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F. GRAY

2,197,042

ELECTRON DISCHARGE DEVICE

Filed Oct. 22, 1938

FIG. 1

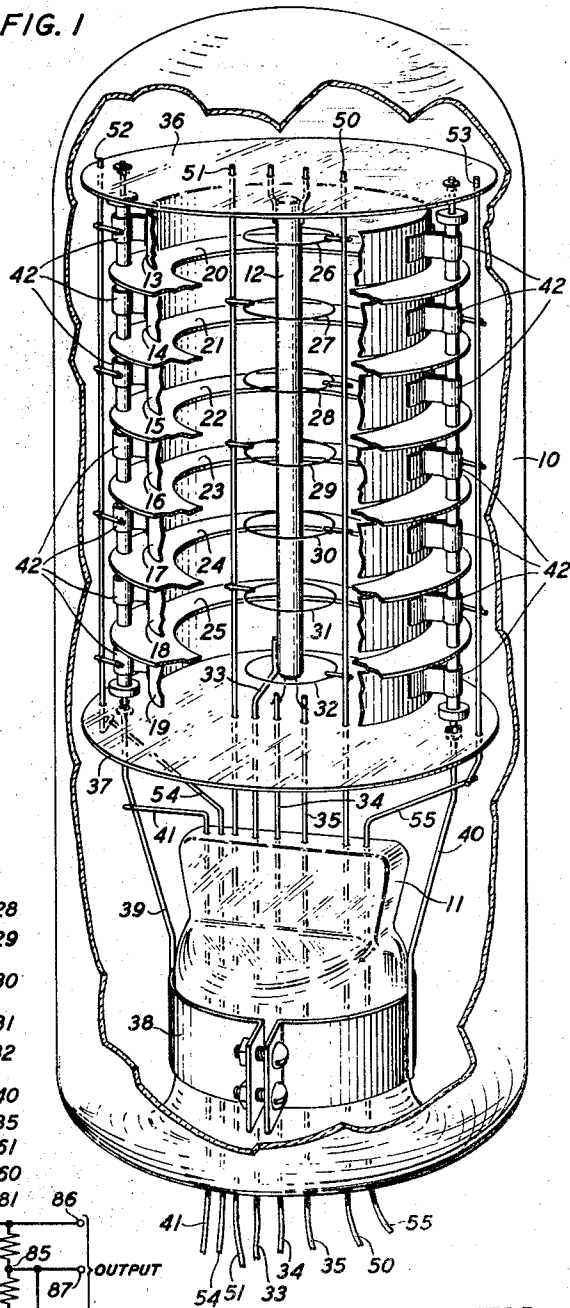


FIG. 2

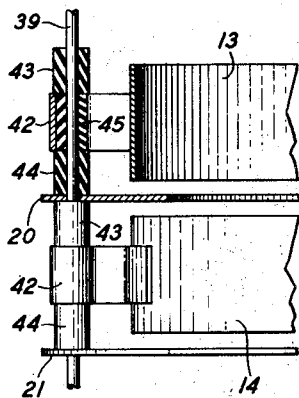
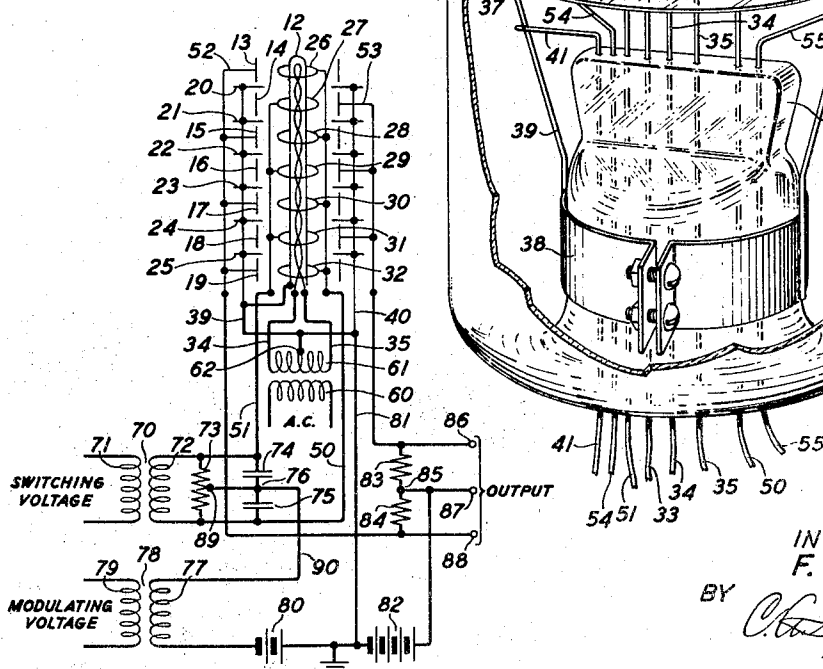


FIG. 3



INVENTOR
F. GRAY

BY *C. G. Sprague*
ATTORNEY

UNITED STATES PATENT OFFICE

2,197,042

ELECTRON DISCHARGE DEVICE

Frank Gray, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application October 22, 1938, Serial No. 236,533

9 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices and more specifically to devices of this character which operate by controlling the deflection of an electron beam or beams.

8 In a copending application of F. Gray, Serial No. 188,648, filed February 4, 1938, there is disclosed an electron discharge device which is provided with electrostatic grids which have the multiple function of forming the electron discharge into beams, which are preferably converging, switching all or a portion of each beam from a portion of a divided anode to another portion thereof, and at the same time, controlling the strength of the beam current.

15 In the device described in that application, the axes of the beams are parallel to the cathode and the anode members are segments of a cylinder. In some cases, it is desired to have a multiplicity of beams (much more than can be conveniently obtained with the structure in the copending application) in order to have a large total current without increasing the current per beam. The structure shown in the copending application is not applicable for such multi-beam operation unless the diameter of the tube is made relatively very large to accommodate a large number of anode segments and grids.

20 It is an object of this invention to provide a novel multi-beam electron discharge device in which two or more of the functions of modulating, focusing and deflecting the beam are performed by the same element or elements.

25 A feature of the device of this invention is that the axes of the beams are substantially at right angles to the axis of the cathode.

30 In accordance with this invention in a preferred form, an electron discharge device is provided which comprises an elongated cathode surrounded by a cylindrical plate or anode member which is split into an odd number of small rings or cylinders as, for example, seven, as shown in the accompanying drawing. Between the cathode and the anode sections are a number of control rings, one for each anode section. As each control ring performs the function of a grid in the ordinary vacuum tube, they will hereinafter be referred to as grid rings or wires. The grid rings are all similarly biased negatively with respect to the potential of the cathode to form (in cooperation with the positively biased anode sections) the electrons into six toroidal-shaped beams, each of which, in the absence of deflection voltage or signals, impinges upon the narrow ring-shaped area between adjacent anode sections or cylinders. These areas, or at least a portion

thereof, are filled with ring-shaped electrode elements which are placed at a negative potential with respect to the adjacent anode sections, as, for example, they are placed at the same potential as the cathode. These electrode elements prevent cross currents between the anode sections due to secondary emission. Being at a negative potential with respect to the anode sections they also tend to deflect the electrons and thus enhance the deflection of the electron beams and also to furnish a sharp line of demarcation between the anode sections. The potential of all the grid wires in common may be varied to control the intensity of the beams. The grid rings or wires are preferably connected into two groups, alternate grid wires being electrically connected together with separate leads for each group. A varying voltage, which may be, for example, an alternating current voltage, is applied between the two groups of grids to cause the beams to swing from one group of anode sections to another group thereof or to divide the energy of each beam between two anode sections, depending on the amplitude of the varying voltage. Alternate sections or cylinders comprising the composite anode are also connected in common; in effect, there are thus two electrically separate plates in the tube and electron stream (considered as a composite of the six beams of the disclosed embodiment) divides its energy between or among the various plate or anode cylinders in accordance with the switching or deflecting voltage. The grid rings thus serve to focus the electron beams, control the strength of the beam currents (if desired), and to deflect the beams.

35 A tube of this type may be used in high frequency switching operations serving, for example, as a high frequency commutator for dividing the transmission time between two image currents, portions of each of which are alternately transmitted over the line. It will also be apparent from the detailed description below that it may be used for amplifying, for detecting, for single or double modulation of a high frequency carrier wave with voice or image currents, and for the modulation of a high frequency carrier wave with an intermediate carrier wave and also with voice or image currents, etc.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof in which:

Fig. 1 is a perspective view of an electron discharge device embodying the principles of this invention;

Fig. 2 is an enlarged view of a portion of Fig. 1 showing the method of mounting the anode sections and the ring-shaped electrode elements therebetween; and

Fig. 3 shows a circuit in which a tube of the type shown in Fig. 1 may be used.

Referring more specifically to the drawing, Fig. 1, by way of example, shows in perspective an electron discharge device embodying the principles of this invention, the envelope being partly broken away in order to show more clearly the electrode structure therein. The device comprises a gas-tight envelope 10 of, for example, glass, containing a press 11, in which are held in position a cathode 12, seven anode cylinders 13, 14, 15, 16, 17, 18 and 19, ring electrode elements 20, 21, 22, 23, 24 and 25 located between adjacent anode elements, and grid rings or wires 26, 27, 28, 29, 30, 31 and 32. While seven anodes 20 and seven grid wires are shown in the electron discharge device of Fig. 1, it is to be understood that any odd number of anodes and an equal number of grid wires may be used.

The cathode 12 is preferably a metallic cylinder of either the open end or closed end type. It is heated by any suitable means such as by a source applied to the primary winding of the transformer 60 (see Fig. 3) and is coated on the outside with a layer of electron emissive material. A connection to the cathode from an external circuit is made through the terminal 33. Terminals 34 and 35 are connected to the heating means for the cathode 12. If desired, the terminal 33 may be connected to the mid-point 62 of the secondary winding 61 of the transformer 60 to prevent the possibility of a "free" input or "floating" element.

The anode sections 13, 14, 15, 16, 17, 18, 19 and 20 are preferably cylinders of the same diameter and of equal height located concentric to the cathode and distributed uniformly along the axis of the cathode.

The anode elements or sections are arranged between two discs 36 and 37 of mica or other suitable material which discs are supported from a band 38 encircling the press 11, by means of support wires 39 and 40. A lead wire 41 makes connection to the guide wire 39 from the external circuit in order to apply a voltage to the electrode elements 20 to 25, inclusive.

With reference to Fig. 2 it will be noted that the anode sections 13, 14, etc. have attached thereto metallic lugs 42. By means of insulating spacers 43 and 44 and the insulating bushings 45 the anode members 13, 14, 15, 16, 17 and 18 are firmly supported from the press 11 and spaced at predetermined distances apart. These spacers also serve to hold in position the ring electrodes 20 to 25, inclusive. As the bushings 45 of the lugs 42 and the spacers 43 and 44 are made of insulating material, the anode members 13 to 19, inclusive, are insulated from the support wire 39 and, on the other side of the tube, from the support wire 40. The holes in the electrode rings 20 to 25, inclusive, are made just large enough so that the ring members tightly engage the support wires 39 and 40, thus placing these electrode elements at the same potential as the wires 39 and 40.

The grid wires 26 and 32, inclusive, are supported by means of wires 50 and 51 which are fastened into the press 11. The wires 50 and 51 are further supported by means of the mica discs 36 and 37. As shown in Fig. 1, the grid wires 26 to 32 are supported by and connected alternately

to wires 50 and 51. If desired, however, additional supports may be provided so that each wire is supported from both supports 50 and 51 although it is only electrically connected to one for reasons which will be more fully pointed out below. While these grid wires have been shown as rings they may be made small cylinders or any other convenient shape.

Anode cylinders 13, 15, 17 and 19 are electrically connected to wire 52 while cylinders 14, 16 and 18 are electrically connected to wire 53. Wire 52 is in turn electrically connected to lead wire 54 which is supported by the press 11 and wire 53 is electrically connected to lead wire 55, also supported by the press.

Reference will now be made to Fig. 3 for an example of a circuit in which the tube shown in Fig. 1 may be used. A deflecting voltage is applied between the two electrical grid structures by means of the transformer 70, the primary winding 71 of which is connected to any suitable generator of switching or deflecting voltage. Across the secondary winding 72 of the transformer 70 is connected a high resistance 73 which, in turn, is shunted with a pair of equal capacities 74 and 75, the common terminal 76 of which is connected to the mid-tap 89 of the resistance 73 and also through the secondary winding 77 of a transformer 78, a source of biasing potential 80, and a conductor 81 to the cathode 12. The primary winding 79 of the transformer 78 is connected to a source of modulating voltage. As the positive terminal of the source 80 is connected to the cathode 12, a negative bias is placed on all of the grid wires 26, 27, 28, 29, 30, 31 and 32 together. A positive potential with respect to cathode 12 is applied to all the anode sections by means of the source of plate voltage 82 acting through the resistances 83 and 84. The common terminal 85 of these resistances is connected to the positive terminal of the source 82. The negative potential on the grid rings causes the electron stream from the cathode to be formed into six beams each focussing upon the division line between adjacent anode cylinders, in the absence of a deflecting or switching voltage, so that each beam impinges partly upon one plate and partly upon another, the electrode rings 20 to 25, inclusive, serving to split the beams. The output is taken off from the terminals 86, 87 and 88.

In the circuit shown in Fig. 3, it is assumed that the switching voltage on transformer 70 is of lower frequency than the modulating voltage on transformer 78. The condensers 74 and 75 then block the switching voltage, but pass the modulating voltage to the grid as a whole. If the switching voltage on transformer 70 is of higher frequency than the modulating voltage on transformer 78, the condensers 74 and 75 may be replaced by inductances that block the switching voltage, but pass the modulating voltage to the grid as a whole. The resistance 73 can then be omitted. The operation of the tube will then be the same as in the case of the switching voltage being higher than modulating voltage.

The operation of the circuit shown in Fig. 3 will now be described. The cathode 12, heated by a heater element (not shown) is caused to emit a stream of electrons, which electrons are focussed by the action of the negative potentials of the grids 26, 27, 28, 29, 30, 31 and 32 and the positive potentials of the anode segments 13, 14, 15, 16, 17, 18 and 19 into six beams, there being in any case (with the construction shown in Fig. 75

1) one less beam than there are anode segments. In order for the device to be symmetrical, there must be an even number of beams so hence there are an odd number of grid and anode elements although there are, of course, as many grids as anodes. In the absence of a deflecting voltage or signal in the primary winding 71 of the transformer 70, each grid ring or element is placed at the same potential by means of the source of direct current 80 acting through the potentiometer resistance 73. With this condition existing, the six electron beams are formed and focussed upon the electrode rings 20 to 25, inclusive (as they are between the anode or plate cylinders 13 to 19, inclusive), which, because of their negative potential with respect to that of the anode cylinders, serve to equally divide the beams between adjacent plate elements.

Assume for purposes of example that the tube is to be used as an electronic switch and that no signal is flowing. In this situation, electrons from the cathode will be focussed by the negative potential on the grids 26 and 27 into a beam which is divided equally between the anodes 13 and 14. Similarly, a beam is focussed by the grids 27 and 28 and caused to be divided equally between the anodes 14 and 15, a beam is focussed by grids 28 and 29 and caused to be divided between plates 15 and 16, a beam is focussed by means of the grids 29 and 30 and caused to be divided between the plates 16 and 17, a beam is focussed by means of the grids 30 and 31 and caused to be divided between the anode sections 17 and 18 and a beam is focussed by the grids 31 and 32 and divided equally between the anode sections 18 and 19. In such a case equal currents flow through the resistances 83 and 84 as the composite beam energy flows equally through the two resistances.

Now assume that the potential of the grid terminal 50 swings positive with respect to that of the terminal 51 by an amount sufficient to cause each beam to wholly impinge on a single anode member. In this situation the potentials of grids 26, 28, 30 and 32 swing positive with respect to the potentials of grids 27, 29 and 31 and one complete beam impinges on anode section 13, two beams on the anode section 15, two beams on the anode section 17 and one beam on the anode section 19, there being substantially no electrons impinging upon anode sections 14, 16 and 18. This causes substantially all of the current to flow between terminal 52 and the cathode 12 and hence through the resistance 84 (and to the output circuit between terminals 87 and 88). Now if the potential of terminal 50 swings negative with respect to that of the terminal 51, the reverse will be true and two beams will impinge upon plate section 14, two upon plate section 16 and two upon plate section 18, there being no electron flow to the odd numbered plates 13, 15, 17 and 19 in this case. Thus, substantially all of the current flow will be between the terminal 53 and the cathode 12 and thus the output will be taken off between terminals 86 and 87.

If the switching voltage applied to the primary winding 71, for example, is a square-topped alternating wave, a wave peculiarly adapted for switching in this manner, there will first be current in the resistance 83 and then in the resistance 84 and if one output circuit is connected between the terminals 86 and 87 and the other output circuit between the terminals 87 and 88 the output signals are alternately switched from

one circuit to the other. The intensity of the beam may be modulated by means of voice or image current supplied to the primary winding 79 of the transformer 78, the secondary winding of this transformer being connected in circuit with all of the grids in common inasmuch as one terminal of the secondary winding is connected to the mid-point of the potentiometer resistance 89.

If it is desired to use the tube as an amplifier, for example, the beams in general always divide their energy between both sets of plates rather than having all their energy first on one set of plates and then on the other as in the case of the switching arrangement. In this case, a portion of the plate current flows through the resistance 83 and a portion through the resistance 84, the output circuit connected between the outside terminals 86 and 88 receiving the differential current flowing through these resistances. As only a very small deflecting voltage is required to move the composite beam and this controls a relatively large beam current, an amplified output is obtained in the output circuit between the terminals 86 and 88.

It may be noted that the type of tube herein described is suitable for so-called "push-pull" operation, the circuit shown in Fig. 3 being a push-pull circuit for as one grid or grid assembly swings in the positive direction, the other grid or grid assembly swings in the negative direction. The current in one of the differential output circuits is thus increased while that in the other is correspondingly decreased. By combining the currents of these differential circuits an amplified current is obtained. The principle is that of the well-known Colpitts amplifier disclosed for example in Patent 1,128,292, February 16, 1915. See also "Principles of Radio Communication" by J. H. Morecroft 1933, page 1004, for a description of push-pull amplification.

When a suitable feedback is provided, the arrangement becomes a push-pull oscillator, the circuit connection being, for example, like that shown in Scriven 1,396,786, November 15, 1921, or Carson 1,463,796, August 7, 1923.

Obviously, the arrangement shown in Fig. 3 may be employed as a modulator of high frequency current as in the well-known push-pull modulator circuit employing ordinary vacuum tubes. The source of switching voltage 71 is then the source of carrier frequency and the modulating signals are applied by means of the transformer 78 in the common portion of the divided input circuit. For a description of push-pull modulating circuits like that here shown and modified forms in which a tube of the type here disclosed may be employed, if desired, see for example page 324 of "Principles of Radio Communication" by Morecroft, or Carson 1,463,796, August 7, 1923.

The circuit shown in Fig. 3 may be used for double modulation by opening up the lead 90 and inserting therein the secondary winding of another transformer, to the primary winding of which may be applied an intermediate frequency signal. Thus a low frequency signal and an intermediate frequency signal are applied to all of the grid wires of the tube through a suitable circuit of inductances (replacing the resistance 73) which have a negligible impedance at these frequencies. The low frequency signal may comprise voice or image currents and is applied to the primary winding 79 of the transformer 78. The intermediate frequency is applied to the

primary winding of the added transformer and the high frequency carrier is applied to the primary winding 71 of the transformer 70. All of the grid wires act as ordinary grids or control members for the low and intermediate frequencies and the intermediate frequency is modulated by the low frequency voice or image currents in a manner that is well known. The beams are simultaneously switched from one set of plates to the other and back again by the high frequency carrier applied to the primary winding of the transformer 70, this high frequency being applied to the two parts of the split grid assembly through the coupling condensers 74 and 75, the series inductances which replace the resistance 73 now acting to block the high frequency carrier and prevent the two halves of the grid assembly from being shorted at that frequency. These inductances, however, are so small that they pass the low frequency signal and the intermediate carrier to the grid assembly as a whole. A suitable filter arrangement may be included in the output circuit to eliminate spurious components that may result from the non-linear control of the current in the tube. The inductances in the filter circuit block the carrier and by-pass spurious low frequency components to remove them from the signal. The combination of capacities and inductances in the filter is tuned to the carrier frequency and thus frees the output signal of spurious components.

When the deflecting or switching voltage of Fig. 3 is a modulated carrier and the source of varying voltage applied to the primary winding 79 of the transformer 78 is of carrier frequency, the arrangement functions in a reverse manner and becomes a detector. Any of the well-known push-pull detector circuits may be used.

It will be obvious to one skilled in the art of vacuum tube circuits how this tube may be used in push-pull circuits for uses other than those mentioned above.

It will be apparent that the grid wires 26, 27, 28, 29, 30, 31 and 32 ordinarily serve the triple function of focussing the electron beams, deflecting the beams so that the current or energy of the composite beam is divided between the effective parts of the anode, and controlling the strength of the beam current. The electrode rings 20, 21, 22, 23, 24 and 25 serve a triple purpose in that they suppress the flow of cross current due to secondary electrons passing between the anode members, they cause the beam to switch more sharply from one anode or plate to another somewhat analogous to a snap switch action, and also they furnish a sharp line of demarcation between the anode sections. For a more complete description of the operation of electrode elements between anode sections which electrode elements are placed at a negative potential with respect to that of the adjacent anode sections, reference may be made to the above-mentioned Gray application.

Obviously the grid wires 26 to 32, inclusive, may be given various forms and configurations and may be spaced at any desired distances between the cathode and anode sections, the results of such modifications of the exact illustrated arrangement described herein being obvious to one familiar with ordinary vacuum tube and cathode ray tube design. It is also obvious that there may be 9, 11, 13, 15, 17, 19, 21 or more anode sections and grid elements in a single tube instead of the number shown in the drawing. Other modifications of the embodiment herein

described may obviously be made without departing from the spirit of the invention.

What is claimed is:

1. An electron discharge device comprising an electron emitting cathode, an anode member surrounding said cathode, said anode member comprising a plurality of cylinders of the same diameter placed so that their axes coincide with that of said cathode and so that each is separated from adjacent cylinders by substantially the same distance, alternate cylinders being connected together, a plurality of control elements, alternate control elements being connected together, and disc members extending between adjacent cylinders.

2. An electron discharge device comprising an electron emitting cathode, an anode member surrounding said cathode, said anode member comprising a plurality of cylinders of the same diameter placed so that their axes coincide with that of said cathode and so that each is separated from adjacent cylinders by substantially the same distance, alternate cylinders being connected together, a plurality of control rings, alternate control rings being connected together, and annular electrodes coaxial with said cathode and extending between adjacent cylinders.

3. An electron discharge device comprising an electron emitting cathode, an anode member surrounding said cathode, said anode member comprising a plurality of cylinders of the same diameter placed so that their axes coincide with that of said cathode and so that each is separated from an adjacent cylinder by substantially the same distance, a ring electrode in the space between adjacent cylinders, means for connecting all of the cylinders together, a plurality of control elements, and means for connecting alternate control elements together.

4. An electron discharge device comprising a cathode, a cylindrical anode member surrounding said cathode, said anode member being divided into an odd number of rings, alternate rings being connected in common, a plurality of control rings, alternate control rings being connected in common, and disc-shaped members positioned between adjacent said anode rings.

5. An electron discharge device comprising an enclosure containing a press, a pair of support wires supported from said press, two circular discs of insulating material supported from said pair of wires so that they are spaced apart and parallel to each other, a plurality of cylindrical anode members supported from said support wires, insulated therefrom and spaced along the axis of said device between said insulating discs, a pair of conductors extending between said discs, means connecting some of said anode members to one of said conductors, means connecting the remainder of said anode members to the other of said conductors, an additional pair of support wires supported from said press, and a plurality of ring-shaped control member supported from said additional pair of support wires and spaced along the axis of said device between said discs.

6. An electron discharge device comprising an enclosure containing a press, a pair of support wires supported from said press, two circular discs of insulating material supported from said pair of wires so that they are spaced apart and parallel to each other, a plurality of cylindrical anode members insulatingly supported from said support wires and spaced along the axis of said device between said discs, a pair of conductors

extending between said discs and adjacent said support wires, means connecting one group of alternate anode members to one of said conductors, means connecting the other anode members to the other of said conductors, an additional pair of support wires supported from said press, and a plurality of ring-shaped control members supported from said additional pair of support wires and spaced along the axis of said device between said discs, said control members being alternately connected to opposite ones of said additional pair of support wires.

7. An electron discharge device comprising an enclosure containing a press, a pair of support wires supported from said press, two circular discs of insulating material supported from said pair of wires so that they are spaced apart and parallel to each other, a plurality of cylindrical anode members supported from said support wires and spaced along the axis of said device between said insulating discs, an additional pair of support wires supported from said press, a plurality of ring-shaped control members supported from said additional pair of support wires and spaced along the axis of said device between said discs, said control members being alternately connected to opposite members of said additional pair of support wires, and a plurality of ring-shaped electrode members supported from said first pair of support wires in the spaces between adjacent cylindrical anode members.

8. An electron discharge device comprising an enclosure containing a press, a pair of support

wires supported from said press, two circular discs of insulating material supported from said pair of wires so that they are spaced apart and parallel to each other, a plurality of cylindrical anode members supported from said support wires and spaced along the axis of said device between said insulating discs, an additional pair of support wires supported from said press, a plurality of ring-shaped control members supported from said additional pair of support wires and spaced along the axis of said device between said insulating discs, said control members being alternately connected to opposite ones of said additional pair of support wires, a plurality of ring-shaped electrode members supported from said first pair of support wires in the spaces between adjacent cylindrical anode members and electrically connected to said support wires.

9. An electron discharge device comprising an enclosure containing a press, two support wires supported from said press, two circular discs of insulating material supported from said wires so that they are spaced apart and parallel to each other, a plurality of cylindrical anode members spaced along the axis of said device between said insulating discs, a plurality of ring-shaped electrode members each respectively in the space between adjacent anode members, means for supporting said anode members from said wires, and insulating spacers on said wires positioning said supporting means along the axis of the device.

FRANK GRAY.