April 15, 1941. E. G. LINDER 2,238,272

MAGNETICALLY CONTROLLED MAGNETRON

Filed Dec. 30, 1937 3 Sheets-Sheet 1

Fig. 1.

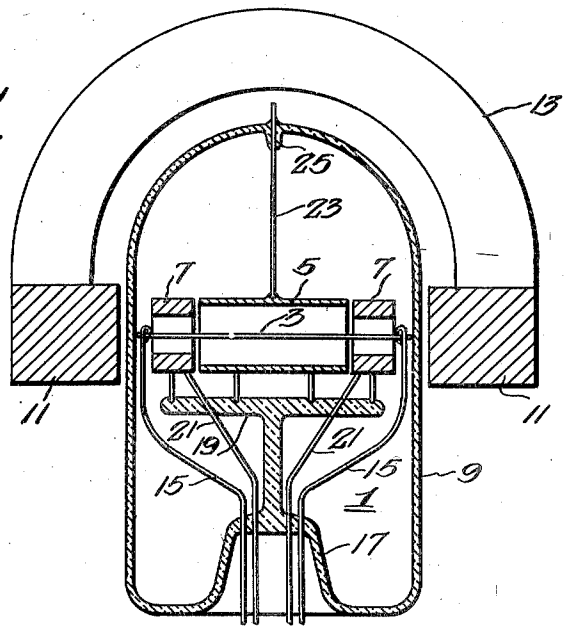


Fig. 2.

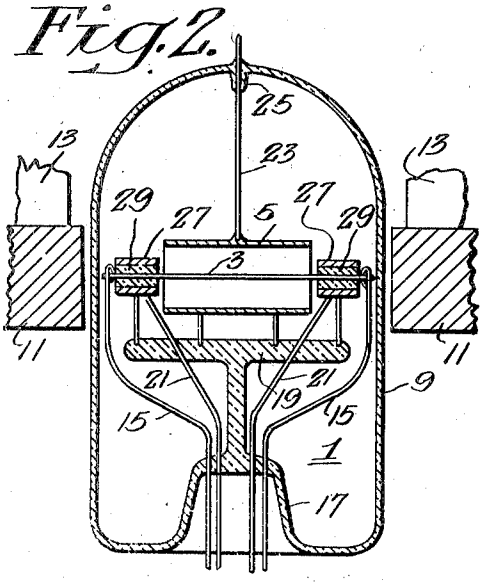
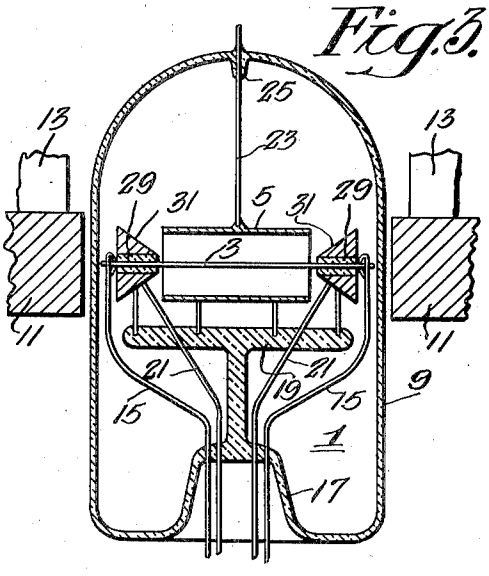


Fig. 3.



Inventor

Ernest G. Linder

By

Attorney

April 15, 1941. E. G. LINDER 2,238,272

MAGNETICALLY CONTROLLED MAGNETRON

Filed Dec. 30, 1937 3 Sheets-Sheet 2

Fig. 4.

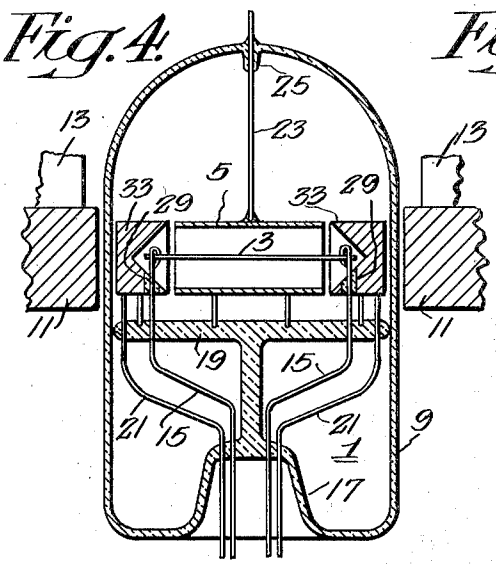


Fig. 5.

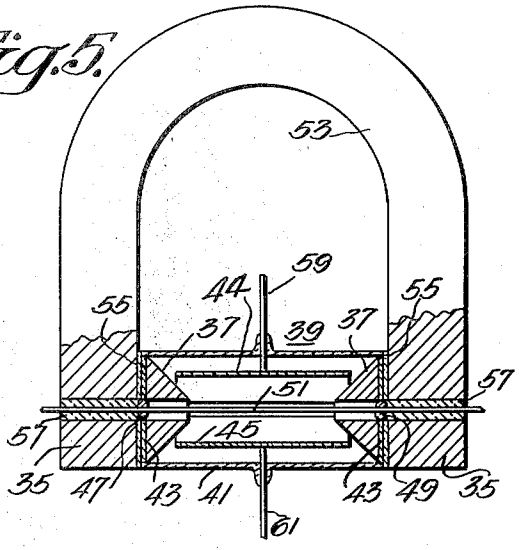
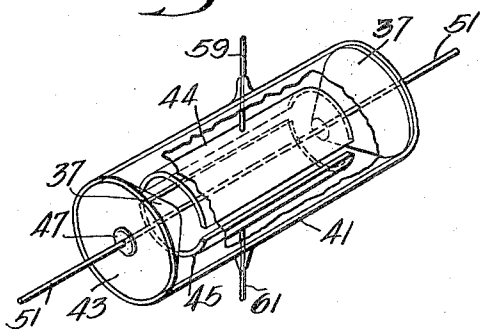


Fig. 6.



Inventor

Ernest G. Linder

By

Attorney

April 15, 1941. E. G. LINDER 2,238,272

MAGNETICALLY CONTROLLED MAGNETRON

Filed Dec. 30, 1937 3 Sheets-Sheet 3

Fig. 7a Fig. 7b Fig. 7c Fig. 7d Fig. 7e

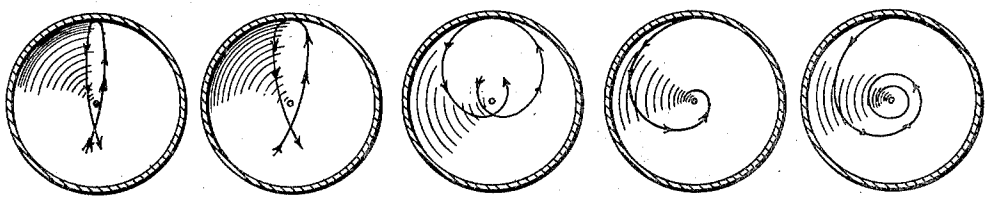


Fig. 8a Fig. 8b Fig. 8c

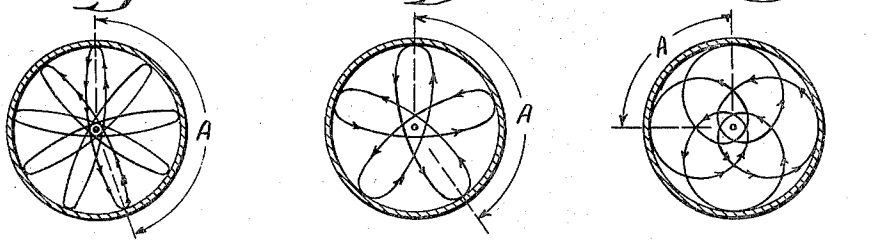
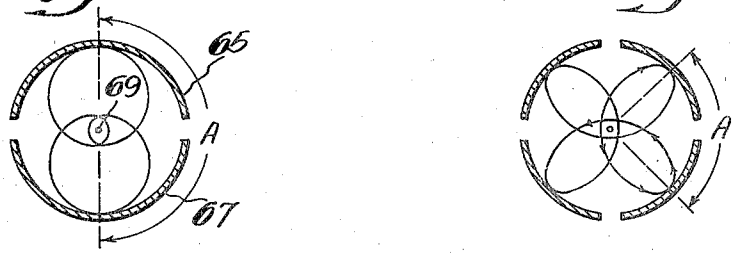


Fig. 9a Fig. 9b



Inventor

Ernest G. Linder

By J. Fuchs

Attorney

Patented Apr. 15, 1941

2,238,272

UNITED STATES PATENT OFFICE

2,238,272

MAGNETICALLY CONTROLLED MAGNETRON

Ernest G. Linder, Philadelphia, Pa., assignor to Radio Corporation of America, a corporation of Delaware

Application December 30, 1937, Serial No. 182,401

14 Claims. (Cl. 250—27.5)

My invention relates to magnetron devices in which the electron transit time governs the period of oscillation, and more particularly to one in which the electron orbit is controlled by inserting elements of a high magnetic permeability in the magnetic field.

In order to explain the nature and operation of my invention, a brief discussion of the prior art is necessary. Oscillators of this type generally consist of a cylindrical anode enclosing a coaxial cathode, and a magnetic field parallel to the axis of the cathode. Electrons are given off by the cathode and move through a curved path which is determined by combined magnetic and electrostatic fields. It is well known that in this type of oscillator the frequency of oscillation is determined by the time required for an electron following its orbit to complete one cycle. It may thus be seen that the frequency is dependent upon the length of the electron path and the speed of the electron.

It is well known that the speed of the electron, and consequently the frequency of oscillation, may be controlled by changing the density of the magnetic flux acting on the electrons. My invention relates to means by which a non-uniform magnetic field is used to change the curvature of the electron orbit at various points, and thereby greatly to increase the efficiency of the oscillator, and, in addition, to control the frequency of oscillation and the space charge within the tube.

It is an object of my invention to provide an improved magnetron oscillator.

Another object of my invention is to provide means for controlling the curvature of the electron orbit.

Another object of my invention is to provide means for controlling the length of the electron orbit.

Another object is to provide a more efficient magnetron discharge device.

A further object is to provide a magnetic field within the cathode-anode space of a magnetron oscillator having non-uniform flux density which may be concentrated in the vicinity of either of the electrodes.

A still further object of my invention is to provide means for controlling the space charge within a magnetron oscillator.

An additional object of my invention is to control the angle between the radius vectors corresponding to the maximum electron excursion from the cathode.

The new features and the scope of my invention are set forth in the appended claims. My invention itself, both as to its operation and construction, will be better understood from the following description, when considered in connection with the accompanying drawings.

Figure 1 is a cross-sectional view of one embodiment of my invention wherein the magnetic flux is concentrated in the region adjacent to the anode;

Figure 2 is a cross-sectional view of another form of my invention in which the magnetic flux is concentrated in the region of the cathode;

Figure 3 is a cross-sectional view of still another form of my invention wherein the magnetic flux is concentrated at the cathode, but in which the flux density from cathode to anode decreases more slowly than that in Fig. 2;

Figure 4 is a cross-sectional view of another form of my invention in which the flux density from cathode to anode increases more slowly than that of Fig. 1;

Figure 5 is a cross-sectional view of an alternate construction applied to a split-anode magnetron;

Figure 6 is a perspective view of the magnetron of Fig. 5;

Figure 7 (*a* to *e*) shows the path of one electron cycle as the relative magnetic flux density is increased in the region of the cathode;

Figures 8*a*, 8*b* and 8*c* show a series of electron orbits within magnetrons corresponding to the respective single-cycle orbits of Figures 7*a*, 7*b* and 7*c*; and

Figures 9*a* and 9*b* show two complete electron orbits, one within a two-anode magnetron and the other within a four-anode magnetron.

In Fig. 1 is shown a magnetron oscillator **1** consisting of a cathode **3**, a cylindrical anode **5**, and at **7** two annular elements of high magnetic permeability, mounted within an evacuated envelope **9** and placed between the two poles **11** of a permanent magnet **13**. The cathode is fastened between two supports **15** which are also conductors, and which are brought out of the envelope **9** through a glass seal **17**. The annular elements **7** are held in a position coaxial with the anode, and while they may be mounted in any convenient way, I have found it satisfactory to mount them on a T-shaped glass support **19**. Conductors **21** are connected to and assist in supporting the annular elements. The conductors **21** are brought out of the glass envelope through the seal **17**. Connection to the anode is made by means of a conductor **23**, which is brought out through the top of the envelope and

sealed at 25. While I have indicated the magnet 13 to be a permanent magnet, it may be an electromagnet. The size of the annular elements 7 is not critical, but their length must be sufficient to substantially decrease the reluctance between the pole pieces. The outer diameter must bear such relation to the diameter of the anode 5 that the reluctance of the magnetic path between the pole pieces 11 will thereby be a minimum in the region just within the inner surface of the anode. Consequently, the magnetic flux density in this region will be a maximum. The diameter of the opening which extends axially through the center of element 7 must be large enough so that the magnetic reluctance between the pole pieces 11 will be high in the region adjacent to the cathode 3, which results in a low flux density in this region. The result is a sudden increase of flux density in the region near the anode, the effect of which will be discussed hereinafter.

Refer now to Fig. 2, in which a magnetron similar to Fig. 1 is shown. For convenience, identical parts are identified by similar reference numerals throughout the specification. The difference between Fig. 2 and Fig. 1 is in the proportions of the annular elements marked 27 in Fig. 2. These elements 27 are placed concentric with the cathode 3, as before, but their outer diameter has been decreased. Likewise, the axial opening through the center has been decreased until there is just clearance for the cathode 3 and the insulating ceramic sleeve 29. The dimensions of the elements 27 are not critical, but their outer diameter must be small enough so that a substantial proportion of the magnetic flux is concentrated in the region of the cathode. Due to the higher reluctance of the magnetic path in the region of the anode, the flux density will be less in that region. It may be seen, therefore, that the apparatus shown in Fig. 2 has the same purpose of controlling the flux density gradient within the anode as the apparatus shown in Fig. 1.

Referring to Fig. 3, the essential difference between this figure and the preceding figures is in the substitution of truncated conical elements 31 for the annular elements shown in Figs. 1 and 2. The purpose of elements 31 is to provide high magnetic flux density in the region surrounding the cathode 3, and a low magnetic flux density in the region just within the anode, and in addition, to provide a substantially uniform decrease of magnetic flux density at successive points approaching the anode along a line at right angles to the cathode. This result is obtained by the uniformly receding external face of the element 31.

The distinguishing feature of Fig. 4 is the shape of the flux-controlling elements 33 which are substantially cylindrical in shape, and are mounted coaxially with the cathode. Each element has a conical recess in the end toward the anode. They are slotted in the lower edge formed by said conical recess to provide clearance for the cathode supports 15 and the ceramic insulating tubes 29. This configuration of element 33 provides a substantially linear variation of flux density, decreasing uniformly along radii perpendicular to the cathode.

Fig. 5 shows a variation in construction which has the advantage of decreasing the air gap between the magnet pole pieces 35 and the magnetic flux control elements 37 within the magnetron tube 39. While a "split anode" or "two-plate" magnetron is shown, the invention is applicable to magnetrons employing single anode, double anode, or having a plurality of anode sections. While the flux-controlling elements shown are of the truncated-cone type, the construction of Fig. 5 may be combined with other types of flux-control elements to obtain any required flux gradient within the anode-cathode area.

In Figs. 5 and 6, the magnetron is arranged within an evacuated glass envelope 41, having two disc shaped metal end plates 43 sealed into the ends of the glass envelope. The cathode 51 is held concentrically within the envelope 41 and the split anodes 44 and 45 by means of two sealing beads 47 and 49 which are sealed into openings in the center of the end plates. An aperture extends axially through each flux-control element 37 to permit the cathode to be brought out of the magnetron through the beads 47 and 49. The pole pieces 35 of the magnet 53 are insulated from the end plates 43 by means of insulating washers 55. The pole pieces and washers include an aperture through which the extremities of the cathode 51 extend. The cathode is insulated from the pole pieces by means of ceramic or other suitable insulator tubes 57. Connection to the two anode sections is made by means of the two leads 59 and 61 which extend through the glass envelope.

Fig. 7*a* shows the electron path when the magnetic flux density, indicated by concentric lines, is a maximum in the region just within the anode, but which abruptly decreases on approaching the region surrounding the cathode. This causes the curvature of the electron path to be a maximum near the anode. Such a distribution of flux density is obtained by the use of the density control elements 7 shown in Fig. 1.

Fig. 7*b* is representative of one cycle of an electron path when the flux density is a maximum in the area just within the anode, and gradually decreased toward the cathode. This distribution of flux density is obtained by the use of the elements 33 of Fig. 4. As shown, the curvature of the electron path changes less abruptly in the region near the anode.

Fig. 7*c* is representative of one cycle of an electron path in a magnetic field uniformly distributed from anode to cathode.

Fig. 7*d* is representative of one cycle of an electron path in a magnetic field whose intensity is a maximum in the region surrounding the cathode, and which decreases substantially uniformly on approaching the anode. A flux distribution of this type is produced by the control elements 31 in Fig. 3, or as shown by 37 in Figs. 5 and 6.

Fig. 7*e* is representative of one cycle of an electron path in a magnetic field whose intensity is a maximum in the region surrounding the cathode, and which abruptly decreases on approaching the anode.

It is thus clear that my invention provides means for controlling the electron path within a magnetron oscillator. I will now show the importance of such control and the practical advantage derived therefrom.

In Fig. 8*a* is shown a cross-sectional view representing a series of 9 cycles of electronic oscillation under conditions identical to those of Fig. 7*a*. It is to be noted that each successive excursion of the electron from the cathode takes place in a new direction, and that the electron revolves completely around the cathode. Fig. 8*b* represents 5 complete cycles of an electron under conditions identical to those of Fig. 7*b*. The angle between the radius vectors corresponding to suc-

cessive maximum excursions from the cathode, illustrated by angle A, has decreased in Fig. 8b. Fig. 8c represents four cycles of the electron path in a substantially uniform field. It is to be noted that each cycle occurs about a radius vector which has rotated in a counter-clockwise direction from the preceding cycle. Angle A has now decreased to 90°.

In Fig. 9a is indicated a cross-section representing a controlled electron path in a split-anode magnetron consisting of two anode sections 65 and 67 and a cathode 69. By increasing the magnetic flux density in the region of the cathode, the maximum curvature of the electron path occurs at that point, and the angle between successive electron excursions has become 180°. The effect of this is to greatly increase the efficiency of the magnetron, because the electrons no longer rotate at random about the cathode, but alternate consistently between the two anodes. In a magnetron oscillator the strength of oscillation depends upon the number of electrons which oscillate between the anodes. Therefore, this control increases the efficiency by preventing the electrons from rotating at random and by putting them to work in each cycle.

Fig. 9b is a cross-sectional view representing the desired electron paths for a four-anode magnetron. Each cycle of the electron takes it from one anode to the next succeeding one.

Thus I have described means by which the magnetic flux density within the cathode-anode area may be controlled, have shown how various distribution patterns of magnetic flux influence electron travel, and have shown that the efficiency of a magnetron is thereby improved. While I have shown particular embodiments of my invention, it is not my intention to be limited thereby. Other shapes of flux-control elements will be apparent to those skilled in the art, as well as numbers or locations of such elements not particularly shown herein.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A magnetron comprising means for producing a magnetic flux, an electron discharge tube having a cathode and an anode electrode located in the path of said flux, and means of high permeability within said tube for establishing a flux density gradient measured along a radial path between said cathode and anode electrodes.

2. A magnetron comprising means for producing a magnetic flux, an electron discharge device having cathode and anode electrodes, said magnetic flux passing within said device parallel to said cathode, and one or more suitably shaped elements of high magnetic permeability so designed and arranged within the magnetic field as to make said magnetic field non-uniform within said discharge device.

3. In combination, a magnet having a pair of opposed magnetic pole pieces, a discharge device having electrodes mounted between said pole pieces, and elements of high magnetic permeability within said discharge device so designed and arranged that the magnetic flux density is made non-uniform within the area bounded by the electrodes of said discharge device.

4. In combination, a magnet having opposed pole pieces, an electronic discharge device having coaxial cathode and anode electrodes located in the field of said magnet, and annular elements of high magnetic permeability interposed between said pole pieces and said cathode and anode electrodes, whereby the magnetic flux between said pole pieces is concentrated substantially in the region adjacent to said anode electrodes.

5. In combination, a magnet having opposed pole pieces, an electronic discharge device within the field of said magnet and having coaxial cathode and anode electrodes, and annular elements of high magnetic permeability interposed between said pole pieces and said cathode and anode electrodes whereby the magnetic flux between said pole pieces is concentrated substantially in the region surrounding said cathode.

6. In combination, a magnet having opposed pole pieces, an electronic discharge device within the field of said magnet and having coaxial cathode and anode electrodes, and conical elements of high magnetic permeability interposed between said pole pieces and said electrodes whereby the magnetic flux between said pole pieces is concentrated substantially in the region surrounding said cathode.

7. In combination, a magnet having opposed pole pieces, an electron discharge device within the field of said magnet and having coaxial cathode and anode electrodes, and elements of high magnetic permeability interposed between said pole pieces and said electrodes, said elements being cylindrical in shape and having a substantially conical recess on the surface adjacent to said cathode and anode electrodes, whereby the magnetic flux is concentrated in the region adjacent said anode electrodes and diminished in the region surrounding said cathode electrode.

8. In combination, a magnet having a pair of opposed magnetic pole pieces and an electronic discharge device mounted between said pole pieces, said discharge device having a substantially cylindrical envelope, anode electrodes mounted within said envelope and coaxial thereto, a substantially coaxial cathode within said anode electrodes, metal end-plates sealed into the ends of said cylindrical envelope, and flux-control elements of high magnetic permeability mounted on said end-plates within said envelope, so designed and arranged as to distort the magnetic flux within the region bounded by said cathode and anode electrodes.

9. An electron discharge device comprising an enclosing vessel, an anode, an elongated cathode in cooperative relation with said anode, and magnetic members within said vessel and adjacent the ends of said cathode.

10. An electron discharge device comprising an enclosing vessel, a tubular anode within said vessel, a linear cathode within said anode and substantially coaxial therewith, and a pair of magnetized members adjacent opposite ends of said anode for producing a magnetic field adjacent and parallel to said cathode.

11. A magnetron comprising an enclosing vessel, a cathode, an anode in cooperative relation with said cathode, a pair of magnetic members at the ends of said cathode and within said vessel, and magnetic means external to said vessel including pole-pieces in juxtaposition to said magnetic members.

12. An electron discharge device comprising an enclosing vessel, a tubular anode within said vessel, a linear cathode within said anode and substantially coaxial therewith, and a pair of magnetizable members within said vessel and adjacent opposite ends of said anode for producing a magnetic field adjacent and parallel to said cathode.

13. An electron discharge device comprising a tubular anode, a cathode extending through and beyond the ends of said anode, and a pair of mag-

netizable members within said vessel adjacent the ends of said anode and enclosing the ends of said cathode for producing a magnetic field adjacent and parallel to said cathode.

14. A magnetron comprising means for producing a magnetic flux, an electron discharge device having cathode and anode electrodes, said magnetic flux passing within said device parallel to said cathode, and one or more suitably shaped elements of high magnetic permeability so designed and arranged within the magnetic field as to make said magnetic field non-uniform within said anode electrodes.

ERNEST G. LINDER.