Feb. 28, 1939. N. E. LINDENBLAD 2,149,024

ELECTRON DISCHARGE DEVICE AND CIRCUIT FOR HIGH FREQUENCY OSCILLATIONS

Original Filed Nov. 28, 1934 2 Sheets-Sheet 1

Fig. 1

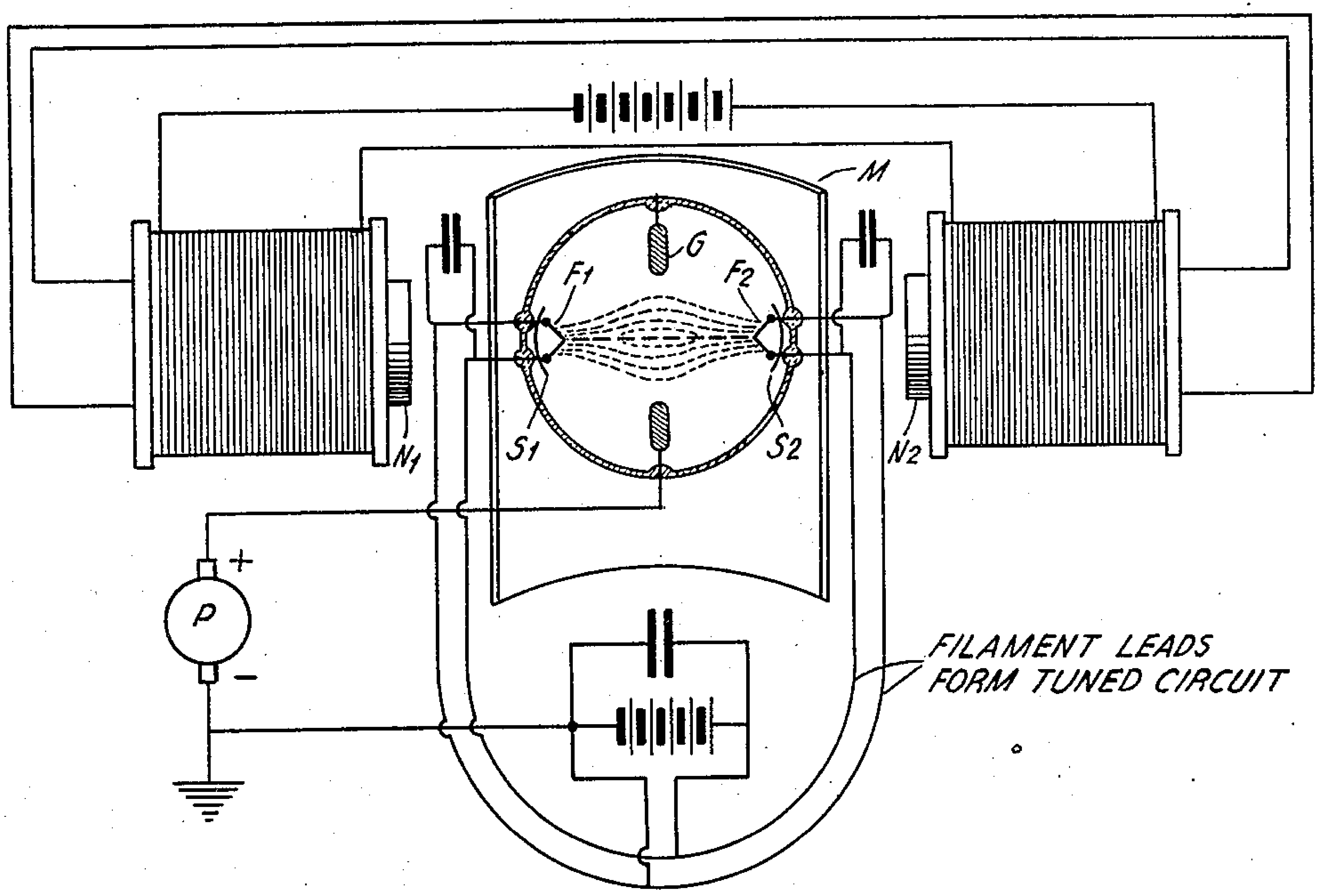
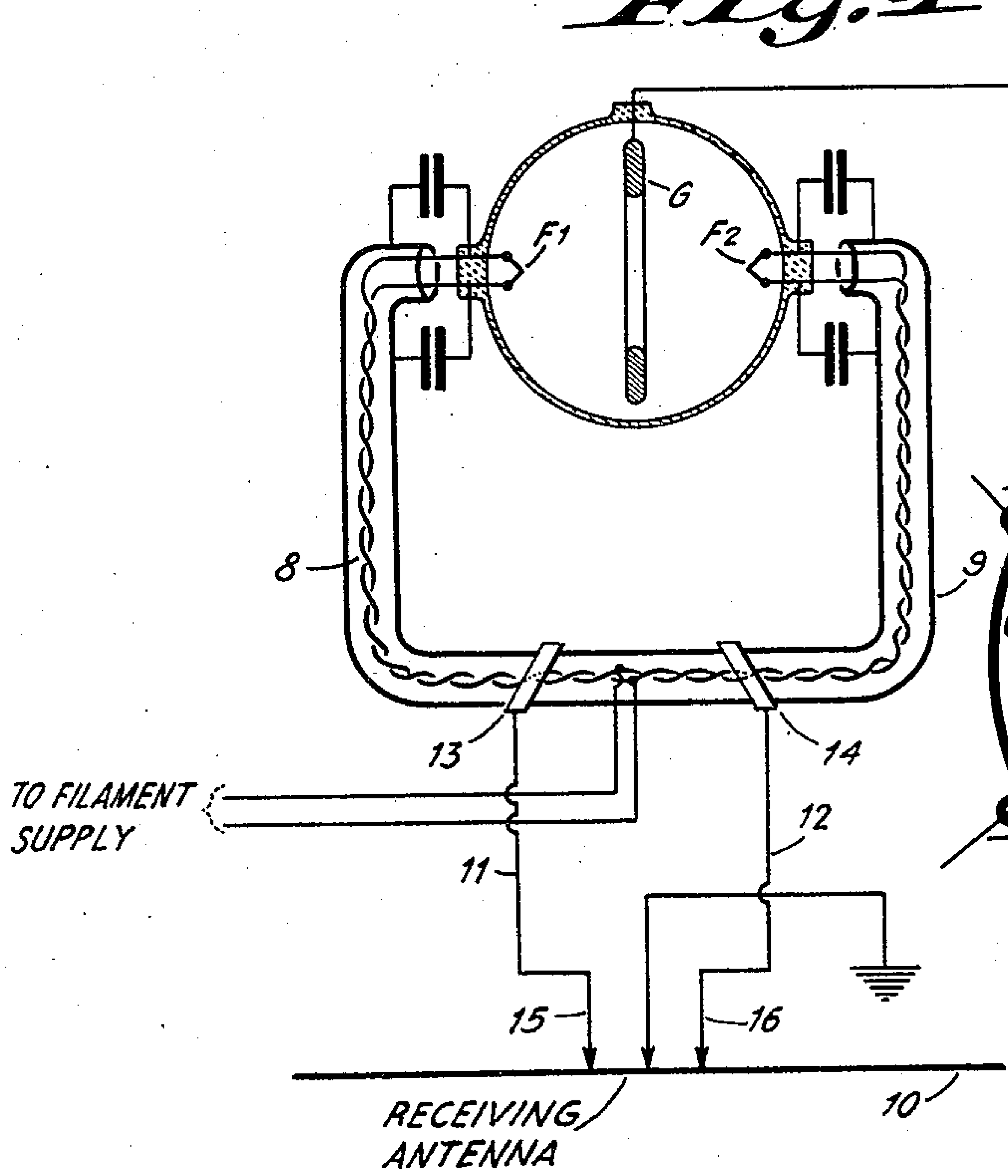



Fig. 4



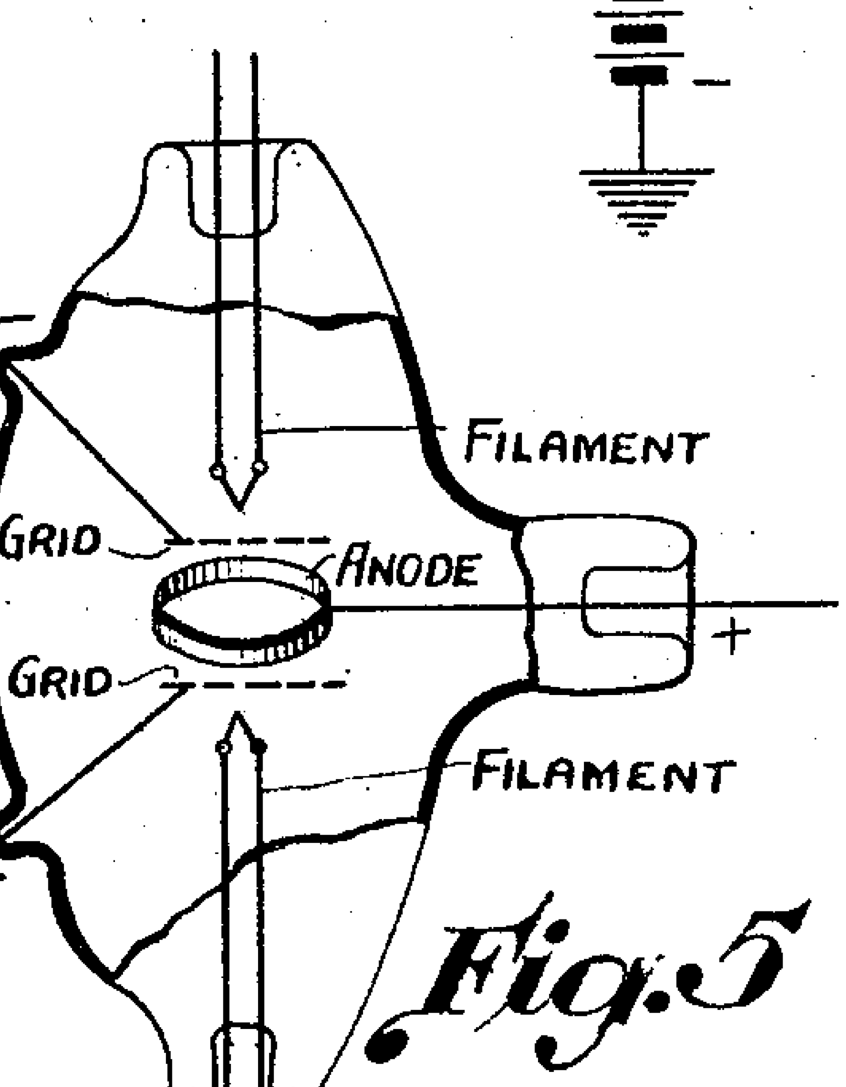




Fig. 5

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Original Filed Nov. 28, 1934 2 Sheets-Sheet 2

Fig. 2

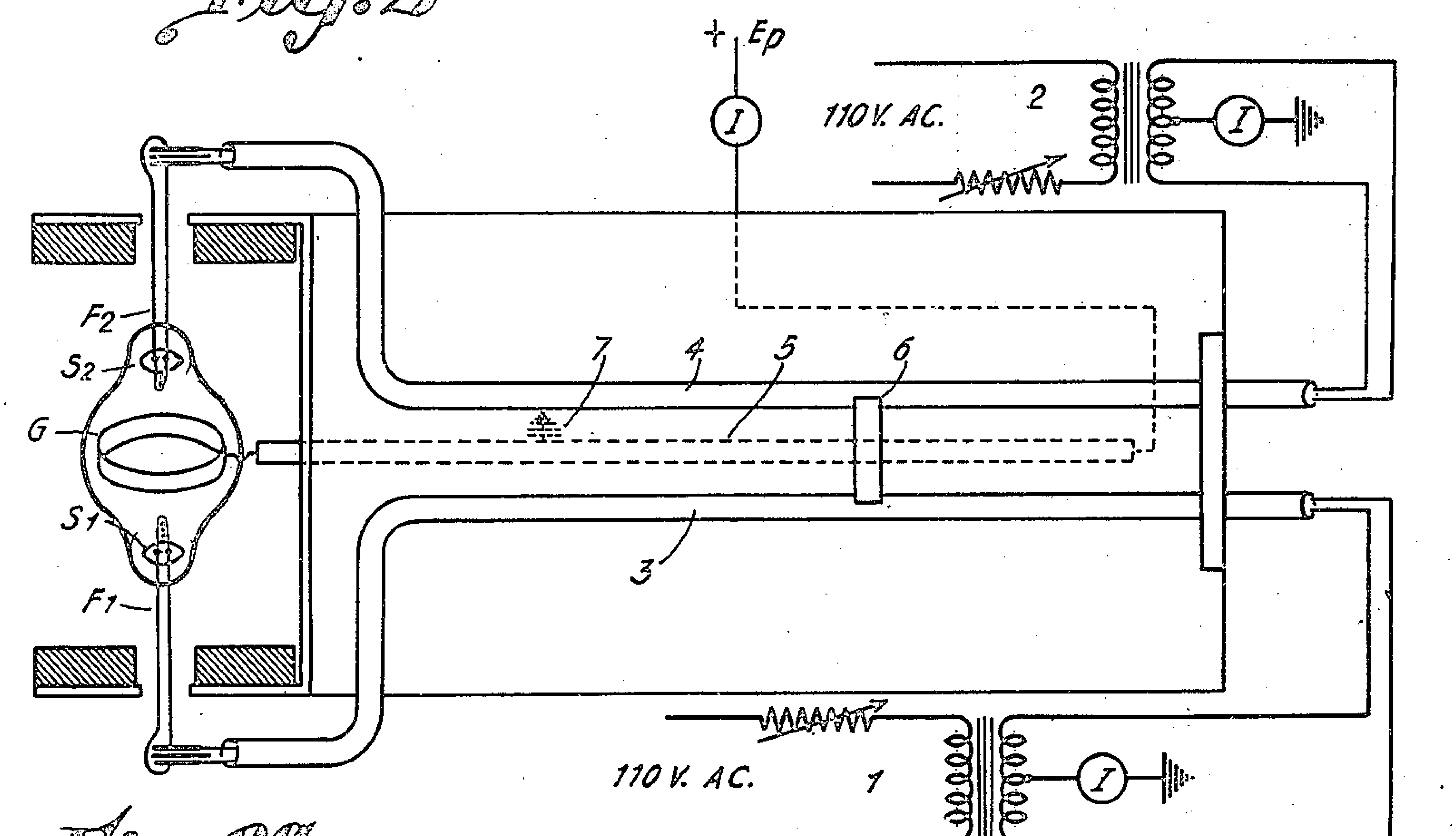



Fig. 2a

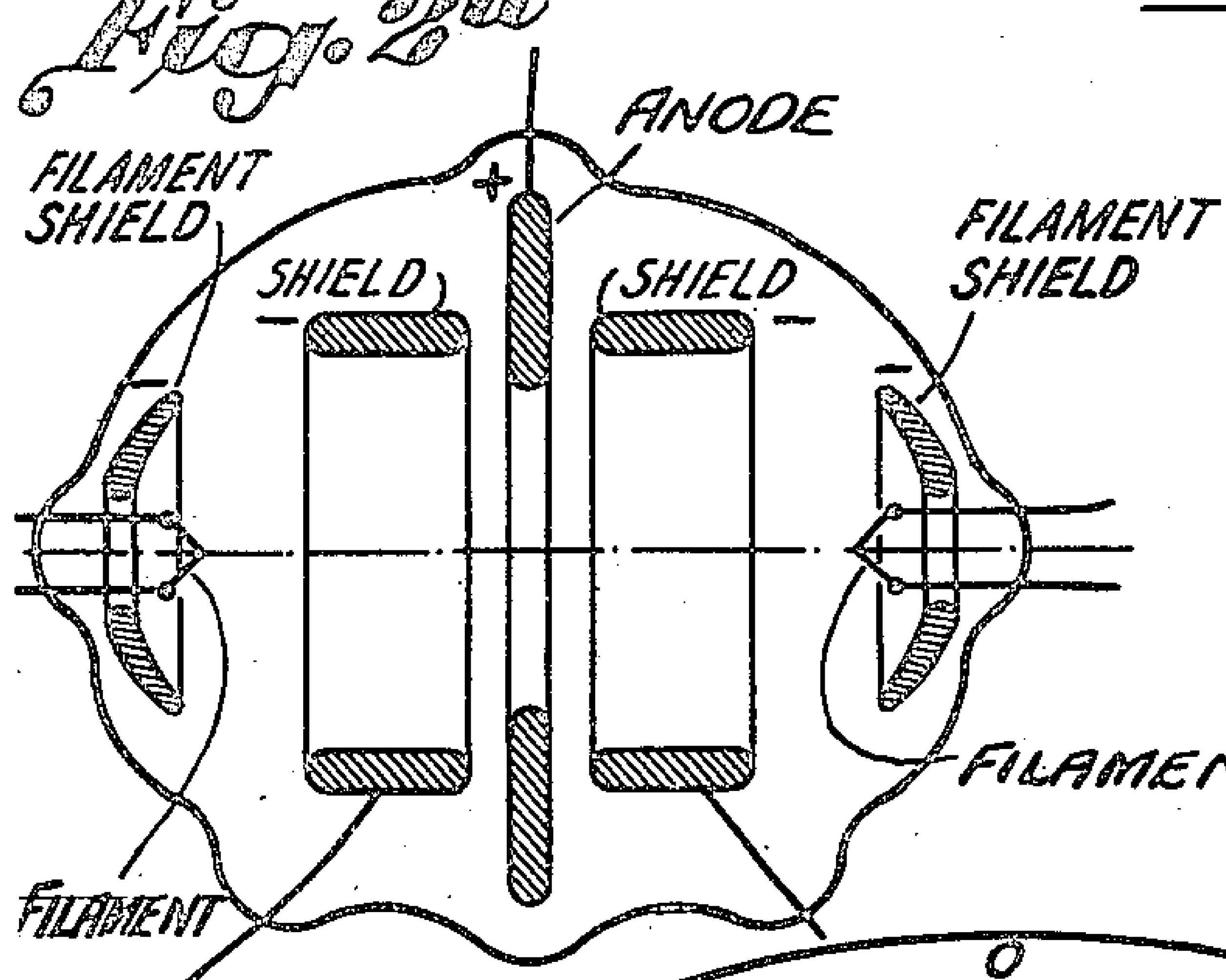
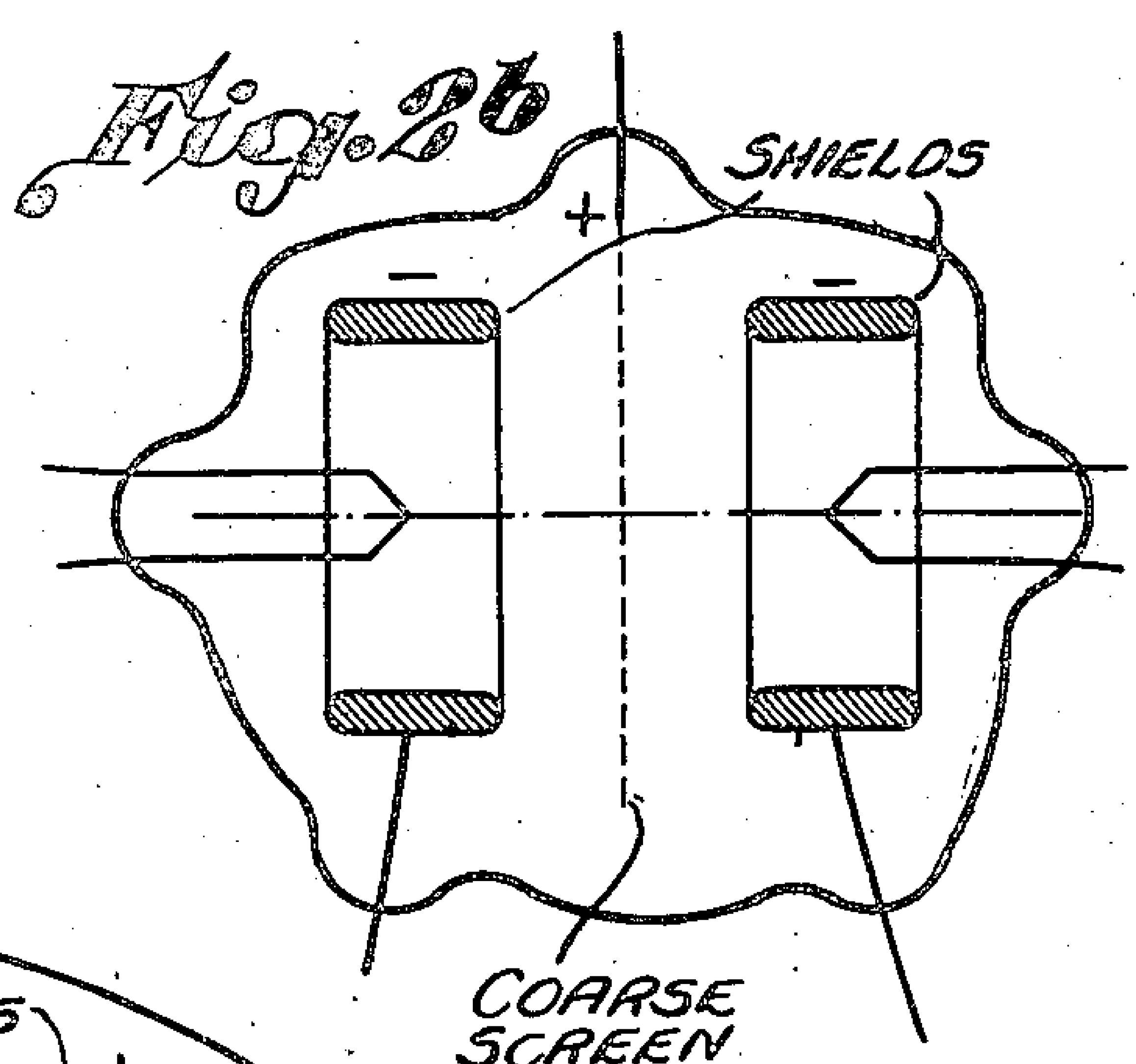



Fig. 2b



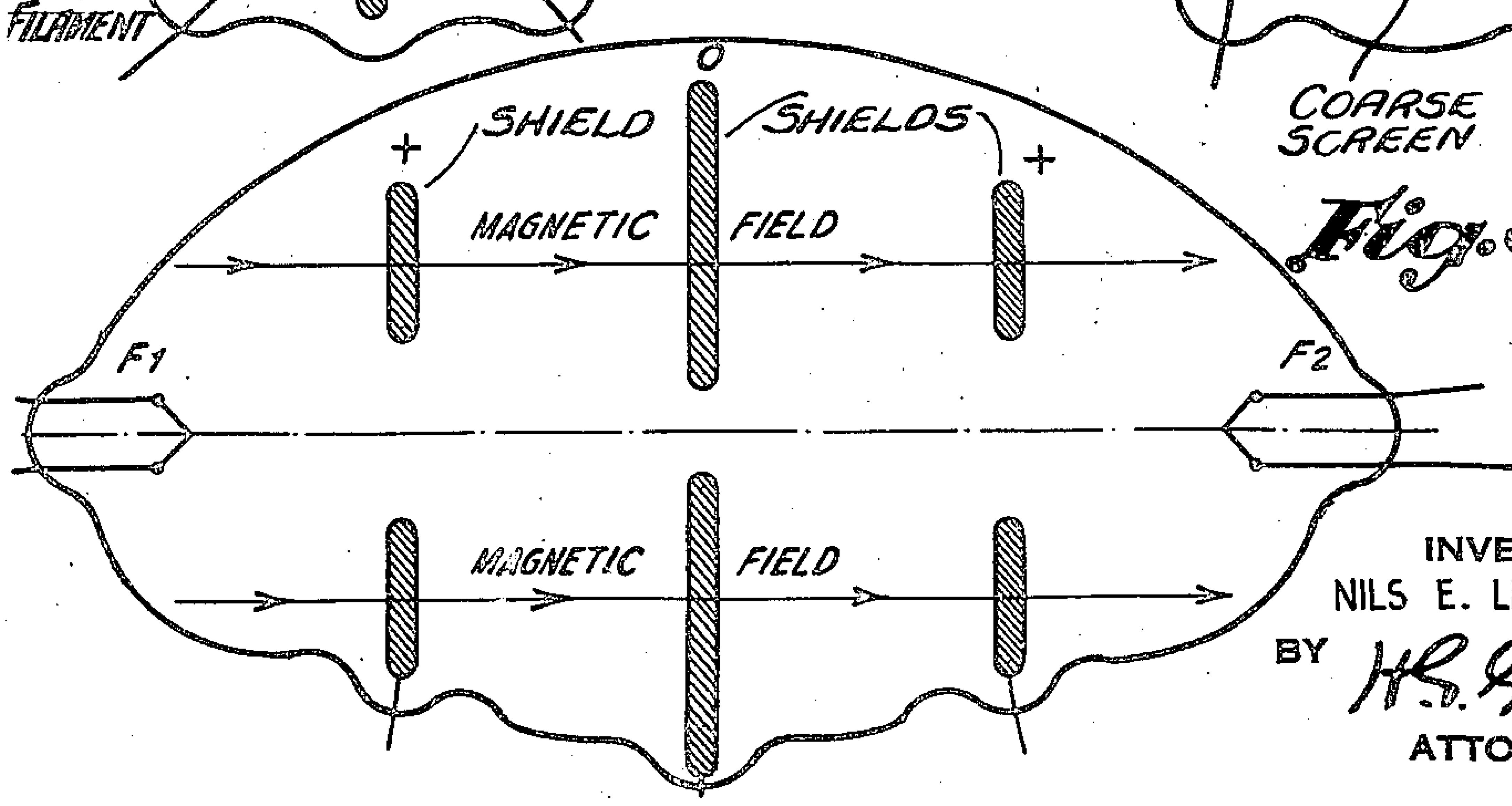




Fig. 3

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# UNITED STATES PATENT OFFICE

2,149,024

## ELECTRON DISCHARGE DEVICE AND CIRCUIT FOR HIGH FREQUENCY OSCILLATIONS

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Application November 28, 1934, Serial No. 755,153
Renewed September 1, 1938

26 Claims. (Cl. 250—36)

The present invention relates to high frequency oscillation circuits, and particularly to a novel method of and apparatus for producing ultra high frequency oscillations.

One of the objects of the present invention is to provide an ultra high frequency oscillator which depends for its operation upon the time of travel of electrons between the elements of the tube.

In accordance with the principles of the present invention, there is provided an oscillation generation circuit comprising a tube having two filaments and a ring-like or cylindrical anode between them. A strong magnetic field functions to influence the electrons emanating from one filament to travel to the vicinity of the other filament; consequently the electrons pass through the field of the anode. The ring-like anode and magnetic field thus act as electron lenses, making each filament lie in the focus of emission from the other. In this way, the time taken for the electrons to travel from one filament to the other is substantially independent of the path taken by the electrons. It has been found that under these conditions, the tube is in unstable equilibrium and capable of producing push-pull oscillations between the filaments, at any frequency to which the filaments are tuned, up to the point where the time of travel of the electrons becomes appreciable compared with the time of one cycle of oscillation.

A better understanding of the invention may be had by referring to the following detail description which is accompanied by drawings, wherein:

Fig. 1 illustrates schematically an oscillator circuit embodying the principles of the present invention;

Fig. 2 illustrates another embodiment with several refinements over that of Fig. 1;

Figs. 2*a* and 2*b* illustrate cross sectional views of details for obtaining more concentrated beam focusing of the electrons;

Fig. 3 illustrates diagrammatically how the system may be cascaded;

Fig. 4 schematically illustrates one way in which the oscillator may be used for reception of radio waves; and

Fig. 5 illustrates a modification wherein the electron discharge device of the invention is provided with grids.

Referring to Fig. 1, there are shown two sources of electrons, namely filaments $F_1$ and $F_2$, one on each side of an anode G in the form of a shield with a hole in the center thereof, the filaments being axially aligned with the axis of the hole in the anode. The elements of the tube are subjected to a linear magnetic field between poles $N_1$, $N_2$, which field is co-axial with the electrode system $F_1$, G, $F_2$. For directing the emission of the electrons more or less in a cone toward the hole in the anode G, there are provided suitable shields $S_1$, $S_2$ in back of the filaments. A source of energy P supplies a high positive potential to the anode G with respect to the filaments.

The motion of the electrons emanating from the filaments $F_1$, $F_2$ will, with the exception of those that move axially, have a projected or component motion at right angles to the axis of the system, and also at right angles to the magnetic field. This projected motion, which in its origin was intended to be linear, is transformed into a circular motion by the magnetic field. The total motion of an electron will therefore describe a curve or helix.

As the group motion of the emitted electrons is represented by a cone expanding toward the shield G, the helix will also be expanding. The electrons, however, are kept from striking the anode and are directed through the hole thereof by the magnetic field which tightens up the helical path of the electrons. Due to the minuteness of the size of an electron and their tremendous number, there is no effect on the operation of the system by collisions between electrons emanating from the opposite filaments. An analogous situation takes place in Barkhausen and magnetron circuits wherein electrons function under similar conditions.

While the electrons are travelling towards the anode G, they are subjected to an accelerating force from the electromotive force on the anode. After passing through the hole in the anode and towards the other filament, the accelerating force changes to a retarding force as the electrons now travel away from the anode. Their motion is consequently slowed down and the magnetic field therefore exerts a greater and greater influence on the curvature of their path; the helical spiral is tightened up and the electrons which were diverging from one another on the launching side of the anode are now converging toward the opposite filament. This phenomenon of changing a diverging beam into a converging beam is known as electron focusing.

Oscillations are produced in the following manner. The electrons arriving at the filament opposite the one from which they originate, have, upon their arrival, lost all their velocity due to a retarding force to which they have been subjected since their passage through the hole in the anode G. They will, therefore, much in the same fashion as in the case of a returning electron in a Barkhausen or in a magnetron tube, form a cloud around the filament with a subsequent effect of cutting off emission from this filament. The cloud represents a negative charge which greatly or entirely neutralizes the gradient around the filament as produced by the positive electromotive force on the anode shield G. In other words, the electrons arriving at a filament opposite the one from which they have emanated, will cause the emission of the nearest filament to be interrupted or decreased because of the accumulated space charge. This space charge will disperse and the action will be repeated in the opposite direction. Thus, the time of travel or velocity of the electrons, plus the time required for the space charge to disperse, will determine the frequency of oscillation. The push-pull functioning of the system may perhaps be explained by making an analogy to the difficulty of trying to balance an egg on end. If there is the least unbalance, the disturbance will increase or regenerate because the system is intrinsically unstable. In the present invention push-pull tuning is made correct and to coincide with the direct current voltage and the magnetic field adjustment which determines the transit time of the electrons, and thus the push-pull tuning is synchronized with the electron transit time.

Returning to the consideration of the convergence effect, it will be noted that this is spherical or, as has been previously expressed, conical. The convergence effect, of course, is not that of a full sphere, although it is possible to make the angle of the cone large enough to exceed the two dimensional convergence of a cylinder. A three dimensional convergence effect will, of course, cause better emission cut off than a two dimensional effect.

It is preferred that the two filaments be connected together to form a tuned circuit in order to transmit to external circuits the oscillating power generated within the system. The electrons, however, in their oscillatory motion, may find sufficient radiation resistance so as to radiate directly, in which case one may simply mount the tube directly in the focus of a mirror M which has its axis parallel with the axis of the tube in order to obtain radiation.

Fig. 2 shows an arrangement which has been used with good results. The location and approximate dimensions of the elements of the tube, which were enclosed in a UX852 envelope, are shown. In this figure the filament leads, which are energized from sources of energy **1** and **2**, and the lead from the anode ring G are enclosed in tubular shields **3**, **4**, and **5** respectively. A sliding tuning element **6** is shown shunted across the filament shields **3** and **4** for aiding in filament tuning. The anode shield **5** is shown grounded for radio frequency currents through a condenser **7**. With the arrangement indicated in this figure, it was noticed upon varying the voltage applied to the anode, that the frequency of oscillation is determined for lower anode voltages to a greater extent by the length of the tuning circuit, while at the higher voltages the anode voltage and magnetic field seem to be the factors determining the frequency. This is evidenced by sharper tuning effects at high anode voltages and magnetic fields, by varying the latter factors than by varying the tuning circuit.

From the tests made, indications are that the filaments oscillate 180 degrees out of phase with respect to each other while the anode is at zero radio frequency potential.

As indicated in Figs. 2*a* and 2*b*, and in accordance with the principles of the present invention, the phenomenon of changing a diverging beam into a converging one may be accomplished simply by electrostatic means alone. In the present case the space circuit over which the electrons travel is made to behave in similar manner in two directions of the axis (back and forth). These figures only indicate diagrammatically and by way of illustrating the principles involved, simple arrangements of an all electric, two-way focusing scheme. The systems shown in these figures are considered to be more efficient than that of Fig. 1 because of their high convergence effect.

Inasmuch as the system of Fig. 1 can be looked upon as either a double acting split plate magnetron or as a double acting Barkhausen arrangement, it can be equipped with symmetrical tuning circuits, which in itself is a great advantage. Higher frequencies may be obtainable with the tube of the system operating in a manner similar to a Barkhausen-Kurz or a Gill-Morell oscillator.

Fig. 3 indicates how the system of the invention may be cascaded. Instead of allowing the electrons to return to their original filament after having arrived at the second filament, it is proposed to have the electrons continue their journey towards another positive shield, whereupon they are finally permitted to return after having passed through their second positive shield. The arrows show the direction of the magnetic field. The electrons here cascade from one section of the device into the next section, the purpose being to get synchronization between the two sections so that their outputs may easily integrate. After having left the filament at one end of the device, the electrons are focused together as toward the second filament as in the simple case already described in connection with Fig. 1. There is, however, no filament at the second converging point. This filament is replaced by a shield O with a small hole through which the electrons may pass. On the other side of this shield the electrons emerging through the hole act as a source of emission. This emission then spreads toward a second anode and is thereafter focused toward another hole. Where the series of cascades terminate the electrons are finally focused toward a second filament where they may turn around and go through the whole cascade in the opposite direction.

Fig. 4 illustrates diagrammatically, the application of the oscillator to a radio receiving circuit. In this figure the two filaments are supplied in parallel from a common filament supply source, and the energizing leads **8** for the filaments are enclosed within a metal tube **9**. For receiving the radio waves there is provided an antenna **10** which is coupled to the filament tuning circuit by means of connections **11**, **12** which extend from straps **13** and **14** surrounding the tube **9** to taps **15** and **16** on antenna **10**, these taps being so spaced as to match the impedance of the antenna. The two terminals of the inter-electrode space, which are the filaments $F_1$ and $F_2$, receive voltage excitation from the incoming signal which signal is detected in the anode circuit.

It is to be understood that the invention may be employed in both transmitting and receiving circuits and is not limited to the precise structure shown in the drawings, since various modifications may be made without departing from the spirit and scope thereof. For example, if desired, the electron discharge device of the invention may be used as an amplifier, and if used as an oscillator in a transmitter may be anode modulated in Heising fashion. Also an auxiliary grid may be placed in the vicinity of each cathode for improving the action of the device, each grid being maintained preferably at a negative potential with respect to its associated cathode. Such an arrangement is disclosed in Fig. 5, wherein the grid may be connected to a suitable modulation circuit. The centers of the grids may, if desired, coincide with the axis of the tube.

In devices in general based upon pendulum action of electrons (like the Barkhausen, magnetron, etc.) the electrons are originally accelerated by the anode. If the other electrodes carry insufficient potential to attract the electrons to such a degree that they (the other electrodes) become bombarded, the electrons will describe a to and fro motion. Since electrons are electric charges, they cause opposite charges to be distributed over the electrodes. As the electrons move, the charges on the electrodes vary. The change in charge on the electrodes then causes electric currents to flow in the external circuit connected to the electrodes. This is the way in which the electron motions induce currents in the external circuit. If the external circuit is resistively loaded, not only by its own circuit loss, but, by useful load, the current produced in the external circuit produces an ohmic voltage drop which is such that it varies the electrode potential in opposition to the electron motion. This is simply Lentz law applied to thermionic devices. It can therefore be seen that the electrons are retarded as they perform work in the external circuit; their motion is attenuated. We have so far considered only the motion of one electron. If the electrons move about at random, it is easily understood that the motion of one cancels the effect of the motion of another and no work is performed in the external circuit. Their motion is then not attenuated. It is, therefore, necessary that the electrons be organized into groups. This is done in various ways. In the conventional triode feedback circuit the throttling effect of the grid produces this organization. In this case electrons only flow intermittently, i. e., there are no disorganized electrons at any time. In electron pendulum devices such as Barkhausen, the magnetron and the device of the present invention, electrons are always present in the interelectrode space. The efficiency of these devices depends upon the degree to which these electrons may be organized. Thus for certain electric and magnetic fields the electrons will oscillate but at random and their oscillation gives no external evidence. Organization is obtained when the electrons begin to fall into groups. This group formation is, for instance, produced by space charges around the point where the electrons turn around. When the anode voltage is applied, electrons are accelerated toward it. Some reach the anode on their first trip and the high kinetic energy they possess at the time of collision is a great loss. Some miss the anode and pass on. They are then retarded and will eventually come to a standstill and turn around. Whenever traffic on a highway slows down, congestion occurs; so with the electrons. Electron congestions are equivalent to space charges and space charges produce electric fields. Now, the electrons which arrive first at the turning point are kept there a little longer by the later arriving or oncoming electrons and the later ones are made to turn around a little sooner due to the negative charge from the earlier arriving electrons. This action thus promotes group formation or organization. The electrons can now perform work in the external circuit and become attenuated in their to and fro motion. The electrode potential from a signal of course also has such organizing effects. Thus if the device is adjusted so that the electrons oscillate at the right frequency but at random by having such a magnetic field that the electrons largely miss the anode, the incoming signal will produce organization and the electrons will receive attenuated motion since (as a group) they now act on the external circuit. When the electrons are attenuated, the field conditions are no longer correct to keep the electrons from landing on the anode. This then indicates both why the device works as a detector and as an amplifier; as an amplifier because most of the energy of the electron motion is already given by the electric field. The signal to be amplified only needs to supply the organizing effect.

What is claimed is:

1. The method of producing high frequency oscillations which comprises projecting a stream of electrons in one direction in conical fashion, causing said stream of electrons to first diverge and then converge, projecting another stream of electrons in an opposite direction in a similar manner, and reversing the directions of travel of said streams.

2. The method of producing high frequency oscillations which comprises projecting from a pair of reference points two streams of electrons in opposite directions, applying a magnetic field axially to the main direction of travel of said streams of electrons, and causing each stream to converge at the point of origination of the other stream.

3. A high frequency oscillator comprising a pair of relatively concentrated electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the electron emitting element toward which they are travelling after having passed through the aperture of said anode.

4. A high frequency electron discharge device comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and a magnetic field axially disposed with respect to the electron emitting elements and the aperture of said anode for influencing the electrons to travel in a helical path and for focusing the electrons around the element towards which they are travelling after having passed through the aperture of said anode, whereby substantial electron emission cutoff is momentarily effected.

5. A high frequency oscillator comprising a pair of relatively highly concentrated electron emitting elements, a shield for each of said elements arranged to aid in directing the electrons toward the other electron emitting element, an anode with a central aperture located between

said elements all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for influencing the electrons to travel in a helical path and for focusing the electrons around the element toward which they are travelling after having passed through the aperture of said anode.

6. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the element toward which they are travelling after having passed through the aperture of said anode, said means comprising ring-like shields on both sides of said anode and being provided with apertures to enable the electrons to pass through them, and a source of energy for applying negative potentials to said shields with respect to said electron emitting elements.

7. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the element toward which they are travelling after having passed through the aperture of said anode, a pair of leads for each of said electron emitting elements extending externally from said envelope to a source of heating current, and a tuning element coupled to said leads for tuning same.

8. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the element toward which they are travelling after having passed through the aperture of said anode, a pair of leads for each of said electron emitting elements extending externally from said envelope to a source of heating current, a lead extending from said anode to said first source of energy, a tubular shield surrounding each of said pairs of leads and a tubular shield surrounding said anode lead, and an adjustable strap connected across the tubular shields for said two pairs of leads for tuning said oscillator.

9. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the element toward which they are travelling after having passed through the aperture of said anode, a pair of leads for each of said electron emitting elements extending externally from said envelope to a source of heating current, a lead extending from said anode to said first source of energy, a tubular shield surrounding each of said pairs of leads and a tubular shield surrounding said anode lead, and an adjustable strap connected across the tubular shields for said two pairs of leads for tuning said oscillator, and a condenser, one plate of which is connected to ground and the other of which is connected to said tubular shield surrounding said anode lead.

10. A high frequency oscillator comprising a pair of electron emitting elements, a shield for each of said elements arranged to aid in directing the electrons toward the opposite element, an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and a means for applying a magnetic field which is axially disposed with respect to the electron emitting elements and the aperture of said anode for influencing the electrons to travel in a helical path and for focusing the electrons around the electron emitting element towards which they are travelling after having passed through the aperture of said anode, a pair of leads for each of said electron emitting elements extending externally from said envelope to a source of heating current, a lead extending from said anode to said first source of energy, a tubular shield surrounding each of said pairs of leads and a tubular shield surrounding said anode lead, and an adjustable strap connected across the tubular shields for said two pairs of leads for tuning said oscillator, and a condenser, one plate of which is connected to ground and the other of which is connected to said tubular shield surrounding said anode lead.

11. In combination, a high frequency electron discharge device comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, means including leads for heating said electron emitting elements, a receiving antenna, connections coupling said leads to said antenna, and a utilization circuit including apparatus for detecting the signal located between said anode and said source of energy.

12. In combination, an electron discharge device having within a single envelope a hollow cylindrical anode, and a pair of electron emitting elements oppositely disposed with respect to said anode, the latter being so arranged that there is an unobstructed passage from one electron emitting element to the other, an external source of energy for applying a positive potential to said anode with respect to said electron emitting elements, a tuned circuit coupled between said pair of electron emitting elements and conductively connected thereto, one terminal of said source being connected to said anode and the other terminal of said source being connected substantially to the center of said tuned circuit, and a focusing coil for causing the electrons emanating from one of said elements to focus around the other electron emitting element.

13. The method of producing high frequency oscillations which comprises projecting a stream of electrons in one direction, causing said stream to first diverge and then converge, and reversing the direction of travel of said stream in the same order.

14. The method of producing high frequency oscillations which comprises projecting a stream of electrons in one direction, influencing said stream of electrons to first diverge, and then converge, then diverge, and then converge, and projecting another stream of electrons in an opposite direction in a similar manner.

15. In combination, a high frequency electron discharge device oscillator having a pair of heated electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit comprising an inductance and capacitance located between and conductively coupled to said electron emitting elements, and magnetic means adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons.

16. In combination, a high frequency electron discharge device having a pair of heated electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit comprising an inductance located between said electron emitting elements, and a coil adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons, a source of oscillations coupled to said tuned circuit, and a utilization circuit coupled to said anode.

17. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a relatively wide central aperture located between said elements, all within a single envelope, said electron emitting elements having an appreciably smaller emitting area than the area of said central aperture of said anode, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the electron emitting element toward which they are travelling after having passed through the aperture of said anode.

18. A high frequency oscillator comprising a pair of electron emitting elements, each so constructed and arranged as to emit electrons from a substantially concentrated point, an anode with a relatively wide central aperture located between said elements, a reflecting shield located behind each electron emitting element for directing the electrons toward the element on the opposite side of said anode, and means for focusing the electrons around the electron emitting element toward which they are traveling after having passed through the aperture of said anode, whereby substantial electron emission cut-off is momentarily effected.

19. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a relatively wide central aperture located between said elements, all within a single envelope, said electron emitting elements having an appreciably smaller emitting area than the area of said central aperture of said anode, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, and means for focusing the electrons around the electron emitting element toward which they are travelling after having passed through the aperture of said anode, and a curved shield behind each electron emitting element for aiding in directing the electrons towards the other electron emitting element.

20. A high frequency oscillator comprising a pair of electron emitting elements and an anode with a central aperture located between said elements, all within a single envelope, said elements being axially aligned with the axis of said aperture, a source of energy for applying a positive potential to said anode with respect to said electron emitting elements, a grid having a central aperture located between each electron emitting element and said anode, and means for maintaining each of said grids at a negative potential relative to its associated electron emitting element.

21. An oscillation generation system comprising within a single envelope a pair of heated sources of electrons, an element permitting the passage of electrons located between said sources, a resonant circuit connecting said sources together, means for maintaining said element at a positive potential relative to said sources, said resonant circuit being tuned to have its natural frequency correspond substantially to the frequency of electron oscillation between said sources.

22. In combination in a receiver, a high frequency electron discharge device having a pair of heated electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit located between said electron emitting elements, and magnetic means adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons.

23. In combination, a high frequency electron discharge device oscillator having a pair of electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit comprising an inductance and capacitance located between and conductively coupled to said electron emitting elements, and magnetic means adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons.

24. In combination, a high frequency electron discharge device having a pair of electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit comprising an inductance located between said electron emitting elements, and a coil adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons, a source of oscillations coupled to said tuned circuit, and a utilization circuit coupled to said anode.

25. An oscillation generation system comprising within a single envelope a pair of sources of

electrons, an element permitting the passage of electrons located between said sources, a resonant circuit connecting said sources together, means for maintaining said element at a positive potential relative to said sources, said resonant circuit being tuned to have its natural frequency correspond substantially to the frequency of electron oscillation between said sources.

26. In combination in a receiver, a high frequency electron discharge device having a pair of electron emitting elements, and an anode with a central aperture located between said elements, all within a single envelope, a source of energy for applying a potential to said anode which is positive with respect to the electron emitting elements, a tuned circuit located between said electron emitting elements, and magnetic means adjacent said envelope for applying a magnetic field to the path of travel of said electrons for influencing the motion of said electrons.

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