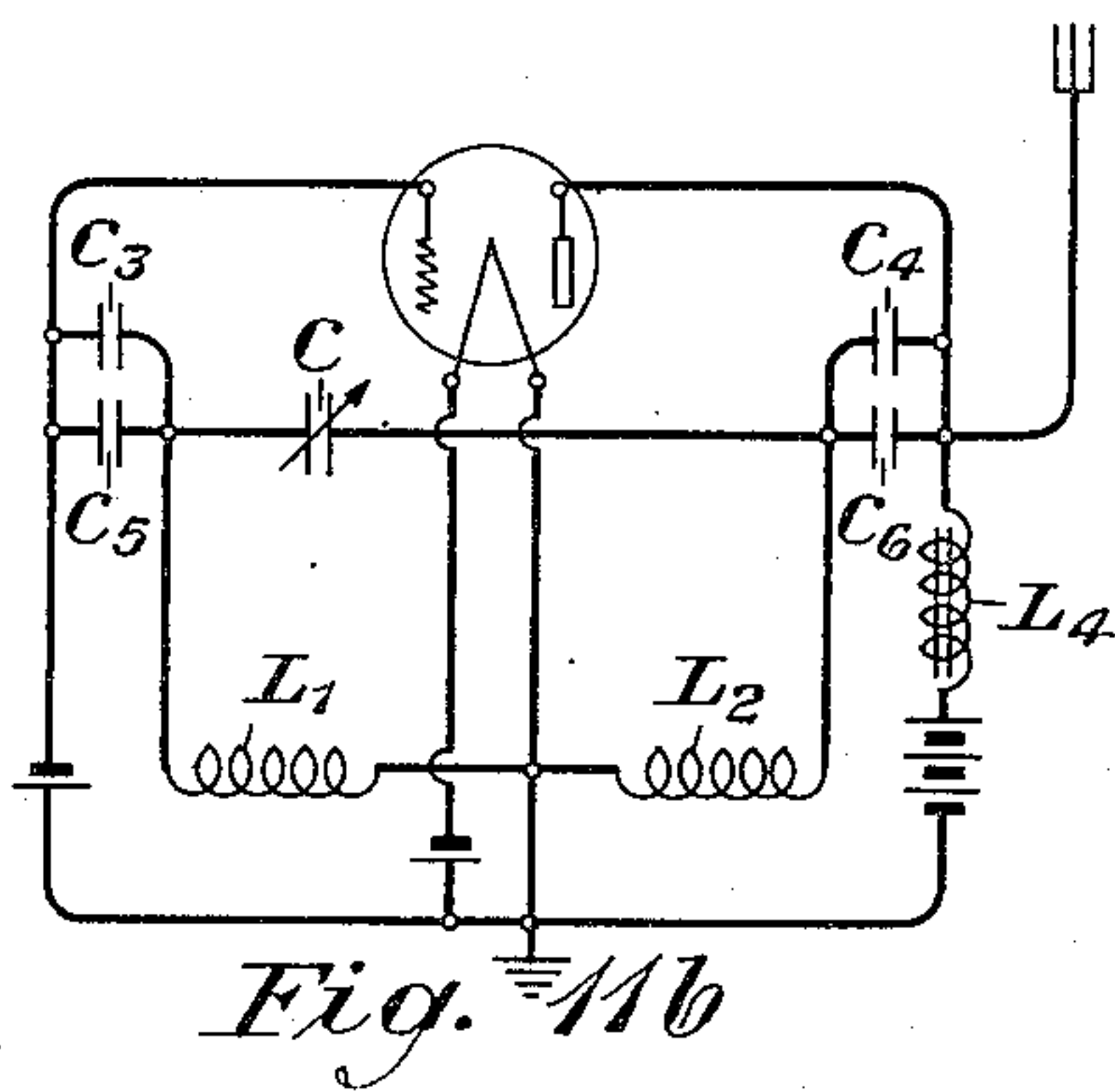


Fig. 11b

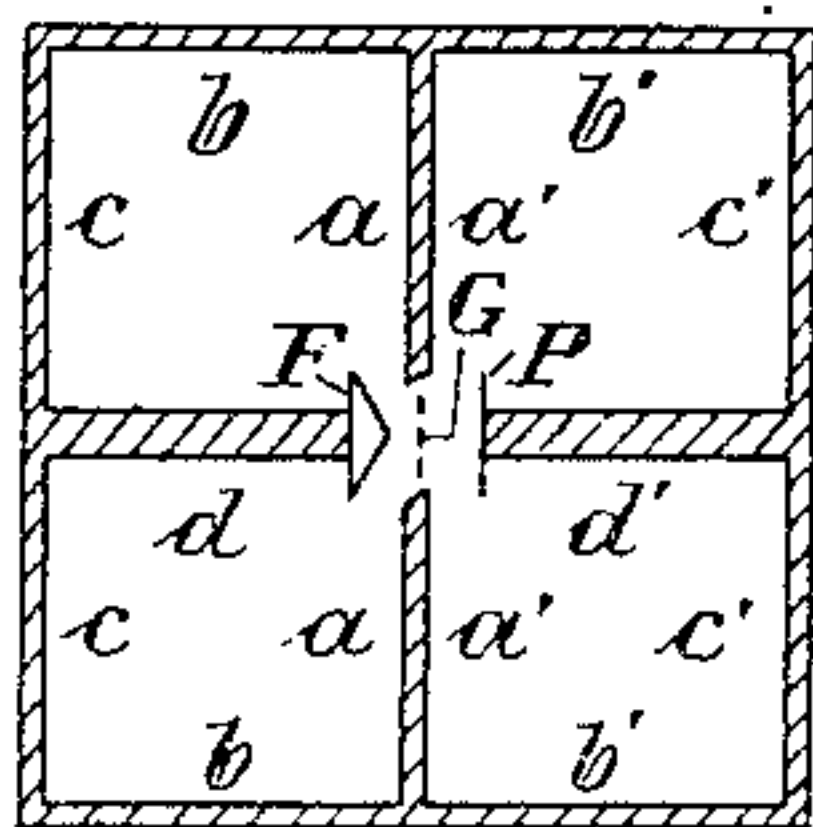


Fig. 12a

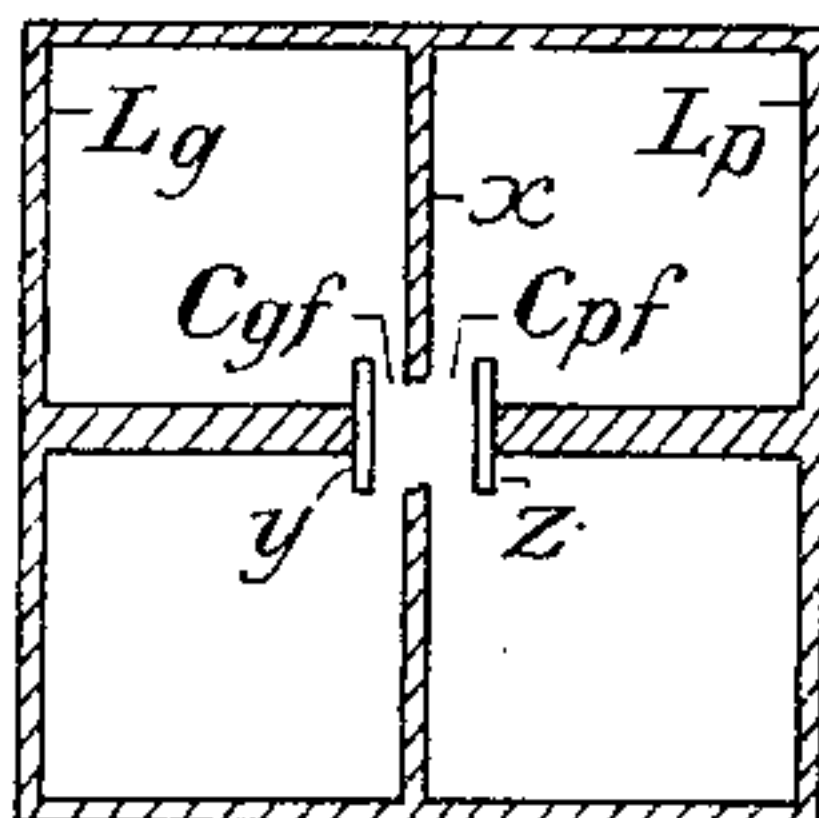


Fig. 12b

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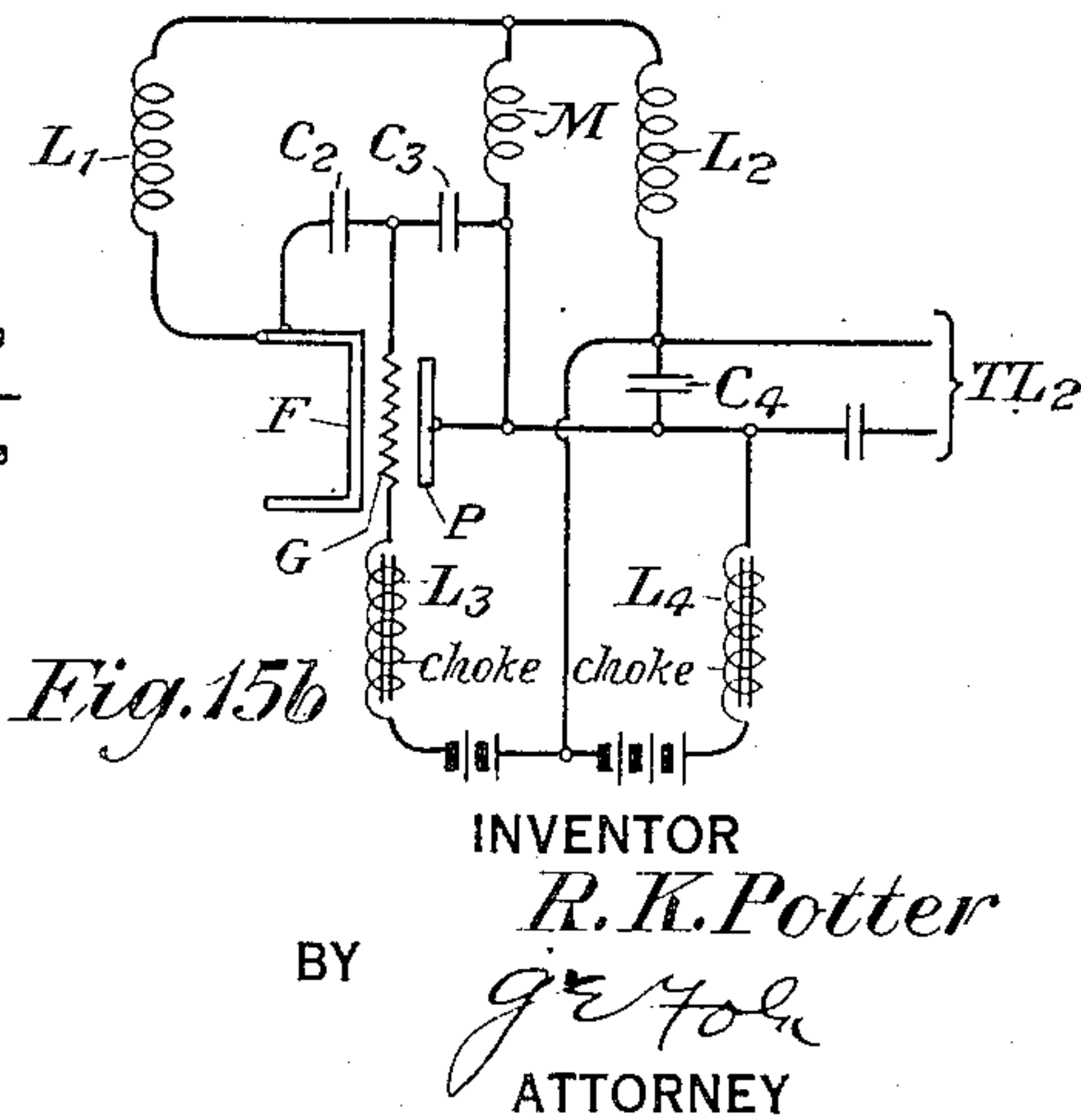
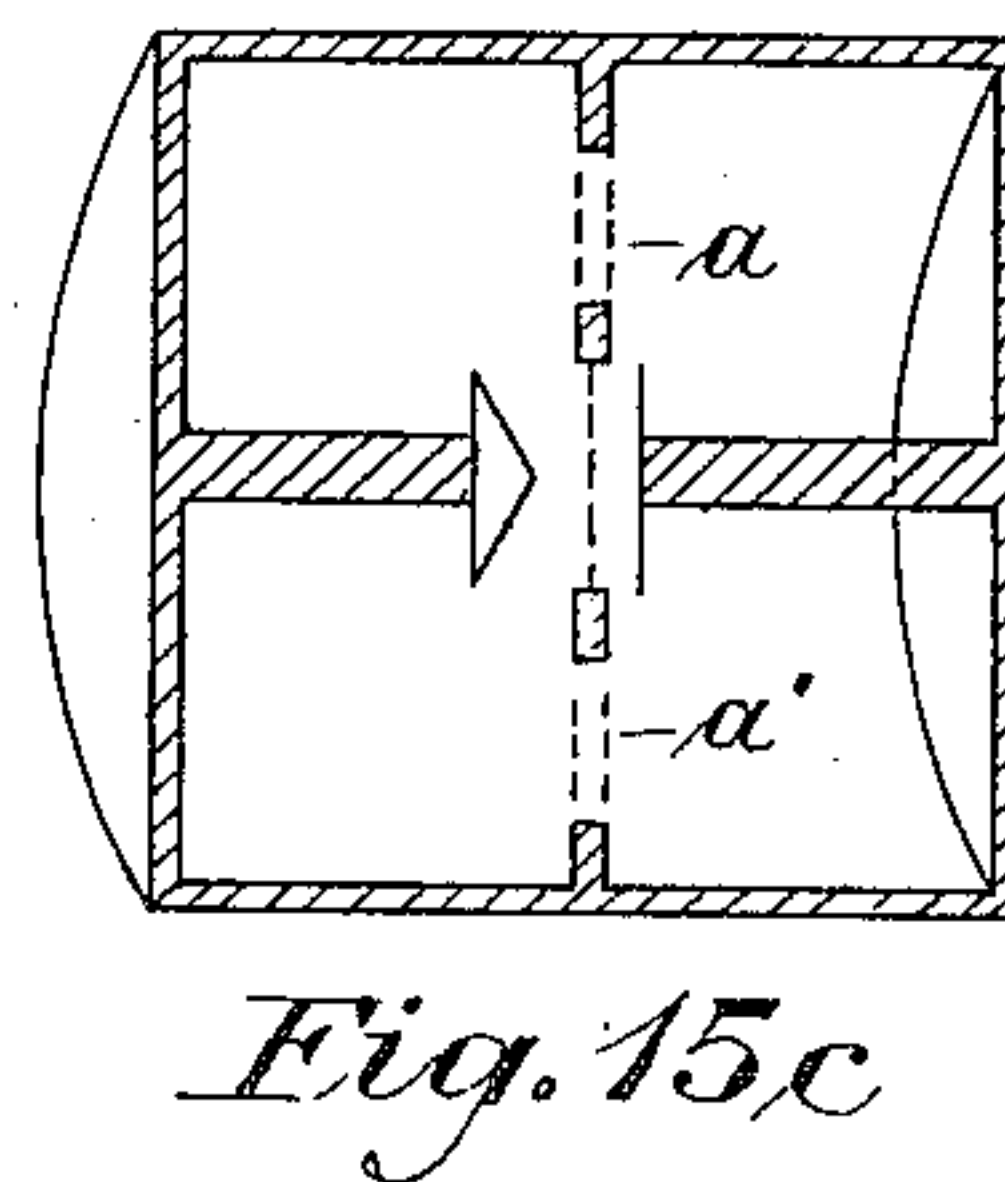
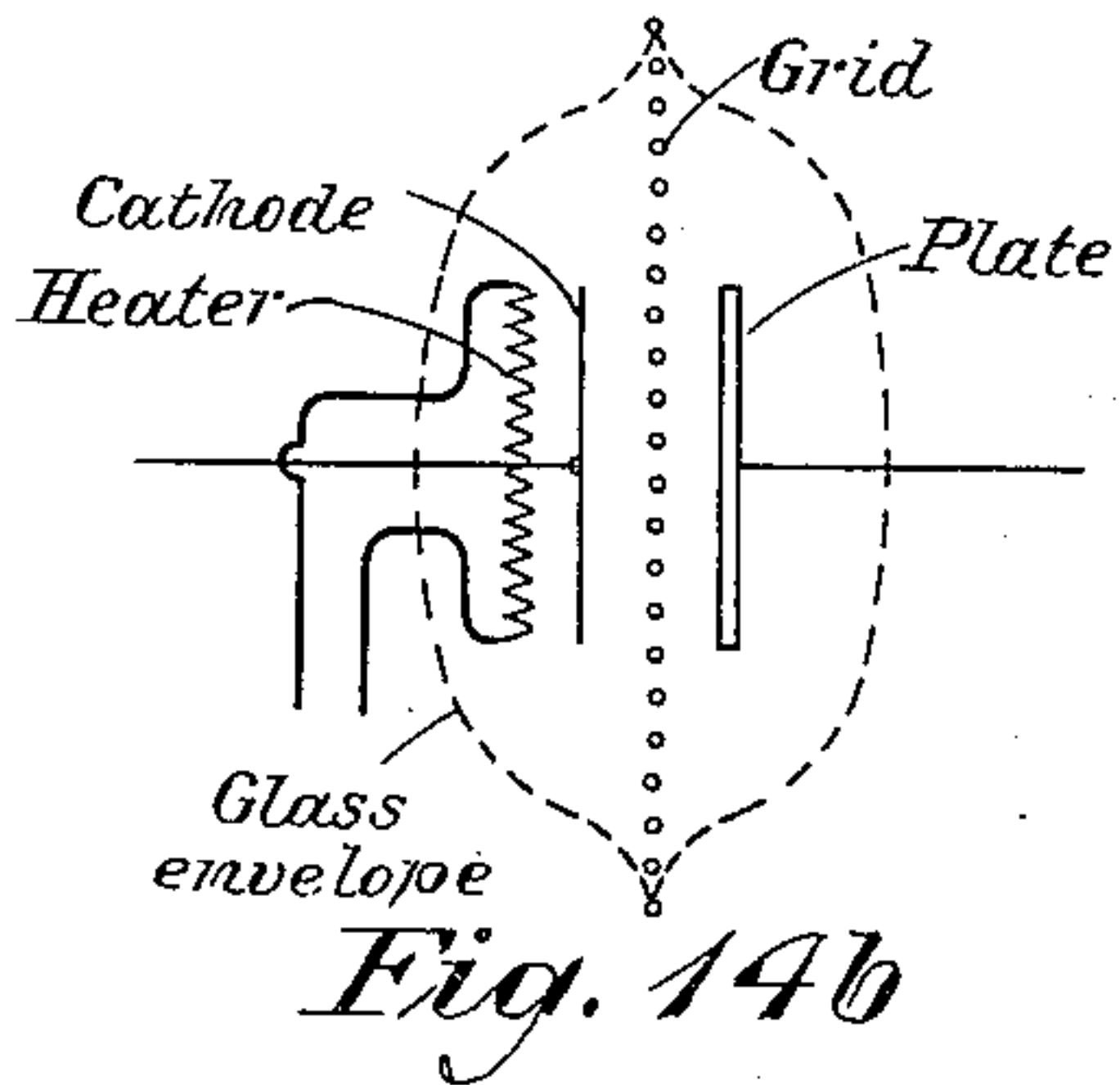
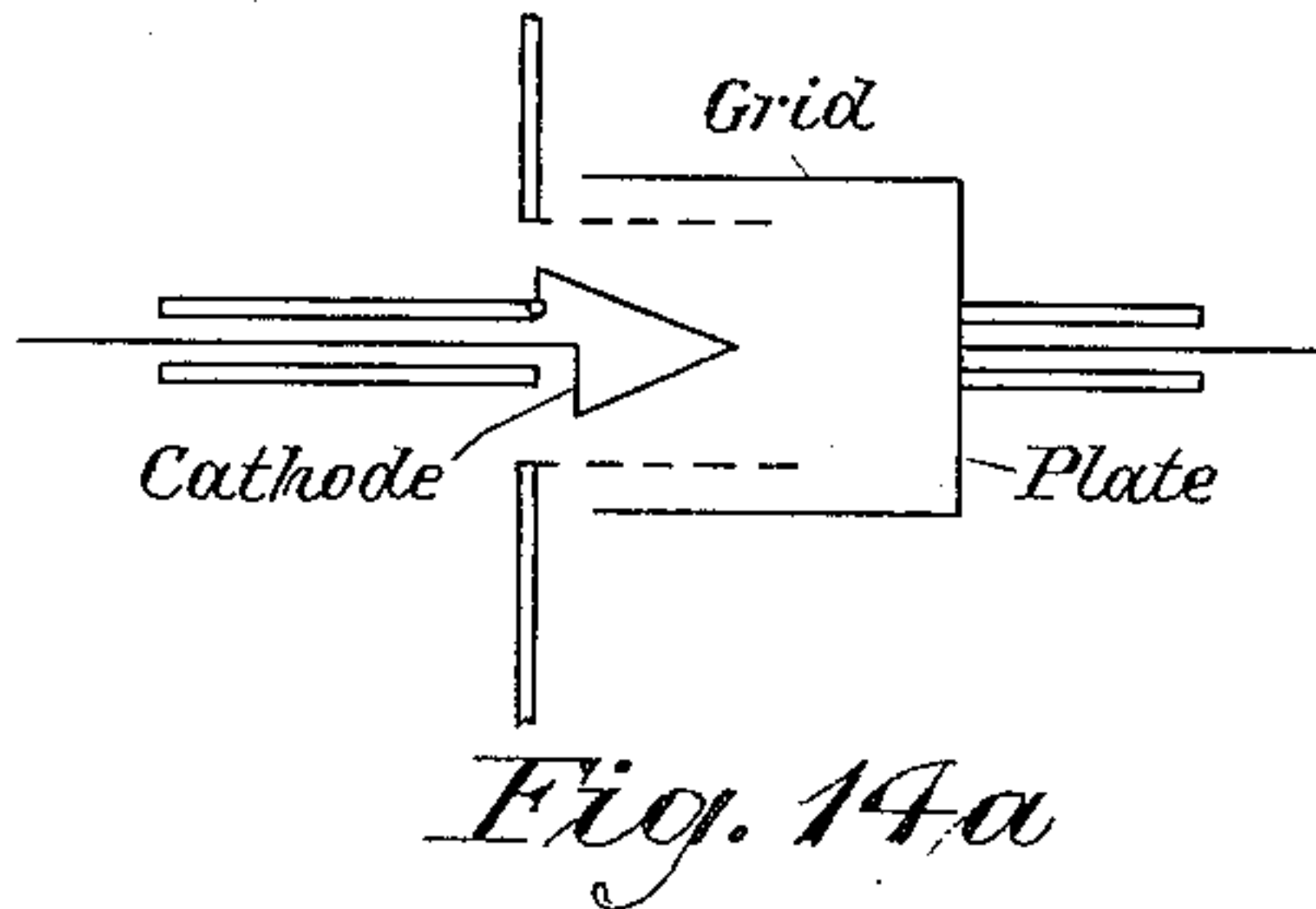
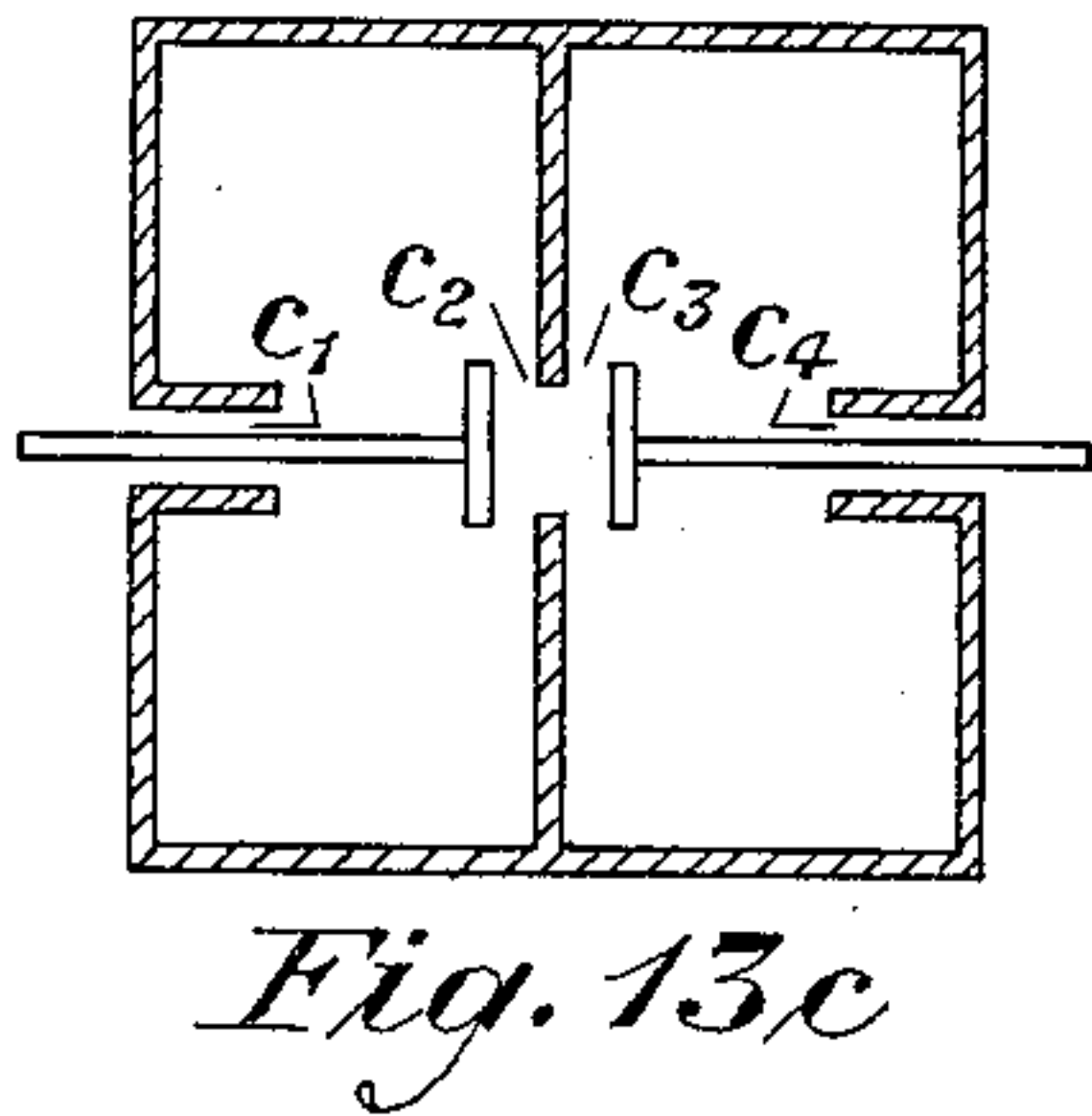
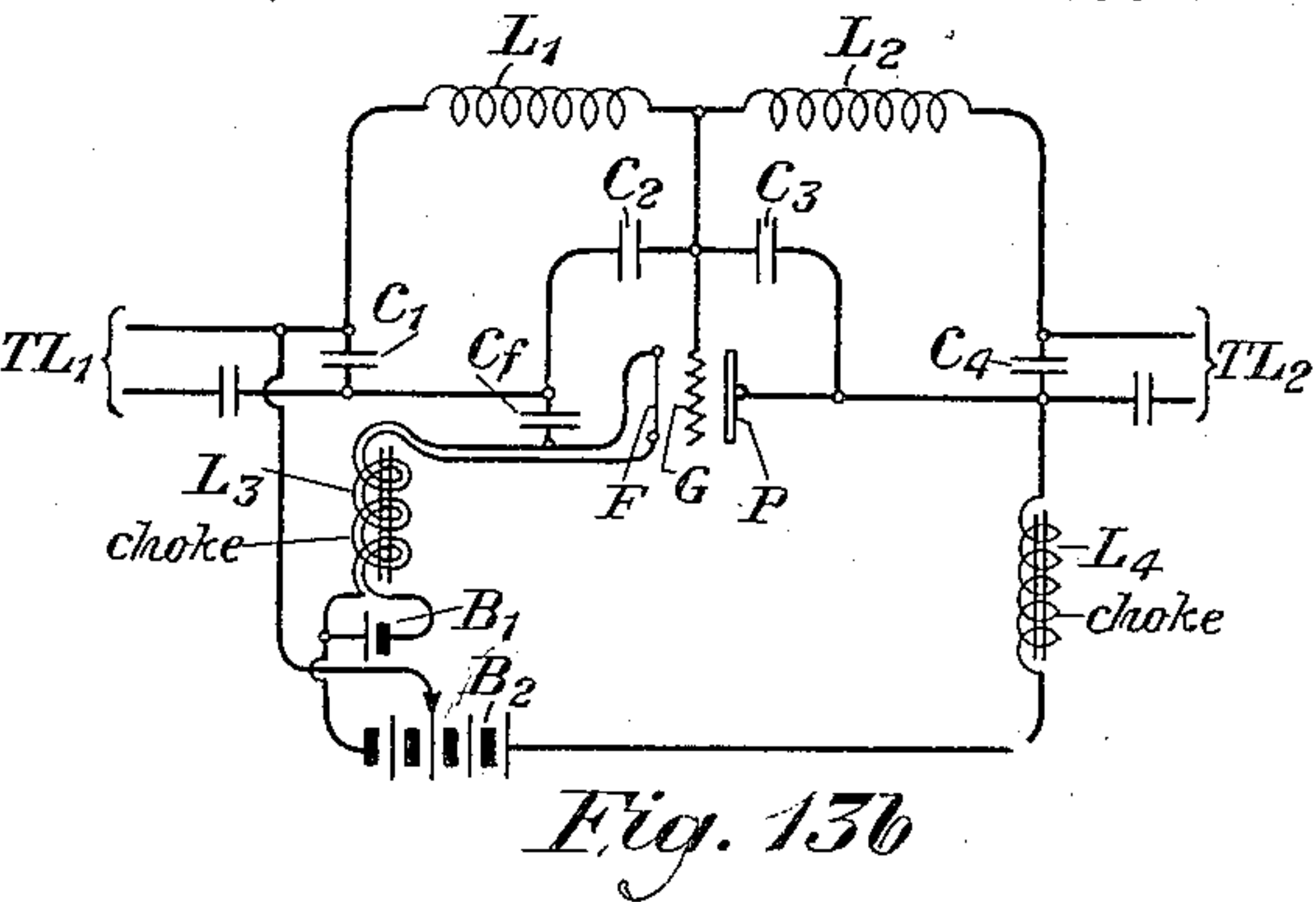
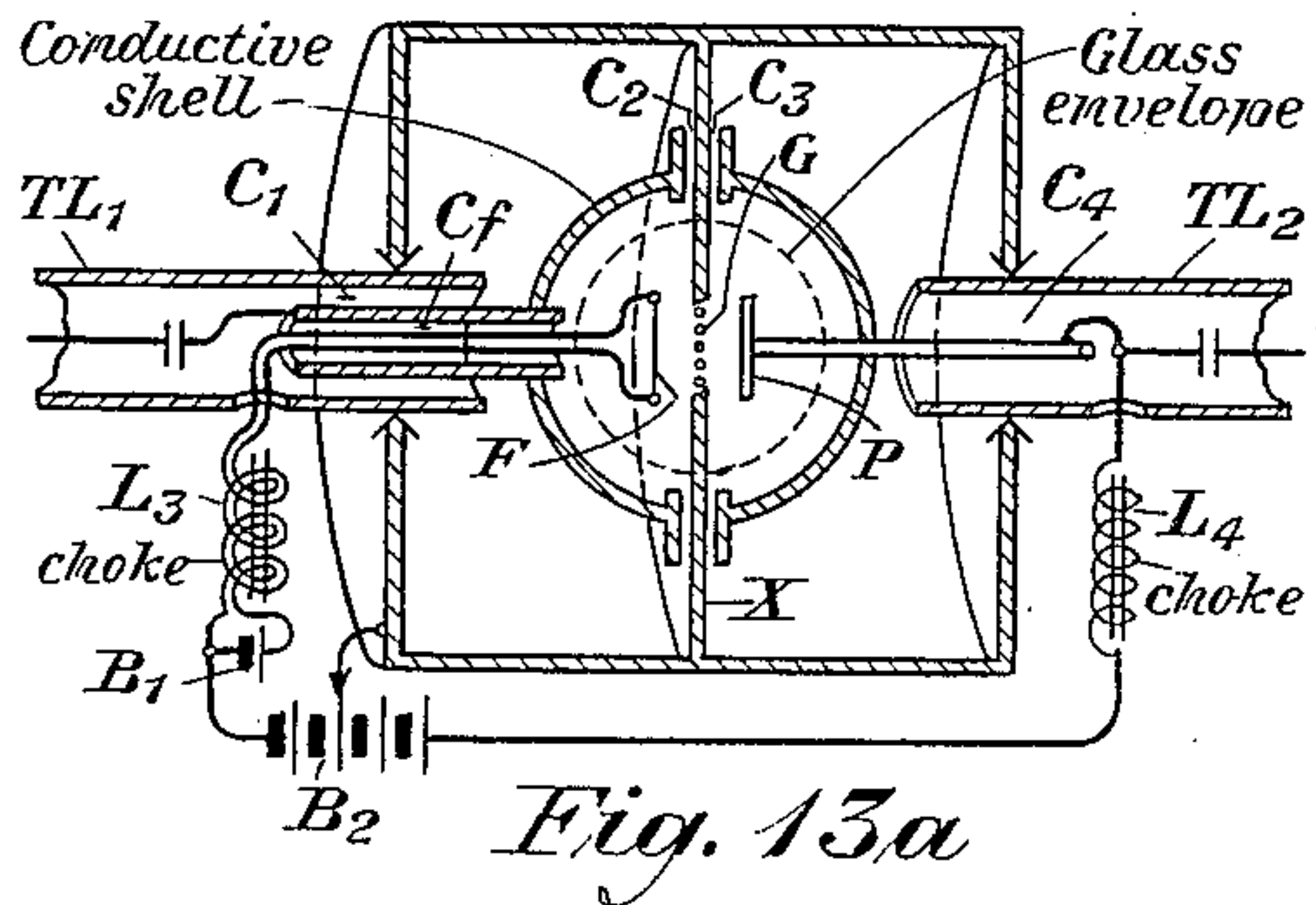
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2,107,387

VACUUM TUBE WITH TANK CIRCUITS

Filed June 12, 1936

3 Sheets-Sheet 3



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2,107,387

VACUUM TUBE WITH TANK CIRCUITS

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Application June 12, 1936, Serial No. 84,967

12 Claims. (Cl. 250—36)

This invention relates to radio frequency oscillation generators and more particularly to generators of very high frequencies such as are used in so-called short-wave signaling.

5 This application is a continuation as to common subject matter of my United States application Serial No. 746,902, filed October 4, 1934.

Its purpose is to design an arrangement in which very high frequencies of great stability are
10 obtained and in such manner that the oscillations shall be relatively free from disturbances outside its own circuit and shall produce a minimum of disturbances on or in adjacent surroundings. Its purpose is also that of providing an oscillatory
15 circuit for a generator of very low damping factor.

To accomplish these purposes I make use of certain forms of impedances, described in my Patent No. 2,030,178 issued February 11, 1936. In that patent I describe a type of impedance which
20 may be called a "tank impedance" and which, in one form, may consist essentially of a cylindrical conductor with both ends closed or nearly closed. One simple form which the tank with a line circuit may take is that of two relatively small concentric
25 conductors constituting the line over one end of which is placed a large concentric conductor with the one end closed by a disk to the inner of the pair of conductors and the other end closed by a disk to the outer of the pair of
30 conductors. As pointed out in my said application, such a circuit acts as a small but concentrated or "lumped" inductance at the one end of the pair of conductors and equations are given for the approximate magnitude of the inductance in
35 any given case. It is also pointed out how "lumped" capacity may be introduced in such a device, leading to resonant and anti-resonant circuits. In this invention I show some applica-
40 tions of such circuits to oscillation generators and to tuned amplifiers both in a manner to yield low damping in the oscillatory circuits and to yield a generator or amplifier which is especially well shielded from extraneous disturbances which
45 become so serious at the high frequencies here contemplated.

The invention will be better understood by reference to the following specification and the accompanying drawings, in which Figures 1a to 1d illustrate the type of inductances and tuned circuits which I propose to use; Figs. 2a and 2c show
50 the connection of such an inductance into a certain type of circuit and Fig. 2b shows the equivalent more conventional appearance of that circuit; Figs. 3a to 3b show a series of circuits in
55 pairs, the one giving the circuit with my new

form of inductance and the other the equivalent circuit in more conventional form; Figs. 9a to 13b show important modifications of my circuit in which the amplifier elements necessary for the generator or amplifier are included within
5 the tank; Fig. 13c is a simplified showing of the device of Fig. 13a; Figs. 14a and 14b are showings of the tube elements contained in Fig. 13a in modified form; Fig. 15a shows the device of Fig. 13a modified to be an oscillation generator; and
10 Fig. 15b is an equivalent circuit and Fig. 15c is a simplified showing of the oscillation generator of Figure 15a.

In the conventional oscillatory circuit the magnetic and electric fields exist outside as well as
15 inside the coils and condensers of those circuits. In the case of most inductance coils the external field may be quite extensive but also may be very materially reduced by having it take the well known form of a toroid. At very high frequen-
20 cies where radiation from oscillatory circuits and spurious coupling effects are of more than usual importance, the characteristics of the toroid coil are desirable. At extremely high frequencies,
25 however, the inductance and capacities required become small and also the skin effect increases in such manner that large conductors are needed in order to provide low loss circuits. The inductance
30 itself may then reduce to a single turn of heavy conductor, as illustrated in Fig. 1a, but in this case the magnetic field is widely distributed. To confine the field to a small region, I have found it is necessary, as pointed out in my
35 copending application, to make this single turn the equivalent of a coil, the surface of which is reentrant in the same way as in toroidal coils, and the single turn coil in this reentrant form becomes then what may be called a "tank" because of its physical appearance.

The term "tank" or "tank circuit" as used in
40 this specification and the claims, is defined as an enclosing conducting vessel of one or more compartments, enclosing various associated elements, and in which the inner surface of the vessel constitutes an essential part of the path for high
45 frequency currents. Such a tank circuit with capacity included to form a resonant circuit is shown in Fig. 1b and may be looked upon as a figure of revolution, obtained by rotating the circuit of Fig. 1a about the line *b—b* as an axis al-
50 though not shown to scale, particularly as respects flanges *a* and *d*. If the circuit of Fig. 1a had been circular instead of rectangular and a similar rotation had occurred, a tank of the form shown in Fig. 1c would have resulted, possessing
55

the same electrical properties as Fig. 1b. Here, however, a portion of the flange extending toward the center of Fig. 1c is omitted for structural simplicity, the electrical effect of the omission being negligible. In these two cases the capacity of the circuit is included within the tank and is effectively shielded so far as external objects are concerned. A somewhat different form of tank, but substantially equivalent, is shown in Fig. 1d, obtained by rotating the circuit of Fig. 1a about the line $d-d$ as an axis, and in this case the condenser is on the external edge of the tank. These, as well as many other forms which the tank circuits may take, are described in my copending application mentioned above.

In Fig. 2a there is shown a tank circuit replacing the conventional arrangement of coils and condensers. Thus the lead L , which may be an antenna or any other output is shown connected to ground through the resonant circuit consisting of inductance and capacity. Again, as in Fig. 1c, the shape of the flanges is slightly modified, one of the extensions being omitted and the other being connected completely across the center for greater convenience in connecting the antenna. The conventional form of circuit which is equivalent is shown in Fig. 2b. In Fig. 2a it should be emphasized that, at the frequencies contemplated, the currents are surface effects only and cannot pass through the body of the metal. Thus, in this case one path to ground is across the condenser $a-d$ and the other is around the inductive path $a-b-c-d$ inside the tank, that is, the circuit comprises a condenser and inductance in parallel as in Fig. 2b. It will be recognized that the high frequency magnetic field due to the current flowing on the outer surface of the inner cylinder of the tank cannot penetrate through the outer boundary of the tank, and thus the magnetic field due to current on the inner conductor is confined within the tank. Furthermore, it will be recognized that any of the high frequency currents flowing on the inner side of the outer cylinder will produce no magnetic field within the tank. Also high frequency currents flowing on the outer surface of the outer cylinder will produce no magnetic field within the tank. Thus there is no coupling between the inside of the tank and the outside of the tank through the walls of the tank. The outside of the tank may be considered the ground in the same way that a metal shield around a circuit is ordinarily taken as ground. To visualize the conditions more clearly, the tank might actually be buried in the ground, as shown in Fig. 2c. The impedance to ground at resonance is determined by the resonant circuit constants similarly in all three cases. The tank circuit here shown is of the type illustrated by Fig. 6a in my copending application.

Fig. 3a shows the use of the tank circuit in a vacuum tube oscillation generator, this being equivalent to the circuit of Fig. 3b, which in turn is a well known generator, frequently spoken of as the "ultraudion oscillator."

Fig. 4a shows another circuit including my tank circuit and which is the equivalent of the circuit of Fig. 4b, this being an oscillator generator commonly spoken of as the "dynatron oscillator."

In Fig. 5a I show a generator with two of my tanks, the circuit being the equivalent of that shown in Fig. 5b, sometimes called the "tuned grid tuned plate oscillator." It will be observed

that each of the oscillator circuits of Fig. 5b has been replaced by tanks.

Figs. 6a and 6b are a pair of equivalent circuits and are the familiar "Colpitts oscillators." The conventional oscillatory circuit comprising condensers C_1 , C_2 and inductance L , is replaced by a tank of the form illustrated by Fig. 13 or 19 of my copending application. In this tank the plates a , d and b make the condensers C_1 and C_2 of Fig. 6b. Potential variations coming from the plate of the tube give rise to currents across the condensers in series and, in parallel to these condensers, through the inductance of the tank in a manner analogous to the circuit of Fig. 6b. In order to illustrate how a load may be connected to this circuit, there is shown an antenna connected to the plate b and earth connected to the plate d , this corresponding to an antenna and earth connected in parallel to the condenser C_2 of Fig. 6b, with the midpoint or filament connected to earth.

Figs. 7a and 7b also show a pair of equivalent circuits, the circuit of Fig. 7b being that commonly known in the art as the "Hartley oscillator." Here the conventional oscillatory circuit, comprising inductances L_1 , L_2 and condenser C , is replaced by a tank. The connection in the Hartley circuit from the filament to the point between the two inductances finds its equivalence in Fig. 7a by the connection to the midpoint of the tank inductance at M , and it is evident that this may be made adjustable to vary the ratio of the inductances L_1 and L_2 . Such a connection may consist of a single radial conductor but for better current distribution may consist of several radial conductors or even a partition with a number of apertures which would determine the coupling between the two inductances. This connection is obviously similar to the usual connection to some midpoint of a single turn inductance coil.

Figs. 8a and 8b represent the so-called "Meissner oscillator", in which the resonant circuit, consisting of inductance L and capacity C , is replaced by my tank circuit. The method of coupling L' and L'' to L is clearly shown in Fig. 8a and is equivalent to the usual method of coupling to a solenoid inductance. The loops L' and L'' of Fig. 8a are arranged to include a sufficient amount of the magnetic flux within the tank inductance L to provide the required coupling.

One of the marked advantages of the circuits which have just been described is the comparative freedom from electric or magnetic coupling with external circuits and conducting bodies. An important part of my invention consists in carrying this shielding effect to an even greater extent by enclosing the vacuum tube amplifier within the tank itself so that all parts of the circuit are within the tank, with the possible exception of the batteries, to which connection can be made by short leads through the walls of the tank. Such arrangements are shown in Figs. 9a, 10a and 11a.

The arrangement shown in Fig. 9a is similar to that of Fig. 7a; that is to say, it is a Hartley type of oscillator circuit, but in Fig. 9a all of the parts, excepting the batteries, are placed within the tank circuit. In Fig. 9a the axis of the tank may be looked upon as a vertical axis through the center of the tank. In general this tank will be of ample capacity to accommodate the vacuum tube and accompanying elements with suitable supports. As will be clear from the draw-

ings, the vacuum tube VT with its filament, grid and plate, is mounted in the tank as shown and the condenser C_b , leading from the grid to one terminal of the inductance formed by the tank, the resistance R connected between the grid and the filament, and the capacity C_a in the connection from the filament to the midpoint of the surface of the tank, may all be suitably mounted within the tank itself. Connections will extend out through an opening in the bottom of the tank to the batteries for supplying the filament and plate currents. The grid potential is, of course, derived through the drop of the resistance R . The flanges near the center of the tank provide the main capacity C of the oscillator.

Fig. 9b shows an equivalent circuit employing conventional types of electrical elements. In Fig. 9b the main capacity C of the Hartley circuit corresponds to the capacity of the flanges in the center of the tank, and the two inductances L_1 and L_2 are the inductances formed by the interior surface of the tank, from the midpoint along the inner surface of the wall to the upper flange on the one hand, and over the inner surface of the wall of the lower half of the tank to the lower flange on the other hand. The high frequency currents flowing over the inner surface of the tank will not be propagated out of the tank along the battery connections because the oscillatory currents are propagated over the interior surface of the tank and flow around the opening, instead of across it, to the load circuit.

Fig. 10a shows an oscillator of the Colpitts type and is essentially the same in principle as the circuits of Figs. 6a and 6b. In Fig. 10a the axis of the tank is longitudinal instead of vertical as in Fig. 1b. The outlet tubes of the tank are of smaller diameter and the capacity forming flanges are omitted, capacities being formed, however, between the inner surfaces of the outlet tubes and the outlet wires as shown at C_5 and C_6 . In Figure 10a the vacuum tube is shown at VT within the tank and the two main tuning capacities C_1 and C_2 of the Colpitts type circuit are likewise mounted within the tank and are connected at their common point to the filament F , with their other terminals connected to the conductive outlet tubes through which external connections are made. These outlet tubes are also connected through capacities C_3 and C_4 to the grid G and plate P , respectively, of the vacuum tube. The capacities C_3 and C_4 will also be mounted within the tank. The grid potential is supplied from a battery which has one terminal connected to the outer surface of the tank (which may be grounded, if desired), the other terminal of the battery being connected to a conductor leading concentrically through the cylindrical outlet tube to the grid. There will be, of course, some capacity at C_5 between this conductor and the inner wall of the cylindrical outlet tube. Likewise the plate battery has one terminal connected to the outer surface of the tank and the other terminal is connected through a choke coil L_4 to a conductor passing concentrically through the cylindrical outlet tube to the plate. A capacity C_6 will exist between the conductor and the outlet tube. If the capacities C_5 and C_6 are sufficiently large, the separate capacities C_3 and C_4 may be omitted. The two conductors from the filament are connected through a double wound choke coil L_3 , the one to the inner wall of the tank and the other through an opening in the wall of the tank to the filament battery, the other

terminal of which is connected to the outer wall of the tank. The currents flowing over the inner walls of the tank from the terminals of the choke L_3 to the capacities C_5 and C_6 are subjected to the inductive effect of the walls of the tank.

The equivalent circuit is shown in Fig. 10b. As is well understood the Colpitts type circuit has two capacities C_1 and C_2 with their common terminal connected to the filament and with their opposite terminals connected to the grid and plate as shown in Fig. 10b, and with a single inductance connected from grid to plate in parallel to the two condensers. In Fig. 10b as shown, the single inductance is divided into two parts L' and L'' which, from the high frequency alternating current standpoint, function as a single inductance. A mid tap is provided, however, for the necessary connection to permit the battery current to be supplied to the filament. The inner surface of the tank walls provides an inductance (corresponding to L' and L'' in Fig. 10b) whose midpoint, the junction of L' and L'' , is connected to the filament through L_3 , the other terminals of the inductance being connected to the capacities C_1 and C_2 by the connection of said capacities to the outlet tubes of the tank. Unlike the tank circuit of Fig. 3a, the main tuning capacity or capacities (C_1 and C_2) are not part of the tank circuit of Fig. 10a. The choke coil L_3 prevents alternating current from entering into the filament leads. From an alternating current standpoint, therefore, the circuit is a true Colpitts circuit, as the two elements L' and L'' function as a single inductance without high frequency connection to the filament. It will be clear from Fig. 10b that the capacities C_5 and C_6 which exist between the outlet conductors and the tubular cylindrical outlets through the walls of the tank are effectively in parallel to the capacities C_3 and C_4 .

In Fig. 11a the tank has a horizontal axis and the circuit is essentially that of a Hartley oscillator. The filament is connected to the midpoint of the inner surface of the tank by having one of the filament leads connected to the wall of a cylindrical outlet tube through the side wall of the tank, the other filament connection passing concentrically through this outlet tube to the battery, the other terminal of which is connected to the outer wall of the tank. Thus from an alternating current standpoint the inner surface of the tank is divided into two paths for the flow of current—from the filament to the grid on one hand and from the filament to the plate on the other, thus forming the two inductances L_1 and L_2 of the Hartley type oscillator as shown in Fig. 11b. The main condenser C of the Hartley circuit has its terminals connected, respectively, to the outer surfaces of the cylindrical outlet tubes. As in Fig. 10a, capacities C_3 and C_4 are connected between the outer surfaces of the outlet tubes and the grid and plate, respectively. These two capacities and capacity C are mounted within the tank as in the vacuum tube VT itself. Capacities C_5 and C_6 effectively in parallel with the capacities C_3 and C_4 exist between the outlet conductors and the cylindrical outlet tubes, the electrical equivalent being shown in Fig. 11b. As in the case of Fig. 10a, capacities C_3 and C_4 may be omitted if capacities C_5 and C_6 are sufficiently large. The direct current potentials for the grid and plate are supplied in the same way as in Fig. 10a.

In the three arrangements shown in Figs. 9a, 10a and 11a, respectively, the output of the oscil-

lator would be a radiating antenna or something equivalent thereto and, for illustrative purposes, antennae have been shown connected to the plate of the tube VT in each of these figures. In Fig. 9a, for example, the antenna is connected to the flat disc-like flange forming the lower plate of capacity C, and the current flows over this flange to the plate electrode of the tube VT. In Figs. 10a and 11a, on the other hand, the antenna is lead in to the plate by a lead-in wire passing through the interior of the outlet tube of the tank.

This feature of enclosing the vacuum tube and certain auxiliary apparatus within the tank is suitable not only for oscillators but for amplifiers, and it may well be that in any given case one could wish to redesign the vacuum tube in order to adapt it to the particular situation in hand. For example, the vacuum tube might be redesigned so as to be built into and form a part of the tank structure itself.

If one were to use the tank and vacuum tube as an amplifier, then the essential elements would be those shown in Fig. 12a where the tank axis is horizontal. In this case a double tank of the kind illustrated in Fig. 16 of my copending application, Serial No. 746,902 is shown. For purposes of discussion the elements of a simple three-element vacuum tube are illustrated schematically by F, G and P, for filament, grid and plate, respectively. The capacities in resonant circuits are, for the purpose of argument, provided by the capacities between tube elements. In the input there is a resonant circuit containing the capacity between F and G and the inductance $a-b-c-d$. In the output there is a resonant circuit with capacity between G and P and inductance $a'-b'-c'-d'$. The equivalent of this circuit is shown in Fig. 12b where the tube element capacities are C_{gf} , C_{pt} . Depending upon the effectiveness of shielding provided by the grid G, or any other more complicated structure replacing this grid, there will be more or less capacity between F and P of Fig. 12a. The equivalent in Fig. 12b is determined by the size of the hole in the partition x between plates y and z . If the partition were solid the capacity coupling between y and z would be zero.

To make use of the circuit of Fig. 12a, as an amplifier for example, it is necessary to provide means to get into and out of the tank. A practical amplifier circuit arrangement is shown in Fig. 13a with an input at the left and an output at the right in the form of concentric conductor transmission lines TL_1 and TL_2 . Here the three tube elements, filament F, grid G and plate P are surrounded by a glass envelope to provide for the evacuation. The envelope may in turn be and is here shown as enclosed within a conductive shell which provides additional capacity shunting the inter-element capacities. The filament battery B_1 is connected through the choke coil L_3 (with a winding in each filament lead) to conductors led in through the interior of a pipe forming the continuation of the central conductor of the concentric conductor transmission line TL_1 . From the inside of this pipe the filament leads pass through the glass walls of the vacuum tube to the two terminals of the filament F. The plate supply from battery B_2 is also led through a choke coil L_4 to the central conductor of the output line TL_2 , and to the plate of the tube as shown.

Capacities C_2 and C_3 are formed between the two halves of the conductive shell with its flanges, and the mid-wall x of the tank, and hence are in effect connected to the grid G which is mounted

in the mid-wall. This is shown in the equivalent circuit of Fig. 13b where capacities C_2 and C_3 are connected from the grid to the central conductors of the transmission lines TL_1 and TL_2 , respectively. The capacity C_3 is in this manner connected directly to the plate but capacity C_2 is connected to the filament through the capacity C_1 which exists between the inner wall of the inner concentric tube and the filament leads. A capacity C_1 exists between the inner surface of the concentric conductor and the inner conductor of the transmission line TL_1 . A similar capacity C_4 exists between the inner and outer conductors of the concentric transmission line TL_2 . High frequencies will not pass from the interior of said transmission line over the plate battery connection because of the choke coil L_4 and because the high frequencies find a low impedance path around the opening in the wall.

The equivalent circuit shown in Fig. 13b illustrates the relative arrangements of the various capacities, inductances and other elements of the circuit. The inductances L_1 and L_2 are formed by the separate inner surfaces of the two compartments of the tank. It will be seen that a high frequency tuned circuit exists between filament F and grid G and between plate P and grid G. The former may be traced from the filament F, through the capacity C_1 , through the capacity C_1 and the inductance L_1 to the grid, a parallel path extending from the capacity C_1 through the capacity C_2 to the grid. Likewise the plate-grid circuit may be traced from the plate P through the capacity C_4 in series with the inductance L_2 to the grid, this capacity and inductance being shunted by the capacity C_3 .

The essential elements of the circuit of Fig. 13a are shown in simplified form in Fig. 13c and it will be noted that the input and output circuits are capacity coupled to the resonant tank circuits, since the capacities C_1 and C_4 of Fig. 13b are across the transmission lines TL_1 and TL_2 and form with capacity C_2 and C_3 , respectively, the total tuning capacities included in each of the circuits.

A signal input from the transmission line TL_1 of Fig. 13a sets up oscillations within the associated tank circuit and produces a resonant voltage between F and G. The steady flow of electrons between F and P provided by the D. C. field between these elements is, accordingly, modulated in the well known manner, and the field between G and F is varied in such a way as to set up amplified oscillations in the second circuit similar to those impressed in the first. It is, of course, necessary to adjust these circuits to provide resonance as in any conventional amplifier of this type. This may be accomplished by varying the positions of the two conductive shells S_1 and S_2 , or by any design of the structure which will permit equivalent variations. For example, we might make the length of one of the tank circuits adjustable, as indicated, by the sliding contact to the conductor TL_1 .

The vacuum tubes used in Fig. 13a may be physically modified forms of any of a variety of tubes, either three-element or four-element tubes, or others, which are suitable for amplifiers or oscillation generators. The elements may be concentrically arranged as shown in Fig. 14a where the grid and plate elements of the vacuum tube are in cylindrical form about a common axis with the filament located in said axis. Again the cathode, grid and plate may be related to each other in the manner indicated in Fig. 14b. In

the latter, a heater, a cathode, a grid and a plate element are shown with the grid placed between cathode and plate and forming a continuous mesh disc with a mesh or solid edge that is brought outside of the whole periphery of the vacuum tube. When this vacuum tube is set into an aperture of the partition x of Fig. 12a or Fig. 13a and contact is made all the way around by a clamp or other mechanical means, the coupling between the two tank circuits is restricted to that through the grid which functions as a control element. If it should be desirable to apply a D. C. bias to the grid the above mentioned contact may be broken by a spacer of some insulating material which would provide a low impedance path for the high-frequency currents while isolating the D. C. potential.

To make the amplifier arrangement of Fig. 13a function as an oscillator, it is necessary to provide coupling of suitable magnitude and phase between the oscillation in the first and second tank circuits. Such coupling may be provided in a number of ways and, in particular, may be provided by apertures in the partition x . Such apertures are shown at a and a' in Fig. 15c which, it will be noted, is similar to Fig. 12a in the showing of a few essential elements. The coupling between the two tank circuits will be dependent, among other things, upon the total area of the apertures.

In Fig. 15a there is shown schematically an oscillator arrangement in which an aperture coupling between tank circuits, of the type just described, is used. There is also shown a capacity which isolates the grid. The coupling aperture is provided in the mid-wall x which, in this case, is connected directly to one-half of the conductive shell. The grid is then mounted in another conductive plate between which and the mid-wall x of the tank (a part of which is formed by one-half of the conductive shell) a capacity C_3 exists. This capacity isolates the grid from the mid-wall of the tank. A similar capacity C_2 exists between the plate in which the grid is mounted and the other half of the conductive shell with its flanges, thereby isolating the grid from any connection to the walls of the tank through the tubular conductor which permits of the battery connections to the heater H . The capacity C_2 also isolates the grid from the cathode F .

The aperture coupling is in reality an inductive coupling since it permits current in one chamber to flow into the other and this forms a conductor (or inductance) common to the two circuits. The effect of this will be clear from the equivalent circuit shown in Fig. 15b where L_1 and L_2 represent the inductances due to the current flowing over the inner surfaces of the two compartments of the tank, while M represents the inductive coupling between the two parts of the tank due to the current flowing from one compartment of the tank to the other through the aperture.

In addition to the coupling due to the aperture in the partition wall, there may be another kind of coupling between the two compartments. For example, an opening in the partition running all the way around the vacuum tube, as illustrated by the "grid isolating capacity" previously mentioned, forms a capacity common to the input and output circuits. As previously mentioned, the grid is not only isolated by the capacity C_3 , as just stated, but it is also isolated from another standpoint by the capacity C_2 between the conductive shell and the mounting of the grid.

The effect of these capacities is shown in the

equivalent circuit of Fig. 15b. Here it will be seen that the grid circuit and the plate circuit are coupled not only by the mutual inductance M but by the capacity C_3 . It will be evident that the magnitude of the coupling depends upon the size of the aperture or isolating capacity. The phase of the feed-back from one tank circuit to the other, depends upon the relative size of these two coupling elements as in any conventional circuit. This provides means for adjusting the phase of the feed-back as is required.

While the figures have thus far been described with the implication that they are right circular cylinders, it is to be understood that no such restriction is necessary. The enclosing vessel might, for example, be a cube or other parallelo-piped with the main entrances to the vessel at the centers of two opposite faces or at two opposite corners. Again the vessel may take on the form of a sphere with the chief entrance points at the ends of a diameter. In any of these cases the magnetic field set up within the vessel would probably be somewhat more distorted than in the case of a circular cylinder, but each vessel would have a definite inductance. It is not even necessary that the entrance points shall be symmetrically arranged as indicated above, but they might be at any two points on the vessel, although in that event the distortion in the magnetic field would be greater and the lack of symmetrical distribution of the surface currents would tend to make the losses somewhat larger.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In an amplifier circuit, an amplifier tube having cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, two of said electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves as an inductance connected to said electrodes, and a connection from the third electrode to said tank.

2. In an amplifier circuit, an amplifier tube having a cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, two of said electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves as an inductance connected to said electrodes, a connection from the third electrode to said tank, and capacities within said tank connected between certain of said electrodes.

3. In an amplifier circuit, an amplifier tube having cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, two of said electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves as an inductance connected to said electrodes, a connection from the third electrode to said tank, said tank including elements constituting a capacity connected between certain of said electrodes.

4. A three-electrode vacuum tube, inductance

connected to two electrodes thereof having different potentials, said inductance consisting, in part at least, of a substantially closed conducting vessel constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, said tube being enclosed within said tank, and a connection from the third electrode to said tank.

5. A three-electrode vacuum tube, inductance and capacity connected to two electrodes thereof having different potentials, said inductance and capacity consisting, in part at least, of a substantially closed conducting vessel constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it and whose walls are so formed as to constitute a capacity, said tube being enclosed within said tank, and a connection from the third electrode to said tank.

6. In a vacuum tube oscillation generator, a tube having a cathode, anode and control electrodes, a substantially closed conducting vessel constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, the control and anode electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, and two series capacities within said tank with a midpoint connection to said cathode and having their opposite terminals connected to said anode and control electrodes, said capacities and said inductance being included in an oscillating circuit for said tube.

7. In a vacuum tube oscillation generator, a tube having cathode, anode and control electrodes, two series capacities with a midpoint connection to said cathode and having their opposite terminals connected to said anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting a tank whose inner surface acts as an inductance with respect to high frequency currents flowing over it, said anode and control electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, said inductance and capacities being included in an oscillating circuit for said tube.

8. In a vacuum tube oscillation generator, a tube having cathode, anode and control electrodes, two series capacities with a midpoint connection to said cathode and having their opposite terminals connected to said anode and control electrodes, a substantially closed conducting vessel enclosing said tube and said capacities, said vessel constituting a tank whose inner surface acts as an inductance with respect to high frequency current flowing over it, said anode and control electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, said inductance and capacities being included in an oscillating circuit for said tube.

9. In a vacuum tube oscillator, a tube having

cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting a tank whose inner surface acts as an inductance with respect to high frequency currents, said anode and control electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, and a high frequency connection from an intermediate point on the inner surface of said tank to said cathode electrode, so that said tank serves as a divided inductance between said anode and control electrodes with an intermediate connection to said cathode.

10. In a vacuum tube oscillator, a tube having cathode, anode and control electrodes, a substantially closed conducting vessel constituting a tank whose inner surface acts as an inductance with respect to high frequency currents, said anode and control electrodes being connected to points of different potentials on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, a high frequency connection from an intermediate point on the inner surface of said tank to said cathode electrode, so that said tank serves as a divided inductance between said anode and control electrodes with an intermediate connection to said cathode, and a capacity in parallel to at least a portion of said inductance.

11. In a vacuum tube oscillator, a tube having cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting the tank whose inner surface acts as an inductance with respect to high frequency currents, said anode and control electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, a high frequency connection from an intermediate point on the inner surface of said tank to said cathode electrode, so that said tank serves as a divided inductance between said anode and control electrodes with an intermediate connection to said cathode, and a capacity in parallel to at least a portion of said inductance.

12. In a vacuum tube oscillator, a tube having cathode, anode and control electrodes, a substantially closed conducting vessel enclosing said tube and constituting the tank whose inner surface acts as an inductance with respect to high frequency currents, said anode and control electrodes being connected to points of different potential on the inner surface of said tank so that the tank serves, in part at least, as an inductance connected to said electrodes, a high frequency connection from an intermediate point on the inner surface of said tank to said cathode electrode, so that said tank serves as a divided inductance between said anode and control electrodes with an intermediate connection to said cathode, and a capacity in parallel to at least a portion of said inductance, said capacity being within said tank.

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