

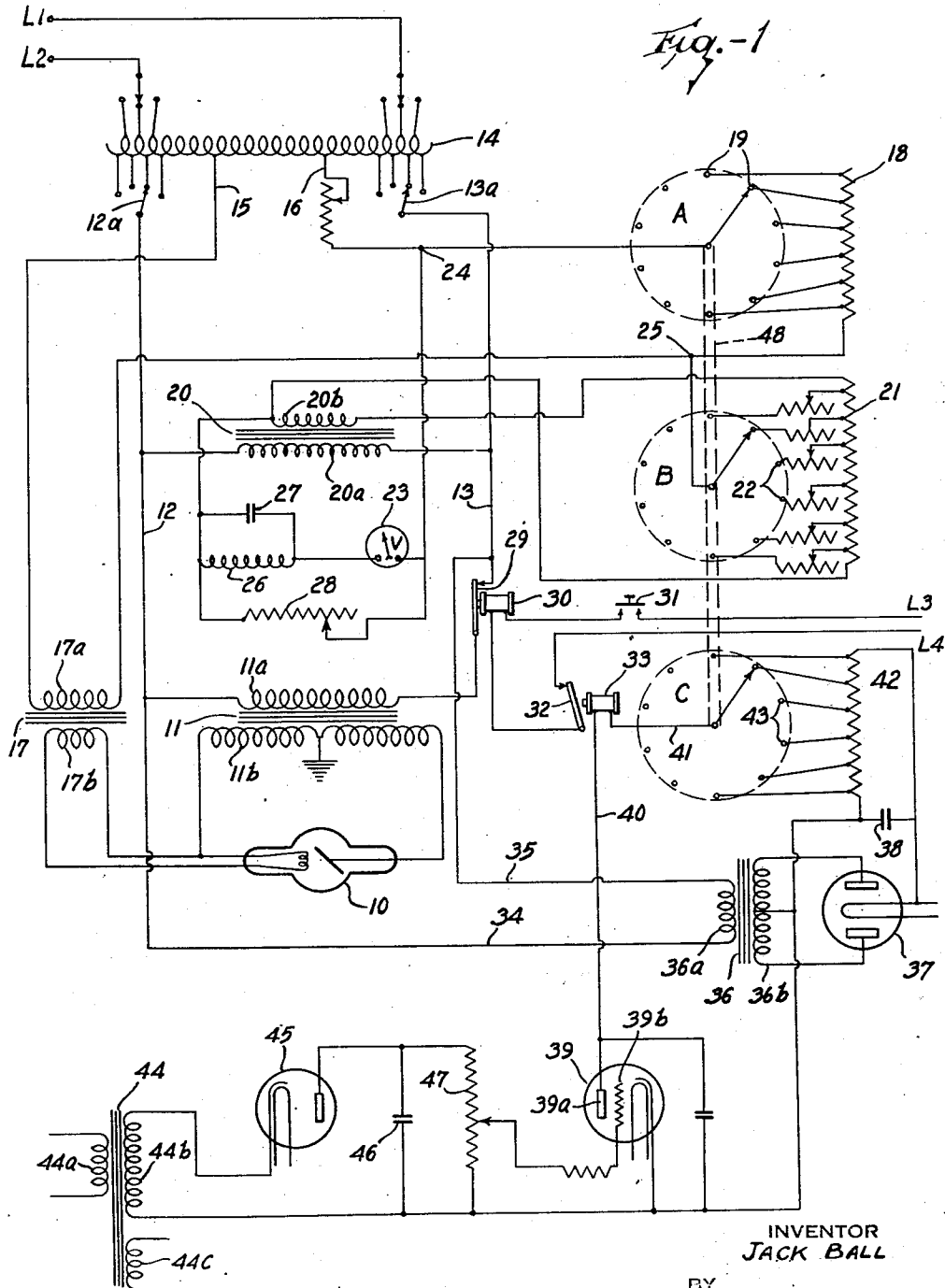
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J. BALL

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MAXIMUM KILOVOLTAGE LIMITER FOR X-RAY TUBES

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INVENTOR
JACK BALL
BY *Hyde and Meyer*
ATTORNEYS

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MAXIMUM KILOVOLTAGE LIMITER FOR
X-RAY TUBES

Jack Ball, Euclid, Ohio, assignor to Picker X-Ray
Corporation Waite Manufacturing Division,
Inc., Cleveland, Ohio, a corporation of Ohio

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This invention relates to improvements in control means for X-ray tubes, and more particularly to prevent any exposure being made on the X-ray apparatus when the peak voltage exceeds a predetermined value.

My invention may be used in various ways but one embodiment is shown in the accompanying drawing marked "Fig. 1" and it will be understood by those skilled in the art how the same principle may be applied in various ways.

It will be understood by those skilled in this art that it is desirable to limit the maximum kilovoltage used at any given tube load when making an exposure. To exceed this desirable kilovoltage may damage the tube or in any case shorten its life. The purpose of the present invention, therefore, is to provide an automatic control making it impossible for the operator to exceed a predetermined kilovoltage when the apparatus has been set for a fixed load.

In the accompanying diagrammatic drawing an X-ray tube at 10 is supplied with high tension current through the transformer 11 having a primary 11a and a secondary 11b. The primary is supplied with current through lines 12 and 13 by means of dial selector switches 12a and 13a. These engage various contacts connected with the autotransformer 14 which in turn receives a current supply from the lines L₁, L₂. This is a simple circuit using only half-wave rectification but it will be understood by those skilled in the art that this is for illustrative purposes only and that my device is applicable to any type of circuit. Current for the tube filament is supplied from the taps 15 and 16 of the autotransformer to the primary 17a of the filament transformer 17. Means is provided for varying the filament current for various tube loads. In the present instance this takes the form of a series of resistances 18 connected with taps 19 on deck A of a selector switch of the monitor type.

A known means for changing the indication of current supplied to the tube filament to compensate for changes in the saturation of the X-ray tube at various kilovoltages is included in the diagram of Fig. 1. This is similar to that described and claimed in Patent No. 2,231,622, granted February 11, 1941, to Edward B. Graves, to which further reference may be had if necessary to understand this portion of the diagram. It is sufficient to state here that the compensator device is provided with current through the transformer 20, the primary 20a of which is connected across lines 12 and 13. The secondary 20b of the transformer is in circuit with a series

of resistances 21 which are connected with taps 22 on the deck B of a monitor selector switch. The voltmeter 23 is in circuit between the points 24 and 25 so as to read the current flowing in the filament circuit. The resistances 21 are thus placed in the metering circuit in series with the compensating coil 20b and vary the indication of the voltmeter to apply a correction to compensate for changes in tube output due to changes in the high tension voltage supplied to the transformer 11. The purposes of the inductor 26, capacitor 27 and resistor 28 are fully described in the above mentioned patent.

The present invention adds to the known circuits above described a control circuit for breaking the energizing circuit through lines 12 and 13 if the predetermined peak kilovoltage is exceeded. To this end a disconnecter switch 29 is provided in line 13 which is held closed by relay 30 so long as the latter is energized. The electricity for the relay 30 is provided through lines L₃, L₄ from any 110-volt source. A timer or exposure switch is indicated at 31. In the relay circuit is provided a normally closed switch 32 which is opened by relay 33 whenever the latter is energized. The present invention provides for the energization of this relay 33 if too high a kilovoltage is applied to the tube. For this purpose the control circuit is supplied with current which varies in step with the current in lines 12 and 13 in the primary of the transformer 11. For this purpose lines 34 and 35 are connected with lines 12 and 13 to the primary 36a of the transformer 36. The secondary 36b of this transformer is connected to a rectifier 37 and filter 38 to supply rectified current to the control circuit. It will be noted that the line 35 is connected to line 13 ahead of the switch 29 so as to provide a steady voltage to the control circuit. This control circuit is normally nonconducting and is under the control of a thyatron tube 39, the grid 39b of which is supplied with a fixed voltage as will later be described. Whether the tube is conducting or nonconducting will then depend upon the circuit connected with the plate 39a of the tube. This plate is connected by line 40 to relay 33 which in turn is connected by line 41 to a selector switch on deck C of the monitor switch. The resistor 42 is connected with the taps 43 on the deck C. Obviously the greater the resistance placed in series along the resistor 42 the greater must be the current supplied through transformer 36 to supply sufficient voltage to plate 39a to overcome the grid bias on the grid 39b and to cause the thyatron to be-

come conducting. The grid 39b of the thyatron tube is biased by means of transformer 44 and the rectifier and filter circuit 45, 46. The resistor 47 in this circuit is adapted so as to be able to adjust the grid bias for individual tubes and characteristics. The primary of transformer 44 is connected to a stabilized 110 volt source. The transformer 44 is supplied with a secondary 44c for providing current for the filaments of tubes 37, 39 and 45 in the well understood manner.

The operation of the circuits thus far described is as follows: The main switch is closed to energize the autotransformer 14. The desired tube load is selected by rotating the monitor switch which has a number of decks, only three of which are shown and all of which are connected together by a shaft 48 which is here diagrammatically represented. The deck A may be calibrated in terms of tube output. At the same time the deck B adjusts the calibration of the voltmeter 23 so that it is only necessary to adjust the dial switches 12a and 13a until the voltmeter hand registers with the single indication shown. At the same time that this is done the deck C of the monitor switch is selecting a suitable resistance on the resistor 42 so as to limit the kilovoltage which may safely be applied to the tube 10. At this time the grid 39b is supplied with a biasing current of such value that the thyatron tube 39 is nonconducting. Switch 32 is therefore in its normally closed position. Exposure switch 31 is then closed, energizing relay 30 to close switch 29 and provide an X-ray tube exposure. If the current across the lines 12 and 13 is of such an order as to provide too high a peak kilovoltage on the tube 10, the transformer 36 which is being supplied with current of the same order will supply to the control circuit sufficient current to produce a plate voltage at 39a sufficient to overcome the grid bias and to cause the tube 39 to become conducting. It requires only one alternation of the current in the source lines 12 and 13 to cause the tube 39 to become conducting under these conditions. When this is true relay 33 is energized opening switch 32, thus deenergizing relay 30 and permitting switch 29 to open (this being a normally open switch).

Since rectified current is applied to plate 39a, once the thyatron tube is rendered conducting it will stay that way until the voltage to transformer 36 is interrupted and lowered below the tripping value of tube 39. This occurs automatically when the dial switches 12a and 13a are moved to lower the peak kilovoltage because between the taps switches 12a and 13a are nonconducting and this interrupts the current flow to transformer 36. Upon such interruption the grid 39b again resumes control of tube 39 ready for the next operation.

It will be seen that the tripping voltage of tube 39 depends upon the current supplied to the plate 39a and this in turn is varied by changing the taps on resistor 42 by means of the switch on deck C. Thus each position of this switch on deck C corresponds to a maximum voltage which can be applied to the tube 10 and to the transformer 36 of the control circuit before the thyatron tube will become conducting and trip the relay.

The control apparatus here disclosed is very positive in action and will trip on one minor selector dial movement over the tripping value set and the setting is very consistent and may

be depended upon to give absolute protection for the tube.

Obviously the control principle here disclosed depends upon the relative voltage between the grid and plate of the tube 39 and it is immaterial which of these is held constant while the other is varied. It is also well understood that a thyatron or trigger tube like that shown at 39 may be utilized in circuits either normally conducting or normally nonconducting. It will also be understood by those skilled in this art that the flow controlling element, indicated at 42 as a resistor might in some other controlling circuit be an inductor or a capacitor.

What I claim is:

1. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means responsive to a predetermined condition of said control circuit for disconnecting said energizing circuit, means supplying current to said control circuit varying in accordance with current variations in said energizing circuit, and a control device in said control circuit responsive to said current supplying means and arranged to produce said predetermined condition of said control circuit in response to current in said energizing circuit above a predetermined level.

2. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means responsive to a predetermined condition of said control circuit for disconnecting said energizing circuit, means supplying current to said control circuit varying in accordance with current variations in said energizing circuit, and a control device in said control circuit responsive to said current supplying means and arranged to produce said predetermined condition of said control circuit in response to a single alternation of the current in said energizing circuit above a predetermined level.

3. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means responsive to a predetermined condition of said control circuit for disconnecting said energizing circuit, means supplying current to said control circuit varying in accordance with current variations in said energizing circuit, settable means in said control circuit having various positions for varying an electrical characteristic of said control circuit, and a control device in said control circuit responsive to said current supplying means and to said settable means and arranged to produce said predetermined condition of said control circuit in response to current in said energizing circuit above a level predetermined by said settable means.

4. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a device normally blocking current flow in said control circuit but adapted to be overcome and rendered conducting by voltage above a predetermined level, whereby when said current supplied to said control circuit raises said voltage above said predetermined level said device permits said flow of current in said control circuit and operates said first named means.

5. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said con-

control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein and having two tube control elements, the conductivity of said tube depending upon the relative voltage supplied to said elements, means supplying current to one of said control elements from said current supply means, and means supplying a fixed voltage current to the other of said tube control elements, whereby when said current supplied to said one control element overcomes the fixed voltage supplied to said other control element, said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

6. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein, said tube having a control grid and a plate, means supplying current to said plate from said current supply means, and means supplying a fixed voltage current to said grid of a valve biasing said tube nonconducting at a safe predetermined value of current supplied to said plate, whereby when current above said predetermined value is supplied to said plate said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

7. In combination with an X-ray tube and an energizing circuit therefor including a transformer having a low tension primary and a high tension secondary, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying direct current to said control circuit including a transformer having a primary in parallel circuit with said first named primary and a secondary, a rectifier in circuit with said last named secondary, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein, said tube having a control grid and a plate, means supplying current to said plate from said rectifier, and means supplying a fixed voltage current to said grid of a valve biasing said tube nonconducting at a safe predetermined value of current supplied to said plate, whereby when current above said predetermined value is supplied to said plate said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

8. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a device normally blocking current flow in said control circuit but adapted to be overcome and rendered conducting by voltage above a predetermined level, a plurality of current flow controlling means in said control circuit and in circuit with said device, means for selecting the tube load for said X-ray tube, and means for concurrently setting said predetermined level by selecting the proper flow controlling means, whereby when said current sup-

plied to said control circuit raises said voltage above said predetermined level said device permits said flow of current in said control circuit and operates said first named means.

9. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein and having two tube control elements, the conductivity of said tube depending upon the relative voltage supplied to said elements, means supplying current to one of said control elements from said current supply means, said last named current supplying means including a plurality of flow controlling means in said control circuit and in circuit with said one tube control element, and one control means for selecting the tube load for said X-ray tube and for selecting a corresponding one of said plurality of flow controlling means, and means supplying a fixed voltage current to the other of said tube control elements, whereby when said current supplied to said one control element overcomes the fixed voltage supplied to said other control element, said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

10. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein, said tube having a control grid and a plate, means supplying current to said plate from said current supply means, said last named current supplying means including a plurality of flow controlling means in said control circuit and in circuit with said plate, and one control means for selecting the tube load for said X-ray tube and for selecting a corresponding one of said plurality of flow controlling means, and means supplying a fixed voltage current to said grid of a valve biasing said tube nonconducting at a safe predetermined value of current supplied to said plate, whereby when current above said predetermined value is supplied to said plate, said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

11. In combination with an X-ray tube and an energizing circuit therefor including a transformer having a low tension primary and a high tension secondary, a control circuit, means energized by a flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying direct current to said control circuit including a transformer having a primary in parallel circuit with said first named primary and a secondary, a rectifier in circuit with said last named secondary, a thermionic vacuum tube positioned in said control circuit and controlling current flow therein, said tube having a control grid and a plate, means supplying current to said plate from said rectifier, said last named current supplying means including a plurality of flow controlling means in said control circuit and in circuit with said plate, and one control means for selecting the tube load for said X-ray tube and

for selecting a corresponding one of said plurality of flow controlling means, and means supplying a fixed voltage current to said grid of a value biasing said tube nonconducting at a safe predetermined value of current supplied to said plate, whereby when current above said predetermined value is supplied to said plate, said tube and therefore said control circuit becomes conducting and causes disconnection of said energizing circuit.

12. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means controlled by one conductive state of said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with current variations in said energizing circuit, a device in said control circuit normally maintaining said control circuit in the other conductive state from that first mentioned, and said device changing said control circuit to said first mentioned one conductive state responsive to current in said control circuit corresponding to current in said energizing circuit above a predetermined level.

13. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means controlled by one conductive state of said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with the load on said tube, a device in said control circuit normally maintaining said control circuit in the other conductive state from that one first named, said device changing said control circuit to and maintaining said control circuit in said first named one conductive state responsive to current in said control circuit corresponding to tube load above a predetermined level, and resetting means for returning said device to said normally maintaining condition.

14. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means controlled by one conductive state of said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with the load on said tube, a space discharge device in said control circuit having two control elements controlling the conductive state of said control circuit, means providing a biasing current for one of said elements such that said device normally maintains said control circuit in the other conductive state from that one first named, means supplying current to the other of said elements varying as the current varies in said control circuit, and the relation between the currents supplied to said elements being such that said device changes to said

first named one conductive state responsive to current in said control circuit corresponding to tube load above a predetermined level.

15. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means energized by flow of electric current in said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with the load on said tube, a space discharge device having two control elements controlling the conductive state of said control circuit, means providing a biasing current for one of said elements such that said device is normally non-conducting, means supplying current to the other of said elements varying as the current varies in said control circuit, the relation between the currents supplied to said elements being such that said device changes to a conducting state responsive to current in said control circuit corresponding to tube load above a predetermined level, and the current supplied to one of said control elements of said space discharge device being rectified, whereby said device upon becoming conducting tends to remain in that state.

16. The combination of claim 15 including a plurality of separate current flow controlling means in said control circuit, and selector means movable from one to the other of said last named separate flow controlling means and breaking said control circuit when in intermediate position between them, whereby when said space discharge device is in conducting state movement of said selector means to an intermediate position breaks said control circuit permitting said device to return to its normal non-conducting state.

17. In combination with an X-ray tube and energizing circuit therefor, a control circuit, means controlled by one conductive state of said control circuit for disconnecting said energizing circuit, means for supplying current to said control circuit varying in accordance with the load on said tube, a plurality of flow controlling means adapted to be selectively connected in said control circuit, a device in said control circuit controlling the conductive state thereof and normally maintaining said control circuit in the other conductive state from that one first named, said device changing said control circuit to and maintaining said control circuit in said first named one conductive state responsive to current in said control circuit above a predetermined level, and one control means for selecting the tube load for said X-ray tube and for selecting a corresponding one of said plurality of flow controlling means.

JACK BALL.