

Nov. 17, 1959

Z. L. COLLINS ET AL

2,913,582

X-RAY APPARATUS

Filed Dec. 20, 1954

2 Sheets-Sheet 1

Fig. 1.

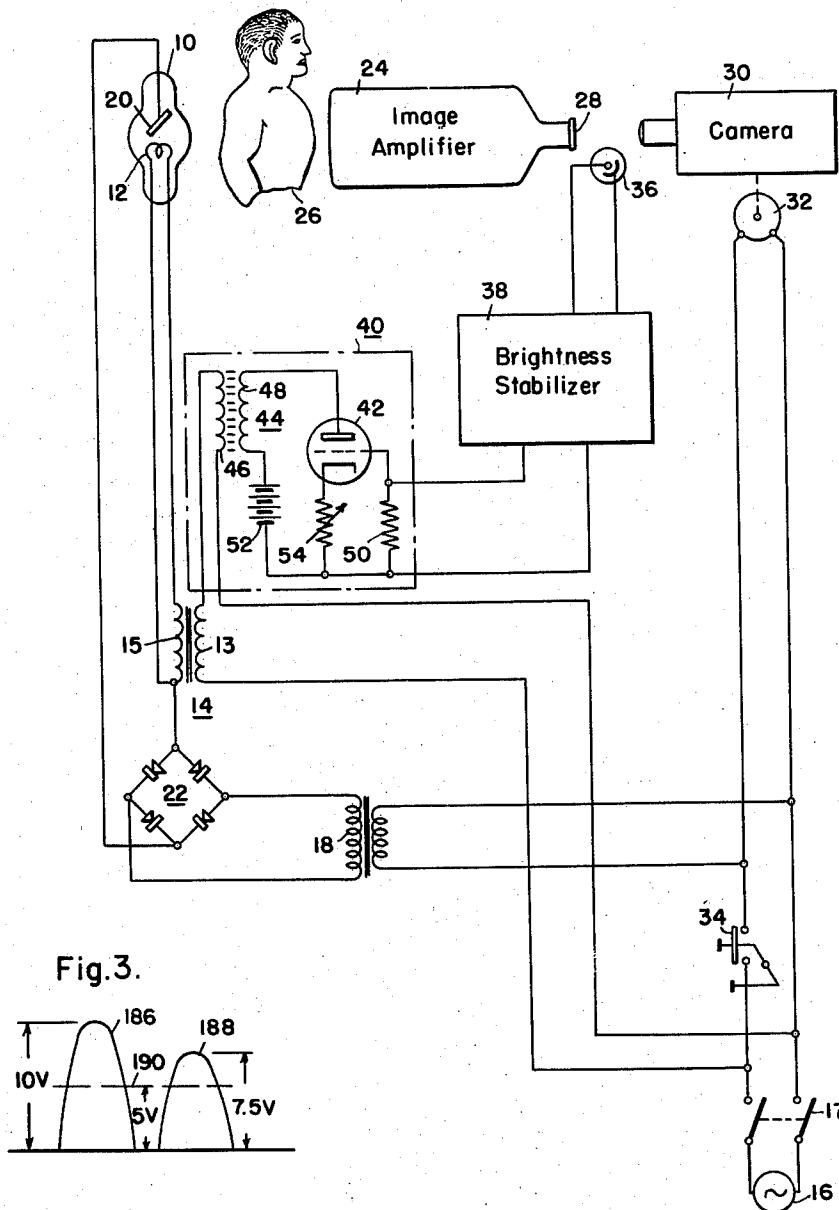


Fig. 3.

WITNESSES:

E. A. M. L. K. K.
R. J. Brodahl

INVENTORS
Zane L. Collins,
Martin E. Hayes
and Kenneth A. Kiesel.

BY
F. E. Browder
ATTORNEY

Nov. 17, 1959

Z. L. COLLINS ET AL

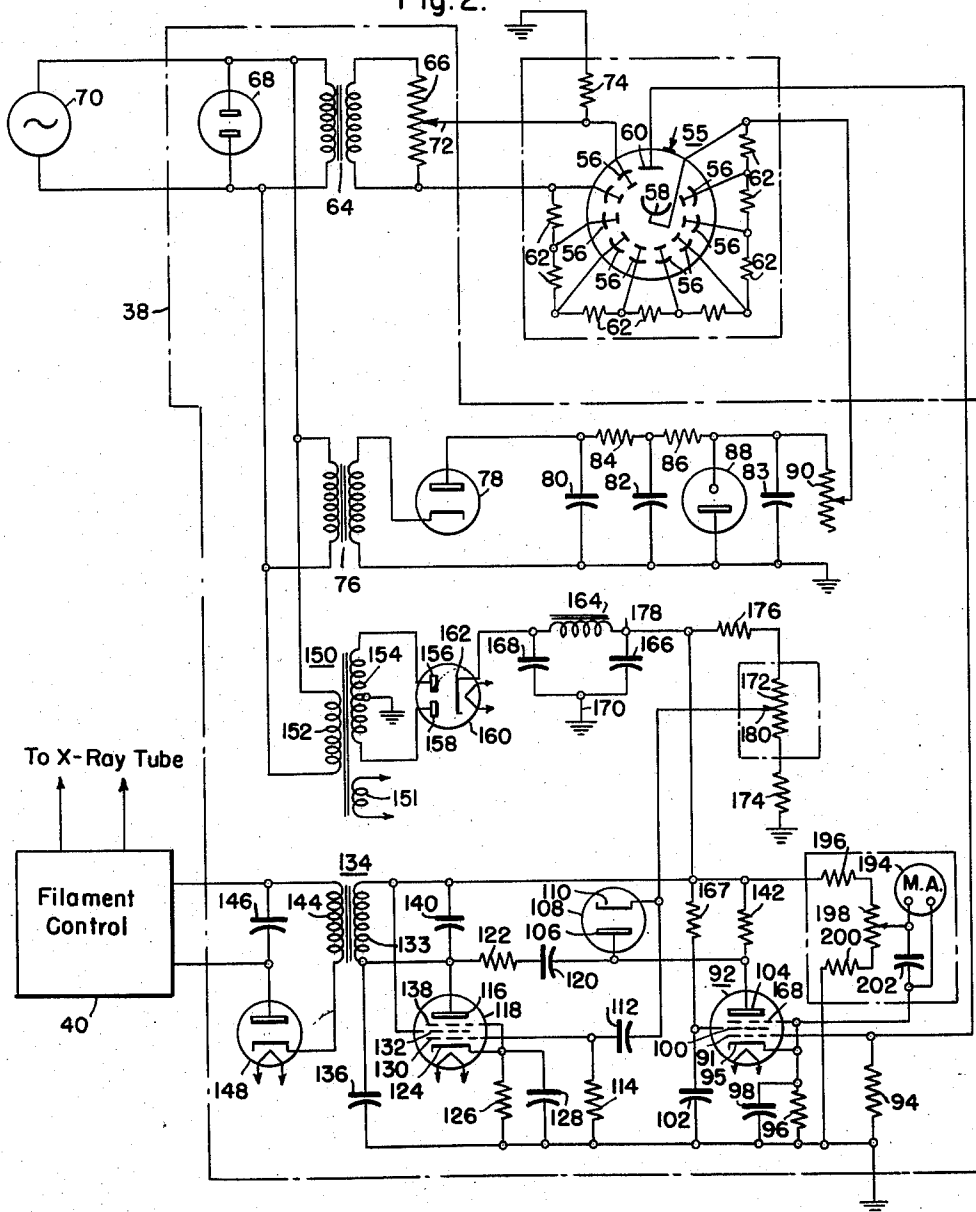
2,913,582

X-RAY APPARATUS

Filed Dec. 20, 1954

2 Sheets-Sheet 2

Fig. 2.



1

2,913,582

X-RAY APPARATUS

Zane L. Collins, Linthicum Heights, Martin E. Hayes, Severna Park, and Kenneth A. Kiesel, Catonsville, Md., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application December 20, 1954, Serial No. 476,246

7 Claims. (Cl. 250—103)

The present invention relates to improved X-ray apparatus, and more particularly to an improved control for the X-ray tube current to maintain substantially constant the brightness of the resultant X-ray picture.

In X-ray apparatus including a fluorescent screen and operative to provide an X-ray picture, there is a problem of maintaining the brightness of the resultant X-ray picture substantially constant as different thicknesses of objects are subjected to the X-rays or when objects having various opacities are subjected to the X-rays. This occurs when the X-ray apparatus is used for the purpose of taking motion pictures, and where the area of the object subjected to the X-rays is changed to a different area having a new thickness or where material having a different opaqueness is moved into the field of the X-rays. It is desired in these applications to maintain the X-ray intensity substantially constant and optimum for film exposure.

Accordingly, it is an object of the present invention to provide an improved control for the X-ray tube current.

It is another object of the present invention to provide improved X-ray apparatus including a brightness stabilizing arrangement responsive to the X-ray picture.

It is a different object to provide an improved X-ray picture brightness control circuit.

It is a further object to provide an improved X-ray tube filament control circuit which is operative to establish the desired X-ray picture brightness.

It is an additional object to provide an improved X-ray apparatus for maintaining the picture brightness substantially constant particularly for use in combination with a motion picture camera.

These and other objects and advantages of the invention will be apparent during the course of the following description. The invention, however, both as to its organization and method of operation, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figure 1 is a generalized diagram of apparatus in accordance with the present invention;

Fig. 2 is a schematic diagram of the apparatus in accordance with the present invention; and

Fig. 3 illustrates the operation of a portion of the apparatus in accordance with the present invention.

In Fig. 1 there is shown an X-ray tube 10 having a filament 12 which is supplied energy by a filament transformer 14 having a primary winding 13 and a secondary winding 15 connected to a suitable power supply 16 through a control switch 17. A conventional high tension transformer 18 is connected between the filament 12 and the anode 20 of the X-ray tube 10 through a bridge rectifier circuit 22. An image amplifier device 24 is positioned relative to a patient or object 26 to be subjected to X-rays from the X-ray tube 10. The image amplifier 24 is operative to produce a brightened and minified image on its fluorescent screen 28. A motion

2

picture camera 30 is positioned relative to the fluorescent screen 28 such that the X-ray picture on the latter screen can expose the film within the camera 30. A camera motor 32 is connected to the power source 16 through a control switch 34.

A light responsive member 36 is positioned to respond to the brightness of the X-ray picture on the fluorescent screen 28 and is connected to a brightness stabilizer circuit 38. The output of the brightness stabilizer circuit 38 controls the operation of a filament current control circuit 40, including an electron control discharge device 42 and a saturable reactor member 44 having an A.C. winding 46 and a D.C. winding 48. The output of the brightness stabilizer circuit 38 is applied to the grid of the control discharge device 42 across a grid resistor 50. A plate voltage supply 52 is connected across the discharge device 42 through the D.C. winding 48 of the saturable reactor 44 and a cathode bias control resistor 54.

In Fig. 2 there is shown a schematic diagram of particularly the brightness stabilizer circuit 38 shown in Fig. 1. The light responsive member 36 shown in Fig. 1 is illustrated in Fig. 2 as a photomultiplier type tube including nine dynodes 56, a cathode 58 and a plate 60. A direct current voltage of approximately 1000 volts is applied across the nine dynodes of the photomultiplier tube 55 by means of a voltage divider network including a plurality of resistors 62, with all but one of said resistors being connected between the respective dynodes 56 and said one resistor being connected between the cathode 58 and the first of the dynodes 56. An alternating current power supply source is shown connected between the eighth and ninth of the plurality of dynodes 56, and includes a transformer 64 and a variable resistor 66. A power indicator lamp 68 is connected across the power supply 70 which may be the same power supply as the power supply 16 shown in Fig. 1. A tap connection 72 is provided on the variable resistor 66 and is connected to the ninth of the plurality of dynodes 56. The tap connection 72 is further connected to ground through a resistor 74.

The regulated high voltage direct current power supply for the voltage divider network comprising the resistors 62 includes a transformer 76 which is connected across the power supply 70, a cold cathode rectifier tube 78, a filter network including condensers 80, 82 and 83 and resistors 84 and 86, a corona regulator tube 88 and a variable resistor 90 for adjusting the output of the regulated high voltage direct current power supply. The output of the photomultiplier tube is applied to the control grid 91 of an amplifier tube 92 in the main stabilizing circuit of the brightness stabilizer 38. The control grid 91 is connected to ground through a grid bias resistor 94. The cathode 95 of the amplifier tube 92 is connected to ground through a parallel connected cathode bias resistor 96 and capacitor 98. The screen grid 100 is connected to ground through a capacitor 102. The suppressor grid 138 is connected to the cathode 91. The plate 104 of the amplifier tube 92 is connected to the plate 106 of a clipper tube 108. Cathode 110 of the clipper tube 108 is connected to ground potential through condenser 112 and resistor 114. The plate 104 of the amplifier tube 92 is also connected to the plate 116 of a second amplifier tube 118 through condenser 120 and resistor 122. The cathode 124 of the second amplifier tube 118 is connected to ground potential through a parallel connected cathode resistor 126 and condenser 128. The control grid 130 is connected to the cathode 110 of the clipper tube 108 through condenser 112. The screen grid 132 is connected to ground potential through the primary winding 133 of a transformer 134 and a con-

denser 136. The suppressor grid 138 is connected to the cathode 124. The plate 116 is connected to the screen grid 132 through a condenser 140 and is connected to the plate 104 of the first amplifier tube 92 through the latter condenser 140 and a resistor 142. The secondary winding 144 of the transformer 134 is connected across a smoothing condenser 146 through a diode rectifier tube 148. The filament control circuit 40 shown in Fig. 1 is connected across the latter smoothing condenser 146.

A low voltage D.C. power supply comprises a transformer 150 having its primary winding 152 connected across the power supply source 70. The secondary winding 154 of this transformer has a center tap which is grounded and the ends of the secondary winding 54 are connected to the respective plates 156 and 158 of a full wave rectifier tube 160. The cathode 162 of the latter tube 160 is connected through a filter network including a filter choke 164 and capacitors 166 and 168, and through a resistor 167 to the screen grid 100 of the first amplifier tube 92. The filter network is connected to ground potential through a lead 170. A variable brightness control resistor 172 is connected to ground potential through a resistor 174, and through a resistor 176 to the junction 178 between the filter choke 164 and the capacitor 166. The brightness control resistor 172 has an adjustable tap 180 which is connected to the cathode 110 of the clipper tube 108.

The transformer 150 may be provided with another secondary winding 151 to provide voltage for the filaments of the various tubes in the described circuits.

In Fig. 3 there is shown a pair of half wave pulses corresponding to the output of the photomultiplier tube 55 for illustrating the operation of the clipper tube 108. The first pulse 186 has been given an illustrative value of 10 volts and the second pulse 188 has been given an illustrative value of 7.5 volts to illustrate the operation of the clipper tube 108 to clip these two pulses at an illustrative 5 volt level 190, such that the stabilizer circuit can respond to a smaller change in brightness. Due to the operation of the clipper tube 108 to clip the pulses 186 and 188 at the level 190, the remaining 5 volt value of the first pulse 186 need be compared to only the 2.5 volt remaining value of the pulse 188 such that a smaller percentage change in the relative values of these two pulses can be made to appear as a much larger percentage change in the signal fed to the second amplifier tube 118. In this respect the pulse 186 may be proportional to the X-ray picture brightness for a first area of the object 26, and the pulse 188 may be proportional to the picture brightness or X-ray intensity through a second area.

In accordance with the operation of the apparatus shown in Fig. 1, the camera 30 is started by closing the switch 34 to energize the camera motor 32. This also energizes the brightness stabilizer and filament current control circuits. The X-rays from the X-ray tube 10 pass through the patient 26 and fall upon the image amplifier device 24 which in turn produces a brightened and minified image at the fluorescent screen 28. The camera 30 photographs the X-ray picture or image appearing on the fluorescent screen 28. Also, the light responsive member 36 which corresponds to the photomultiplier tube 55 shown in Fig. 2 responds to the X-ray picture produced on the fluorescent screen 28 and is energized to provide an output current which is proportional to the brightness of the X-ray picture. The current generated by the light member 36 is fed to the brightness stabilizer circuit 38 and the output of the latter circuit is applied to the control discharge device 42 to determine the D.C. current flowing in the D.C. winding 48 of the saturable reactor 44 and thereby determine the impedance of the alternating current winding 46 to the flow of alternating current in the primary winding 13 of filament transformer 14. The flow of the latter current in turn determines the flow of current in the secondary

winding 15 and in the filament 12 of the X-ray tube 10. The cathode bias resistor 54 is operative to provide a maximum setting to prevent the current in the filament 12 from exceeding a maximum value which would exceed the maximum safe current in the X-ray tube 10.

The operation of the apparatus shown in Fig. 2 is such that the photomultiplier device 55 responds to the brightness of the X-ray picture appearing on the fluorescent screen 28 of the image amplifier device 24, as shown in Fig. 1, and provides an output signal from the anode 60 which is applied to the control grid 91 of the first amplifier tube 92. The signal produced by the photomultiplier device per se is a direct current signal which as such is more difficult to amplify and utilize than an alternating current signal. Therefore, an alternating current modulating signal is applied between the eighth and ninth of the plurality of dynodes 56 from across the adjustable resistor 66 such that the peak value of the alternating current wave form applied between the eighth and ninth of the plurality of dynodes is equal to the value of the direct current voltage applied between these same dynodes by the voltage divider network including the resistors 62. Thus, the variable resistor 66 can be adjusted such that the output signal from the anode 60 is in the form of negative half wave pulses, since the phototube 55 is effectively cut off whenever the ninth of the dynodes 56 is at a negative potential with respect to the eighth of the dynodes 56. In this respect, for the normal operation of the phototube 55, the ninth of the dynodes 56 must be positive with respect to the eighth of the dynodes by a value which may correspond to 100 or so volts, and the alternating current applied between the latter dynodes from across the portion of the adjustable resistor 66 as determined by the center tap 72 may be made to correspond to the same 100 volts, such that the output signal from the anode 60 is in the form of only half wave pulses with the magnitude of these pulses being proportional to the light striking the cathode 58 from the X-ray picture appearing on the fluorescent screen 28 of the image device 24 as shown in Fig. 1. Any variation in the applied alternating current voltage from the adjustable resistor 66 may cause a slight variation in the magnitude of the output signal from the anode 60. However, the regulation of this applied alternating current voltage is not particularly critical compared to the regulation of the direct current voltage applied to the phototube by means of the voltage divider network including the resistors 62.

The latter direct current voltage is provided by the regulated high voltage direct current power supply including the transformer 76, the rectifier tube 78, the filter network including the resistors 84 and 86 and the capacitors 80, 82 and 83, the regulator tube 88 and the variable resistor 90. The latter resistor 90 is variable for adjusting the direct current voltage applied across the voltage divider network including the resistors 62. The plate voltage for the first amplifier tube 92 and second amplifier tube 118 in the main stabilizing circuit of the brightness stabilizer 38 is provided by the power supply including the transformer 150, the full wave rectifier tube 160, the filter network including the filter choke 164 and the capacitors 166 and 168.

The output of the photomultiplier tube 55 is applied from the anode 60 of the latter device to the control grid 91 of the first amplifier tube 92 in the form of negative half wave pulses, the magnitude or amplitude of which are proportional to the brightness of the X-ray picture. The output of the first amplifier tube 92 is passed through a clipper stage including tube 108 which is operative to clip the output signals to a predetermined level 190 as shown in Fig. 3 corresponding to 5 volts such that the remainder of the circuit can respond to a much larger percentage change in the pulses 186 and 188, each of which correspond to the brightness of the X-ray picture, and thereby responding to smaller changes in brightness

5

of the X-ray picture. The level of operation of the clipper tube 108 is determined by the adjustable tap 180 on resistor 172 which is operative as a brightness control resistor.

The output signal of the first amplifier tube 92 is clipped by the clipper tube 108, and it is applied to the second amplifier tube 118 where it is amplified and impressed across the transformer 134 which is connected between the plate 116 and the screen grid 132 of the second amplifier tube 118. The latter transformer 134 serves as an isolation member between the brightness stabilizer circuit and the filament control circuit 40. The diode 148 is operative to reestablish the negative polarity to the pulses which are fed to the filament control circuit 40, and the capacitor 146 is operative to provide a smoothing effect upon these pulses. The resistor 122 and capacitor 120 is provided as a feedback circuit which is operative to provide a more linear response of the stabilizing action over the complete range of current in the X-ray tube 10. Capacitors 140 and 136 are provided to substantially reduce the low frequency hunting effect which is inherent in a circuit of this type.

The output pulses which are fed from the secondary winding 144 of the transformer 134 are applied to the control grid of the discharge device 42 in the filament control circuit 40 as best shown in Fig. 1. These pulses are operative to determine the flow of direct current in the winding 48 of the saturable reactor 44 and thereby determine the impedance of the alternating current winding 46 in the circuit of the filament transformer 14. If the brightness of the X-ray picture is lower than desired, then the apparatus is operative to increase the flow of direct current in the winding 48 to lower the impedance of the alternating current winding 46. Conversely, if the brightness of the X-ray picture is too high, the flow of direct current in the winding 48 is decreased to thereby increase the impedance of alternating current winding 46 to reduce thereby the current flowing through the filament 12 and hence to reduce the current in the X-ray tube 10.

The variable cathode bias resistor 54 is provided to determine the maximum desired current in the X-ray tube 10 and prevent a value of the current in the X-ray tube 10 above the maximum safe rated value for the particular tube employed. In this respect, if the brightness of the X-ray picture appearing at the fluorescent screen 28 is too low, the operation of the brightness stabilizer circuit 38 would be to increase the alternating current flowing in the filament 12 and the cathode bias resistor 54 prevents the value of the current in the latter filament 12 from going above the maximum safe value.

As shown in Fig. 2, a brightness level meter 194 may be provided to give a visual indication of the relative brightness of the X-ray picture. This meter may comprise a suitable ammeter connected in a balanced bridge type circuit including resistors 196, 198 and 200, and a capacitor 202. The meter 194 receives a signal from across the cathode resistor 96 of the first amplifier tube 92 such that the brightness level meter 194 will give a visual indication of the relative brightness of the X-ray picture. The brightness level meter 194 is of particular usefulness during the initial installation of the apparatus and is operative as an exposure meter for cinephographic work when a motion picture camera 30 is employed to make a record of the X-ray picture appearing at fluorescent screen 28. Also, the brightness level meter 194 is operative to provide a human operator with a visual means of adjusting the brightness level and after establishing the level which will produce the desired film exposure, the meter 194 can be used to check and readjust the X-ray picture brightness to the desired and correct value.

Although we have shown and described certain specific embodiments of the present invention, it should be

6

apparent to those skilled in the art that many modifications thereof may be made.

We claim as our invention:

1. In X-ray apparatus including an X-ray picture producing member for producing X-ray pictures of objects examined by X-rays at respective times, and an X-ray tube having a filament, in combination therewith, a light responsive member positioned relative to said picture producing member to be responsive to the brightness of the X-ray picture, a filament current control circuit including a variable impedance member connected to the filament of said X-ray tube, and a picture brightness stabilizer circuit connected between said light responsive member and said filament current control circuit for varying the impedance of said impedance member to thereby control the current flowing through said filament, hence X-ray output from said tube, for maintaining a selected degree of brightness of said picture in the presence of differences in the X-ray transmissiveness of the objects being pictured.

2. In X-ray apparatus including a fluorescent screen operative to provide an X-ray picture of objects examined by X-rays at respective times, and an X-ray tube having a filament, in combination therewith, a light responsive member responsive to the brightness of said picture, a filament control circuit including a saturable reactor member having an alternating current winding and a direct current winding with said alternating current winding connected to said filament, and a picture brightness stabilizer circuit connected between said light responsive member and said direct current winding to automatically regulate the X-ray output from said tube for maintaining a selected degree of brightness of said picture in the presence of differences in the X-ray transmissiveness of the objects being pictured.

3. In X-ray apparatus including a fluorescent screen operative to provide an X-ray picture of objects being examined by X-rays at respective times and an X-ray tube having a filament, in combination therewith, a light responsive member having a direct current output voltage proportional to the brightness of said picture, a source of an alternating current modulating voltage connected to said light responsive member to provide an alternating current output voltage proportional to the brightness of said picture, and a picture brightness stabilizer circuit connected between said light responsive member and said filament current control circuit, with the latter stabilizer circuit being responsive to said alternating current output voltage for controlling the current flowing through said X-ray tube filament to automatically regulate the X-ray output from said tube for maintaining a selected degree of brightness of said picture in the presence of differences in the X-ray transmissiveness of the objects being pictured.

4. In X-ray apparatus including a fluorescent screen operative to provide an X-ray picture of objects examined by X-rays at respective times and an X-ray tube having a filament, in combination therewith, a light responsive member having an output voltage responsive to the brightness of said picture, said light responsive member including a photomultiplier device having a plurality of dynodes, a source of a direct current voltage connected across said plurality of dynodes, a source of an alternating current voltage connected between two of said plurality of dynodes, and a picture brightness stabilizer circuit connected between said light responsive member and said filament of the X-ray tube to automatically regulate the X-ray output from said tube for maintaining a selected degree of picture brightness in the presence of differences in the X-ray transmissiveness of the objects pictured.

5. In X-ray apparatus including a fluorescent screen operative to provide an X-ray picture of objects examined by X-rays and an X-ray tube having a filament, in combination therewith, a filament current control circuit

7

to control the flow of heating current to the filament of said X-ray tube, a light responsive member having a direct current output voltage proportional to the brightness of said picture, a source of an alternating current modulating voltage connected to said light responsive member to provide an alternating current output voltage proportional to the brightness of said picture, and a picture brightness stabilizer circuit connected between said light responsive member and said filament current control circuit, with the latter stabilizer circuit being responsive to said alternating current output voltage for controlling the current flowing through said X-ray tube filament to automatically regulate the output from said tube for maintaining a selected degree of brightness of said picture in the presence of variation in X-ray transmissiveness of the objects pictured, said stabilizer circuit including a clipper device for clipping said alternating current output voltage to increase variation thereof as seen by said filament current control circuit.

6. The combination of a fluorescent screen to provide an X-ray picture of objects to be examined at respective times, a radiation producing discharge device for producing a beam of penetrative radiation to irradiate the objects to be examined, said discharge device having a cathode to be heated, an excitation circuit for said device including a high tension transformer having its secondary winding connected for supplying anode current to said discharge device, a source of alternating current electrical energy for heating the cathode of said discharge device, inductive means associated with said source of heating energy and responsive to the imposition thereon of a control current component to control the flow of heating current to the filament of said discharge device, radiation detection means disposed adjacent to said fluorescent screen to derive an electrical control signal corresponding to the brightness of said picture resultant from the radiation passing through said object, circuit means electrically associated with both said radiation detection means and said inductive means and responsive to said electrical control signal to cause the imposition of a current component upon said inductive means such that the heating current supplied to the cathode of said tube is varied inversely in response to variations in the

8

brightness of said picture, thereby automatically regulating the output from said discharge device to maintain such brightness substantially constant in the presence of variation between the X-ray transmissiveness of the objects examined at respective times.

7. X-ray apparatus including an X-ray tube having a filament for projecting a beam of X-rays through objects to be examined at respective times, picture producing means for producing a luminous X-ray picture of such objects, X-ray detection means disposed adjacent said picture producing means to produce an electrical control signal corresponding to the brightness of said picture, a source of alternating current electrical energy for heating current supply to the filament of said X-ray tube, a filament current control circuit associated with said source of alternating current electrical energy and responsive to the imposition thereon of a unidirectional current signal to control the flow of heating current to said filament, and a stabilizer circuit electrically associated with both said filament current control circuit and said X-ray detection means and responsive to a variation in said electrical control signal to impose a unidirectional current component upon said filament current control circuit to cause an inverse variation in the heating current supplied to said filament relative to a variation in the brightness of said picture to automatically regulate the intensity of said beam produced by said tube for maintaining such brightness substantially constant in the presence of variation in the transmissiveness of one object relative to another.

References Cited in the file of this patent

UNITED STATES PATENTS

2,023,453	Von Wedel	Dec. 10, 1935
2,236,195	McKesson	Mar. 25, 1941
2,407,485	Essig	Sept. 10, 1946
2,503,075	Smith	Apr. 4, 1950
2,509,380	Walker	May 30, 1950
2,626,360	Wright	Jan. 20, 1953
2,632,117	Vossberg	Mar. 17, 1953
2,723,350	Clapp	Nov. 8, 1955
2,825,816	Rogers	Mar. 4, 1958