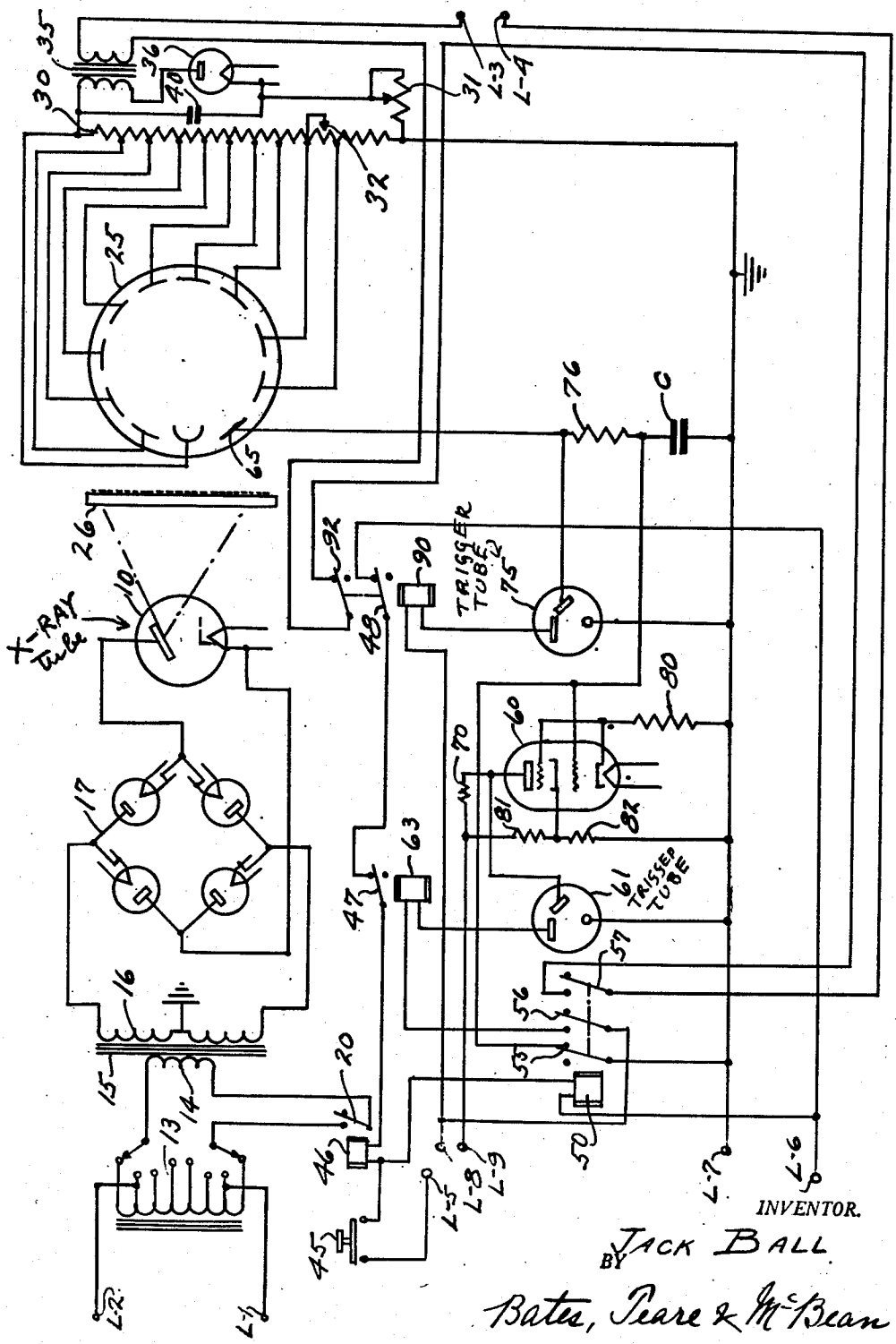
250/201

June 15, 1954 J. BALL 2,681,417

PROTECTIVE CIRCUIT FOR PHOTOELECTRIC TUBES

Filed July 21, 1951



Patented June 15, 1954 2,681,417

UNITED STATES PATENT OFFICE

2,681,417

PROTECTIVE CIRCUIT FOR PHOTO-ELECTRIC TUBES

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

Application July 21, 1951, Serial No. 237,953

7 Claims. (Cl. 250—95)

1

This invention relates to X-ray apparatus and particularly to equipment for protecting the photo-tube which is customarily used for automatically terminating the X-ray exposure in accordance with predetermined conditions of operation.

Heretofore, photo-tubes have been utilized as part of the equipment employed for automatically terminating an X-ray exposure, and such equipment has included a trigger tube and condenser in the output circuit of the photo-tube, and the electrical characteristics thereof have been such that the trigger tube would operate to disconnect the power supply to the input of the X-ray tube after the photo-tube has been operated for a sufficient length of time to charge the condenser. In practice, the photo-tube, together with its associated fluorescent screen, has been mounted in a box beneath the X-ray table, and, in such position, the screen has been protected against impingement of light thereon from any source other than the X-ray beam. Recent developments, however, in X-ray apparatus, particularly in the use of a "spot filmer" wherein the photo-tube is positioned above the X-ray table and is used in conjunction with a movable frame which carries the photo-sensitive film, the photo-tube has, of necessity, been placed in a position where it is not protected against the impingement of light other than from the X-ray tube. Thus, if light, which is used for general illumination in the room wherein the X-ray exposure is being made, should be inadvertently turned on, or if someone should attempt to make an exposure, by way of demonstration, without darkening the room, then the photo-tube would be subjected to such an excessive amount of light as to damage the photo-tube before the condenser could be charged sufficiently to fire the trigger tube.

A further problem in the operation of photo-tubes has been the fact that although the trigger tube might function normally to open the circuit to the X-ray tube, nevertheless, if the operator should inadvertently maintain pressure upon the push-button control member after the circuit to the X-ray tube has been disconnected, then a high voltage would still be impressed upon the photo-tube, with consequent liability to damage it in case the screen at such time should be subjected to an abnormal amount of light.

An object of the present invention is to provide an apparatus by means of which the photo-tube can be located in an exposed position and will still be protected against damage in the event of impingement of an excessive amount of light

2

upon the photo-tube screen, irrespective of whether or not the X-ray tube is connected to its source of current supply, and irrespective of whether or not the operator manually maintains the push-button control member closed after the power supply to the X-ray tube has been disconnected. The invention contemplates a protective apparatus which will permit the trigger tube assembly, heretofore utilized, to function, upon the impingement of a normal amount of radiation upon the photo-tube screen during use of the X-ray equipment, to disconnect the power input thereto, in the event of the occurrence of an excessive amount of radiation impingement upon the screen.

The present invention has solved a problem in the protection of the photo-tube by disconnecting the power input thereto automatically whenever the output of the tube exceeds a predetermined amount. Under such conditions, the apparatus operates automatically to disconnect the power supply to the X-ray tube, as well as to the photo-tube, and prevents normal operation of the equipment until the defect is remedied.

Briefly, the present invention includes an auxiliary trigger tube with a suitable resistance connected in the output circuit of the photo-tube and intermediate the primary trigger tube assembly heretofore used, and the photo-tube. The characteristics of the resistance are such that the auxiliary trigger tube will not be fired, consequent upon the normal flow of current in the output of the photo-tube, whereby the desired selected interval of time for operation of the X-ray tube can be utilized for charging the condenser and firing the primary trigger tube. The firing of that tube operates a relay to disconnect the power input supply to the X-ray tube, but if at any time the photo-tube is connected to its power supply and if at such time an excessive amount of radiation is impinged upon the tube screen, then the resistance used in the circuit of the auxilitry trigger tube will cause such tube to be fired which, in turn, will energize a relay to disconnect the input power to the X-ray tube and to the photo-tube respectively. Thus, even though the operator should maintain the manually operable switch closed so that the power supply to the photo-tube is maintained, nevertheless, the present invention will operate to protect the photo-tube against damage until the source of excess impingement of light upon the tube screen is eliminated.

The drawing is a schematic diagram showing a circuit arrangement for X-ray apparatus embodying the present invention.

In the drawing, 10 designates an X-ray tube, the power input to which is supplied from a source of alternating current through lines L–1 and L–2 through a k. v. selector indicated in general at 13, which is connected to the primary winding 14 of a power transformer 15. The secondary 16 of the transformer is connected to the X-ray tube through a bridge rectifier indicated in general at 17. The circuit for the primary winding of the power transformer includes a normally open switch 20.

The X-ray apparatus includes a photo-tube 25 with its associated fluorescent screen 26. The tube may be of the Zworykin electron-multiplier type with its customary associated network of resistances 30, density control potentiometer 31, and calibrator 32, these being adjustable for the type of film that is to be used. Energizing current is supplied to the photo-tube at L–3 and L–4 through a transformer 35, the secondary of which includes in its circuit a diode 36, the plate of which is connected to one end of the secondary winding of the transformer 35, and the cathode of which is connected to the potentiometer 31. A condenser 45 is shunted across the circuit of the secondary winding.

For operating the X-ray tube under normal conditions, there is provided a primary trigger circuit, to which current is supplied at the leads L–5 and L–6. Such circuit includes a manually operable push button control switch 45, a relay 46, a normally closed switch 47, and a normally closed switch 48, and the arrangement is such that when the switch 45 is closed the relay 46 is energized and the switch 20 is thereby closed. Thus the X-ray tube is connected to its source of power supply. Shunted across such circuit is a relay 50 which controls the operation of a primary trigger circuit by means of which the X-ray tube is controlled under conditions of normal operation.

The primary trigger circuit may include an amplifier tube 60 and a trigger tube 61 which are in circuit with the anode 65 of the photo-tube. A condenser C is employed in the trigger tube circuit and may be shunted by a normally closed switch 55 so long as the relay 50 is not energized. Upon energization of the relay 50, however, the switch 55 is opened whereupon the output from the photo-tube charges the condenser sufficiently to fire the tube 61 which in turn energizes a relay 63 from a source of current supply through the leads L–7 and L–8 to open the switch 47. This interrupts the flow of current in the circuit L–5 and L–6 thus deenergizing the relay 46 and allowing the switch 20 to open. This disconnects the source of supply to the X-ray tube.

Under normal conditions of operation, the primary trigger circuit operates to interrupt the source of current supply to the X-ray tube after the tube has been operated for an intended length of time, conditioned upon the intensity and duration of radiation desired. Such interval of time is co-extensive with the time required to charge the condenser C, and the charging of the condenser interposes a time lag of a desired extent, so that when the trigger tube 60 fires, a relay will be energized which would disconnect the X-ray tube from its source of power supply.

The present invention embodies an auxiliary trigger circuit which includes a trigger tube 75 and a resistor 76 connected in the output circuit of the photo-tube and adapted for energizing a relay to disconnect the power supply to the X-ray tube and also to the photo-tube. The electrical

characteristics of the resistor 76 are such that under normal conditions of operation, the output from the photo-tube will charge the condenser C and fire the primary trigger tube but, under abnormal conditions of operation, such as upon the impingement of radiation upon the screen 26 in excess of that intended for normal operation, the output will fire the auxiliary trigger tube 75, thereby energizing the relay and interrupting the source of current supply to the X-ray tube and to the photo-tube, as aforesaid.

The leads L–7 and L–8 provide a direct current supply at 160 volts for the trigger tubes 61 and 75 while the leads L–7 and L–9 provide a direct current supply at 100 volts for operation of the amplifier tube 60. The lead L–7 is shown as being connected to ground and to the resistance network 30 for the photo-tube.

I have found, where the input to the photo-tube from the secondary to the transformer 35 is of the order of 1,000 volts, that normal operation of the primary trigger tube unit will occur if the condenser C has the capacity of .1 mfd., and if the resistors in the primary trigger tube circuit have the following values.

	Ohms
Resistor 70	200,000
Resistor 80	1,000
Resistor 81	5,000
Resistor 82	3,000

I have also found that the photo-tube will be adequately protected if the resistor 76 has a resistance of 500,000 ohms. By placing the resistor 76 between the condenser C and the photo-tube, in circuit with the anode 65 thereof, then the trigger tube 75 can be fired upon the occurrence of an electrical surge in the photo-tube output circuit even though the surge occurs within the space of time required for one cycle. Under normal operations, the photo-timer is usually operated within the range of 1/5 of a second up to 10 seconds, this being determined by the setting of the capacity of the condenser, and the calibrators 31 and 32, it being understood that the calibration is initially preset in accordance with the electrical characteristics of the photo-tube and of the sensitivity of the film, and in accordance with the k. v. setting of the power supply for the X-ray tube. These settings are well known in the art.

In operation, assuming that a source of 220 volts of alternating current supply is provided for the leads L–1 and L–2, that a source of 110 volts of alternating current supply is provided for the leads L–3 and L–4, that a source of 160 volts direct current supply is provided for the leads L–7 and L–8 and a source of direct current supply of 100 volts is provided across the leads L–7 and L–9, and assuming that the X-ray tube and photo-tube, with its associated network and protective circuits, are connected as aforesaid, then whenever the operator closes the push-button switch 45, a circuit is established which energizes the relay 46 thereby closing the switch 20 and completing the circuit for the power input to the X-ray tube. At the same time the relay 50 is energized which opens the switch 55 (which normally shunts out the condenser C), thereby putting the condenser into the output circuit of the photo-tube. Energization of the relay 50 also closes the switches 56 and 57. When the switch 56 is closed, then the primary trigger tube is cocked and the input circuit to the primary winding of the photo-tube trans-

former 35 is established. Under normal operation, the output from the photo-tube will charge the condenser C which when adequately charged will fire the trigger tube 61 thus energizing the relay 63. Energization of the relay 63 opens the switch 47, thereby deenergizing the relay 46, opening the switch 20 and disconnecting the power supply to the X-ray tube.

Under normal conditions of operation as aforesaid, the trigger tube 75 would not be fired. However, if an abnormal amount of radiation should strike the screen 26 so as to create a surge in the output from the photo tube, then irrespective of the amount of charge upon the condenser C, the auxiliary trigger tube will be fired thereby enabling the flow of current across the lines L–7 and L–8 through relay 90 which, when energized, opens the switches 48 and 92, the first of which opens the circuit through the relay 46 thereby interrupting the source of current supply to the X-ray tube, as aforesaid, while opening of the switch 92 interrupts the source of current supply to the photo-tube. This condition prevails even though the operator may maintain pressure manually against the push button control 45. Thus, it is necessary to remedy the abnormal condition which is causing the impingement of excessive radiation upon the screen 26 before normal conditions of operation can be re-established.

Under normal conditions, a flow of current of the order of 30 micro-amperes, or less, in the output circuit of the photo-tube, will operate to fire the trigger tube 61, whereas an abnormal flow of current, of the order of 100 micro-amperes will operate to cause a sufficient voltage drop across resistor 76 to fire the trigger tube 75.

As soon, however, as the operator opens the switch 45, the relay 50 is deenergized, whereupon the switch 57 is automatically opened and the supply circuit to the photo-tube is automatically disconnected. Deenergization of the relay 50 also enables the switch 55 to be automatically closed, thereby shunting the condenser out of the circuit and enables the switch 56 to be automatically opened, which deenergizes the relay 63. This allows the switch 47 to close, thereby resetting the conditions for normal operation upon a succeeding actuating of the push button control member 45.

An advantage of the present invention is that the photo-tube is protected under abnormal conditions of operation, consequent upon the impingement of an abnormal amount of radiation upon the photo-tube screen. The apparatus embodying the present invention can be readily applied to existing X-ray apparatus without extensive changes in the construction thereof, and is equally adapted for inclusion in original equipment.

I claim:

1. In combination, an X-ray tube, an electrical circuit connecting said tube to a source of current supply, switch means in said circuit, a photo-tube having an anode, a light-sensitive cathode and multiplying electrodes, a fluorescent screen positioned adjacent said photo-tube, a trigger tube having an anode, a cathode and a control grid, an electrical circuit, including a capacitor sensitive to firing of said trigger tube for actuating said switch means to disconnect said X-ray tube from its source of current supply, consequent upon charging of the capacitor under normal conditions of impingement of radation upon said screen during operation of said X-ray tube, a second trigger tube having an anode, a cathode and a control grid, a connection, including a resistor, between the anode of the photo-tube and the grid of the second trigger tube, switch means operatively connected with an electrical circuit sensitive to the firing of said second trigger tube independently of the charge on said capacitor for terminating the operation of the photo-tube consequent upon the impingement of an abnormal amount of radiation upon said fluorescent screen during the X-ray exposure.

2. An X-ray exposure control circuit comprising in combination, a photo-tube having an anode, a light-sensitive cathode and multiplying electrodes, a source of current supply for said photo-tube, a fluorescent screen positioned adjacent said photo-tube, a trigger tube having an anode, a cathode and a control grid and adapted to fire at a predetermined potential, switch means coacting in response to an electrical circuit sensitive to the firing of said trigger tube for disconnecting the source of current supply to the photo-tube, and a circuit connecting the anode of the photo-tube and the control grid of the trigger tube, said circuit being connected to utilize the photo-tube current for developing the predetermined potential to fire the trigger tube before the impingement of radiation upon the fluorescent screen can reach an amount sufficient to cause damage to the photo-tube.

3. In combination, an X-ray tube, an electrical circuit connecting said tube to a source of current supply, switch means in said circuit, a photo-tube having an anode, a light sensitive cathode and multiplying electrodes, a fluorescent screen positioned adjacent said photo-tube, a trigger tube having an anode, a cathode and a control grid, an electrical circuit sensitive to firing of said trigger tube for actuating said switch means to terminate said X-ray exposure consequent upon operation of said X-ray tube under normal conditions for a predetermined length of time, a second trigger tube having an anode, a cathode and a control grid, an electrical circuit coupling the second trigger tube to the photo-tube and including means for utilizing the photo-tube current to fire said second trigger tube consequent upon the impingement of an abnormal amount of radiation upon said fluorescent screen during the X-ray exposure, and an electro-responsive switch having energizing means in said coupling circuit responsive to firing of said second trigger tube for positioning the switch to terminate the operation of the photo-tube.

4. In combination, an X-ray tube, an electrical circuit connecting said tube to a source of current supply, switch means in said circuit, a photo-tube having an anode, a light-sensitive cathode and multiplying electrodes, a fluorescent screen positioned adjacent said photo-tube, a trigger tube having an anode, a cathode and a control grid, an electrical circuit sensitive to firing of said trigger tube for actuating said switch means to terminate said X-ray exposure consequent upon operation of said X-ray tube under normal conditions for a predetermined length of time, a second trigger tube having an anode, a cathode and a control grid, an electrical circuit coupling the second trigger tube to the photo-tube and including means for utilizing the photo-tube current to fire said second trigger tube consequent upon the impingement of an abnormal amount of radiation upon said fluorescent screen during the X-ray exposure, and electro-responsive switch

having energizing means in said coupling circuit responsive to the firing of said second trigger tubes for positioning the switch to terminate the operation of the photo-tube and the X-ray tube.

5. In combination, an X-ray tube, an electrical circuit connecting said tube to a source of current supply, switch means in said circuit, a photo-tube having an anode, a light-sensitive cathode and multiplying electrodes, an energizing circuit for conditioning said photo-tube for operation, a fluorescent screen positioned adjacent said photo-tube, a trigger tube having an anode. a cathode and a control grid, an electrical circuit including a capacitor sensitive to firing of said trigger tube for actuating said switch means to disconnect said X-ray tube from its source consequent upon the charging of the capacitor under normal conditions of impingement of radiation upon said screen during operation of said X-ray tube, a second trigger tube having an anode, a cathode and a control grid, an electrical circuit coupling the second trigger tube to the photo-tube and including resistance means for utilizing the photo-tube current to fire said second trigger tube independently of the charge on said capacitor consequent upon the impingement of an abnormal amount of radiation upon said fluorescent screen during the X-ray exposure, and an electro-responsive switch having energizing means in said coupling circuit responsive to the firing of said second trigger tube for positioning the switch to terminate the operation of the photo-tube and the X-ray tube.

6. In an X-ray exposure control circuit having a photo-tube responsive to X-ray radiations from an X-ray generator, a source of electrical energy for activating the X-ray generator, means for electrically conditioning the photo-tube to actively respond to X-ray radiations by developing an electrical current therein proportional to the impinging quantity of X-ray radiation, means for isolating the source from the X-ray generator consequent upon a predetermined X-ray exposure time interval, and electro responsive means for isolating the source from the X-ray generator in response to a predetermined maximum amount of X-ray radiation and including a control circuit having a voltage responsive trigger tube normally isolating said electro-responsive means from the photo-tube, a resistance in the photo-tube output for developing a voltage across the trigger tube sufficient to render it conductive in response to such predetermined maximum radiation, and means coacting in the circuit in response to the firing of said trigger tube for removing the electrical conditioning means from the photo-tube.

7. In an X-ray exposure control circuit having a photo-tube responsive to X-ray radiations from an X-ray generator, a source of electrical energy for activating the X-ray generator, means for electrically conditioning the photo-tube to actively respond to X-ray radiations by developing an electrical current therein proportional to the impinging quantity of X-ray radiations, circuit means including a switch for removably connecting the source to the X-ray generator, a control circuit having electrically responsive means for opening such switch consequent upon a predetermined quantity of electrical current flowing through the photo-tube, said control circuit including a voltage responsive trigger tube normally isolating said electrically responsive means from the current in said electrical tube, storage means coupled between the photo-tube and the trigger tube to develop a voltage sufficient to fire the trigger tube and open the switch, a second trigger tube responsive to a higher voltage in said control circuit normally isolating said electrically responsive means from the current in said photo-tube, a resistance coupled between the photo-tube and said second trigger tube and adapted to develop the higher voltage to fire the second trigger tube and open the switch, and means responsive to the firing of said second trigger tube for removing said electrical conditioning means from the photo-tube.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,401,289	Morgan et al.	May 28, 1946
2,412,423	Rajchman et al.	Dec. 10, 1946
2,442,985	Rajchman	June 8, 1948
2,454,169	Haynes	Nov. 16, 1948
2,541,187	Ball et al.	Feb. 13, 1951
2,571,838	Connor et al.	Oct. 16, 1951
2,640,160	Collins	May 26, 1953