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ELECTRON DISCHARGE APPARATUS

2,509,065

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FIG. 1

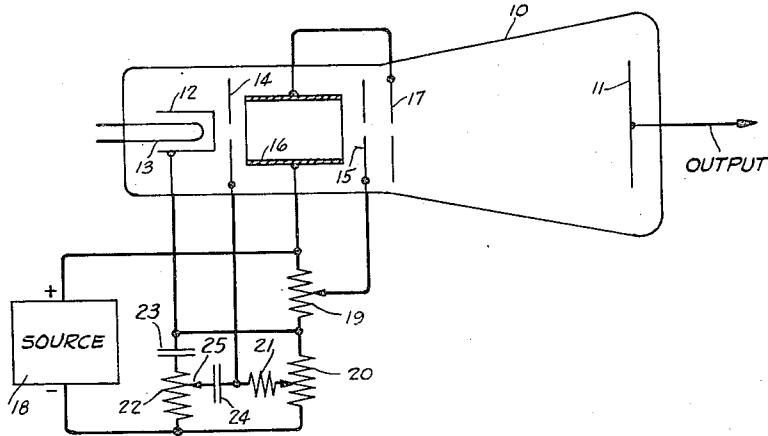


FIG. 2

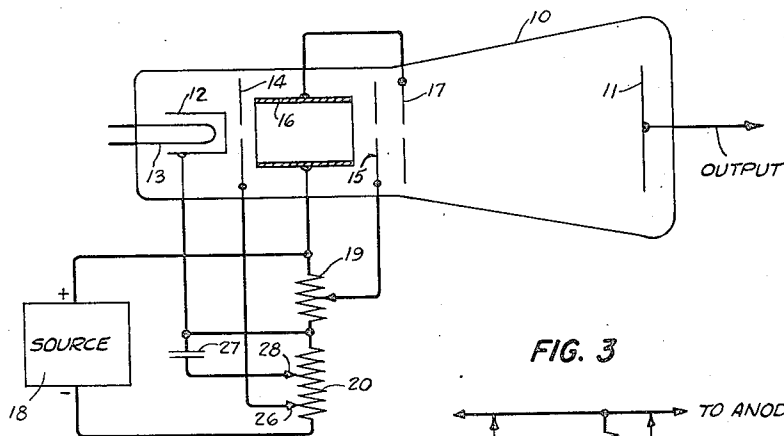
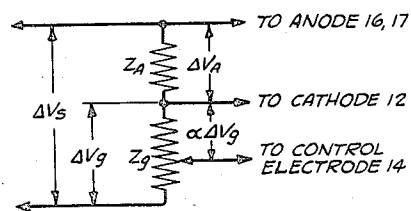


FIG. 3



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ELECTRON DISCHARGE APPARATUS

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9 Claims. (Cl. 315-14)

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This invention relates to electron discharge apparatus and more particularly to energizing circuits for electron guns such as are utilized in cathode ray devices.

Electron guns of one known type comprise, in general, a cathode, an anode in association with the cathode for accelerating the electrons emanating from the cathode, away therefrom, and a control electrode for controlling the intensity of the electron beam projected by the gun. It is desirable, from the standpoint of convenience and of simplicity of circuit design, that the control and accelerating electrodes be energized from a common direct current source. However, in such cases variations of the potential applied to the electrodes due to periodic or transient disturbances may result in substantial variations in the beam intensity inasmuch as the beam intensity or current is dependent upon the potential upon both the control and accelerating electrodes. Such variations in beam current are highly objectionable in many cathode ray devices.

One general object of this invention is to improve energizing or biasing circuits for electron guns. More specifically one object of this invention is to reduce or substantially eliminate variations in the beam intensity with changes or fluctuations in the voltage supplied from a common biasing source for the control and accelerating electrodes of an electron gun.

In accordance with one feature of this invention, the energizing circuit for biasing the gun electrodes from a common source is constructed as a network including a resistance-capacitance portion, such that the control electrode bias is regulated to counter balance changes in the beam current due to variations in the anode potential whereby the beam intensity is maintained substantially constant despite variations in the supply voltage.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Figs. 1 and 2 are circuit diagrams showing two illustrative embodiments of this invention, and

Fig. 3 is a diagram which will be referred to hereinafter in the explanation of certain principles involved in the circuits of Figs. 1 and 2.

Referring now to the drawing, the embodiment illustrated in Fig. 1 comprises a cathode ray device including an evacuated enclosing vessel 10 having an output anode or target 11 at one end and

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an electron gun at the other end, for projecting a concentrated electron stream or beam to the output anode. The electron gun comprises a cathode 12, which may be of the indirectly heated type including a heater element 13, a control electrode or grid 14, for example in the form of a centrally apertured disc axially aligned with the cathode, and a focussing electrode 15, which also may be a centrally apertured disc axially aligned with the cathode. The gun includes also an accelerating anode axially aligned with the cathode and comprising, for example, a cylindrical portion 16 between the control and focussing electrodes and a centrally apertured disc 17 between the focussing electrode and output anode and adjacent the former. The two portions 16 and 17 of the accelerating anodes are connected together to be electrically integral, as shown.

The electrodes of the gun are biased relative to one another from a direct current source 18, such as a battery or rectifier, which is connected across a pair of potentiometer resistors 19 and 20 in series. As illustrated in Fig. 1, the cathode 12 is connected directly to the common terminal of the resistors 19 and 20, the anode 16, 17 is connected to the positive terminal of the resistor 19, the focussing electrode is connected to an intermediate point on this resistor 19 and the control electrode 14 is connected, through a resistor 21, to an intermediate point on the resistor 20. The relative potentials of the electrodes 14 to 17 are made such as to produce a concentrated beam of prescribed intensity, projected toward the target 11. It is apparent that the anode 16, 17 is biased positive relative to the cathode 12, whereas the control electrode 14 is biased negative relative to the cathode.

Any variation in the voltage supplied from the source 18 will result in a change in the bias upon the control electrode 14 and the anode 16, 17. Both of these electrodes affect the beam intensity and changes in the bias tend to change the beam current differently both in sense and magnitude. For example, if the voltage of the source 18 increases, the anode bias increases, i. e. becomes more positive and, thus, tends to increase the beam current, whereas the bias upon control electrode 14 increases, i. e. becomes more negative, and hence tends to decrease the beam current. Because of the differences in the current-voltage relations for the cathode-control electrode and cathode-anode, the variations in beam current due to changes in the bias on the control electrode and anode are different in magnitude as well as in sign. The relation of the current varia-

tions which would result from change in the voltage of the source will be understood from the following analysis with reference to Fig. 3.

Fig. 3 is the alternating current form of the biasing circuit illustrated in Fig. 1. As indicated in Fig. 3, a change, ΔV_s , of pulse or periodic form in the voltage from the source 18, due, for example, to a disturbing source, results in a change ΔV_A in the bias of anode 16, 17 and of $\alpha \Delta V_g$ in the bias upon the control electrode 14. The change in the anode bias will tend to produce a change in beam current of $k_1 \Delta V_A$ and the change in control electrode bias will tend to produce a change in beam current of $\alpha k_2 \Delta V_g$, where k_1 and k_2 are constants, specifically the slopes of the current-voltage characteristics of the cathode and anode, and cathode and control electrode respectively, at the operating point. As pointed out heretofore, the two current changes are of opposite sign.

If the net change in beam current is to be zero for a change ΔV_s in source voltage, it is evident that the two current changes above noted must be equal. This will obtain if

$$k_1 \Delta V_s \left(\frac{Z_A}{Z_A + Z_g} \right) = \alpha k_2 \Delta V_s \left(\frac{Z_g}{Z_A + Z_g} \right) \quad (1)$$

or

$$k_1 Z_A = \alpha k_2 Z_g \quad (2)$$

as is clear from Fig. 3 and noting that

$$\Delta V_A = \Delta V_s \left(\frac{Z_A}{Z_A + Z_g} \right) \quad (3)$$

and

$$\Delta V_g = \Delta V_s \left(\frac{Z_g}{Z_A + Z_g} \right) \quad (4)$$

The condition requisite for zero net change in beam current with variations in the supply voltage can be obtained independently of any particular relation between the direct current biases for the anode and control electrodes. That is to say, the energizing circuit can be constructed so that the requisite or desired direct current biases can be set independently of the adjustment of the alternating current impedances to realize zero net beam current change with variations in the source voltage. One manner of effecting the alternating current circuit adjustment to obtain the zero net change in beam current desired is illustrated in Fig. 1.

The desired direct current operating biases for the anode 16, 17 and control electrode 14 are set by the resistors 19 and 20. The network for effecting the alternating current adjustment of the energizing circuit comprises the resistor 22 and condenser 23 in series and bridged across the resistor 20, and a second condenser 24 connected between the control electrode 14 and an adjustable tap 25 on the resistor 22. The resistor 22 corresponds to the impedance Z_g in Fig. 3 and the resistor 19 corresponds to the impedance Z_A in Fig. 3. The condenser 23 serves as a blocking condenser to keep direct current from the resistor 22 and is constructed to have a reactance small compared to Z_g at the lowest frequency of variation in source voltage for which no change in beam current is to obtain. The condenser 24 also serves as a blocking condenser and is constructed to have a small reactance compared to the impedance between cathode 12 and control electrode 14, looking into the cathode ray device. The resistor 20 has a resistance very small in comparison to that of resistor 22. Resistor 21 is large and prevents shunting of the adjustable tap 25.

In practice, the tap on the resistor 20 is set

so that the desired beam current flows to the output electrode or target 11. A voltage of the lowest frequency of disturbance likely to be encountered in the operation of the drive is impressed across source 18 and the tap 25 then is adjusted until no change from the desired value occurs in the current to the target 11.

In a specific embodiment of this invention, the energizing circuit constants for an electron gun for producing a beam current of the order of 25 milliamperes with a control electrode bias of -50 volts and an anode bias of 1000 volts, the cathode to control electrode impedance looking into the device being many megohms, found satisfactory to result in no change in beam current for source voltage fluctuations of frequencies down to 60 cycles per second were:

Resistor 19—200,000 ohms

20 Resistor 20—40,000 ohms

Resistor 21—1.0 megohm

Resistor 22—400,000 ohms

Condensers 23 and 24—1 microfarad

The parameters k_1 and k_2 in the analysis presented above may vary for different potentials upon the control electrode and anode. Hence, exact balance of the current modulations due to changes in the voltages on these two electrodes will obtain only for relatively small changes in supply voltage. However, even for relatively large variations in this voltage, substantial balancing is realized with consequent substantial reduction in change in the beam current.

In the embodiment of the invention illustrated in Fig. 2, the focussing electrode 15 and anode 16, 17 are biased by way of the resistor 19, as in the embodiment illustrated in Fig. 1, and the control electrode 14 is biased by way of an adjustable tap 26 on the resistor 20. A condenser 27 is connected between a second adjustable tap 28 on the resistor 20 and the common terminal of resistors 19 and 20. The resistor 19 corresponds to Z_A in Fig. 3 and the resistor 20 corresponds to Z_g .

The tap 26 is set to provide the desired bias and, hence, the desired beam current. The tap 28 is adjusted to realize the balance of beam current modulations due to disturbances in the supply voltage and, hence, in the potentials of the control electrode and anode. By an analysis similar to that followed hereinabove on the discussion of Fig. 1, it can be shown readily that if condenser 27 is sufficiently large to act as a short circuit at the lowest frequency for which balance is desired, for the circuit illustrated in Fig. 2 the condition requisite for balance is

$$k_1 R_A = k_2 \alpha \beta R_g \quad (5)$$

where k_1 , k_2 are as discussed before, R_A and R_g are the resistors 19 and 20, respectively, α is the proportion of the resistor 20 between the taps 26 and 28, and β is the proportion of the resistor 20 between the negative terminal thereof and the tap 28. A change of ΔV_s in the source voltage results in a change ΔV_A in the potential of anode 16, 17 and a change of ΔV_g across the portion βR_g of resistor 20.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising an electron gun including a cathode, a control elec-

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trode and an anode, means for biasing said control electrode and anode relative to said cathode comprising a resistance and a direct current source connected across said resistance, a direct current connection from said cathode to an intermediate point on said resistance, a direct current connection from said anode to a point on said resistance positive with respect to said intermediate point, a direct current connection from said control electrode to a point on said resistance negative with respect to said intermediate point, and means for controlling the potential of said control electrode in accordance with variations on the voltage across said resistance, said controlling means comprising a condenser and resistor in series between said cathode and a point on said resistance more negative than that to which said control electrode is connected and a condenser connected between said resistor and said control electrode.

2. Electron discharge apparatus comprising an electron gun including a cathode, an anode and a control electrode, means for biasing said anode and control electrode relative to said cathode including a first and a second resistor connected in series, a source for impressing a direct current voltage across said resistors and having its positive pole connected to said first resistor, a direct current connection from said cathode to the common terminal of said resistors, a direct current connection from said first resistor to said anode and a direct current connection from a first point on said second resistor to said control electrode, and means for regulating the potential of said control electrode in accordance with variations in said direct current voltage to maintain the current projected by said gun substantially constant, said regulating means comprising a condenser bridged between said common terminal and a point on said second resistor less negative than said first point.

3. In combination, an electron gun comprising a cathode, a control electrode and an anode, a direct current voltage divider having a first portion and a second portion, a direct current source for impressing a voltage across said portions and having its positive terminal connected to said first portion and its negative terminal connected to said second portion, a direct current connection between said cathode and a point between said first and second portions, a condenser and a resistor connected in series relation across said second portion with said condenser toward the cathode end of said second portion, said condenser having a reactance small in comparison to the impedance of said resistor at a preassigned frequency and said resistor being large in comparison to the resistance of said second portion, a resistive connection between said control electrode and said second portion, a capacitive connection between said resistor and said control electrode and having reactance small in comparison to the impedance between said cathode and said control electrode, and a direct current connection between said anode and said first portion.

4. In combination, an electron gun comprising a cathode, a control electrode and an anode, a direct current voltage divider having a first portion connected between said cathode and said anode and having a second portion in series with said first portion, a condenser and a resistance connected in series across said second portion with said condenser connected to the end thereof toward said first portion, means for impressing

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a direct current voltage across said voltage divider, a direct current connection between said control electrode and said second portion, and a capacitive connection between said control electrode and a point on said resistance such that

$$k_1 Z_A = \alpha k_2 Z_g$$

where k_1 and k_2 are respectively the slopes of the cathode-anode and cathode-control electrode characteristics, Z_A is the impedance of said first portion, Z_g is the impedance of said resistance and α is the portion of said resistance connected between said cathode and said control electrode, said second portion being of impedance small in comparison to said resistance.

5. In combination, an electron gun comprising a cathode, a control electrode and an anode, a direct current voltage divider having a first resistive portion connected between said cathode and said anode and having a second resistive portion in series with said first portion, a source for impressing a supply voltage across said portions in series, a direct current connection between said control electrode and a first point in said second portion, and a condenser bridged between said cathode and a second point on said second portion between said first point and said first portion and such that

$$k_1 R_A = k_2 \alpha \beta R_g$$

where k_1 and k_2 are respectively the slope of the cathode-anode and cathode-control electrode characteristics, R_A is the resistance of said first portion, R_g is the resistance of said second portion, α is the proportion of said second portion between said first and second points and β is the proportion of said second portion between said second point and said course.

6. In combination, an electron gun comprising a cathode and a pair of electrodes in juxtaposition thereto, each of said electrodes affecting the intensity of the current projected by said gun in accordance with the potential of the electrode, and means including a source of direct current voltage for biasing said cathode and said electrodes, said means being subject to spurious variations which superimpose an alternating current voltage component upon the direct current voltage, said means including a first adjustable direct-current connection between said source and said electron gun for controlling said direct current voltage bias between one of said electrodes and said cathode and a second adjustable alternating-current connection between said source and said electron gun for controlling the bias component between said one electrode and said cathode due to said superimposed voltage components.

7. In combination, an electron gun comprising a cathode, a control electrode and an anode, and means including a source of direct current voltage and superimposed alternating current voltage for biasing said cathode, said control electrode and said anode, said means including a first adjustable direct-current connection between said electron gun and said source for controlling said direct voltage bias between said control electrode and said cathode and a second adjustable alternating-current connection between said electron gun and said source for controlling said superimposed alternating voltage bias between said control electrode and said cathode.

8. Electron discharge apparatus comprising an electron gun including a cathode, a control electrode and an anode, means for biasing said control electrode and said anode relative to said

cathode including a voltage divider, means for impressing a supply voltage across said divider, means for imposing a direct-current bias upon said control electrode and said anode relative to said cathode including direct-current connections from spaced points on said divider to said cathode, control electrode and anode respectively, and means for impressing an alternating-current voltage between said control electrode and said cathode to control the potential of said control electrode in accordance with variations in said supply voltage to maintain the current projected by said gun substantially constant, said alternating-current voltage imposing means comprising a separate alternating-current connection to said voltage divider and between said cathode and said control electrode including a condenser connected across a portion of said divider.

9. In combination, an electron gun comprising a cathode and a pair of electrodes in juxtaposition thereto, each of said electrodes affecting the intensity of the current projected by said gun in accordance with the potential of the electrode, means for biasing one of said electrodes positive with respect to said cathode and the other

of said electrodes negative with respect to said cathode, said biasing means including a voltage divider, means for impressing a voltage across said divider, direct-current connections from said cathode and each of said electrodes to spaced points on said voltage divider, and a separate alternating-current connection to said voltage divider and between said cathode and one of said electrodes for regulating the potential of said one electrode in accordance with variations in said voltage to maintain the intensity of said current constant.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,169,831	Cawein	Aug. 15, 1939
2,173,221	Ballard	Sept. 19, 1939
2,276,455	Beers	Mar. 17, 1942
2,449,524	Witherby et al.	Sept. 14, 1948