Sept. 4, 1928. 1,683,194

W. K. KEARSLEY

REGULATING SYSTEM FOR THERMIONIC DEVICES

Filed March 24, 1927

Fig. 1.

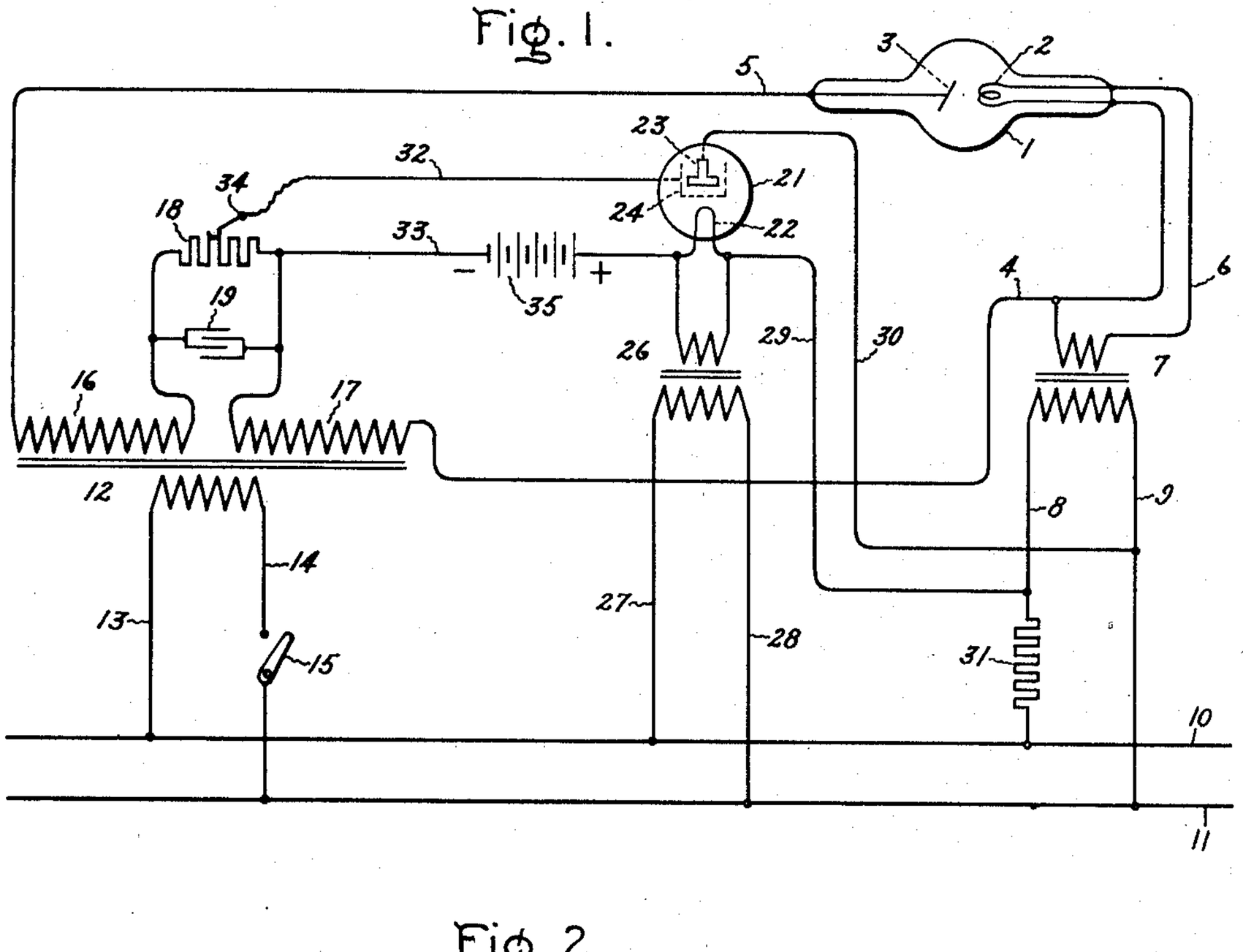
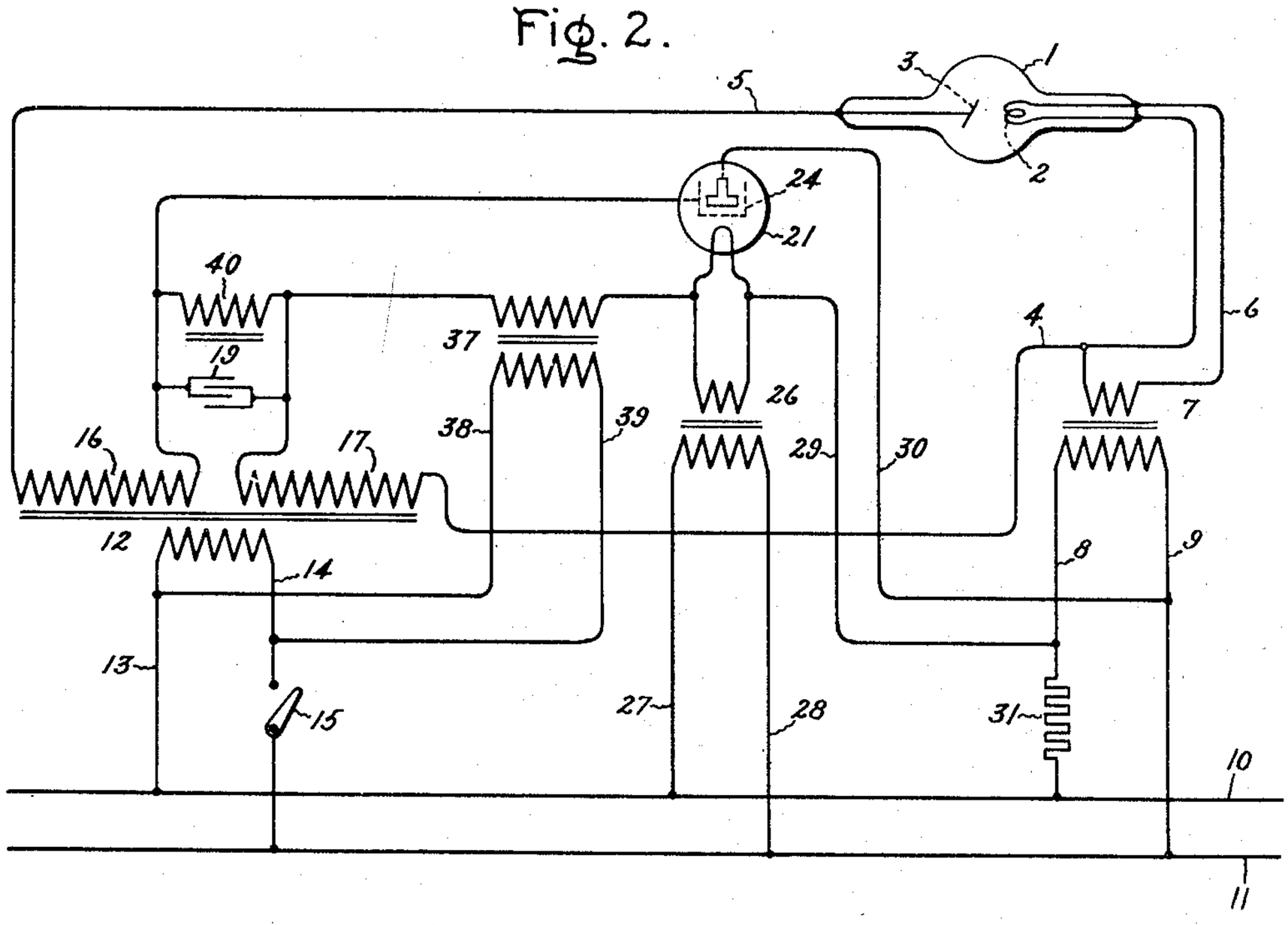


Fig. 2.



Inventor:
William K. Kearsley,
by Alexander S. Lowe
His Attorney.

Patented Sept. 4, 1928. 1,683,194

UNITED STATES PATENT OFFICE.

WILLIAM K. KEARSLEY, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

REGULATING SYSTEM FOR THERMIONIC DEVICES.

Application filed March 24, 1927. Serial No. 178,106.

The present invention relates to thermionic apparatus, and in particular to the regulation of thermionic X-ray tubes and its object is to provide a stabilizer or regulator for maintaining a desired electron emissivity and thereby a desired space current in a thermionic device.

The X-ray output of an X-ray tube varies directly with the electron emission of the cathode. The electron emission varies both with variations of cathode temperature and variations of gas conditions in the X-ray tube. When an X-ray tube is operated by current derived from commercial circuits, variations in voltage are constantly occurring thereby altering the cathode temperature. Also ordinary X-ray tubes are subject to changes in residual gas content. Tubes containing targets backed with copper or other metal, which can be freed from gas only with great difficulty, are particularly subject to such changes.

It has been found desirable, therefore, to provide a stabilizer whereby the electron emission of such a thermionic device as a Coolidge X-ray tube is maintained constant even though its gas content or the supply voltage for the cathode of the tube should vary. In my prior United States patent No. 1,653,102, issued December 20, 1927, and in a paper published by me in the Journal of Radiology for July, 1921, I have described a vibrating stabilizer whereby in response to the space current in an X-ray tube the duration of the flow of heating current for the cathode is so controlled by mechanical make and break contacts during the half wave impulses when current flow occurs through the X-ray tube that the electron emission is maintained at the desired value.

In accordance with my present invention the control of the cathode heating current in the X-ray tube, or other thermionic device to be regulated, is carried on by an auxiliary thermionic device which is provided with means, such as a grid, for controlling the duration of flow of space current therein. This auxiliary tube operates in conjunction with regulating means to so vary the voltage of the heating current for the cathode of the main device that a desired space current is maintained in the main device. The novel feature of my invention will be pointed out with greater particularity in the appended claims.

The accompanying drawing shows in Fig. 1 a diagrammatic illustration of my invention as applied to an X-ray tube, and Fig. 2 illustrates a modification.

In the system shown in Fig. 1, the thermionic device in which a predetermined space current is desired is indicated at 1. This device, for illustration, may be a highly exhausted X-ray tube, such as the Coolidge tube, which is described in U. S. Patent 1,203,495 issued October 31, 1916. This tube is provided with a thermionic cathode 2 and an anode 3, these electrodes being connected in the usual manner to current supply conductors 4, 5. The cathode 2 is supplied with heating current by the conductors 4, 6 which are connected to the secondary of a transformer 7. The primary winding of this transformer is connected by the conductors 8, 9 to the supply mains 10, the current in the main circuit 4, 5 and in the heating circuit 4, 6, therefore, being in synchronism. The main supply conductors 4, 5 for the X-ray tube are connected to the high potential secondary of a transformer 12. The primary winding of the transformer 12 is connected by the conductors 13, 14 in circuit with a switch 15 to the supply mains 10. The secondary windings 16, 17 of the transformer 12 are connected in series through a non-inductive resistance 18, which is shunted by a condenser 19. The condenser 19 prevents transient current impulses from starting the operation of the device 21 prematurely.

Assuming the device 1 to be operated at saturation current for any given cathode temperature, which is the usual method of operating a thermionic X-ray tube, then in the system described the space current through the tube would vary with the variation of voltage in the supply mains 10 or with a variation of gas content of the tube. In order to prevent such variation of space current, I have provided a thermionic regulator tube 21. As diagrammatically indicated, the tube 21 has a thermionic cathode 22, an anode 23 and a grid 24, which has been represented by a dotted line and which preferably surrounds the anode. This aux-

iliary tube should be first highly evacuated and freed of water vapor and then provided with a gas or a source of vapor, such as mercury. It may be provided with some inert gas, such as argon, at a pressure, for example, of about five and one-half centimeters of mercury. An electrical valve tube of this general character is known as a thyratron.

In a thyratron the current flow is initiated suddenly from zero to full normal value when the charge of the grid changes from negative to positive. Should the grid charge become negative while space current is flowing through a thyratron, no change of space current results.

The cathode 22 of this valve tube is supplied with heating current by a transformer 26, the primary of which is connected by the conductors 27, 28 to the supply mains 10. The cathode and the anode of the regulator tube 21 are connected by the conductors 29, 30 to the primary circuit of the supply transformer 7 and receive current from the supply mains 10 through a non-inductive resistance 31. The grid 24 and the cathode 22 are connected respectively by the conductors 32, 33 to the resistance 18, one of the terminals 34 preferably being adjustable, as indicated. A biasing battery 35 is provided in the grid circuit 32, 33 and is connected as indicated to impress a negative potential on the grid 24.

In the system described a space current through the thermionic tube 1 produces a drop of voltage in the resistance 18 which is connected to oppose in potential the biasing battery 35. As long as the grid potential is negative no current flow will take place through the valve tube 21. When the space current through the tube 1 increases in any half wave impulse to a value at which the potential drop across the resistance 18 exceeds the potential drop across the battery 35, then the grid becomes positive and an electronic current flow begins through the valve tube 21. As the current which flows through the valve tube 21 is derived through the resistance 31, an increase of current through this valve tube increases the potential drop in the resistance 31 and lowers the voltage of the heating current for the cathode 2 of the main thermionic tube 1. The temperature of the cathode thereby is lowered, decreasing the electron emission or preventing its undesired increase and consequently maintaining the space current through the thermionic tube 1 at a desired average value.

Any tendency for the current in the tube 1 to fall below a desired value, for example due to a decrease of voltage in the supply mains 10, 11, or to the evolution of deleterious gas, is immediately counteracted through the intermediary of the regulator tube 21 by a decrease of voltage drop in the resistance 31 and an increase of cathode temperature so that the right amount of heating current is delivered to the cathode 2 to maintain the space current at the desired value.

The operation of the regulator tube 21 occurs without time lag and the system is free from all mechanically moving parts and therefore remains at all times in proper working condition without mechanical adjustments. The regulation is so quickly responsive to conditions and is so positive in its action that no perceptible variation of average space current occurs in the circuit of the main tube 1 as shown by a meter. During each half wave of alternating current passing through the main thermionic tube the voltage of the heating current is so regulated that the electron emission of the cathode in the main device is maintained at the desired value.

The system shown in Fig. 2 is similar in most respects to the system shown in Fig. 1 but differs therefrom by the insertion of the secondary winding of the transformer 37 in place of the biasing battery 35. The primary winding of this transformer 37 is connected by the conductors 38, 39 to the conductors 13, 14 which supply current to the main high potential transformer 12. It also differs from the system shown in Fig. 1 by the use of an inductance coil 40 as an impedance device in place of the non-inductive resistance 18. The potential of the inductance coil 40 is opposed to the potential of the secondary of the transformer 37. Upon a rise of current in the main circuit 4, 5, the potential of the grid 24 of the regulator tube 21 becomes positive so that current flow begins through the regulator tube. Current through the regulator tube will occur during periods of such duration that the space current through the tube 1 is maintained at the desired predetermined value. Should the space current in the main tube tend to rise, flow of current through the regulator tube will occur earlier during the cycle and should the space current therein tend to fall then current flow through the regulator tube will occur later to maintain the voltage of the heating current at a value which will produce a desired electron emission from the cathode of the tube 1.

In the operation of either of the systems shown in Figs. 1 and 2 no perceptible departure from a predetermined value of the space current in the X-ray or other tube to be regulated occurs as the described parts of the system are so arranged and the values of the resistances and other regulating elements are so chosen that a required amount of cathode heating current is supplied to the cathode during each half wave impulse.

Although I have described my invention with particular reference to the regulation

of the space current in an X-ray tube in order to regulate its X-ray output, I wish it to be understood that it is of general application to thermionic devices in which a regulation of space current is desired.

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

1. The combination of a main thermionic device, means for delivering impulses of current to the cathode of said device, thermionic regulating means for decreasing said current impulses, means for initiating the operation of said regulating means when the space current in said main thermionic device has reached a predetermined value thereby opposing further increase of space current.

2. The combination of a thermionic X-ray tube, means for delivering impulses of current to the cathode of said tube, thermionic regulating means for controlling said current impulses, means for rendering said device non-operative during a part of each such impulse of current, and means put into operation when the space current in said X-ray tube reaches a predetermined value for rendering operative said thermionic means.

3. The combination of a thermionic tube to be regulated, a heating circuit for the cathode of said tube, a voltage-consuming means in said heating circuit, an auxiliary thermionic device which is provided with a grid and contains a supply of gas at a pressure sufficiently high to neutralize space charge by ionization, electrical connections whereby space current will be delivered to said auxiliary device in circuit with said voltage-consuming means, and means whereby said grid will be charged to a positive potential when the space current through the tube to be regulated rises to and above a predetermined value.

4. The combination of a thermionic X-ray tube, a circuit for delivering current to heat the cathode of said tube, a voltage-consuming means in said circuit, an auxiliary thermionic device of the gas ionization type provided with a grid for preventing the initiation of current flow therethrough in response to a negative potential applied to said grid, circuit connections for deriving current for said auxiliary device through said voltage-consuming means, means for biasing said grid at a negative potential and means for opposing said negative potential by a positive potential varying directly in response to variations in space current in said X-ray tube.

5. The combination of a main thermionic device, a heating circuit for the cathode of said device, voltage-consuming means in said circuit, an auxiliary thermionic device connected to vary the voltage drop in said voltage-consuming means, and means for timing the flow of space current in said auxiliary thermionic device to occur when the space current of the main thermionic device has reached a predetermined value.

6. An X-ray apparatus comprising an X-ray tube having a cathode adapted to be heated by passage of current, a source of alternating current connected to the main electrodes of said X-ray tube, a heating circuit for the cathode arranged to receive alternating current in synchronism with said source, and thermionic regulating means responsive to load current in said X-ray tube, means for rendering said means non-operative at the beginning of successive current impulses through said X-ray tube, and means for withdrawing current by said thermionic means from said heating circuit for periods of such duration that the electron emission of said cathode is maintained at a substantially constant average value.

7. An electric apparatus comprising a thermionic device, a cathode heating circuit therefor, a thyratron, circuit connections for delivering impulses of variable current to said device, means for initially charging the grid of said thyratron to a negative potential, means for superimposing a positive potential upon said grid varying directly with the current through said thermionic device and circuit connections for regulating the electrical heating current of the cathode of said thermionic device inversely with current flow through said thyratron.

8. An X-ray apparatus comprising a thermionic pure electron discharge X-ray tube, a source of alternating current connected to the main electrodes of said tube, an impedance device in said circuit, a cathode heating circuit also connected to said source, a thyratron having a cathode, an anode and a grid, connections from the grid and cathode of said thyratron to said impedance device whereby an increase of current in said X-ray device produces an increase of length of the conductive periods of said thyratron and circuit connections from the cathode and anode of said thyratron whereby current is withdrawn therethrough from the heating circuit of said X-ray tube.

In witness whereof, I have hereunto set my hand this 23d day of March, 1927.

WILLIAM K. KEARSLEY.