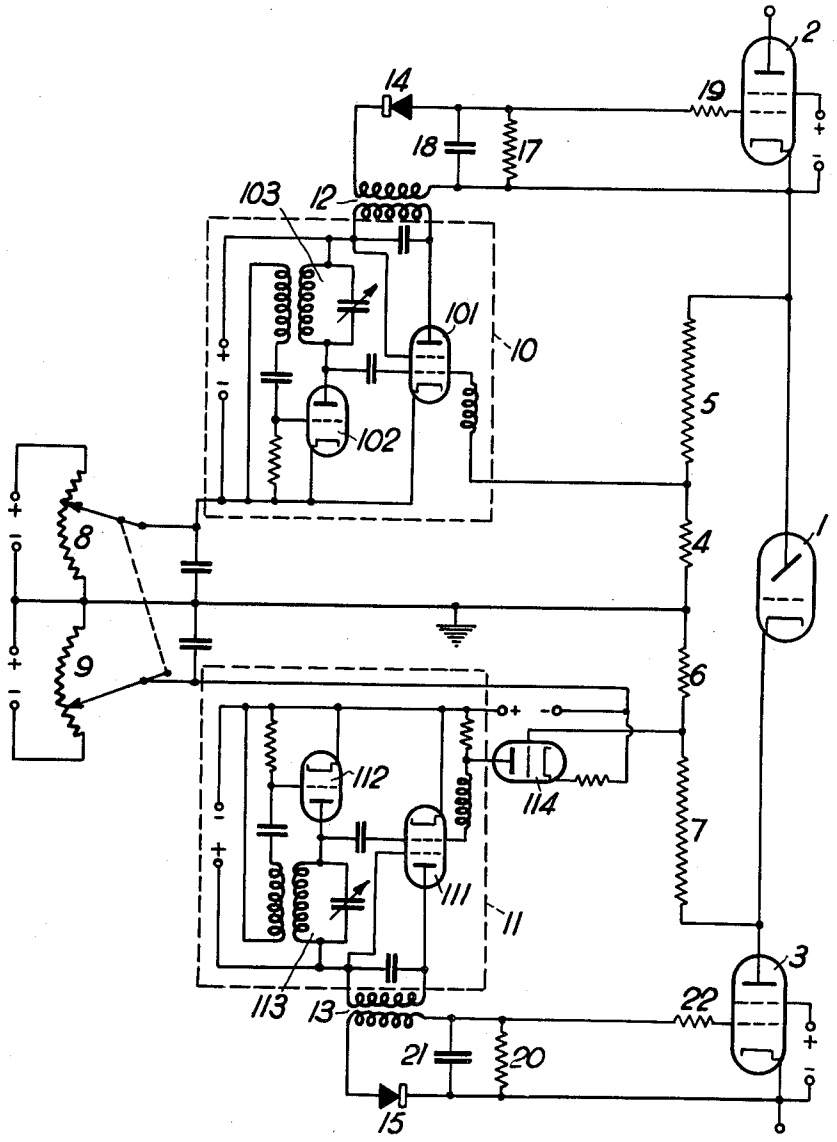
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OPERATION OF X-RAY TUBES

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# OPERATION OF X-RAY TUBES

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4 Claims. (Cl. 250—103)

A known way of switching on and off an X-ray tube is by the use of a grid-controlled switch tube in series with it, the grid bias of the switch tube being governed by a switch in a low voltage circuit. Such a grid-controlled tube may also serve, as first described by Street and Johnson in the Journal of the Franklin Institute, vol. 214, pages 155 to 162, and since widely used, to maintain constant the voltage across a load, by deriving its grid bias from a potentiometer connected across the load, the tube being put next the positive terminal of the load.

If an X-ray tube be operated by the aid of such a switch tube the switching off of the X-ray tube leaves its cathode connected to the high tension supply, and therefore, usually, at a high negative voltage with respect to earth. A further disadvantage is that as the regulation of the X-ray tube voltage takes place on one side of the X-ray tube the potentials of its electrodes cannot be always symmetrical, and therefore a minimum, with respect to earth.

The present invention is a scheme of operating an X-ray tube, that is to say switching it on and off and controlling the value of and keeping constant the voltage at its terminals, by the aid of two switch tubes one on each side of the X-ray tube. This scheme has the advantages that the X-ray tube is wholly disconnected from the high tension circuit when not in use, the electrode potentials are symmetrical with respect to earth whatever the difference between them, and the switch tubes need be built to withstand only half the supply voltage.

The switch tubes must be capable of carrying the maximum current required in the X-ray tube while it is working.

The grid voltage of each switch tube relative to its cathode must be variable between a negative value sufficiently high to render the tube non-conductive under at least one half of the high-tension supply voltage and a less negative or positive value at which the full current of the X-ray tube can be carried by the tube without excessive voltage drop in it. When tetrodes or pentodes are used the grid voltage may remain on the negative side throughout. With triodes as switch tubes, and high tube currents, positive grid voltages are indispensable, and, in this case, an auxiliary switch tube with a separate voltage source is usually provided in order to supply the grid current required by the main control tube. This auxiliary switch tube acts at the same time as an amplifier and so increases the sensitivity of the control system.

To switch the X-ray tube on and off and to select the tube voltage a manually operated control device is provided which brings about the requisite changes in the grid voltage of the switch tubes. If the X-ray tube voltage is required to remain constant, notwithstanding variations of mains voltage, and independent of the value of the tube current, the control device must include, in addition to the manual means of adjustment, an element dependent on the voltage applied to the X-ray tube. This can be provided by a potentiometer connected across the X-ray tube.

It is desirable that the manually operated part of the



voltage controller shall be at low potential. To this end the potentiometer may be connected, not across the X-ray tube, but between one of its electrodes and earth. It is better to provide independent automatic potential stabilisation on each electrode by using a pair of potentiometers connecting the X-ray tube anode and cathode respectively to earth. Each potentiometer is tapped near its earthed end, and the voltages between these tappings and earth are balanced against two equal stabilised standard D. C. voltages, the values of which are adjusted simultaneously by hand to select the tube voltage. As the two standard voltages are kept exactly equal this system not only stabilises the total tube voltage but also ensures symmetric distribution of this voltage with reference to earth, even if the two switch tubes or auxiliary switch tubes are not alike.

An alternative method is to use a fixed comparison voltage and shift the tapping of the potentiometer for voltage selection. But as it is desirable to have the potentiometer as a whole immersed in oil (to make the voltage ratio independent of temperature variation) the first-mentioned method is preferable.

The present invention is not limited to any particular means of transmitting the control from the low potential controller to the high potential switch tubes.

A preferred scheme for this purpose is described in the specification of my co-pending application 237,560, filed July 19, 1951, now Patent No. 2,659,016, and is shown in a simplified form in the accompanying diagram of connections.

In this diagram the X-ray tube is indicated by **1**, and the two switch tubes by **2** and **3** respectively. For controlling X-ray tubes which have only to take a small current, for instance for tubes used for crystallographic investigations, the switch tubes may be triodes. As a rule it will be convenient to use beam tetrodes as indicated in the diagram or pentodes for the sake of their higher amplification. Between the X-ray tube electrodes and earth are connected potentiometers or tapped resistances **4, 5,** and **6, 7.** These will usually be immersed in oil so that is is inconvenient to vary the tappings. Instead the voltage drawn from each potentiometer is balanced against a steady but adjustable low voltage drawn from a source **8, 9** respectively; these sources have a common earthed terminal. The means of adjustment of the two sources are ganged so that a single control knob on the control panel of the apparatus serves to vary both to corresponding extents.

The control voltages so obtained in a low potential circuit, in part by manual setting of the sources **8, 9,** and in part from the X-ray tube itself, are required to govern the bias of the switch tube in a high potential circuit. The particular means of transmitting the control here illustrated is the subject of my application 237,560. The control voltages are employed to govern the output of high frequency generators **10** and **11,** in any manner usual in modulation for communication purposes. In the scheme shown the voltage across the resistance **4** is applied to the grid and the voltage of the source **8** to the cathode of a tube, for instance an amplifying tube **101,** in the high frequency generator **10,** so that the difference of the two voltages is the grid bias of the tube. Tube **101** amplifies the output of an oscillator comprising a tube **102** having a tunable anode circuit **103** coupled to its grid in well-known manner. Similarly the difference between the voltage across resistance **6** and that of source **9** could govern the output of the correspondingly numbered generator **11.** The generators **10, 11** supply transformers **12, 13** respectively, which are high frequency transformers with adequate insulation between their windings to withstand the potentials at which the switch tubes operate. The transformers apply grid bias to the respective switch tubes

through rectifiers **14**, **15** and smoothing elements **17**, **18**, **19** and **20**, **21** and **22**.

But the voltages applied to the generator **10** are of opposite sign to those applied to the generator **11**; yet a chance increase in the voltage between either X-ray tube electrode and earth must increase the negative bias on the corresponding switch tube. This may be taken care of either by including a source of steady negative bias in the grid circuit of one switch tube, or by making the generators **10**, **11** differ in the respect that increase in the positive tapped bias of the one and increase in the negative tapped bias of the other alike increase the generator output. In the diagram shown a reversing tube **114** changes the sign of the bias applied to tube **111**.

Whatever the means employed to transfer the control from a low potential circuit to the X-ray tube circuit, it is important that it should introduce as little delay as possible or an oscillation of X-ray tube voltage may be set up.

I claim:

1. A circuit for operating an X-ray tube comprising a high tension source of direct current, a grid-controlled switch tube, an X-ray tube and a second grid-controlled switch tube connected in series in that order across the high tension source, the cathode of one tube being joined to the anode of its neighbour, like resistances connected between the respective electrodes of said X-ray tube and earth, tappings on said resistances near their earthed ends, and bias means controlled by the potential of said tappings and connected to the grid and cathode of the respective switch tubes to apply between them a voltage varying with the potential of the adjacent X-ray tube electrode.

2. A circuit for operating an X-ray tube comprising a high tension source of direct current, a grid-controlled switch tube, an X-ray tube and a second grid-controlled switch tube connected in series in that order across the high tension source, the cathode of one tube being joined to the anode of its neighbour, like resistances connected between the respective electrodes of said X-ray tube and earth, tappings on said resistances near their earthed ends, high frequency generators having their output controlled by connection to said tappings, and high frequency transformers having their primary windings connected to the respective high frequency generators, and their secondary windings to the cathode-grid circuits of the respective switch tubes, said circuits including each a rectifier and smoothing elements.



3. A circuit for operating an X-ray tube comprising a high tension source of current, an X-ray tube and two grid-controlled control tubes one on each side of the X-ray tube, all connected in series, a potentiometer connected across said X-ray tube, manually variable means for producing a bias voltage, and means for applying to the grids of both said control tubes a bias dependent on the difference between the voltage tapped from said potentiometer and the voltage produced by said manually variable means.

4. A circuit for operating an X-ray tube comprising a high tension source of current, an X-ray tube and two grid-controlled control tubes one on each side of the X-ray tube, all connected in series, a potentiometer connected across said X-ray tube and earthed at its mid point, tappings on opposite sides of said earthed mid point, means for applying to one control tube a bias voltage varying with the potential of one of said tappings, and means for applying to the other of said control tubes a bias voltage reversed in sign and varying with the potential of the other of said tappings.

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