July 5, 1949. V. QUITTNER 2,475,197

HIGH-TENSION SWITCHING MEANS

Filed Oct. 21, 1947

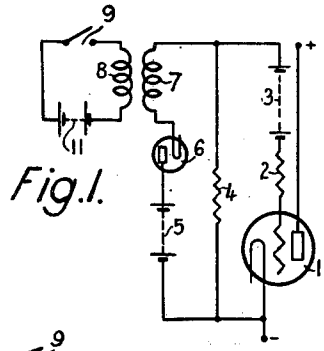


Fig. 1.

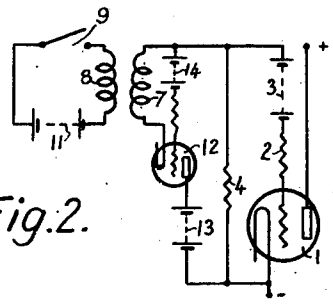


Fig. 2.

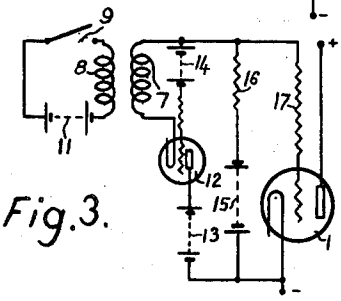


Fig. 3.

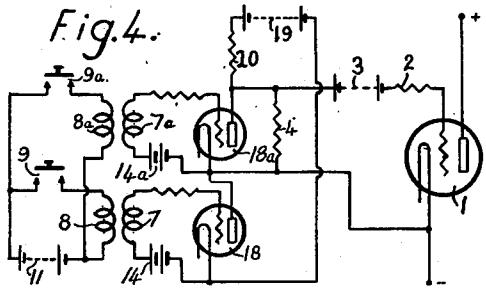


Fig. 4.

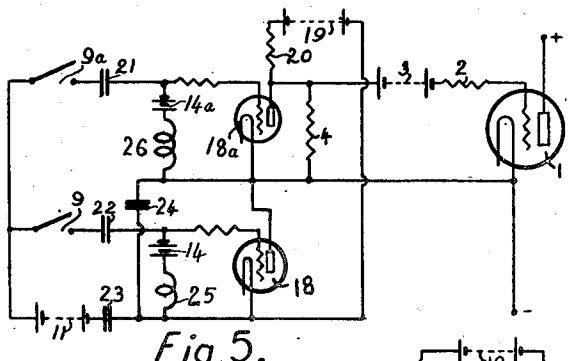


Fig. 5.

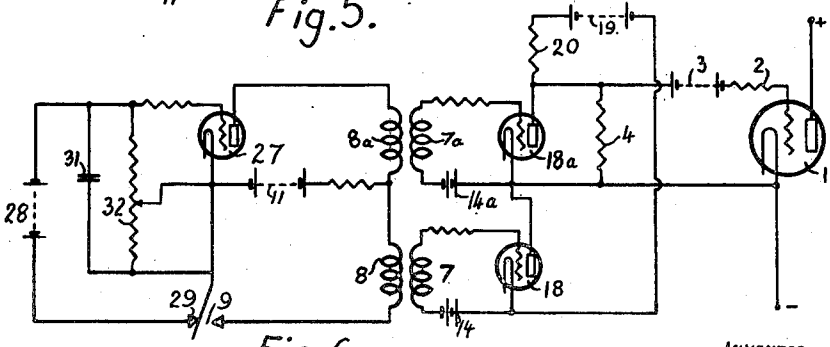


Fig. 6.

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HIGH-TENSION SWITCHING MEANS

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This invention relates to the control of high tension electric circuits.

Its purpose is to make it possible to control such circuits with a high degree of precision of timing by the aid of low tension control means.

In particular, but not exclusively, the invention is concerned with the control of the high tension supply circuits of X-ray tubes, more especially in X-ray photography, to make possible short exposures of the order, say, of one fiftieth of a second, or a rapid succession of short exposures such as are required for kinematography with X-rays.

To control the heavy currents which necessarily flow in the primary circuit of an X-ray tube supply network necessitates the use of robust contactors or like switching apparatus which cannot readily be operated with great precision. For this reason it has been proposed to control the high tension circuit of the X-ray tube by means of a grid-controlled thermionic valve, or by means of a grid in the X-ray tube itself. Moreover when the X-ray tube is supplied from high tension condensers—a method which diminishes the surge of current drawn from the mains by the transformer supplying the tube on switching on—interruption of the supply must necessarily be effected on the high tension side. But the manual means, or, where used, the automatic means, employed for switching the X-ray tube on and off should preferably be at a low voltage relatively to earth for reasons of safety and to save expense in insulation.

The problem therefore arises of operating a switch tube in a high tension circuit from low voltage control means; the term "switch tube" is to be understood hereinafter as including the X-ray tube itself where the operation of an X-tube is controlled by its own grid, as well as any other grid-controlled tube controlling a high tension circuit.

With this problem in view one object of the present invention is a control apparatus for high tension circuits which includes besides the switch tube a gas-filled tube governing the grid circuit of the switch tube, and itself governed by impulses conveyed to it from a low tension circuit thoroughly insulated from it.

A further object of the invention is a control apparatus for high tension circuits in which each operation upon the high tension circuit, whether of closing it or opening it, is effected by rendering conductive a gas-filled tube by means of an impulse conveyed to it from a low tension circuit.

Yet another object of the invention is a control apparatus for high tension circuits comprising a switch tube and a grid-controlled gas-filled tube governing the grid circuit of the switch tube.

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These and other objects of the invention will be more fully understood from the following description of embodiments of the invention illustrated, by way of example, in the accompanying drawings.

In these drawings,

Figure 1 is a diagram of connections of a switch tube controlled by a gas-filled diode;

Figure 2 is a diagram of connections of a switch tube controlled by a gas-filled triode;

Figure 3 is a modification of the scheme of Figure 2;

Figure 4 is a diagram of connections of a switch tube which is switched on by rendering conductive a gas-filled tube, and is switched off by rendering conductive another gas-filled tube;

Figure 5 is a diagram of connections generally similar to Figure 4 utilising capacitative coupling to convey control impulses from a low tension circuit to gas-filled valves;

Figure 6 is a diagram of connections generally similar to Figure 4 showing the use of automatic timing means in the low tension control circuit.

In all these figures 1 is a grid-controlled switch tube which may itself be an X-ray tube which it is the purpose of the circuit to control, or may have an X-ray tube or other high tension apparatus included in its anode circuit. Its cathode and anode are connected directly or through other apparatus to be controlled to the negative and positive terminals marked — and + of a high tension source of supply. The grid circuit of tube 1 includes the usual protective resistance 2 a source of negative bias 3 and a substantial resistance 4. The source of bias is indicated for simplicity as a battery, but the bias may be obtained in any well-known way; it is sufficient in amount to render the tube 1 non-conductive notwithstanding the high tension supplied to its cathode-anode circuit.

The resistance 4 is included with a source of voltage 5, also indicated as a battery but which can be any convenient source, in the circuit of a gas-filled diode 6. This circuit also includes the secondary winding 7 of a cored or coreless transformer 7, 8.

As is well known a gas-filled tube requires the application of a certain voltage to render its substantially conductive; but when it has been rendered conductive a less voltage is sufficient to maintain the current through it; the least voltage necessary to produce substantial conductivity

may be distinguished as the "striking" voltage, and the least voltage sufficient to maintain the flow of current as the "extinction" voltage. The source of anode voltage 5 has a voltage intermediate between the extinction voltage and the striking voltage of tube 6.

In the primary circuit of the transformer 7, 8 there is a switch 9, which may be operated manually or mechanically, as by the mechanism of a kinematographic camera; and there is a source of current 11. The circuit controlling part of the switch will usually be a thermionic tube, with a grid circuit controlled manually or mechanically or by electronic timing means such as described hereinafter with reference to Figure 6.

The source 11, and the transformer 7, 8 are so designed that the closing of the switch 9 produces in the secondary winding 7 a pulse of voltage in a direction assisting the source 5 and of a magnitude exceeding the difference between the voltage of source 5 and the striking voltage of tube 6. The tube 6 therefore becomes conductive and current from the source 5 flows through it and the resistance 4, and continues to flow notwithstanding the cessation of the pulse of voltage in the secondary winding 7 since the voltage of source 5 exceeds the extinction voltage of the tube 6.

The circuit 4, 5, 6, 7 is so designed that the current flow in the resistance 4 produces across the resistance a voltage opposing the bias voltage of 3 and of sufficient magnitude to make the tube 1 conduct.

When the switch 9 is opened a reverse pulse of E. M. F. is generated in the secondary winding 7 of sufficient magnitude to reduce momentarily to zero the current through the diode 6. The diode does not again become conductive when this reverse pulse ceases because the voltage of the source 5 is less than the striking voltage of the tube.

Thus the high tension circuit is closed and opened as if it were under the immediate control of the switch 9.

Figure 2 shows the use of a gas-filled triode 12 in place of the diode 6. Its anode circuit contains a source of voltage 13 sufficient, when the triode is rendered conductive, to pass through the resistance 4 such a current as will make the voltage drop across 4 adequate to overcome the cut-off bias 3 upon the switch tube 1. Its grid circuit contains a source of bias 14 sufficient to prevent current flowing through the triode 12 under the voltage applied to its anode.

In some gas-filled tubes the flow of current once started cannot be, or cannot readily be, influenced by the grid alone. For this reason the secondary winding 7 is placed in the cathode circuit of the tube 12, that is to say it is common to both the grid circuit and the anode circuit. If the tube 12 is of a kind in which a moderate negative grid voltage will suffice to interrupt the curent flow, the secondary winding 7 may be in the grid circuit alone.

The impulse of E. M. F. generated in the winding 7 upon the closing of the switch 9 opposes the bias 14 and makes tube 12 conduct; the impulse generated upon the opening of switch 9 adds to the bias 14 and opposes the anode voltage 13 and brings the tube current to zero.

It is likely that a switch tube suitable for the control of a high tension circuit will need a high negative bias to bring it to cut-off, and will have a considerable grid current when anode current is flowing. For such a tube it is desirable to

modify the circuit shown in Figure 2 by putting the high cut-off bias voltage 15 in series with a high resistance 16 in the anode circuit of the gas-filled tube 12, leaving only a relatively low resistance 17 in the grid circuit of 1 and not in the anode circuit of 12. The source 15 now serves as, or as part of, the anode voltage for tube 12 while the voltage produced across resistance 16 when tube 12 conducts opposes as before the grid bias due to 15 and causes the tube 1 to conduct.

To make the gas-filled tube conduct the transformer 7, 8 has only to supply a pulse of voltage. To bring to zero the current in the gas-filled tube the transformer must supply a substantial amount of energy, especially if the switch tube is one that needs a somewhat large positive bias to make it conduct and carried considerable grid current when conducting. It is therefore preferable so to arrange the control circuit that the extinction of the discharge through the switch tube, like the striking of the discharge, is brought about by the striking and not by the extinction, of a discharge through a gas-filled tube. This is readily done by use of two gas-filled tubes connected in series or in parallel.

Figure 4 is an example of such an arrangement. So far as switching on the switch tube 1 is concerned the circuit is substantially like that of Figure 2. The grid circuit of the gas-filled triode receives impulses from the low tension primary circuit 8, 9, 11 through the transformer 7, 8, and its anode circuit contains the resistance 4, flow of current through which modifies the bias on tube 1 causing it to conduct. But in addition to the triode 18 there is a second triode 18*a* connected in series with the triode 18 and in parallel with the resistance 4. A source of anode current 19 and a resistance 20 are common to both the tubes 18 and 18*a*. The tube 18*a* may be controlled by a primary circuit 8*a*, 9*a*, 11 operating through the transformer 7*a*, 8*a*.

On closing the switch 9 tube 18 is made conductive and tube 1 is switched on substantially as explained with reference to Figure 2. On closing the switch 9*a* tube 18*a* is made conductive, and as its anode-cathode impedance is small compared with the resistance 4 it, in effect, short-circuits the resistance restoring the bias on tube 1 to substantially its initial cut-off value.

The circuit may be modified to require only one switch, and indeed only one primary winding, the two secondary windings being put upon a common core; or there may be only a single secondary also.

In all the circuits so far described the low tension control circuit is insulated from the high tension circuit by the use of a well-insulated transformer 7, 8 or 7*a*, 8*a*. It is equally possible to separate the circuits by the insulation of a suitably designed condenser; in other words to use capacitative coupling in lieu of inductive coupling between the low tension circuit and the rest of the apparatus. By way of example this is illustrated in Figure 5 in a circuit otherwise corresponding with Figure 4. In lieu of the transformers 7, 8, 7*a*, 8*a*, three high tension impulse condensers 21, 22, 23 couple the two primary circuits to the grid circuits of the tubes 18 and 18*a* respectively, the connection of the grid circuit of tube 18*a* being completed by a connecting condenser 24. The grid circuit of tube 18 contains a high frequency choke 25, and the grid circuit of tube 18*a* a high frequency choke 26. The condensers 21, 22 and 23 are designed to afford the desired insulation and to pass an impulse of the

desired magnitude; the operation of the circuit is substantially the same as that of the circuit of Figure 4.

In any of these circuits an amplifier stage may be inserted between the gas-filled tube and the switch tube it is to control, to diminish the voltage that the gas-filled tube is to deal with and to provide considerable grid current for the switch tube.

When the action is required to be automatic, the primary circuit may be governed by a timing device, which may be electronic and dependent either directly on time or on the passage of a given quantity of electricity through the X-ray tube circuit. Many such timing devices are already well known. The application of the invention to an automatically controlled high tension circuit will be understood from the instance illustrated in Figure 6. In the main this figure is similar to Figure 4 and its parts are correspondingly numbered. Closing of the switch 9 effects the switching on of the switch tube 1 in the manner already explained. In lieu of the switch 9*a* of Figure 4 there is provided an additional gas-filled triode 27 the grid circuit of which contains a source of cut-off bias 28 and a back contact 29 on the switch 9. There is bridged across the source 28 a condenser 31 shunted by a high resistance 32.

So long as the switch 9 is open, and the contact 29 therefore closed, the tube 27 is biassed to cut-off, and the condenser 31 is charged to the voltage of the source 28. When the switch 9 is closed an impulse is transmitted through transformer 7, 8 which switches on the X-ray tube in the manner explained with reference to Figure 4. The tube 27 remains biassed to cut-off by the voltage across the condenser 31, although the contact 29 is opened and the condenser is now disconnected from the source 28. But because of this disconnection the condenser 31 begins to discharge through the resistance 32, and when its voltage has fallen to a value which permits the tube 27 to conduct, the tube strikes and transmits a voltage pulse through the transformer 7*a*, 8*a* to the grid circuit of tube 18*a*, thereby causing the switching off of the high tension circuit as before explained.

I claim:

1. Apparatus for switching on and off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a gas-filled tube circuit including the said impedance, a gas-filled tube, and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, and a low tension control circuit, including switching means and a non-conductive coupling to said gas-filled tube circuit, for injecting into said gas-filled tube circuit an impulse adequate in conjunction with said source of voltage to start a discharge through said gas-filled tube and an impulse adequate to interrupt a discharge through said gas-filled tube.

2. Apparatus for switching on a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a gas-filled tube circuit including the said impedance, a gas-filled tube, and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, and a low tension control circuit, including switching means and a non-conductive coupling to said gas-filled tube circuit, for injecting into said gas-filled tube circuit an impulse adequate in conjunction with said source of voltage to start a discharge through said gas-filled tube.

3. Apparatus for switching off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a gas-filled tube circuit including the said impedance, a gas-filled tube, and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, and a low tension control circuit including switching means and a non-conductive coupling to said gas-filled tube circuit, for injecting into said gas-filled tube circuit an impulse adequate to interrupt a discharge through said gas-filled tube.

4. Apparatus for switching on and off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a gas-filled tube having at least an anode and cathode and capable of assuming conductive and non-conductive states, an anode-cathode circuit for said gas-filled tube including said impedance and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, and a low tension control circuit comprising a source of voltage, switching means and a non-conductive coupling to at least one circuit of said gas-filled tube for injecting an impulse into at least one circuit of said gas-filled tube of sufficient magnitude to change its state.

5. Apparatus for switching on and off the high tension circuit of an X-ray tube by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a gas-filled tube having at least an anode and cathode and capable of assuming conductive and non-conductive states, an anode-cathode circuit for said gas-filled tube including said impedance, and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, and a low tension control circuit comprising a source of voltage, switching means and a non-conductive coupling to at least one circuit of said gas-filled tube for injecting an impulse into at least one circuit of said gas-filled tube of sufficient magnitude to change its state.

6. Apparatus for switching on and off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, a grid-controlled gas-filled tube, a cathode-anode circuit for said gas-filled tube including said impedance and a source of voltage sufficient to maintain and insufficient to start a discharge through said gas-filled tube, a grid circuit for said gas-filled tube including a source of cut-off voltage, and a low tension control circuit including switching means, a source of voltage and a non-conductive coupling to at least the grid circuit of said gas-filled tube for injecting into at least the grid circuit of said gas-filled tube an impulse adequate to overcome the grid cut-off bias and to start a discharge and an impulse adequate to interrupt the flow of current through said gas-filled tube.

7. Apparatus for switching on and off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias, a grid resistance and an impedance in the grid circuit thereof, a grid-controlled gas-filled tube, a cathode-anode circuit for said gas-filled tube including said impedance, said source of cut-off bias and a source of voltage sufficient in conjunction with said source of cut-off bias to maintain and insufficient to start a discharge through said gas-filled tube, a grid circuit for said gas-filled tube including a source of cut-off voltage, and a low tension control circuit including switching means, a source of voltage and a non-conductive coupling to at least the grid circuit of said gas-filled tube for injecting into at least the grid circuit of said gas-filled tube an impulse adequate to overcome the grid cut-off bias and to start a discharge and an impulse adequate to interrupt the flow of current through said gas-filled tube.

8. Apparatus for switching on and off a high tension circuit by means of a low tension control device, comprising a grid-controlled tube in the high tension circuit, a source of cut-off bias and an impedance in the grid circuit thereof, two

grid-controlled gas-filled tubes connected in series with each other, and one of them in shunt with said impedance, the cathode-anode circuit of said gas-filled tubes including a source of voltage sufficient to maintain and insufficient to start a discharge through either of said tubes, grid circuits for said gas-filled tubes each including a source of cut-off bias, and low tension control means for injecting into the grid circuit of each gas-filled tube in turn a sufficient voltage to start a discharge through the tube.

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