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X-RAY APPARATUS COMPRISING A SAFETY CIRCUIT ARRANGEMENT

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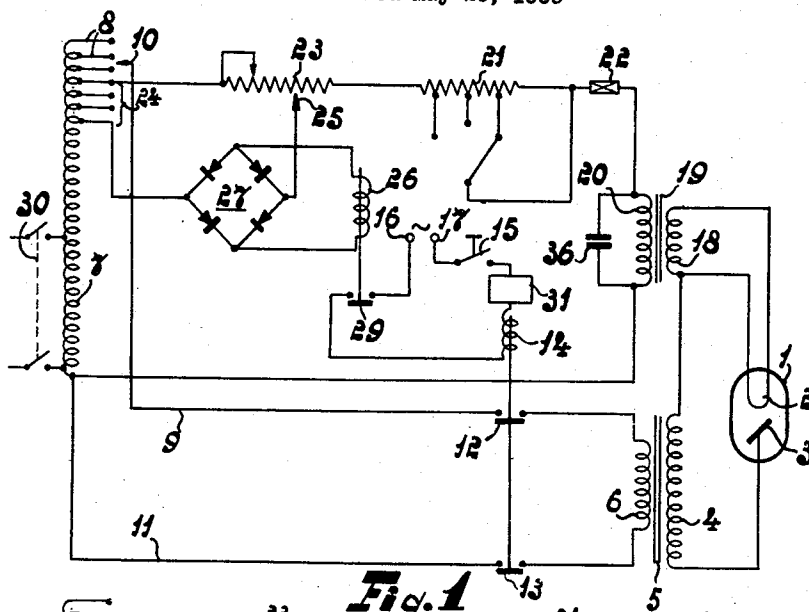


Fig. 1

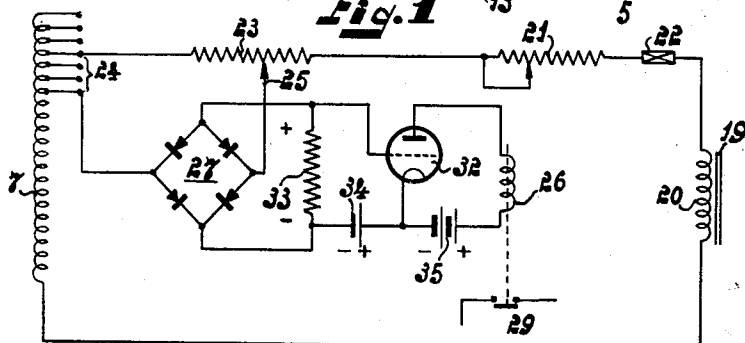


Fig. 2

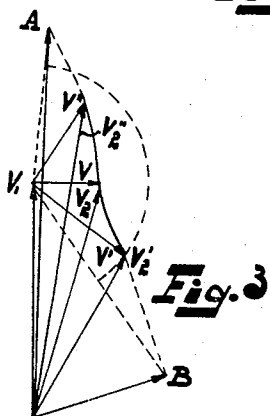


Fig. 3

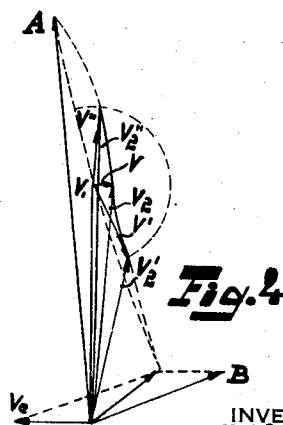


Fig. 4

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X-RAY APPARATUS COMPRISING A SAFETY
CIRCUIT ARRANGEMENT

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9 Claims. (Cl. 250—102)

The present invention relates to an X-ray apparatus safety circuit arrangement.

In an X-ray apparatus the running voltage of the X-ray tube, i. e. the voltage between anode and cathode during operation of the apparatus, is materially lower than the zero-load voltage, since during the load voltage losses occur in the apparatus and in the power supply lines. When placing an X-ray apparatus in operation, first the current for heating the filament cathode is switched on and some time afterwards the high voltage is applied to the tube. The load current then rises immediately to the full value which prevents the tube voltage from increasing excessively.

In the event of an interruption of the filament current circuit, of a short-circuit in the supply transformer or of another disturbance, so that the cathode is not heated to the working temperature, the application of the high voltage may be harmful to the X-ray tube. In this case the tube voltage is equal to the zero-load voltage of the high-voltage transformer and the current supply cables are liable to break down, backfire may occur in the sheath of the tube or internal breakdown effects may damage the tube.

The invention relates to an X-ray apparatus comprising a safety circuit and has for its object to prevent the high voltage from being switched on, if the current circuit for heating the filament cathode of the X-ray tube is disturbed for some reason or other. According to the invention the energization of an electro-magnetic relay, the working contact of which is included in the control-circuit of the high voltage, is determined by the sum of two voltages, which are approximately in phase opposition and of which one is constant and the other depends upon the filament current. If the sum of the two voltages exceeds a particular value, the working contact interrupts the said current circuit.

The voltages are equal to one another or differ at least little from one another, if no disturbance occurs, and if, upon being switched on, the filament current assumes the value required to heat the cathode to the operational temperature. In the event of an interruption of the filament current circuit the voltage varying with the filament current is very low and the relay responds to the constant voltage. However, if a short-circuit occurs, the voltage varying with the filament current predominates and actuates the relay.

For the invention it is unimportant whether use is made of a relay comprising an energizing winding or of a differential relay. The sum of the voltage may be used for controlling the grid voltage of a discharge tube or for the ignition of a gas discharge tube, the anode current of which energizes the relay.

The comparatively high zero-load current of the filament current transformer which continues to flow, if an interruption on the secondary side of said transformer prevents the heating of the filament cathode, adversely affects the sensitivity of the arrangement. The zero-load

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current has a very high reactive component, which may be compensated for the most part by a capacitor connected in parallel with the primary winding of the filament current transformer.

The invention will now be described more fully with reference to the drawing, wherein:

Fig. 1 is a schematic diagram of an embodiment of the circuit arrangement of the present invention;

Fig. 2 is a modification of the circuit arrangement of Fig. 1; and

Figs. 3 and 4 are vector diagrams of the load voltages of the circuit arrangement of the present invention.

In Fig. 1, X-ray tube 1 is connected with the cathode 2 and the anode 3 to the two ends of a secondary winding 4 of a high-voltage transformer 5. In general, however, rectified voltage is used and a number of tubes and capacitors will be included in the current circuit, but for the explanation of the invention the simple arrangement of Fig. 1 may suffice.

A primary winding 6 of the transformer 5 is connected to a control-transformer 7. This is shown as an autotransformer. The voltage produced may be controlled by means of tappings 8. One current supply wire 9 for the primary winding of the transformer 5 is connected to a control-contact 10, another wire 11 is connected directly to the other end of the winding of the autotransformer 7. The current supply wires 9 and 11 include contacts 12 and 13 of a main electro-magnetic relay. The energizing winding 14 of the main relay may be connected by means of a push-button switch 15 to the power supply voltage via connecting terminals 16 and 17.

The filament current circuit of the X-ray tube 1 includes a filament current transformer 19 having a secondary winding 18 and a primary winding 20, the latter being connected to two fixed points of the winding of the control-transformer 7. The current supply lead for the filament current transformer 19 includes a control-resistor 21 for the adjustment of the filament current and a safety fuse 22. The fuse 22 serves to interrupt the operation of the apparatus in the event of serious short-circuits, in order that damage may be avoided as much as possible.

The filament current circuit further includes a resistor 23, which serves to protect the X-ray apparatus. Across the resistor 23 is produced a voltage loss which varies with the filament current. The loss is low if the current circuit is interrupted and it is high, if somewhere a short-circuit occurs.

A few turns 24 of the control-transformer 7 supply the opposite voltage. The two voltages are connected in series through a rectifying bridge 27 and an energizing winding 26 of a safety relay. The direction of the current through the winding 26 is always the same, whether the voltage across the resistor 23 is higher than the counter-voltage across the turns 24, or conversely. The voltages will be adjusted to approximately the same values and to this end use is made of a contact arm 25 of the resistor 23. It is not necessary to use rectifiers, but a direct-current relay operates more quietly than an alternating-current relay. The two voltages may, as an alternative, be connected in phase opposition by magnetic coupling, if use is made of a differential relay, of which each of the windings is connected to one of the voltages.

In another embodiment of the circuit arrangement of the present invention this part of the arrangement comprises a high-vacuum switching tube 32. Fig. 2 shows an arrangement in which a triode is used as the switching tube 32. The sum of the fixed voltage of the windings 24 and the voltage varying with the filament current, which is obtained from the resistor 23, is rectified and applied to a resistor 33. The voltage sum supplies the positive component of the grid voltage for the discharge

tube 32. A voltage source 34 supplies the negative component of this grid voltage. The anode current of a voltage source 35 excites the energizing winding 26 of the safety relay, if a disturbance occurs in the filament current circuit of the X-ray tube.

Instead of a triode, use may be made of a gas-filled discharge tube 32 as a switching tube. The arrangement should be modified to some extent for this purpose however, the necessary modifications do not produce any difficulties for those skilled in the art.

In Figs. 1 and 2, the energizing winding 26 of the safety relay governs a working contact 29. The contact 29 is included in the control-circuit of the main relay 14 and, if it is opened, it prevents the switching-on of the X-ray apparatus.

From the diagram shown in Fig. 3 details of the requirements are evident, which the safety must fulfil. The voltage of the winding section 24 of the control-transformer 7 is represented by the vector V_1 . The vector V_2 , which indicates the voltage across the resistor 23 between one end and the arm 25 in the case of normal current consumption of the filament cathode, exhibits a small phase shift, but it has approximately the same value as the vector V_1 . This correspondence may be ensured by the adjustment of the arm 25. The sum of the two voltages connected in phase opposition is indicated by the vector V . In most apparatus it is common practice to have the filament current variable to some extent in order to adjust the load of the X-ray tube to the desired value. This is carried out by means of the control-resistor 21 and thus the voltage V_2 fluctuates between the limits V_2' and V_2'' . This variation is attended by a small variation of the phase shift. The sum of the voltages V_1 and V_2 thus fluctuates between V and V' . The voltage at which the safety relay becomes operative, must exceed V' , since this is the highest voltage which occurs during the control of the load. Fig. 3 also shows vectors A and B , which indicate the voltage V_2 across the resistor 23 in case the filament current circuit on the secondary side of the filament current transformer is interrupted (vector A) and in case a short-circuit occurs (vector B) on this side. If the primary side of the filament current transformer is interrupted, this voltage will be zero and in case of a primary short-circuit the safety fuse 22 becomes operative. From Fig. 3 it is evident that the sum of the voltages V_1 and A or B both in the case of one disturbance or of the other disturbance exceeds the value V' . For the energizing voltage of the safety relay a value is chosen which lies between V' and the lower of the two voltages resulting under the action of a disturbance from V_1 , and A or B . This value must be as low as possible.

The energizing voltage of the safety relay winding 26 may be reduced by compensation of the reactive component of the primary current of the filament current transformer. To accomplish this a capacitor 36 is connected in parallel with the primary winding 20 of the filament current transformer 19. The vector diagram thus obtained is that shown in Fig. 4. The vectors are designated by the same reference characters as in Fig. 3, and the resulting voltage across the resistor 23 follows from the vector combination of the vectors B and V_0 , of which the latter indicates the influence of the capacitor 36.

From the diagram shown in Fig. 4 it follows that the voltage V_2' across the resistor 23, combined with the fixed voltage V_1 produces a voltage V' , which is materially lower than the voltage V' of Fig. 3. Due to the use of the capacitor 36, the safety relay will respond sooner when a disturbance in the conventional load condition occurs.

If the safety relay is not operative, the load of the X-ray apparatus may be switched on by means of the push-button switch 15. The duration of the operation of the apparatus is determined by a time switch 31.

What is claimed is:

1. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising means for producing a first voltage of substantially constant magnitude, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential.

2. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising means for producing a first voltage of substantially constant magnitude, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and relay means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential.

3. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising means for producing a first voltage of substantially constant magnitude, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential comprising a relay having an energizing winding and means for opening and closing said potential producing and applying circuit under the influence of said winding.

4. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising means for producing a first voltage of substantially constant magnitude, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential comprising a relay having an energizing winding and means for opening and closing said potential producing and applying circuit under the influence of said winding, and full-wave rectifying means interposed between said voltage combining means and said winding.

5. A circuit arrangement as claimed in claim 4, wherein

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said full-wave rectifying means has an output circuit directly connected across the said winding.

6. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising control transformer means for producing a first voltage of substantially constant magnitude and a substantially constant filament current supply voltage, filament current transformer means for applying said filament current supply voltage to the filament of said X-ray apparatus having an input winding and an output winding coupled across the said filament, means for coupling said input winding across said control transformer means, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus comprising resistive means included in said coupling means and connected in series between said input winding and said control transformer means, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential comprising a relay having an energizing winding, a pair of contacts positioned in said potential producing and applying circuit and an arm adapted to normally close said pair of contacts and adapted to open said pair of contacts under the influence of said energizing winding upon the application of a voltage to the said energizing winding having a magnitude greater than said predetermined value.

7. A circuit arrangement as claimed in claim 6, further comprising a capacitor connected in parallel with said input winding.

8. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising means for producing a first voltage of substantially constant magnitude, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential

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comprising a relay having an energizing winding, means for opening and closing said potential producing and applying circuit under the influence of said winding, an electron discharge device having a cathode, an anode and a grid, means for connecting said anode and cathode across said energizing winding and means for applying said control voltage between said cathode and grid thereby energizing the said winding with the anode current of said device.

9. A circuit arrangement for protecting X-ray apparatus from the application thereto of a potential of substantially high magnitude upon the occurrence of a disturbance in the filament current circuit of said apparatus, comprising control transformer means for producing a first voltage of substantially constant magnitude and a substantially constant filament current supply voltage, filament current transformer means for applying said filament current supply voltage to the filament of said X-ray apparatus having an input winding and an output winding coupled across the said filament, means for coupling said input winding across said control transformer means, a capacitor connected in parallel with said input winding, means for producing a second voltage having a magnitude determined by the magnitude of the filament current of said X-ray apparatus comprising resistive means included in said coupling means and connected in series between said input winding and said control transformer means, circuit means for producing a potential of substantially high magnitude and for applying said potential to said X-ray apparatus, means for combining said first and second voltages in electrical phase opposition thereby to produce a resultant control voltage, and means responsive to said control voltage at values thereof greater than a predetermined value for reducing the magnitude of said potential comprising a relay having an energizing winding, a pair of contacts positioned in said potential producing and applying circuit and an arm adapted to normally close said pair of contacts and adapted to open said pair of contacts under the influence of said energizing winding upon the application of a voltage to the said energizing winding having a magnitude greater than said predetermined value, an electron discharge device having an anode, a cathode and a grid, means for connecting said anode and cathode across said energizing winding and means for applying said control voltage between said cathode and grid thereby energizing the said winding with the anode current of said device.

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