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BEAM CURRENT STABILIZATION CIRCUIT FOR X-RAY TUBES

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Fig. 1.

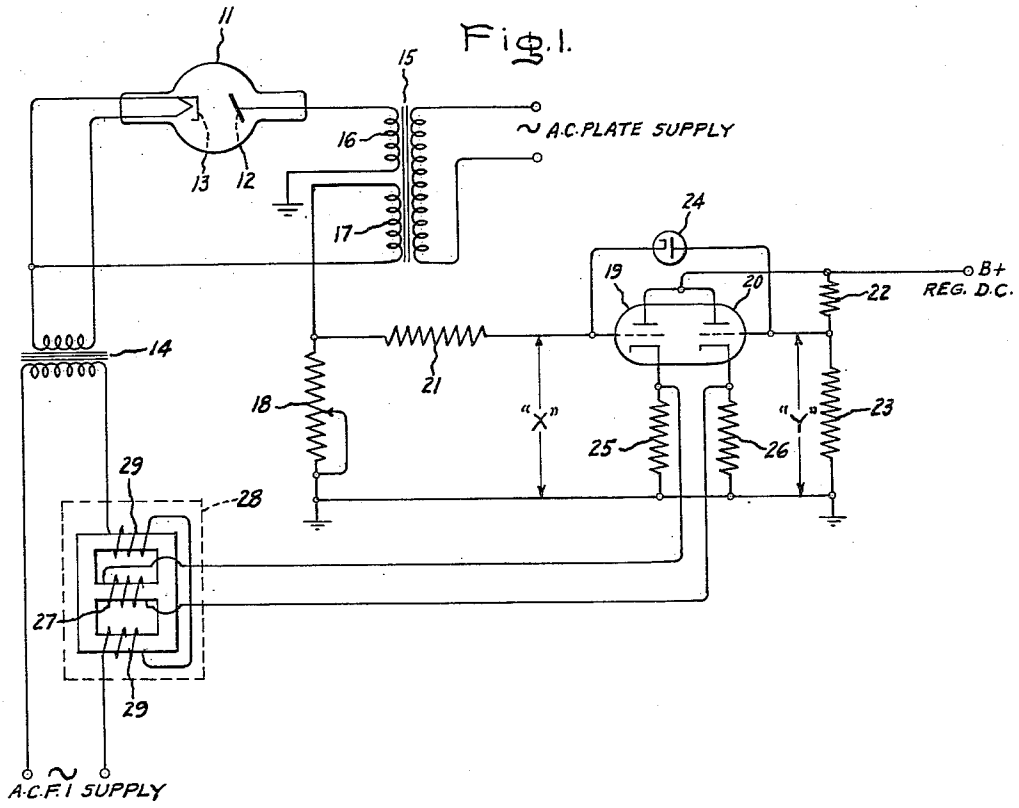
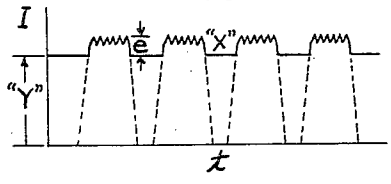



Fig. 2.




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# BEAM CURRENT STABILIZATION CIRCUIT FOR X-RAY TUBES

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7 Claims. (Cl. 250—103)

The present invention relates to an electron tube stabilization circuit.

More specifically, the invention relates to a stabilization circuit that is particularly suitable for use with X-ray tubes and the like which have electron-emitting cathode electrodes, and wherein it is necessary to exercise relatively close control over the electric energy supplied to the heater filament associated with the cathode electrode.

In the production of X-rays for gaging purposes, it is highly essential that the beam current of the X-ray tube used be maintained constant. Previously known techniques for producing a steady X-ray tube beam current include the use of constant speed motors driving alternating current generators connected as plate electrode power supply sources, the use of banks of storage batteries to provide highly stable filament heating current to the cathode heating filaments of the X-ray tube, the use of degenerative voltage regulators inserted in the plate-cathode circuit of the tubes, or the use of a feed-back loop system to control the filament heating current. All of the presently known systems of this general type are relatively complex in design, however, and hence are expensive, or tend to be unstable in operation.

It is therefore one object of the present invention to provide a new and improved stabilization circuit for X-ray tubes and the like, which utilizes a feed-back technique for the purpose of controlling the tube beam current, and which has little or no tendency to hunt or oscillate.

Still another object of the invention is to provide a reliable stabilization circuit having the above set forth characteristics which is relatively simple in design, and cheap to manufacture.

In practicing the invention, a stabilization circuit is provided for electron discharge devices having cathode electrode structures. The stabilization circuit includes an impedance adapted to be connected in the cathode-anode circuit of the device to be stabilized, and a two-electron discharge device differential amplifier having the input of one electron discharge device thereof connected across the above-mentioned impedance, and having the input to the remaining electron discharge device thereof connected to a reference source of electric energy. A unidirectional coupling device is interconnected between the inputs of the two units of the differential amplifier, and a load impedance is connected in the output thereof. Connected across the load impedance is the input of an electrically controllable impedance that is adapted to be included in the filament heating circuit of the electron discharge device to be stabilized.

Other objects, features, and many of the attendant advantages of this invention will be appreciated more readily as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a schematic circuit diagram of a stabilization circuit constructed in accordance with the present invention; and

Fig. 2 is a graph of the current-time relationship of the current flow through the X-ray tube or other similar device being stabilized.



The stabilization circuit comprising the present invention is shown in Fig. 1 of the drawings in conjunction with an X-ray tube 11 having a plate electrode 12 and cathode electrode 13. The heating filament of the cathode electrode 13 is energized by current supplied by the secondary winding of a filament supply transformer 14, and plate voltage is applied to the tube 11 through a plate supply transformer 15 having a split secondary winding comprised of the two winding halves 16 and 17. One end of the winding half 17 is connected to the cathode electrode 13 of the tube 11 with the remaining end thereof grounded, and one end of the winding half 16 is connected to the plate electrode 12 of X-ray tube 11 with the remaining end thereof returned to ground or zero reference point through a plate load impedance 18 preferably comprising a variable resistor. As is well known in the art, the X-ray tube 11 conducts only during the alternate half cycles of the plate supply voltage when the end of winding 16 connected to plate electrode 12 is positive with respect to the end of winding 17 connected to cathode electrode 13. During these alternate conduction periods, plate current flows through the load impedance 18 and develops a potential drop thereacross which is proportional to the current flow through the X-ray tube. As the intensity of the X-rays produced by tube 11 is to a great extent dependent upon the value of the beam current, and the beam current is in turn controlled largely by the temperature of the cathode electrode emitting surface, it is possible to control the intensity of the X-rays produced by the tube 11 to some extent by controlling the heating current supplied to the heating filament of the cathode electrode.

In order to develop a control electric signal to be used in controlling the amount of heating current supplied to the heating filament of the cathode electrode 13 of X-ray tube 11, the stabilization circuit includes a differential amplifier comprised of a pair of grid controlled electron discharge devices 19 and 20. In the embodiment of the invention disclosed, the two grid-controlled electron discharge devices are formed by a duo-triode electron tube wherein the control grid of the first electron discharge device 19 is connected through a limiting resistor 21 to the plate load impedance 18, and the control grid of the second electron discharge device 20 is connected to a reference source of electric energy formed by a potential divider and consisting of a pair of resistors 22 and 23 connected between ground and a regulated source of direct current electric energy. The control grids of each of the electron discharge devices are also intercoupled through a unidirectional conducting device comprised by a diode rectifier 24 having the plate electrode thereof connected to the control grid of the second electron discharge device 20 and the cathode electrode thereof connected to the control grid of the first electron discharge device 19. In this manner, the rectifier 24 serves to clamp the potential of the control grid of the first electron discharge device 19 to at least as high a potential value as the control grid of the second electron discharge device 20, but allows the potential of the control grid of discharge device 19 to swing more positive than the value of the reference potential. To complete the circuit, a separate load impedance 25 and 26 is connected in the cathode circuit of each of the electron discharge devices 19 and 20, respectively.

With the circuit arrangement thus illustrated, the X-ray tube beam current flowing through the secondary winding half 16 and the resistor 18 results in the production of a series of positive pulses, such as are indicated by the dotted lines in Fig. 2 of the drawings, and which are applied to the control grid of the electron discharge device 19. In

order to smooth out the pulsating electric signal thus developed, the rectifier **24** is provided so that a positive bias potential having essentially the value Y is applied to the control grids of both the second electron discharge device **20** and the first electron discharge device **19** simultaneously. Thus, should the value of the potential developed across the impedance **18** be equal to or drop below the predetermined value Y electron discharge devices **19** and **20** are caused to conduct essentially equal amounts of current, and hence the bias developed across the load resistors **25** and **26** in each of the cathode circuits thereof will be essentially equal. However, should the beam current of the X-ray tube **11** be sufficiently great to exceed the biasing potential Y by an amount such as *e*, indicated in Fig. 2 of the drawings, the rectifier **24** is cut off thus allowing the potential of the control grid of the first electron discharge device **19** to rise to a value higher than that of the control grid of the electron discharge device **20**. As a result, electron discharge device **19** will conduct more current than device **20**, and the potential developed across the cathode load resistor **25** thereof will be greater than the potential developed across the cathode load resistor **26**. Consequently, current flow will take place between the two load resistors if they are included in a closed electric circuit, and such current flow can be used to control the beam current, and hence the intensity of the X-rays produced by X-ray tube **11**. In order to properly utilize the control current produced in the above-described manner, a saturable reactor **28** is provided which has the energizing winding **27** thereof connected across cathode load resistors **25** and **26**, and has the output windings **29** thereof connected in series circuit relationship with the primary winding of the filament transformer **14**. The winding **27** is connected in a manner such that if the beam current of X-ray tube **11** increases so as to increase the value of *e*, this results in increasing the amount of impedance that the saturable reactor **28** reflects into the energizing circuit for the filament winding of X-ray tube **11**. Likewise, if the beam current for the X-ray tube decreases so as to decrease the value of *e*, the amount of impedance that the saturable reactor **28** reflects into the filament energizing circuit is decreased. In this manner, the heating current supplied to the heating filament of the cathode of tube **11** is controlled in such a manner as to maintain the beam current of the X-rays produced by the tube essentially constant.

From the foregoing description, it can be readily appreciated that the invention provides a new and improved stabilization circuit for X-ray tubes and the like wherein a feed-back technique is used to derive a control electric signal, which signal is utilized to maintain the beam current produced by the X-ray tube substantially constant. Because of the inherent simplicity of design of the circuit, it is relatively cheap to manufacture, it requires no moving parts, and, due to the fact that it requires no long time constant smoothing filters or the like, no substantial amount of phase shift is introduced into the feed-back control signal, and there is little or no tendency for the system to oscillate. Hence, the circuit is inherently stable in operation, and provides a means for controlling the intensity of the X-rays produced by a X-ray tube to a very fine degree.

In the light of the above teaching, other modifications and variations of the invention will be suggested to those skilled in the art. It is, therefore, to be understood that changes may be made in the invention which are within the full intended scope thereof as defined by the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A stabilization circuit for electron discharge devices including in combination an impedance adapted to be included in the cathode-anode circuit of the device to be stabilized, a differential amplifier having one input thereof connected across said first-mentioned impedance and having the other input thereof connected to a reference source of electric energy, a unidirectional conducting device interconnecting the two inputs of said differential amplifier, a load impedance connected in the output of said differential amplifier, and an electrically controllable impedance adapted to be included in the cathode filament heating circuit of the electron discharge device to be stabilized and having the input thereof operatively coupled across said load impedance.

2. A stabilization circuit for electron discharge devices including in combination an impedance adapted to be included in the cathode-anode circuit of the device to be stabilized, a differential amplifier having one input thereof connected across said first-mentioned impedance and having the other input thereof connected to a reference source of electric energy, a two electrode unidirectional conducting device having the cathode electrode thereof connected to the first-mentioned input of said differential amplifier and having the anode electrode thereof connected to the remaining input of said differential amplifier, a load impedance connected in the output of said differential amplifier, and an electrically controllable impedance adapted to be included in the cathode filament heating circuit of the electron discharge device to be stabilized and having the input thereof operatively coupled across said load impedance.

3. A stabilization circuit including in combination an electron discharge device having a cathode electrode, a resistor connected in the cathode-anode circuit of the device, a two-tube differential amplifier having the input of one tube thereof connected across said first-mentioned impedance and having the input to the remaining tube thereof connected to a reference source of electric energy, a diode rectifier having the cathode electrode thereof connected to the input of the first-mentioned stage of said differential amplifier and having the anode electrode thereof connected to the remaining stage of said differential amplifier, a load resistor connected in the output of said differential amplifier, and an electrically controllable impedance connected in the cathode filament heating circuit of said electron discharge device and having the input thereof operatively coupled across said load resistor.

4. A stabilization circuit for X-ray tubes including in combination an impedance adapted to be included in the cathode-anode circuit of an X-ray tube, a differential amplifier comprised of a pair of grid controlled electron discharge devices, the control grid of one of said electron discharge devices being operatively coupled to said first-mentioned impedance and the control grid of said remaining discharge device being operatively coupled to a source of reference electric potential, a unidirectional conducting device coupled between the control grids of said grid controlled discharge devices, a load impedance connected in the anode-cathode circuit of said grid controlled electron discharge devices, and a saturable reactor adapted to be included in the cathode heating filament supply circuit of the X-ray tube and having the input thereof connected across said load impedance.

5. A stabilization circuit for X-ray tubes including in combination an impedance adapted to be included in the cathode-anode circuit of an X-ray tube, a differential amplifier comprised of a pair of grid controlled electron discharge devices, the control grid of one of said electron discharge devices being operatively coupled to said first-mentioned impedance, a source of reference electric potential, the control grid of said remaining discharge device being operatively coupled to said source of reference electric potential, a two electrode unidirectional conducting device having the cathode electrode thereof connected to the input of the first-mentioned electron discharge device, and having the anode electrode thereof connected to the remaining electron discharge device, a load impedance connected in the anode-cathode circuit of said grid controlled electron discharge devices, and a saturable reactor adapted to be included in the cathode heating fila-

ment supply circuit of the X-ray tube and having the input thereof connected across said load impedance.

6. A stabilization circuit including in combination an X-ray tube, a first resistor connected in the cathode-anode circuit of said X-ray tube, a differential amplifier comprised of first and second grid-controlled electron discharge devices, the control grid of said first electron discharge devices being operatively coupled to said first resistor, a source of reference electric potential, the control grid of said second discharge device being operatively coupled to said source of reference electric potential, a diode rectifier having the cathode electrode thereof connected to the control grid of said first electron discharge device and the anode electrode thereof connected to the control grid of said second electron discharge device, a load resistor connected in the anode-cathode circuit of each of said grid-controlled electron discharge devices, and a saturable reactor connected in the cathode heating filament supply circuit of the X-ray tube and having the input thereof connected between corresponding points of said load resistors.

7. A stabilization circuit for X-ray tubes including in combination an impedance adapted to be included in



the cathode-anode circuit of the X-ray tube to be stabilized, a differential amplifier having one input thereof connected across said first-mentioned impedance and having the other input thereof connected to a reference source of electric energy, a unidirectional conducting device interconnecting the two inputs of said differential amplifier, a load impedance connected in the output of said differential amplifier, and an electrically controllable impedance adapted to be included in the cathode filament heating circuit of the X-ray tube to be stabilized and having the input thereof operatively coupled across said load impedance.

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