May 16, 1939. W. L. MEIER 2,158,564

ELECTRON DISCHARGE DEVICE

Filed March 27, 1937

Fig. 1

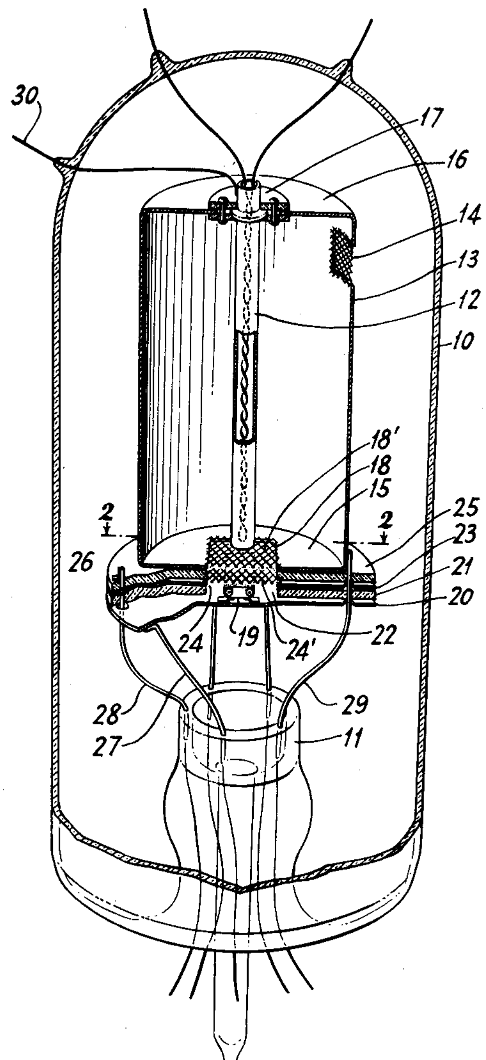


Fig. 2

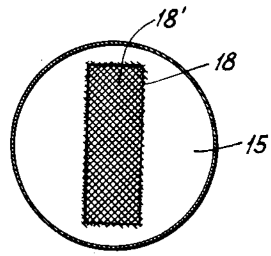


Fig. 4

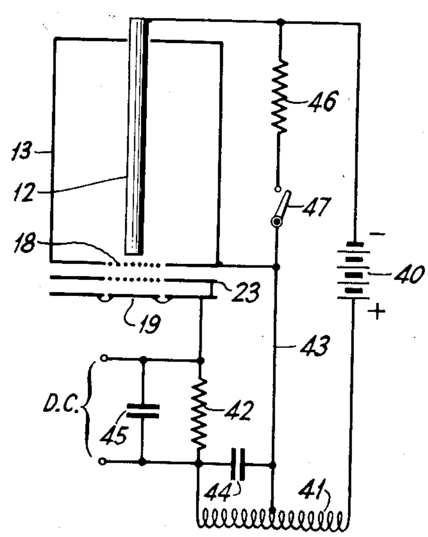
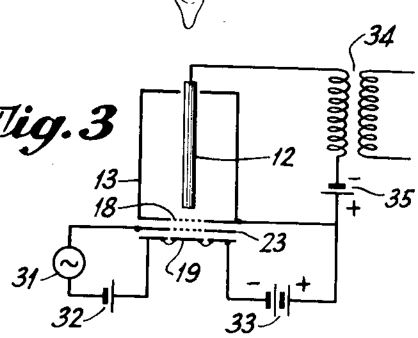


Fig. 3



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Patented May 16, 1939

2,158,564

UNITED STATES PATENT OFFICE

2,158,564

ELECTRON DISCHARGE DEVICE

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Application March 27, 1937, Serial No. 133,300

8 Claims. (Cl. 250—27)

My invention relates to electron discharge devices, more particularly to improvements in such devices having a gaseous atmosphere and capable of being continuously controlled.

In the conventional grid controlled vacuum tubes provided with a thermionic cathode, control grid and anode, the space charge which builds up around the cathode makes necessary the use of comparatively high voltages, such as 100 volts or more, for obtaining current sufficiently large for practical purposes. It is also necessary to use comparatively large grid voltage swings to produce usable variations in the output of the tube. Thus, in the conventional high vacuum tubes comparatively large transconductances are not easily obtainable nor can large anode currents be obtained with small anode voltages. It has been recognized that by introducing a gas in a tube and ionizing the gas the space charge around the cathode could be neutralized and thus large anode currents obtained with the usual anode voltages. However, in the conventional grid controlled tube containing gas, ionization of the gas causes the control grid to lose its control of the electron stream so that while initiation of ionization can be controlled the current cannot be controlled by the control electrode after ionization takes place. Furthermore, in these types of tubes comparatively high voltages, much above ionization voltages, are applied between the anode and cathode to cause a gas discharge between the anode and the cathode. Thus while comparatively high currents can be obtained the loss of grid control and the necessity for high anode-cathode voltages limits the application of this type of tube and prevents its use in conventional radio circuits.

It is the principal object of my invention to provide an improved electron discharge device of the gas type in which a small amount of input power to the device is capable of controlling with small anode voltages and small control grid voltage swings large amounts of power in the output of the device. More specifically it is an object of my invention to provide such a gas tube depending upon gas ionization for its operation but which nevertheless can be continuously controlled.

In accordance with my invention I produce such a tube by introducing gas at a low pressure into an envelope containing the electrodes and ionizing the space between the cathode and the anode to neutralize the space charge and thus make available a large number of electrons. I can then apply only a very small voltage of the order of 6 volts, for example, which is considerably below ionizing voltage between the anode and cathode to obtain a comparatively large anode current. The flow of electrons from the cathode to the anode can then be continuously controlled by an electrode to which is applied comparatively small voltage swings inasmuch as there is no gas discharge between the main cathode and the anode. To produce the ionization of the gas between the cathode and anode I may employ an auxiliary cathode and establish a discharge between this auxiliary cathode and another electrode, the electrode being so positioned that the space between the main cathode and the anode is positioned in the vicinity of the auxiliary discharge between the auxiliary cathode and its cooperating electrode.

In one preferred embodiment of my invention I mount within an envelope containing gas at low pressure, a straight indirectly heated cathode surrounded by a cylindrical anode closed at both ends. An aperture, preferably covered by a mesh material, is provided at one end of the anode. Registering with this aperture are a control grid and an auxiliary cathode for supplying the electrons within the anode to ionize the gas around the cathode within the anode. The auxiliary cathode, grid and the aperture covered by mesh material are all spaced less than the mean free path of electrons in the gas so that no ionization takes place between these electrodes. This arrangement permits continuous grid control of the ionization within the main anode. A voltage less than that required to produce ionization is applied between the main cathode and the main anode. A voltage sufficiently high to cause the electrons to have a great enough velocity in entering the space between the main cathode and the main anode is applied between the auxiliary cathode and the main anode, the control voltage being applied through an input circuit to the control grid.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 is a vertical section in perspective of an electron discharge device made according to my invention, Figure 2 is a section along 2—2 of Figure 1 showing details of construction, Figure 3 is a diagrammatic showing of a tube and circuit made according to my invention, and Figure 4 is a diagrammatic showing of a direct current amplifier arrangement using a tube made according to my invention.

A tube made according to my invention and shown in Figure 1 includes an envelope 10 containing a gas at low pressure for example between 150–600 microns pressure. Helium at pressures between 250 and 300 microns is very satisfactory. A stem 11 supports the electrode mount assembly within the envelope. In accordance with my invention the electrode mount assembly comprises an indirectly heated cathode 12 enclosed within a cylindrical anode 13 provided with a screen covered aperture 14 and closed ends 15 and 16. Aperture 14 is to provide a gas communication between the interior of the anode and the inside of the envelope. The cathode 12 is insulatingly supported from the upper closed end 16 of the anode by means of the insulating bushing 17. The lower end 15 is provided with an aperture 18 covered with foraminous or mesh material 18′, the shape of this aperture being best shown in Figure 2. The cathode 12 and anode 13 are the main discharge electrodes between which the output current passes.

In order to neutralize the space charge around the cathode 12 during operation of the tube I provide an auxiliary electrode system comprising an indirectly heated cathode and grid in registry with the aperture 18 to project electrons from the auxiliary cathode into the space surrounding the cathode 12.

This electrode system comprises an indirectly heated auxiliary cathode 19 supported and electrically connected to the metal disc 20. Insulatingly separated from the disc 20 by means of an insulating disc member 21 having an aperture 22, in which the cathode 19 is positioned, is a grid comprising a metallic disc member 23 having an aperture 24 covered with a mesh material 24′, this aperture being in registry with the aperture 18 in the lower end of the anode. This grid is insulatingly separated from the anode by means of the insulating disc 25 having an aperture 26 in registry with the aperture 18. This whole mount assembly is supported from the stem 11 by means of the supports and leads 27, 28 and 29 connected respectively to the cathode disc, grid disc and anode. The main cathode 12 is provided with a lead 30.

In operation a low voltage less than that required for maintaining ionization is applied between the main cathode 12 and anode 13 so that a gas discharge cannot take place between these electrodes. Voltages are applied between the auxiliary cathode 19 and the anode 13, which are high enough to cause electrons from the cathode to be projected through the aligned apertures into the space around the cathode 12 with sufficient velocity to ionize the gas and thus neutralize the space charge. The grid 23 may have applied to it a control voltage which will control the flow of electrons from the auxiliary cathode 19 into the space surrounding the main cathode 12 to thereby control the ionization and hence the current from cathode 12 to anode 13.

A circuit employing a tube containing helium and made according to my invention, as shown in Figure 3, includes an input circuit comprising a source of varying voltage 31 and biasing battery 32 of about −4 volts connected between the control grid 23 and the auxiliary cathode 19. The output circuit includes the primary of the transformer 34 and biasing battery 35 of the order of 6 volts which provides a low voltage connected between the main cathode 12 and anode 13. A source of voltage supply 33 which may be between 50 to 100 volts, preferably about 70 volts, for helium is connected between auxiliary cathode 19 and anode 13 so that electrons leaving the cathode 19 will be projected into the space around the cathode 12 with sufficient velocity to cause ionization and hence neutralization of the space charge around the cathode 12. The input or control voltage applied to the input inductance 31 controls the ionization and hence the current flowing in the output of the tube. Since the ionization is entirely dependent upon the electrons from the auxiliary cathode 19, the voltage between the main cathode 12 and the main anode 13 being too low to maintain a gaseous discharge even though there is ionization, the current between the cathode 12 and anode 13 is determined substantially entirely by the voltage applied to the control grid 23. Because of the close spacing between grid 23, cathode 19 and anode 18, which is of the order of the mean-free-path of an electron in the gas, continuous grid control over the electron stream from the auxiliary cathode is maintained since ionization cannot take place between these electrodes to cause loss of grid control. In this way very small voltages applied to the control grid control large currents between the main cathode and the main anode resulting in a tube having high transconductance and continuous grid control, although making use of a gaseous atmosphere.

One of the novel applications of a tube made according to my invention is to a D. C. amplifier comprising a self-excited oscillating circuit which can be used to provide a high voltage D. C. output source from a low voltage D. C. source. In Figure 4 the cathode 12 is connected through the low voltage D. C. source or battery 40 to one side of the inductance 41, the other side of which is connected through an output resistor 42 to the auxiliary cathode 19. The voltage obtained from battery 40 is less than that required to maintain ionization between cathode 12 and anode 13. An intermediate point of the inductance 41 is connected by means of conductor 43 to the anode 13. The grid 23 may be connected to the cathode. A condenser 44 connected across a part of the inductance 41 furnishes with the inductance 41 an oscillating circuit. The output resistor 42 is shunted by a filter condenser 45. In order to start oscillations a resistance 46 and switch 47 is provided.

To shock the system into operation switch 47 is momentarily closed causing a flow of current through the right hand portion of inductance 41, which in turn induces a voltage across the left hand portion of inductance 41 and condenser 44. This voltage which is stepped up by proper ratio of turns of the two portions of inductance 41 is applied between the cathode 19 and the anode 13 and causes electrons to discharge into the space surrounding the cathode 12 causing ionization which neutralizes the space charge thereby permitting a large flow of current between the cathode 12 and anode 13. This current flowing through the right hand portion of the inductance 41 again feeds back energy to the left hand portion producing a regenerative action so that the system is maintained in oscillation. Due to the rectifying action between the cathode 19 and anode 18, rectified voltages appear across the output resistance 42, the condenser 45 acting as a filter so that substantially uniform D. C. voltage appears across this output circuit comprising resistor 42 and condenser 45. By proper circuit constants a step-up voltage can be provided across the D. C. output terminals.

While I have indicated the preferred embodiment of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is—

1. An electron discharge device having an envelope containing a gas, a thermionic cathode within said envelope for emitting electrons, a hollow anode surrounding said thermionic cathode for enclosing the space between said thermionic cathode and said anode, means for applying a voltage between said thermionic cathode and anode less than that required for maintaining ionization between said thermionic cathode and anode, and means for ionizing the space between said thermionic cathode and anode and including an auxiliary cathode and an auxiliary electrode through which electrons from said auxiliary cathode can pass into the space between said thermionic cathode and said anode, means for applying a voltage between said auxiliary cathode and said anode for causing electrons to be projected with sufficient velocity into the space between said thermionic cathode and said anode to ionize the gas between said thermionic cathode and anode.

2. An electron discharge device comprising an envelope containing a gas, a thermionic cathode within said envelope, a hollow anode surrounding said cathode to enclose the space between said thermionic cathode and said anode, and having an aperture provided in said hollow anode, means for applying a voltage between said thermionic cathode and anode less than that required for maintaining ionization of the gas between said thermionic cathode and anode, an auxiliary cathode positioned in registry with said aperture and means for applying a voltage between said auxiliary cathode and the anode for causing electrons from said auxiliary cathode to pass through said aperture with sufficient velocity to ionize the gas between said thermionic cathode and anode.

3. An electron discharge device comprising an envelope containing a gas at low pressure, a thermionic cathode within said envelope, an anode surrounding said cathode to completely enclose the space between the cathode and anode, means for applying a voltage between said cathode and anode less than that required for ionization of the gas between said thermionic cathode and anode, said anode having an aperture therein, an auxiliary cathode in registry with said aperture, means for applying a voltage applied between said auxiliary cathode and said anode for causing electrons to pass through said aperture in said anode with sufficient velocity to ionize the gas between the thermionic cathode and anode, and means for confining electrons from said auxiliary cathode so that the electrons can pass only through the aperture in said anode.

4. An electron discharge device comprising an envelope containing a gas at low pressure, a thermionic cathode within said envelope, an anode surrounding said thermionic cathode to completely enclose the space between said thermionic cathode and anode, said anode having an aperture therein, an auxiliary cathode in registry with said aperture for providing electrons which pass through said aperture in said anode to ionize the gas between the thermionic cathode and anode, means for confining electrons from said auxiliary cathode so that the electrons can pass only through the aperture in said anode, and a grid electrode positioned between said aperture and said auxiliary cathode.

5. An electron discharge device having an envelope containing gas at a low pressure, a straight thermionic cathode within said envelope, a cylindrical anode coaxial with and surrounding said cathode and having closed ends for completely enclosing the space between said cathode and said anode, one of said ends being provided with a foraminated aperture, a grid and auxiliary cathode in registry with said aperture, means for applying a voltage between said thermionic cathode and anode less than that required to maintain ionization between said thermionic cathode and anode, means for applying a voltage between said auxiliary cathode and anode to cause electrons from said auxiliary cathode to pass through said foraminated aperture with sufficient velocity to ionize the gas in the space between the thermionic cathode and anode, means for applying a control voltage between said grid and the auxiliary cathode for controlling said ionization.

6. An electron discharge device comprising an envelope containing a gas at a low pressure, a straight thermionic cathode within said envelope, a tubular anode having closed ends coaxial with and surrounding said cathode for enclosing the space between said thermionic cathode and said anode, one of said closed ends being provided with a foraminated aperture, a control electrode and an auxiliary cathode in registry with said aperture, and a sheet of insulating material on each side of said control electrode for separating said control electrode from the closed end of said anode and said auxiliary cathode, each of said sheets being provided with an aperture in registry with the aperture in said anode.

7. An electron discharge device comprising an envelope containing a gas at a low pressure, a straight thermionic cathode within said envelope, a tubular anode having closed ends coaxial with and surrounding said cathode for enclosing the space between said thermionic cathode and anode, one of said closed ends being provided with an aperture, a control electrode adjacent the end of said anode provided with said aperture, a sheet of insulating material between said control electrode and said anode and having an aperture in registry with the aperture in said anode, an auxiliary cathode positioned adjacent said grid and insulatingly supported adjacent said control electrode, in registry with the aperture in said anode.

8. An electron discharge device comprising an envelope containing a gas at a low pressure, a straight thermionic cathode within said envelope, a tubular anode having closed ends coaxial with and surrounding said cathode for enclosing the space between said thermionic cathode and anode, one of said closed ends being provided with an aperture, a control electrode adjacent the end of said anode provided with said aperture, a sheet of insulating material between said control electrode and said anode and having an aperture in registry with the aperture in said

anode, an auxiliary cathode positioned adjacent said grid and insulatingly supported adjacent said control electrode in registry with the aperture in said anode, means for applying a voltage between said anode and thermionic cathode less than that required to maintain ionization between said thermionic cathode and said anode, means for applying a voltage between said auxiliary cathode and said anode sufficiently great to cause electrons from the auxiliary cathode to pass through the aperture in said anode with sufficient velocity to ionize the gas between said thermionic cathode and anode, means for applying a control voltage between said control electrode and the auxiliary cathode for controlling the ionization, and means for confining the electrons from said auxiliary cathode so that the electrons can travel only through the aperture in said anode.

WILBER L. MEIER.