Sept. 3, 1940. H. NELSON 2,213,551

ELECTRON DISCHARGE DEVICE

Filed March 27, 1937

Fig. 1

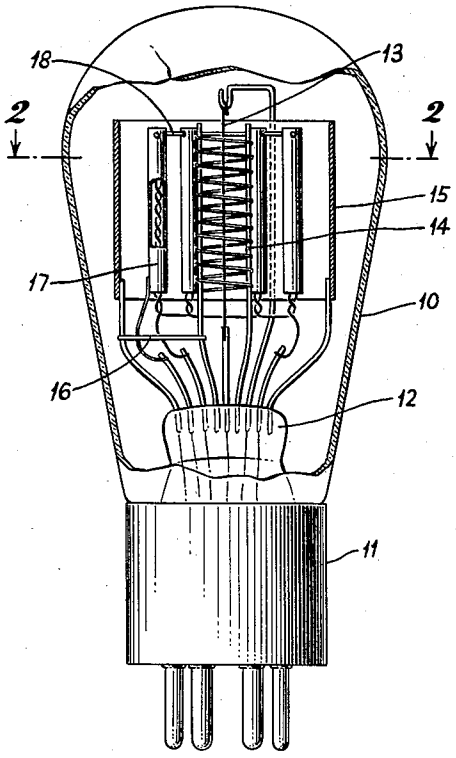


Fig. 2

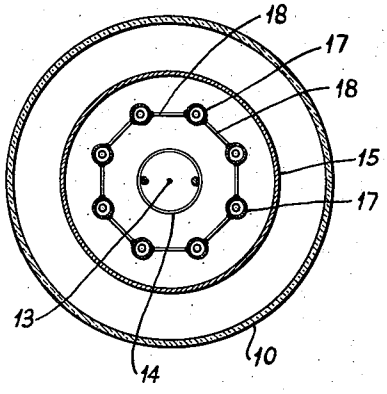
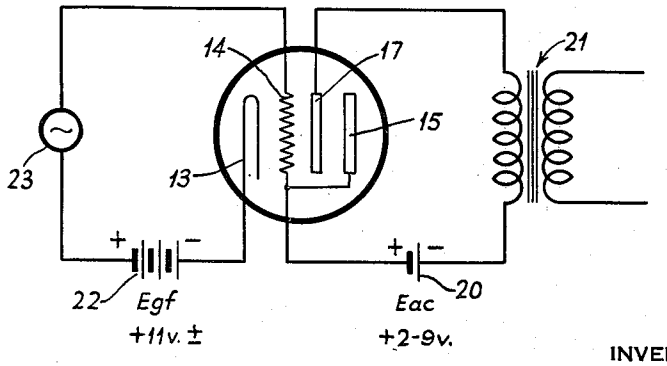


Fig. 3



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ELECTRON DISCHARGE DEVICE

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10 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 grid control voltage swings large amounts of power in the output 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 by means of only a very small voltage of the order of 6 volts, for example, which is considerably below ionizing voltage, between the anode and cathode obtain a comparatively large anode current. 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, these last two electrodes being so positioned that the space between the main cathode and the anode in which the space charge builds up is positioned in the path of the auxiliary discharge between the auxiliary cathode and its cooperating electrode.

The speed of electrons from the auxiliary cathode into the space between the main cathode and the anode can be continuously controlled by an electrode to which is applied comparatively small voltage swings and inasmuch as the ionization of the gas is dependent upon electrons from the auxiliary cathode continuous control of the current between the main cathode and the anode can be maintained.

In a preferred embodiment of my invention the envelope containing the gaseous medium contains a thermionic cathode surrounded by a grid and anode, the grid and anode being electrically connected although this connection is not necessary to successful operation of a tube made according to my invention. Positioned between the grid and anode are a plurality of cathodes which form the main cathode of the device. Between the main cathode and the interconnected grid and anode a voltage is applied less than that required to maintain ionization of the gas. The auxiliary cathode within the grid has applied between it and the grid a voltage sufficiently high to cause electrons from the auxiliary cathode to pass through the grid with sufficient velocity to ionize the gas between the main cathode and the grid and anode thereby neutralizing the space charge and tremendously increasing the anode current. Since the ionization can be maintained only by electrons from the auxiliary cathode and since the speed and therefore the ionizing efficiency of the electrons from the auxiliary cathode is controlled by the grid, the ionization can be continuously controlled, and hence the anode current, by voltages applied to the 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 view, partly in section, of an electron discharge device embodying my invention, Figure

2 is a transverse section taken long the line 2—2 of Figure 1, and Figure 3 is a schematic diagram of a tube and circuit made according to my invention.

In Figure 1 the tube made according to my invention comprises envelope 10 containing a gaseous medium such as mercury, argon, helium or the like at a pressure of 50–500 microns, a base 11 and press 12 upon which the mount is supported. The mount comprises a straight filament cathode 13 surrounded by grid 14 and anode 15, grid 14 and anode 15 being electrically connected by means of a shorting bar 16. In accordance with my invention between the grid 14 and anode 15 I place a plurality of indirectly heated cathodes 17 electrically connected together by conductors 18.

The cathode 13 is operated at a temperature at which the thermionic emission of current from it is temperature limited. Thus no material change in the number of electrons passing from the filament 13 through the grid 14 is effected by variations in the potential of the grid. In a practical tube there may be some slight change in the number of these electrons, but the change in the intensity of ionization in the main cathode region depends substantially only upon the change in the speed of the electrons from filament 13.

In accordance with my invention and as schematically shown in Figure 3, the main cathode 17 is connected through the primary of the output transformer 21, battery 20 to grid 14 and anode 15. This battery applies a potential between the cathode, and the grid and anode less than that required to cause or maintain ionization of the gas between these electrodes, the grid and anode being at the higher potential. The grid 14 is biased positively with respect to the cathode 13 by means of a battery 32 connected in series with the source of alternating voltage potential 23 which provides the input to the device. The voltage applied by the battery 22 is sufficient to cause electrons moving from the cathode to the grid 14 to pass through the grid with sufficient velocity to cause ionization of the space between the cathodes 17 and the grid 14 and anode 15. The alternating voltage applied between cathode 13 and grid 14 varies in accordance with the applied voltage from source 23 and increases or decreases the speed of the electrons passing through the grid 14 into the space between the cathodes 17 and grid 14 and anode 15, the amount of ionization depending upon the speed of the electrons passing through the grid 14.

Inasmuch as the voltage between the cathodes 17 and the grid 14 and anode 15 is less than that required for the ionization of the gas, ionization can be maintained in this space only by electrons from the cathode 13, and this is dependent upon the voltage applied on the grid 14. With an increase in the positive direction the ionization increases and hence the space charge surrounding the cathodes 17 is neutralized to a greater extent so that more current can flow through the output including the primary transformer 21. As the voltage on the grid 14 decreases the ionization becomes less intense and hence the neutralization becomes less and the output current drops. Inasmuch as the voltage between the cathode 17 and grid 14 and anode 15 is less than that required to maintain ionization, a loss of control by the formation of a gaseous discharge between the cathode 17 and the electrodes 14 and 15 on either side cannot take place. In this way a continuous control of the gaseous discharge tube results. As pointed out above this results in a tube which is particularly suitable for use as a relay or audio frequency amplifier.

In one embodiment of a tube made according to my invention gas at a pressure of about .1 millimeter of mercury was used and with a voltage between the cathode 17, grid 14 and anode 15 of between 1 and 9 volts, and a voltage of 18 volts between the cathode 13 and the grid 14 which was increased or decreased by the applied voltage at 23, I obtained a tube which operated very satisfactorily. With a voltage of 1.6 volts between cathode 17, grid 14 and anode 15 and operating in a range of between 15 and 30 volts impressed on the control grid, for small changes of control grid voltage, I was able to continuously control currents in the output of over a half an ampere, for example, I was able to control about $\frac{5}{1000}$ to $\frac{6}{1000}$ of an ampere in the output of the tube, the swing in the applied voltage on the control grid being from 17.2 volts to 19 volts.

A tube made according to my invention is particularly suitable for use as a rectifier because of its plate current grid voltage characteristic which is flat up to a certain grid voltage then rises sharply. By biasing the tube to operate at this sharp knee excellent rectification can be obtained which contrasts with the usual conventional rectifier tube characteristic which has a gradual knee.

While I have indicated the preferred embodiments 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 gaseous medium, a cathode within said envelope, a grid and anode spaced from said cathode and a second cathode between said grid electrode and said anode, the electrodes being constructed and positioned to permit electrons from the first cathode to pass through the grid to the space between the second cathode and the grid.

2. An electron discharge device having an envelope containing a gaseous medium, a cathode within said envelope, a grid electrode surrounding said cathode and an anode surrounding said grid, and a second cathode between said grid electrode and said anode.

3. An electron discharge device having an envelope containing a gaseous medium, a cathode within said envelope, a grid electrode surrounding said cathode and an anode surrounding said grid, and a second cathode between said grid electrode and said anode, said anode being electrically connected to said grid, the electrodes being constructed and positioned to permit electrons from the first cathode to pass through the grid to the space between the second cathode and the grid.

4. An electron discharge device having an envelope containing a gaseous medium, a straight thermionic cathode within said envelope, a grid surrounding said cathode, an anode surrounding said cathode and grid and a plurality of electri-

cally connected cathodes disposed between said grid and anode.

5. An electron discharge device having an envelope containing a gaseous medium, a straight thermionic cathode within said envelope, a grid surrounding said cathode, an anode surrounding said cathode and grid and a plurality of cathodes disposed between said grid and anode, said grid and anode being electrically connected together and said plurality of cathodes being connected in parallel.

6. An electron discharge device comprising an envelope containing a gaseous medium, a cathode, grid and anode within said envelope, a second cathode between said grid and anode, means for applying between said second cathode and said anode a voltage less than that required to maintain ionization between said second cathode and said anode, and means for applying between said first cathode and grid a voltage of sufficient magnitude to cause electrons to pass through said grid into the space surrounding said second cathode with sufficient velocity to produce ionization.

7. An electron discharge device comprising a cathode surrounded in turn by a grid and anode, a second cathode between said grid and anode, means for applying a voltage between said second cathode and said anode, the voltage being less than that required to maintain ionization, and means for applying a voltage between said first cathode and grid to cause electrons to pass through said grid with sufficient velocity to ionize the space surrounding said second cathode.

8. An electron discharge device comprising a cathode surrounded in turn by a grid and anode, a second cathode between said grid and anode, means for applying a voltage between said second cathode and said anode, the voltage being less than that required to maintain ionization, and means for applying a voltage between said first cathode and grid to cause electrons to pass through said grid with sufficient velocity to ionize the space surrounding said second cathode, and a source of variable voltage applied between said first cathode and grid to vary the ionization in the space surrounding said second cathode.

9. An electron discharge device comprising a straight thermionic cathode operated at temperature limited emission surrounded by a grid and anode, said grid and anode being electrically connected together, and a plurality of cathodes positioned between said grid and anode, and means for applying between said plurality of cathodes and grid and anode a voltage less than that required to maintain ionization, and means for applying between said first cathode and grid a voltage sufficiently high to cause electrons to pass through said grid with sufficient velocity to ionize the gas surrounding said plurality of cathodes to neutralize the space charge surrounding said plurality of cathodes during operation of the device.

10. An electron discharge device comprising a straight thermionic cathode surrounded by a grid and anode, said grid and anode being electrically connected together, and a plurality of cathodes positioned between said grid and anode, an output circuit connected between said plurality of cathodes and said grid and anode and comprising an output transformer and a source of voltage less than that required for maintaining ionization between said plurality of cathodes and said grid and anode, an input circuit connected between said first cathode and said grid and comprising a source of voltage sufficiently great to cause electrons to pass through said grid and ionize the gas around said second cathode to neutralize the space charge around said second cathode.

HERBERT NELSON.