Sept. 5, 1939. R. M. BOWIE 2,172,316

ELECTRON DISCHARGE DEVICE

Filed Dec. 30, 1936 2 Sheets-Sheet 1

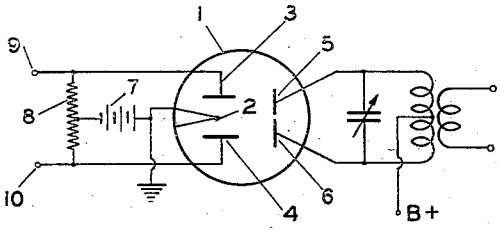


Fig. 1.

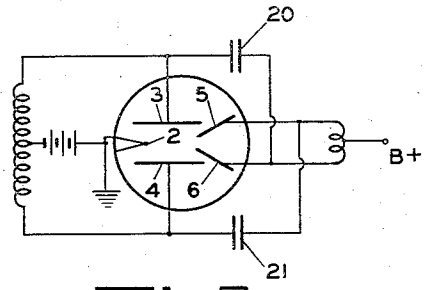


Fig. 3.

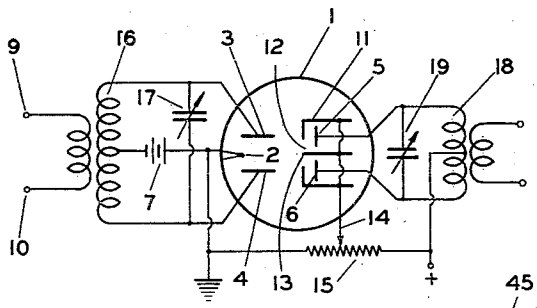


Fig. 2.

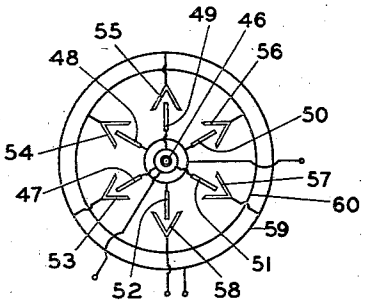


Fig. 5.

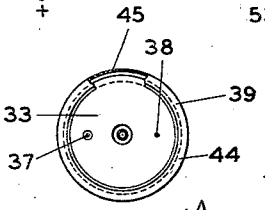


Fig. 4-A

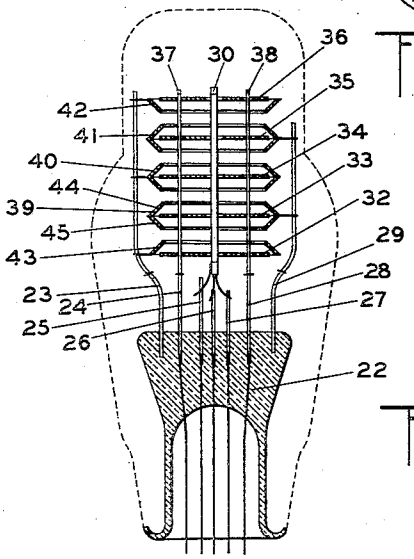


Fig. 4.

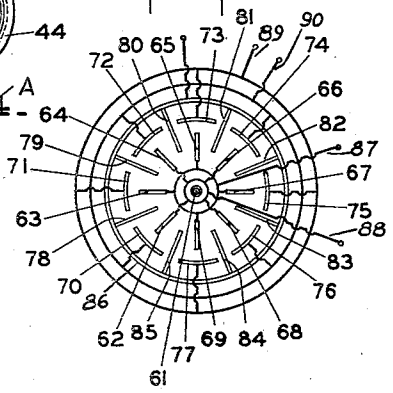


Fig. 6.

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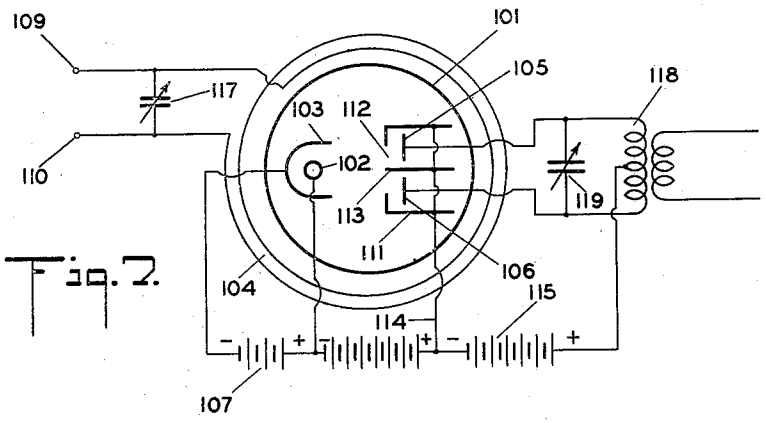


Fig. 7.

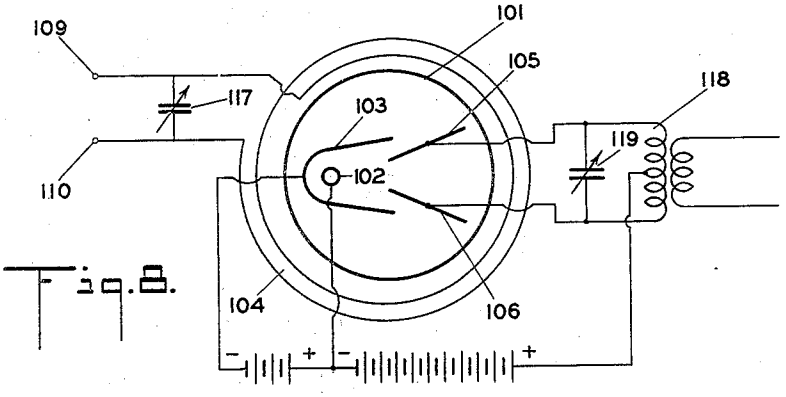


Fig. 8.

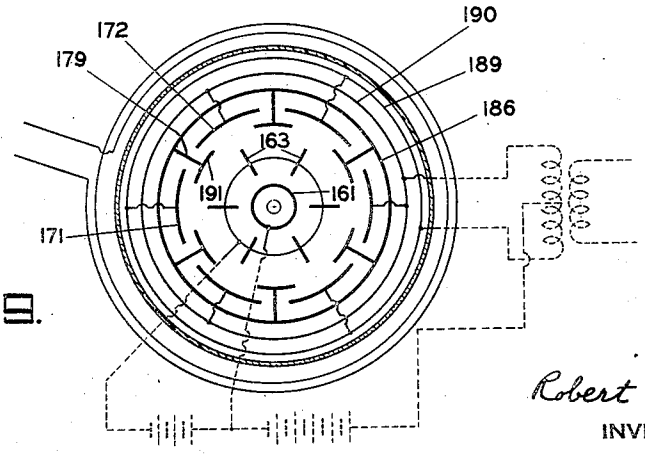


Fig. 9.

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ELECTRON DISCHARGE DEVICE

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Application December 30, 1936, Serial No. 118,241

6 Claims. (Cl. 250—158)

This invention relates to electron tubes and with particularity to electron discharge tubes of the control electrode type.

Generally speaking, grid controlled electron discharge tubes such as amplifier tubes, oscillator tubes and the like may be divided into two categories. One type relies for variation of the output or plate current or voltage, mainly upon a quantitative or valving action of the grid in the manner utilized in the well-known audion. The other type relies mainly upon the deflecting action of the grid on the electron stream. The present invention is concerned chiefly with tubes of the latter type, and has for its principal object the provision of a tube wherein variations of the plate or anode potential are prevented from reacting undesirably on the deflecting action of the control electrode.

Another object is to provide an electron discharge tube of the deflectable electron stream type wherein the deflection of the electrons is effected solely by the input or signal voltage.

Another object is to provide an improved oscillator tube of the deflectable electron stream type.

A feature of the invention relates to an electron discharge tube having a pair of output electrodes or plates with relation to which an electron stream is oscillated, in conjunction with means for preventing plate load variations from affecting the deflection of the electron stream.

Another feature relates to an electron discharge tube of the deflectable stream type wherein the control electrode and the output electrodes are shaped and positioned so as to minimize the reaction of plate potential variations on the stream deflection.

Another feature relates to an electron discharge tube having an electron emitter, dual sets of deflecting electrodes and dual sets of anodes or plate electrodes, the various electrodes being so shaped and positioned as to insure the proper control of the electron deflection by the control electrodes.

A further feature relates to an electron discharge tube having an electron emitter cathode, a plurality of disc-like control electrodes, and a plurality of diverging plate electrodes so positioned as to prevent a difference of potential between the plate electrodes from affecting the distribution of the electron stream thereto.

A still further feature relates to an improved wave amplifying, a wave repeating, or a wave oscillating system employing deflectable electron streams.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

While the invention in certain of its embodiments will be illustrated schematically, it will be understood that this is done merely for explanatory purposes and not by way of limitation to these particular embodiments, and only those parts which are necessary to a complete understanding of the inventive concept are illustrated. Accordingly in the drawings.

Fig. 1 is a composite explanatory tube-circuit diagram.

Fig. 2 shows a system such as that of Fig. 1 modified in accordance with the invention.

Fig. 3 shows a further modification of the system of Fig. 1.

Fig. 4 is a view, partly in section, of one tube structure such as is schematically illustrated in Fig. 3. Fig. 4*a* is a plan view of a section of Fig. 4.

Fig. 5 is a modification of the tube of Fig. 4.

Fig. 6 is a cross sectional view of a tube structure such as is illustrated schematically in Fig. 2.

Figs. 7, 8 and 9 are schematic showings of modifications of the tubes shown in Figs. 2, 3 and 6 respectively, employing magnetic control.

Referring to Fig. 1 there is shown in schematic form a bulb or enclosing envelope 1 which is preferably evacuated, and suitably mounted within the bulb are an electron emitting cathode 2, a pair of control electrodes 3, 4, and a pair of plates or anodes 5, 6. If the electrons which are emitted from the cathode are in the form of a beam or other well-defined stream they are capable of being deflected by means of suitable potentials on the electrodes 3, 4, with the result that the electrons arriving at the anodes are distributed therebetween in accordance with the angular deflection. It will be understood of course that the invention is not necessarily limited to a tube wherein the electrons are emitted in the form of a beam since the action of the electrodes 3, 4 can to a certain extent be utilized with cathodes such as are usually employed in radio tubes and the like, as will appear from the following descriptions. If the electrodes 3, 4 are biassed to the same average steady potential with respect to the cathode, for example by the battery 7 and resistance 8, and if an alternating current is impressed on the input terminals 9, 10 the electrons from the cathode will be oscillated from one to the other of the anodes 5, 6 it being understood that a suitable steady positive potential is impressed on said anodes. The

potential of the anodes will therefore alternate and produce in the output circuit an alternating current. I have found that while the arrangement of Fig. 1 can act as a repeater it is not capable of acting as an oscillator generator, in the absence of an oscillating potential on the input electrodes. I have also found that by employing an additional electrode, the tube can be used not only as a repeater but also as an amplifier or as an oscillator generator.

Thus referring to Fig. 2 the tube 1 is in general similar to the tube of Fig. 1 with the exception that another electrode 11 is provided. Electrode 11 is preferably symmetrically disposed with respect to cathode 2 and the control electrodes 3, 4. Electrode 11 is also preferably provided with a conductive dividing wall or partition 13 disposed symmetrically between plates 5, 6. By this arrangement the plates 5, 6 can be electrostatically isolated from each other, and for this purpose electrode 11 is connected by conductor 14 to a suitable steady positive potential preferably materially lower than the steady positive potential which is applied to the plates 5, 6. For example a voltage dividing resistance 15 may be connected across the terminals which supply the steady plate potential, the electrode 11 being adjustably connected to this resistance as shown. The signals to be amplified are impressed on the input terminals 9, 10 and then, by means of a suitable coupling transformer, across the electrodes 3, 4. Preferably the cathode 2 is connected to the electrical midpoint of the secondary winding 16 through a biasing source 7. If the signals or voltages to be amplified are of high frequency, the input circuit may be tuned to this frequency in any well-known manner for example by the variable tuning condenser 17. The output circuit may include any suitable load impedance such as the primary winding 18 of a coupling transformer, this winding being connected across the plates 5, 6 and being tuned for example by the variable tuning condenser 19. Preferably the plate potential source is connected to the plates at the electrical mid-point of the winding 19 so that the divided input and the divided output circuits may be electrically balanced with respect to ground or with respect to the cathode 2. By adjusting the steady potential of electrode 11 it is possible to achieve good voltage gain between the input and output voltages.

Probably the reason for this is that the electrode 11 prevents the instantaneous variations of the plate potentials from reacting on the electron beam deflected by the electrodes 3, 4, and consequently the deflection of the electrons is entirely controlled by the impressed input voltages. These variations of plate potential may be caused by the varying reactance or varying voltage drop across the load impedance as the plate currents vary from one plate to the other. Thus in the arrangement of Fig. 1 the electrons leaving the cathode 2 pass between the deflecting electrodes 3, 4, which direct the preponderance of the beam alternately toward plate 5 or plate 6. However, the potential of the plate to which the major portion of the stream is directed falls, because of the action of the load or work circuit. The lowered potential of this plate causes the beam to be redirected toward the other plate thus partially annulling the action of the deflecting electrodes. In the tube of Fig. 2 the opening 12 is small enough so that the effect of the changing potentials of plates 5 and 6 scarcely penetrate outside of the electrode 11 and therefore the proper distribution of the deflected beam between the two plates is not interfered with. The partition 13 prevents the field of one plate from pervading the space about the other plate. If the steady potential of electrode 11 is considerably lower than the average steady potential of the plates then most of the beam current reaches one of the two plates. Furthermore there is no part of the cycle during which secondary electrons can leave the lesser positive plate and travel to the other plate or to the electrode 11. On the other hand as the potential of electrode 11 is raised to approach that of the plates, a larger portion of the beam current is drawn to electrode 11, and during a large part of each cycle, secondary electrons can leave the lesser positive plate and travel to electrode 11.

Since the arrangement of Fig. 2 enables considerable voltage gain to be achieved, it is possible to employ the tube of Fig. 2 as an oscillator generator. This can be accomplished by coupling the output circuit to the input circuit so that the variations in the plate potentials regeneratively react on the input circuit. Thus the plate 5 may be connected through a suitable variable impedance such as a condenser to the electrode 4, while the plate 6 is connected through a similar impedance to the electrode 3. It will be obvious to those skilled in the art that this regenerative arrangement may be used for generating sustained oscillations for transmission or reception purposes, and it may be used as a regenerative or as an autodyne detector of modulated high frequency waves impressed on the input terminals.

I have also found that it is possible to utilize the arrangement of Fig. 1 to generate oscillations without employing the additional electrode 11 of Fig. 2. The plate electrodes or anodes must however be so shaped and disposed that the action of the difference in potential between the plates, upon the direction of the beam is minimized. A typical arrangement of this character is schematically shown in Fig. 3. In this embodiment the plates 5, 6 instead of being in the same plane and perpendicular to the deflecting plates 3, 4, are positioned at an angle to each other with the apex of the acute subtended angle located closely adjacent to, or even within, the space between the deflecting electrodes. Preferably the plates 5, 6 slightly overlap the ends of the deflecting electrodes as shown in Fig. 3. With this arrangement the effect of the plate at the lower instantaneous potential, upon the electron beam is decreased sufficiently so that satisfactory voltage gain can be achieved between the input and output voltages. Consequently such a tube can be used as an oscillator generator. Thus as shown in Fig. 3 the plate 6 is capacitively coupled through the condenser 20 to the electrode 3, and plate 5 is capacitively coupled through condenser 21 to electrode 4, the condensers 20 and 21 being of relatively small capacity so as to feed-back only the amount of energy required to maintain the system oscillating. The remainder of the circuit connections may be the same as those of Fig. 1 the divided input and output circuits being symmetrically balanced with respect to ground.

It will be clear that the tube structure illustrated schematically in Fig. 3 may be given a wide variety of structural embodiments. One representative embodiment is shown in Fig. 4. In this embodiment the evacuated enclosing en-

velope is shown in dotted outline and is provided with the usual header or press 22 into which are sealed the lead-in and support wires 23 to 29 inclusive. Supported within the envelope in any manner well-known in the radio tube art is an electron emitting cathode 30 which may be of the unipotential type adapted to be raised to emitting temperature by an insulated heater filament the terminals of which are connected to the lead-in wires 26, 27. The cathode sleeve 31 is connected to the lead-in wire 25. Surrounding the cathode and mounted in superposed relation is a series of annular discs 32 to 36 inclusive which are provided with central openings materially larger than the cathode. The discs 32, 34 and 36 are connected to the support member 37 which in turn is connected to lead-in wire 24, it being understood that the member 37 passes through but is insulated from the discs 33 and 35. Likewise the discs 33 and 35 are fastened to the support member 38 which is connected to lead-in wire 28, but is insulated from discs 32, 34 and 36. Surrounding and in spaced relation to the discs 33, 34 and 35 are V or U-shaped rings 39, 40 and 41 each of said rings being symmetrically positioned with respect to the adjacent disc so that the plane of the disc bisects the angle subtended by the walls of the ring. Preferably also, each V-shaped ring is positioned so that it slightly overlaps the rim of the associated disc as shown. Associated respectively with the uppermost and lowermost discs 32 and 36 are the inclined or half V rings 42, 43. Rings 40, 42 and 43 are electrically connected to the metal upright 23. Likewise the rings 39 and 41 are fastened to the metal upright 29. If desired insulator beads (not shown) may be interposed between the support 23 and the rings 39 and 41 so as to provide the required support at opposite sides of each ring. Similar insulator beads may be interposed between the support 29 and the rings 40, 42 and 43. It will also be understood that any of the insulator spacing arrangements well-known in the radio tube art may be employed to maintain the various electrodes in their proper fixed spaced relation.

The manner of functioning of the tube of Fig. 4 is believed to be as follows. The electrons emitted by the cathode 30 are divided by adjacent discs into a series of separate streams moving towards the rings which are arranged to act as anodes. The discs perform substantially the same function as the electrodes 3, 4 (Fig. 3) and depending upon the relative instantaneous potentials of adjacent discs the electrons will be distributed between adjacent rings. In effect therefore the tube of Fig. 4 is a multi-section reproduction of the tube of Fig. 3. Thus considering the section of the tube comprising the disc 32, disc 33, ring 43, and the lower part 45 of ring 39, it will be noted that by proper electric biassing of the discs 32 and 33, and by applying the same steady potential to rings 39 and 43, the electrons from the lower end of the cathode may be distributed equally between the said two rings. Should the potential of disc 32 be changed with respect to the potential of disc 33 the electrons will be distributed between the said two rings in accordance with the relative difference of potential of said discs. By means of a divided output circuit such as shown in Fig. 3 this variation in distribution of the electrons may be utilized for amplification, oscillation generation and the like. Furthermore because of the fact that the ring 43 and the section 45 of ring 39 are inclined towards each other at a relatively acute angle and because the apex of this angle is located in the space between the discs 32, 33 the distribution of the electrons between 43 and 45 is substantially independent of the instantaneous potential difference betwen 43 and 45, as explained above in connection with Fig. 3. The action of the remaining sections of the tube of Fig. 4 is similar to that just described, and while the drawings show a tube having four sections it will be understood that a greater or less number may be employed.

Instead of arranging the discs or control electrodes in superposed horizontal planes as in Fig. 4, the control electrodes may be arranged vertically and likewise the anodes may also be arranged vertically. Such an arrangement is shown in Fig. 5 which is a schematic vertical plan view of a tube mount. In this embodiment the cathode 46 is supported centrally of the mount and supported around the cathode with their planes extending radially therefrom are a series of metal strips 47 to 52 inclusive which correspond to the electrodes 3, 4 (Fig. 3) and to the discs or control electrodes of Fig. 4. Positioned adjacent the strips and in vertical alignment therewith are V or U-shaped metal members 53 to 58 inclusive. These members are the anodes and correspond to the electrodes 5, 6 (Fig. 3) and to the rings of Fig. 4. Preferably each V-shaped anode is positioned so that the sides of the V overlap the adjacent control electrode as shown. The alternate control electrodes are electrically connected together in two sets by wires as shown, it being understood that this connection is shown schematically in Fig. 5 and that in the actual tube these connections will be made at a point so as not to interfere with the deflecting action of the control electrodes. Likewise the anodes are alternately connected in pairs by means of the wires 59, 60. The manner of functioning is substantially the same as that described in connection with Fig. 4 and further description thereof is not believed necessary. It will be understood of course that the electrode assembly of Fig. 5 is mounted within a suitably evacuated enclosing envelope which has been omitted for purposes of simplicity.

Referring to Fig. 6 there is disclosed in schematic form a multi-section tube embodying the shielding feature of Fig. 2. In this embodiment the cathode 61 is centrally mounted and surrounded by a series of longitudinally extending metal strips or control electrodes 62 to 69 inclusive. Mounted in longitudinal alignment with the control electrodes are the anodes 70 to 77 each in the form of a metal strip. Interposed between adjacent anodes are the longitudinally extending metal strips 78 to 85 inclusive which are electrically connected by a metal ring or cylinder to form shielding compartments 86 for the anodes. Alternate control electrodes are electrically connected by conductors 87 and 88 respectively, and alternate anodes are electrically connected by conductors 89 and 90 respectively. The method of operation of the tube of Fig. 6 is substantially the same as that already described in connection with Fig. 2.

In the foregoing embodiments of the invention reliance is placed upon an electrostatic deflection of the electron streams to achieve signal control however the invention can also be employed with magnetic control. Examples of tubes employing the invention with magnetic control are shown in Figs. 7, 8 and 9. Referring to Fig. 7 the tube is in general similar to that shown in Fig. 2 and

comprises an evacuated enclosing envelope 101 having suitably mounted therein an electron emitting cathode 102, a beam confining or focussing electrode 103. While the drawings show the focussing electrode 103 in the form of a concave member partially surrounding the cathode it will be understood that other well-known forms of electron focussing electrode may be employed. Cooperating with the cathode are two spaced anodes 105, 106 which are provided with a shielding electrode 111 similar to the electrode 11 of Fig. 2 said shielding electrode having an opening 112 to allow the electron beam to pass to the two anodes. Preferably a metal shield 113 extends between the two anodes. It will be understood that the showing of the tube of Fig. 7 in schematic transverse section and the various electrodes may have the desired longitudinal extent perpendicular to the paper. Surrounding the envelope 101 is a coil 104 designed to produce a magnetic field perpendicular to the plane of the paper and while the drawings show a coil of a few turns it will be understood that a greater or less number of turns may be employed. The ends of the coil are connected to the signal input terminals 109, 110 and if desired the coil may be tuned by the variable condenser 117. The electrode 103 is preferably biassed negatively with respect to cathode 102 by a suitable biassing source 107 to form the emitted electrons into a well-defined stream or beam directed towards the opening 112, preferably so that the electrons are divided substantially equally between the anodes 105, 106. The shielding electrode 111 is connected to a suitable positive tap 114 on the steady potential source 115. The anodes 105, 106 are connected to the output coupling coil 118 which may be tuned by the variable condenser 119, the electrical midpoint of the coil 118 being connected to the positive terminal of the plate supply source 115. The manner of functioning of the system of Fig. 7 is along the same lines as those of Fig. 3, the electron beam is deflected by the signal-controlled magnetic field of coil 104 to correspondingly vary the distribution of the electrons between the anodes 105, 106. The electrode 111 prevents the instantaneous difference in potential between the anodes 105, 106 from affecting the distribution of the electrons between the anodes.

Fig. 8 shows a modification wherein the mutual shielding of the anodes is effected by positioning the anodes so that they approach each other at an acute angle, with the apex of this angle approaching closely, or even located within the space defined by the focussing electrode. This positioning of the anodes avoids the necessity of employing a separate shielding electrode such as the electrode 111. In other respects the manner of functioning of the system of Fig. 8 is similar to that of Fig. 7.

While the tubes shown schematically in Figs. 7 and 8 employ one set of electrode elements, it will be understood that the electrode elements may be arranged in a plurality of sections symmetrically around a central cathode. Such a structure is shown in horizontal transverse section in Fig. 9, and corresponds to the embodiment of Fig. 6 with the exception that the distribution of the electrons between adjacent anode pairs is controlled by magnetic deflection. Thus the cathode 161 may be cylindrical in shape such as is employed in the well-known indirectly heated cathode radio tubes. Surrounding the cathode and extending longitudinally thereof is a series of focussing or stream confining metal strips 163 all interconnected by a conductor as shown. Associated with each pair of strips 163 is a corresponding pair of anodes 171, 172 alternate anodes being interconnected respectively by the conductors 189, 190. Adjacent anodes are shielded from each other by being situated within individual shielding compartments formed from a cylindrical member 186 with radially extending walls 179 and arcuate shaped members 191. The tube is surrounded by a coil 104 having its terminals connected to the signal input terminals 109, 110. The wiring connections of Fig. 1 are substantially the same as those of Fig. 7 and the tube functions similarly to that of Fig. 7 so far as each of the multiple sections are concerned, the members 179, 191 preventing the instantaneous potentials of the adjacent anodes 171, 172 from affecting the distribution of the electrons thereto, and the distribution being effected by the magnetic field of the signal-controlled coil 104.

It will be understood that while the drawings show the tubes of Figs. 7, 8 and 9 as repeater or amplifier tubes, they may be used as oscillators by coupling the signal output circuit to the signal input circuit so as to feed back energy to the input circuit of the proper phase to maintain the systems self-oscillating as will be obvious to those familiar with the oscillator tube art.

It will be understood of course that while the invention has been illustrated in certain specific embodiments they are merely representative, and various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What I claim is:

1. An electron discharge device comprising an electron emitting cathode, a pair of deflecting electrodes, a pair of spaced anodes partially projecting into the space between said deflecting electrodes, said anodes being inclined to each other at an angle of less than 180 degrees with the apex of the angle facing the cathode for the purpose of substantially preventing changes of anode potential due to load variations from affecting the distribution of electrons between the anodes.

2. An electron discharge device comprising an evacuated envelope, an electron emitting cathode therein, two oppositely disposed deflecting electrodes, two cooperating anodes partially projecting into the space between said deflecting electrodes, the adjacent edges of said anodes approaching each other at an angle substantially less than 180 degrees, the apex of said angle closely approaching or entering a space between said deflecting electrodes for the purpose of substantially preventing changes of anode potential due to load variations from affecting the distribution of electrons between the anodes.

3. An electron discharge device comprising an electron emitting cathode, a plurality of deflecting electrodes arranged in a plurality of pairs to divide the electrons into a plurality of streams, a plurality of pairs of anodes there being one pair of anodes for each electron stream each anode of a pair receiving electrons from the cathode in symmetrical relation, means electrically connecting alternate deflecting electrodes, means electrically connecting alternate anodes, and shielding means for each anode positioned with relation to the anode to shield adjacent anodes from each other and to shield the field of the deflecting electrodes from instantaneous potential differences between said anodes caused by anode load current.

4. An electron discharge device comprising an

evacuated envelope, an electron emitting cathode therein, a plurality of deflecting electrodes consisting of alternately connected members spaced apart and adjacent said cathode, an equal number of cooperating anodes alternately connected to receive electron emission in symmetrical relation, each anode being associated with one deflecting member, and a shielding member so positioned as to shield adjacent anodes from each other and to shield the field of the deflecting electrodes from instantaneous potential differences between said anodes caused by anode load current.

5. An electron discharge device comprising an electron emitting cathode, a plurality of deflecting electrodes arranged in a plurality of pairs to divide the electrons into a plurality of streams, a plurality of pairs of anodes there being one pair for each pair of deflecting electrodes, each pair of anodes projecting partially into the space between adjacent deflecting electrodes, each pair of said anodes being in the form of plates inclined to each other at an angle substantially less than 180 degrees with the apex of the angle facing toward said cathode for the purpose of substantially preventing changes of anode potential due to load variations from affecting the distribution of electrons between the anodes, means electrically connecting alternate deflecting electrodes, and means electrically connecting alternate anodes.

6. An electron discharge device comprising an electron emitting cathode, a plurality of pairs of anodes surrounding said cathode, means to form the electrons from the cathode into a plurality of streams there being one pair of anodes for each stream, means electrically connecting alternate anodes, shielding means for each anode to minimize the effect of a potential difference between the anodes on the distribution of electrons between said anodes due to the anode load current, and a coil for producing a magnetic field to deflect the electrons away from one anode and towards the adjacent anode.

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