Nov. 14, 1961 C. W. JACOB 3,009,077

GAS DISCHARGE TUBE SENSITIVE TO A.C. SIGNALS

Filed March 12, 1951

FIG. 1.

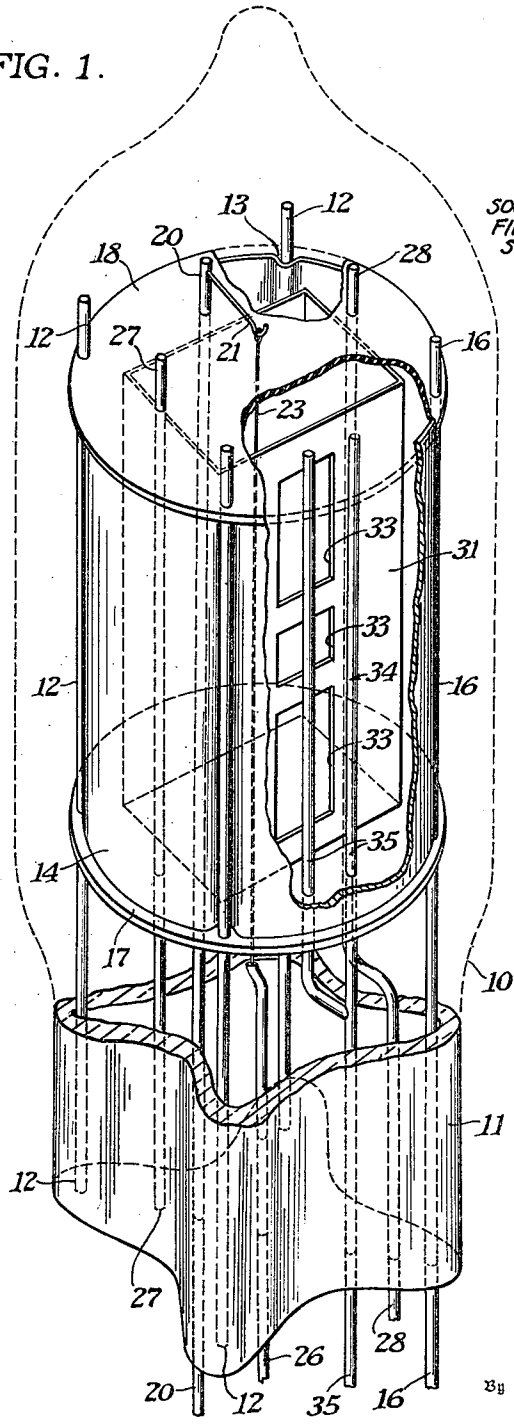


FIG. 2.

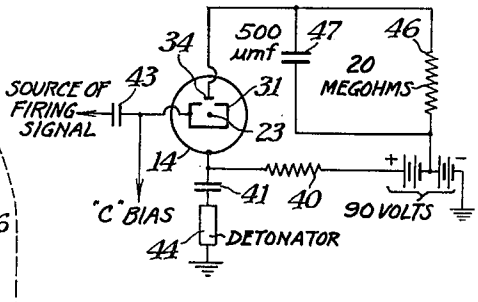


FIG. 3.

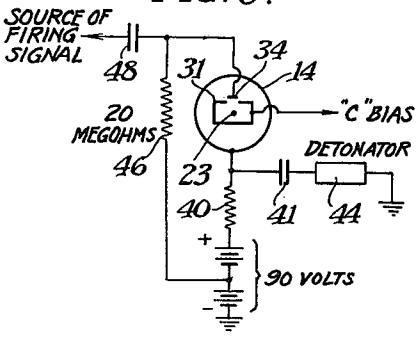
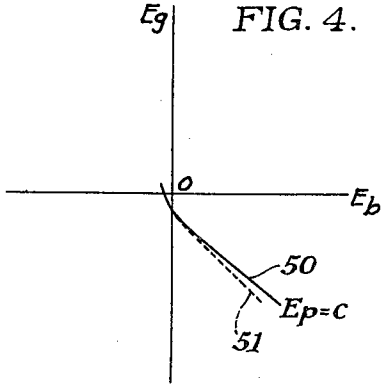


FIG. 4.



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GAS DISCHARGE TUBE SENSITIVE TO A.C. SIGNALS

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7 Claims. (Cl. 313—195)

This application relates to electron tubes and particularly to gas-filled discharge tubes.

Gas-filled grid-controlled discharge tubes are utilized in radio proximity fuzes for ordnance projectiles to initiate the explosion of the bursting charge of the projectile upon the application to the grid of an operating signal of predetermined amplitude and duration. The grid of such a tube has heretofore been conventionally biased considerably more negative than the starting voltage, i.e., the critical firing voltage, as a safety precaution against premature detonations caused by decay during the flight of a projectile of the output voltages of the deferred action type battery that conventionally provides the grid-bias voltage. Biasing the grid well beyond the starting voltage diminishes the sensitivity of the gas-filled discharge device in that a strong firing signal is required to raise the grid above the starting voltage.

It is an object of the invention to provide a stable gas-filled grid-controlled discharge device which is sensitive to weak A.C. firing signals and substantially immune to drifts in D.C. bias voltage.

It is a further object of the invention to provide a stable gas-filled grid-controlled discharge tube and circuit therefor which exhibit differential sensitivity to rapidly varying and to slowly changing signals.

It is a still further object of the invention to provide a stable gas-filled grid-controlled discharge tube and circuit therefor which can be fired by weak A.C. signals and which prevents accidental firings due to drift in grid bias over a range of voltage considerably larger than the peak voltage of the A.C. signal required to fire the tube.

Still another object of the invention is to provide such a gas-filled grid-controlled discharge tube which, without danger of accidental firing of the tube, can be safely operated at lower grid bias voltages than have heretofore been utilized.

The objects of the invention are attained in a gas-filled grid-controlled discharge device by providing a balancing fourth electrode positioned in the electron path through the apertures in the control grid to compensate for changes in electron flow due to drift in the "C" bias voltage on the control grid. In operation, a source of potential positive relative to the cathode is connected to the balancing electrode through a high resistance. A gradual decrease in the control grid negative bias voltage allows a few electrons to emerge through the apertures in the grid. Practically all of the electrons are collected by the balancing electrode and flow through the high resistance. The increased voltage drop across the high resistance drives the balancing electrode more negative and thus increases its shielding action. The balancing electrode voltage E_b is thus dependent inversely upon the control grid bias voltage E_g. For a given anode voltage the tube has a critical flash point function (i.e., control characteristic) of E_b and E_g wherein any combination of such voltages on the non-flash side of the function prevents the establishment of the arc. The control grid "C" bias source and the source of positive potential for the balancing electrode are selected so that the combination of E_b and E_g determines a point just on the non-flash side of the function, and E_b balances, i.e., varies inversely with, drift in E_g to maintain the combination of voltages on the non-flash side of the function, i.e., to limit the anode electron

current to a value below the minimum required to establish the arc, over a wide range of variation of E_g.

Differential sensitivity to A.C. signals and to drifts in control grid bias voltage is obtained by providing a time delay in the variation of E_b when an A.C. signal is impressed on the control grid. In the preferred embodiment of the invention, this difference in sensitivity is provided by connecting a capacitance to the balancing electrode in parallel with the high resistance. The capacitance offers a substantially infinite impedance to slow variations in electron flow and presents an impedance path to rapid fluctuations of electron flow which decreases with frequency. A momentary delay greater than the ionization time of the tube is required to charge the capacitance when an A.C. signal is impressed on the control grid, thus preventing a change in the shielding action of the balancing electrode until after the electron current to the anode has increased beyond the minimum required to establish the arc. Increased electron flow due to an A.C. signal on the control grid divides between the resistance and capacitance paths, and consequently the voltage drop across the resistance is not as great (and thus the balancing electrode is not driven as far negative) as when E_g varies gradually. Alternatively, an A.C. firing signal of sufficient magnitude impressed directly on the balancing electrode immediately increases the anode electron current above the minimum required to start the arc. Thus the A.C. signal may be applied to either electrode while the tube compensates for, and remains relatively insensitive to, D.C. drift.

The various features of the invention will be more clearly understood from the following detailed description in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of one embodiment of a discharge tube made in accordance with the invention with a portion of the enclosing vessel and the anode broken away to show the internal electrode structure;

FIG. 2 is a diagram of the firing circuit of a radio proximity fuze utilizing the novel tube;

FIG. 3 is a diagram of a circuit alternative to that of FIG. 2; and

FIG. 4 is a typical control characteristic curve of the novel tube.

Referring to the drawings, a gas-filled grid-controlled discharge tube according to the invention is provided with the usual subminiature type radio tube glass envelope **10** containing an ionizable gaseous medium, for instance, one of the rare inert gases exemplified by neon and argon, or mercury vapor. The envelope **10** terminates in a press **11** in which are sealed both the lead-in conductors for the electrodes and upwardly-extending rigid rods **12** adapted to support the electrode structure. Each rod **12** fits into a depression **13** provided in, and engages the outer surface of, a metallic cylindrical anode **14**. The rods **12** and a lead-in conductor **16**, which conductor engages and provides partial support for the anode **14**, extend through snug apertures provided in circular discs **17** and **18** of suitable insulating material, such as mica, in planes transverse of the axis of the cylindrical anode **14**. Another lead-in conductor **20** extends through the press **11** and through apertures in the discs **17** and **18**, and a hook **21** fastened to the upper end of the lead-in conductor **20** above the insulating disc **18** supports a filament cathode **23** which extends through apertures in the discs **17** and **18** along the axis of the enclosing vessel **10**. A separate lead-in conductor **26** extending through the press **11** connects to the lower end of the cathode **23** below the insulating disc **17**. The filament cathode **23** is coated along the length between the insulating discs **17** and **18** with thermionically-active material such as

barium and strontium oxides to insure a copious supply of electrons.

A rigid rod **27** and a lead-in conductor **28** extending upward from the press **11** and through apertures in the insulating discs **17** and **18** engage a generally tubular metallic control grid **31** disposed coaxial with the cathode **23** between the insulating discs **17** and **18**. The insulating discs **17** and **18** thus close the upper and lower ends of the control grid **31** and also fixedly position the lead-in conductors **16** and **28** and the rods **12** and **27** to maintain the anode **14** and the control grid **31** coaxial with the cathode **23**. By the word "tubular" in this connection is meant any form having a substantially perimetrically complete contour whether such contour be circular or noncircular. In the preferred embodiment of the invention illustrated in the drawings, a rectangular contour is utilized. A plurality of apertures **33** are provided in the grid **31** aligned along the length of the cathode **23**.

My invention is particularly concerned with a balancing electrode **34** positioned in front of the apertures **33** in the path of electronic flow between the cathode **23** and the anode **14**. The balancing electrode **34** comprises two spaced rigid rods **35** disposed between the control grid **31** and the anode **14** and extending parallel to the cathode **23** through apertures in the insulalting discs **17** and **18**. One rod **35** is an extension of a lead-in conductor extending through the press **11** and is soldered to the second rod **35** below the insulating disc **17**.

While the particular structure of the tube as illustrated in the drawings is the preferred embodiment of the invention, other elements of the electrodes relative to one another, as regards spacing and configuration, which perform the functions explained are within the scope of the invention. It is obvious that the balancing electrode may comprise a single, or any desired number, of rigid rods **35** in the path of electron flow between the anode and cathode.

The utility of such a gaseous device is shown in the circuit of FIG. 2 which represents a conventional firing circuit of a radio proximity fuze. The electrodes of the tube in FIG. 2 bear the same reference numerals as those of FIG. 1 and are schematically represented as though a horizontal sectional view were taken through the electrode structure. After a projectile containing a radio fuze is fired, a source of filament voltage is connected to the cathode **23** and a source of anode potential of approximately 90 volts positive with respect to the cathode **23** is connected to the anode **14** through an arming resistor **40**, conventionally from the "A" and "B" sections respectively of a deferred action type battery (not shown) contained within the fuze. An arming condenser **41** connected to the anode **14** is in series with an electric detonator **44** to ground. The arming condenser **41** provides the energy to fire the electric detonator **44** when the discharge device of the invention fires and conducts current. The arming resistance **40** and the arming condenser **41** in combination provide a time delay to prevent the bursting charge from exploding until the projectile is well away from the gun and from firing personnel. In order to prevent breakdown of the gas-filled tube of the invention in the absence of an operating signal, a source of bias voltage negative relative to the cathode **23** is connected to the control electrode **31**. The operating signal from the amplifier (not shown) of the fuze is coupled to the control grid **31** through a condenser **43**.

Conventionally, the source of negative grid bias for the control grid **31** is the "C" section of the deferred action type battery of the fuze. As hereinbefore explained, this "C" section is subject to decay in output voltage during the flight of the projectile, and in order to eliminate any possibility of premature detonation, it was necessary to maintain the control grid of gas-filled discharge tubes heretofore used considerably more negative than the starting voltage. Consequently an operating signal of considerable amplitude was required to overcome the negative bias and cause discharge of the gas-filled tube.

To provide a gas-filled device which is sensitive to A.C. signals and at the same time prevent any possibility of accidental discharge, the balancing electrode **34** is connected through the parallel arrangement of a resistor **46** and a condenser **47** to a source of potential positive relative to the cathode **23**. For every anode potential the discharge device of the invention has a critical flash point function (i.e., control characteristic) of control grid voltage E_g and balancing electrode voltage E_b. A typical control characteristic curve **50** for a given anode voltage is shown in FIG. 4 of the drawing plotted with values of E_b as abscissae and values of E_g as ordinates. Any combination of E_b and E_g that determines a point above and to the right of the flash point function **50** indicates that the shielding action of the control grid **31** and balancing electrode **34** are insufficient to limit the anode electron current to a value below the minimum required to establish the arc; but if the point is determined below the flash point control characteristic **50**, the shielding action of these two electrodes is sufficient to limit the anode current below this minimum. That is, the arc starts as electrode potentials pass across curve **50** from the lower left to the upper right.

The balancing electrode **34** acts to compensate for changes in electron flow due to drifts in the voltage of the control grid "C" bias source by limiting the electron current to the anode below the minimum required to start the arc even though E_g may drift from its preferred negative value to an excessively low negative value, i.e., drift in a positive direction, due to a defective deferred action type battery. As E_g slowly becomes more positive due to drifts in the voltage of the "C" bias source, a few electrons emerge through the apertures **33** in the control grid **31** and are drawn primarily to the balancing electrode **34**. Substantially all the electrons flowing through the apertures **33** are collected by the balancing electrode **34** and flow through the resistor **46**, thereby lowering E_b by an amount equal to the voltage drop across this resistor **46**. The increased shielding action of the balancing electrode **34** thus prevents increased electron flow to the anode due to gradual changes in E_g.

The voltages of the control grid "C" bias source and the balancing electrode source are selected so that the combination of E_b and E_g are just below, i.e., on the non-flash side of the control characteristic **50** of the tube. E_b and E_g are balancing voltages in that E_b is inversely dependent upon E_g so that the combination of voltages determines points which are on the non-flash side of the critical flash point function **50** even though the output voltage of the "C" bias source may vary over a wide range. The dotted curve **51** in FIG. 4 is drawn through points determined by such combinations of E_b and E_g. It will be noted that all points on this dotted curve **51** are below, i.e., on the non-flash side of, the control characteristic **50** for a considerable range of variation of E_g. As E_g drifts positively it drives E_b less positive so that both move along the curve **51**.

It is apparent that if means are provided to momentarily raise either E_b or E_g, i.e., make either more positive, without significantly changing the voltage of the other, the combination of voltages will then determine a point above the control characteristic and cause the tube to fire. My invention includes means for applying an A.C. signal to either the control grid **31** or the balancing electrode **34** without significantly changing the potential of the other. In the embodiment of the invention illustrated in FIG. 2, the condenser **47** in parallel with the resistor **46** allows the discharge device to exhibit differential sensitivity to gradually changing voltages and to rapidly varying signals. Changes in electron flow due to variations in E_g change the voltage drop across the

resistor 46 which in turn varies E_b and thus the shielding effect of the balancing electrode 34. If the decrease in E_g is gradual, the increase in electron current is gradual, and the shielding action of the balancing electrode 34 increases substantially simultaneously with changes in electron current and prevents the anode current from increasing above the minimum required to start the arc. The capacitance 47 offers a substantially infinite impedance path to gradual changes of electron flow. However, if a rapidly changing signal is impressed on the control grid 31, the sudden increase in electron current does not cause an instantaneous drop in E_b. The 500 micromicrofarad condenser 47 offers a path to alternating electron current flow of decreasing impedance with increase of frequency. This impedance decreases below the 20 megohms of the resistance 47 at frequencies above 50 cycles. The increase in electrons collected by the balancing electrode 34 is momentarily absorbed in charging the condenser 47, thus providing a momentary delay in the decrease of E_b until the electron flow to the anode 14 increases beyond the minimum required to ionize the gaseous medium and thereby distort the electric field and cause the tube to discharge. The time delay provided in changing E_b is greater than the ionization time of the tube. The alternating electron flow divides between the parallel resistance and capacitance paths, and the magnitude of the current through each path is dependent upon the frequency. The voltage drop across the resistance 46 is thus never as great, and the balancing electrode 34 is thus never driven as far negative, as when comparatively gradual changes of voltage are impressed on the control electrode 31. A source of positive potential for the balancing electrode 34 may conveniently be obtained from a tap on the "B" voltage section of the deferred action type battery.

FIG. 3 illustrates an alternative radio fuze firing circuit utilizing the novel tube of the invention and characterized by a high impedance input. A source of bias voltage in the "C" section of the deferred action type battery is connected to the control grid 31 in exactly the same manner as in the circuit shown in FIG. 2, but the operating signal is impressed through a coupling condenser 48 onto the balancing grid 34 instead of onto the control grid 31. Changes in voltage drop across the resistor 46 vary E_b and thus compensate for changes in electron current flow due to drifts in the output voltage of the "C" bias source in exactly the same manner as hereinbefore explained for the circuit of FIG. 2. Likewise, changes in the shielding action of the balancing electrode 34 balance changes in E_g, and the combination of voltages limits the electron current to the anode below the minimum required to start the arc over a comparatively wide range of drift of the "C" bias voltage source in exactly the same manner as hereinbefore explained. However, it is unnecessary to provide a time delay in the change of the shielding effect of one of the electrodes in order to fire the tube on a relatively weak A.C. operating signal. The firing signal is impressed through the coupling condenser 48 directly onto the balancing electrode 34. When E_b is driven positive by an A.C. firing signal of sufficient amplitude, the electron current to the anode is immediately raised above the minimum required to establish the arc. Peak values of the A.C. signal required to start the arc are represented by the vertical distance between the dotted curve 51 and the control characteristic 50 in FIG. 4 of the drawing. It is apparent that the "C" bias voltage source may vary over a voltage range many times larger than the A.C. voltage required to fire the tube without causing accidental detonation. E_b is inversely dependent upon E_g, and gradual changes in E_g are compensated for, or balanced, by varying E_b and thus the shielding action of the electrode 34. Rapidly varying signals impressed on the balancing electrode 34 immediately raise the anode current above the minimum required to establish the arc.

It has been found that satisfactory compensating action is obtained with a source of potential connected to the balancing electrode 34 considerably less positive than the anode potential, e.g., over a range of voltages of from 16 to 90 volts positive relative to the cathode dependent upon the anode potential and the value of the resistance 46. For the application herein described it has been found desirable to bias the control grid 31 negative relative to the cathode, although by decreasing the spacing, the size of the grid apertures 33, and the number of rods 35 in the balancing electrode 34 it is possible to construct positive-grid-potential discharge device, i.e., a tube which prevents the establishment of the arc even though a source of potential positive relative to the cathode is connected to the control grid 31. The control characteristics of such a discharge device are more toward the positive region than the typical control characteristic curve illustrated in FIG. 4. With the circuit of FIG. 3 operated at an anode potential of 90 volts and with a positive potential of 16 volts connected through a resistance of 20 megohms to the balancing electrode 34, it has been found that the negative grid bias on the control grid 31 may drift positive as much as 8 volts without establishing the arc, yet if an A.C. signal of 0.15 volt R.M.S. is impressed on the balancing grid 34 through the condenser 48, the discharge device is triggered. With the circuit of FIG. 2 operated at similar voltage values for the anode 14 and for the source of potential for the balancing electrode 34, the control grid voltage may drift in a positive direction as much as five volts without firing the tube, and yet if an A.C. signal of only 0.5 volt R.M.S. is impressed on the control grid 31, the discharge device definitely fires.

It is apparent from the foregoing description and the drawing that a gas-filled discharge device has been described that is substantially immune to drifts in control grid bias voltage and sensitive to weak A.C. operating signal voltages. While I have indicated only the preferred embodiments of the invention, it will be apparent that the invention is by no means limited to the exact forms illustrated or to 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 the invention as set forth in the appended claims.

I claim:

1. An electron discharge device comprising an enclosing vessel containing an ionizable medium, a cathode extending along the axis of the vessel, a tubular control electrode coaxial with and surrounding said cathode and provided with a plurality of apertures aligned along the length of said cathode, a balancing electrode consisting of at least one rod parallel to said cathode and in front of, and in the path of electronic flow through, said apertures, a cylindrical anode surrounding and in substantial parallelism with said cathode, said control electrode, and said balancing electrode, insulating disks extending in planes coincident with the ends of said grid and centering said cathode coaxially with said grids, and a plurality of lead-in conductors extending through said vessel respectively from said anode, cathode, control electrode and balancing electrode.

2. A circuit for an electron discharge device in accordance with claim 1 adapted to be triggered by an A.C. signal, comprising a source of potential for said anode, a source of bias voltage for said control electrode, and a source of positive potential connected through a high resistance to said balancing electrode of low enough voltage for the combination of said anode and said bias potentials to prevent sufficient electron flow to said anode to establish a discharge arc, whereby changes in the number of electrons collected by said balancing electrode due to slow variations in said bias voltage change the voltage drop across the high resistance, and thus the shielding action of the balancing grid, sufficiently to maintain the electron current to the anode below the

minimum required to establish the arc, and means including a condenser connected to said balancing electrode for providing a time delay in the change of the voltage of said balancing electrode when an A.C. signal is impressed upon said control electrode, said time delay being of greater duration than the ionization time of said electron discharge device.

3. A circuit for a gas-filled electronic discharge tube adapted to be triggered by an A.C. signal, comprising a gas-filled tube having an anode, a cathode, and two control grids, one grid being an apertured shield between the cathode and the anode and the other grid being a balancing grid generally aligned between the aperture and the anode, a source of potential for said anode, a source of bias voltage for said shield grid, means for applying an A.C. signal to said shield grid, means including a source of positive potential connected to said balancing grid through a high resistance and a capacitance also connected to said balancing grid for compensating only for changes in electron current due to gradual variations in the voltage of said bias source, whereby variations in electron current due to an A.C. signal on said control grid will not be compensated for.

4. A circuit for a gas-filled electronic discharge tube adapted to be triggered by an A.C. signal, comprising a gas-filled tube having an anode, a cathode, and two control grids, one grid being an apertured shield between the cathode and the anode and the other grid being a balancing grid generally aligned between the aperture and the anode, means for applying a potential to the anode positive relative to the cathode, means for applying a D.C. bias voltage to said shield grid, means for applying to the balancing grid through a high resistance a voltage positive relative to the cathode, whereby said balancing grid assumes a voltage depending inversely on the grid current through the high resistance which current in turn is greater for more positive values of said bias voltage, and means for applying an A.C. signal to said balancing grid.

5. A circuit for a gas-filled electronic discharge tube adapted to be triggered by an A.C. signal comprising a gas-filled tube having an anode, a cathode and two control grids, one grid being an apertured shield between the cathode and the anode and the other grid being a balancing grid in the path of electronic flow through said aperture, a source of potential for said anode positive relative to said cathode, means for applying to said shield grid a bias potential E_g, means for applying to said balancing grid through a high resistance a potential positive relative to the cathode, whereby said balancing grid assumes a positive voltage E_b depending inversely on the flow of electron current through the high resistance which current is greater for more positive values of E_g, said tube having a critical flash point function of E_b and E_g for said anode potential wherein all values of E_b and E_g on the nonflash side of said function prevent the establishment of a discharge arc, potentials E_b and E_g being balancing potentials on said nonflash side of said function and remaining so for gradual changes of E_g, and means for applying said A.C. signal to one of said grids without significantly changing the potential of the other grid.

6. An electron discharge device comprising an enclosing vessel containing an ionizable medium, a cathode, a control electrode surrounding the cathode except for at least one aperture, a balancing grid in front of, and in the path of electronic flow through, said aperture, and a cylindrical anode encompassing said control electrode and said balancing electrode, whereby said balancing electrode when connected to a voltage positive relative to said cathode tends to collect electrons flowing through said aperture.

7. A circuit for an electron discharge device in accordance with claim 6 adapted to be triggered by an A.C. signal, comprising means for applying a potential to said anode positive relative to the cathode, means for applying to said control electrode a D.C. bias potential E_g, means for applying to the balancing electrode through a high resistance a potential positive relative to the cathode whereby said balancing electrode assumes a positive value E_b depending inversely on the electron current I_b flowing through the high resistance which I_b in turn is greater for more positive values of E_g, said tube having a control characteristic curve for said anode potential with E_b and E_g as coordinate axes wherein all combinations of E_b and E_g which determine points to the left of the curve are insufficient to establish a discharge arc, said E_b and E_g being balancing voltages just on said left side of said curve and remaining so for gradual change in E_g, and means for applying said A.C. signal to one of said grids without significantly changing the potential of the other grid.

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