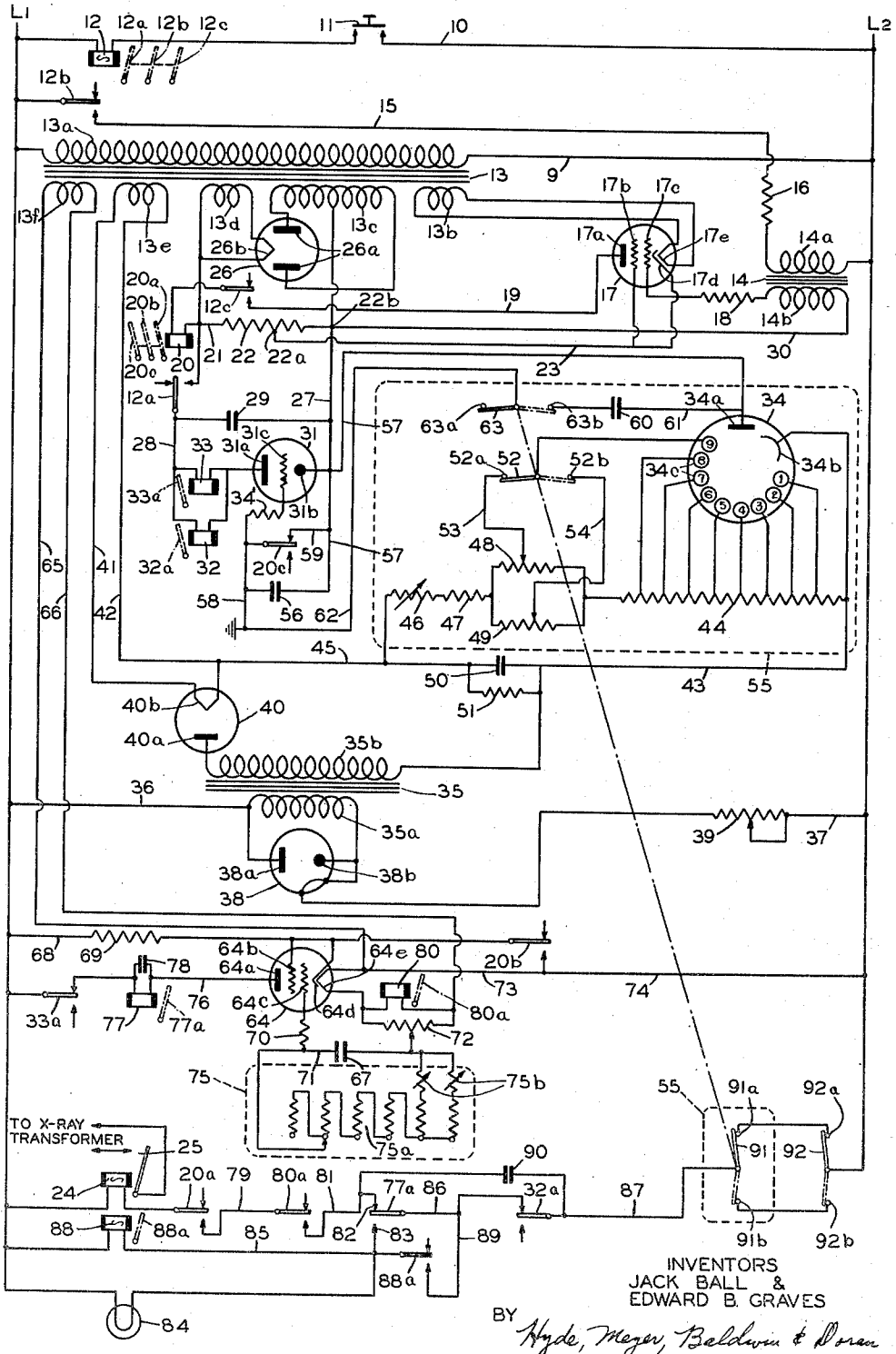
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PHOTOELECTRIC TIMER FOR X-RAY APPARATUS

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PHOTOELECTRIC TIMER FOR X-RAY APPARATUS

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9 Claims. (Cl. 250—71)

1

This invention relates to improvements in a photoelectric timer for use in connection with X-ray apparatus for Roentgen photography.

The purpose and theory of the type of apparatus here disclosed is fully set forth in United States Patent No. 2,401,289, granted May 28, 1946, to Russell H. Morgan and Paul C. Hodges, to which reference may be had for an explanation of the theory. The present invention provides an improvement over the above mentioned patent.

In the Morgan, Hodges patent and in the present application use is made of a phototube of the general type disclosed in United States Letters Patent No. 2,231,697, granted February 11, 1941, to Vladimer K. Zworykin et al. In such a phototube there is provided a light sensitive cathode, an anode, and a series of multiplying electrodes called dynodes. Visible radiation produced on a fluorescent screen by an X-ray exposure fell upon the light sensitive cathode and, through the multiplying electrodes, resulted in an output which was utilized to charge a condenser. When a sufficient charge accumulated on the condenser, it tripped a trigger tube for terminating the X-ray exposure Morgan and Hodges used a Thyratron type control tube. Since this tube is a negative control tube, they found it necessary, as set forth in the above mentioned Patent No. 2,401,289, to use the ninth dynode as a collector so as to obtain a charge of the right polarity to trip the trigger tube since the plate or anode of the phototube would give a negative charge as it is the receiver of electrons. This patented device cut down the sensitivity obtained. It is an object of the present invention to use the plate of the phototube for the tripping of the trigger tube so as to obtain greater sensitivity.

In an attempt to get better results Morgan and Hodges tried different types of trigger tubes and also tried an amplifier between the phototube and the trigger tube. Difficulties were still encountered because a negative potential was supplied on the control grid or starter anode of the trigger tube and at the same time, a positive voltage was being applied to the plate of the trigger tube. They were therefore working this tube in what is termed the second quadrant which is frowned upon by tube manufacturers, who state that the tube operation in anything but the first quadrant will cause the operation to be very erratic and unstable. Operation in the first quadrant calls for a positive potential on the control grid and a positive potential on the plate of the trigger tube. It is an object of the present invention to so connect the trigger tube that it is operated in the first quadrant.

Another object of the present invention is the control of the sensitivity of the phototube in a novel manner. Standard methods known to us,

2

use a series resistor from the high voltage power supply so as to raise or lower the total voltage across the phototube. Another difficulty with this type of control is that if the total voltage is reduced too much the output of the tube drops excessively with resultant erratic response from the phototube. It is an object of the present invention, therefor, to maintain the total voltage fixed and to vary the voltage of one of the dynodes of the phototube in a potentiometer type circuit. In this manner we obtain a control which has a much greater range of sensitivity than the series type mentioned above.

A further object of the present invention is to incorporate certain safety devices so that upon failure of current or failure of important portions of the apparatus, the X-ray tube will be protected.

Still a further object of the invention is the incorporation of an interval timer in combination with the photoelectric timer so that if the latter fails to terminate the X-ray exposure within a safe time limit, the interval timer will take over.

Other objects and advantages of our invention will be apparent from the accompanying drawings and description and the essential features thereof will be set forth in the appended claims.

The drawing is a diagram showing one manner of applying our invention.

A source of alternating current at the usual potential of about 115 volts is indicated at L1, L2. Connected between these lines is line 10 including a push button 11 which is used to cause an X-ray exposure. In series in this line is a relay 12 having three armatures 12*a*, 12*b* and 12*c* which are indicated in dot-dash lines adjacent the relay but are repeated in full lines in the proper place in the diagram. This is done to simplify the diagram. Also connected across the source L1, L2 by means of line 9 is the primary 13*a* of a power transformer 13. This transformer has several secondaries as indicated at 13*b*, 13*c*, 13*d*, 13*e* and 13*f*. A peaking transformer 14 has a primary 14*a* connected by line 15 to the source L1, L2. In series in this line is a resistor 16 and the armature 12*b* of the relay 12 mentioned above. The secondary 14*b* of transformer 14 is connected to the control grid 17*c* of an exposure initiating tube 17 of the Thyratron type through a resistor 18. The filament 17*e* of this tube is supplied from the secondary 13*b* of the transformer 13. The plate 17*a* is connected in a circuit which includes line 19, armature 12*c* of relay 12, relay 20, line 21, resistor 22, line 23 and the cathode 17*d*. It results from this circuit that upon closing the push button 11, the relay 12 is immediately energized and this closes the plate circuit of tube 17 through the armature 12*c*. However,

no current flows because of a negative bias on the tube 17 as will presently be described. At the first positive voltage peak through the transformer 14, the control grid 17c becomes positive and the tube 17 passes current through the plate circuit described so that relay 20 is energized. This relay has an armature 20a shown near the bottom of the diagram and through a circuit to be more fully described later and immediately energizes a relay 24 which closes the contacts 25 which completes a circuit to the X-ray transformer so as to initiate an exposure. The tube 17, having a direct current energizing source remains locked in until the armature 12c opens. It is thus possible to utilize the positive impulse through the peaking transformer 14 and the time delay until contacts 25 close, to close the circuit to the X-ray transformer at a point of zero potential.

A source of rectified current is provided for tube 17 and for certain other purposes as will presently appear by means of the secondary 13c of the transformer 13. A rectifier tube 26 is provided having a pair of plates 26a connected to opposite ends of the secondary winding 13c which has a central tap for the line 27 which of course will be the negative side of the rectified circuit. The filament 26b of the tube is supplied from the secondary 13d of transformer 13. This filament is connected to line 28 which is the positive side of the rectified circuit. The rectified current is filtered by resistor 22 and condenser 29. This rectified current is supplied to the plate 17a of tube 17 previously mentioned. The negative side of the circuit, line 27, is connected through line 30, transformer winding 14b and resistor 18 to the control grid 17c giving the same a negative bias until overcome by positive peaks from transformer 14 as previously described. The screen grid 17b is connected by line 23 to a tap 22a which is more positive than the point 22b.

A trigger tube 31 is shown as of the cold cathode type although it will be understood that a hot cathode or filament type tube might be substituted. The plate 31a of this tube is connected to line 28 through relays 32 and 33 in parallel. These relays have armatures 32a and 33a for purposes which will later appear. The cathode 31b is connected to line 27. The grid 31c is connected through resistor 34' to ground for a purpose which will later appear.

A phototube of the above-mentioned Zworykin type is diagrammatically shown at 34. This tube has a plate 34a, a cathode 34b and a plurality of dynodes 34c which are numbered from one to nine. It should be understood that this showing is purely diagrammatic and that dynodes in the Zworykin tube are actually staggered to produce a particular multiplying effect. The current supply for the phototube is provided through transformer 35 which has a primary 35a connected between lines L1 and L2 by conductors 36 and 37. A voltage regulator tube 38 is provided having a plate 38a connected to one end of the winding 35a and a cathode 38b connected to the other end of the same winding. This stabilizes the voltage supplied at transformer 35. A variable resistor 39 is provided in line 37. The output of the secondary 35b of transformer 35 is rectified through tube 40 which has a plate 40a connected to one end of the winding 35b and a filament 40b which is supplied through lines 41 and 42 from the secondary 13e of transformer 13. The negative side of this rectified circuit is connected through line 43 with the cathode 34b and with the negative

end of resistor 44. The positive side of the rectified circuit is connected through line 45, variable resistor 46, fixed resistor 47 and resistors 48 and 49 in parallel, with the negative end of resistor 44. This rectified current is filtered through condenser 50 and resistor 51. Suitable taps on resistor 44 supply dynodes one to eight inclusive of the phototube. The ninth dynode is connected to switch 52 which in the full line position shown in the drawings engages contact 52a for radiography. This contact is connected through line 53 with a tap on the adjustable resistor 48. Switch 52 may also be moved to the dot-dash position to contact 52b for photofluorography. The contact 52b is connected by line 54 with a tap on the adjustable resistor 49. By making the voltage on number 9 dynode equal to that on number 8 dynode there is provided a minimum sensitivity of the phototube. Making the number 9 dynode approximately 100 volts higher than the number 8 dynode gives a maximum sensitivity. The series resistor 46 is used as a calibrator. The phototube units are sent out fully assembled including the parts within the broken line 55. By adjusting the resistor 46, each phototube unit may be adjusted to the same sensitivity so as to give identical output.

A capacitor 56 is provided for collecting the electrons from the anode 34a of the phototube until a sufficient charge is collected to fire the trigger tube 31. This condenser is connected with line 57 which in turn connects the anode 34a of the phototube with the cathode 31b of the trigger tube. The other side of the condenser is grounded through line 58. The capacitor 56 is normally short-circuited through line 59 and switch 20c until an exposure starts. At that time, the switch 20c opens and the capacitor begins to collect a charge. By proper selection of the capacity of the capacitor 56, the potential to which it is charged in order to fire the trigger tube and the sensitivity of the phototube, an exposure may be terminated when a recording film has been properly exposed.

As previously stated, we work the trigger tube in the first quadrant in the following manner. The grid 31c of the trigger tube is maintained at ground potential. The potential of the cathode 31b is then raised in a negative direction as it receives charges from electrons collected at the anode 34a of the phototube. Making the cathode 31b negative with respect to the grid 31c is electrically the same as making the grid positive with respect to the cathode and since we have the plate 31a at a positive voltage, we are working the trigger tube in the first quadrant. Thus, we are able to get stability and long life without the use of any amplifier tube such as has been attemped by others as previously explained.

The capacitor 56 as described above in one form of our device has a capacity of .01 microfarad for use in radiography carried out in the fashion disclosed in United States Patent No. 2,401,289 mentioned previously. We may also equip our device with another capacitor 60 which, by means of lines 61 and 62 and switch 63 may be connected in parallel with the capacitor 56 by throwing the switch 63 to the dot-dash position indicated. We find that if this capacitor 60 has a capacity of the order of .1 microfarad then the use of the capacitors 56 and 60 in the parallel connection indicated will be satisfactory for the practice of photofluorography as disclosed in the copending application of Edwin R. Goldfield,

Robert J. Stava and Edgar J. Bastin, Jr., Serial No. 624,172, filed October 24, 1945, now Patent 2,496,089. Sensitivity adjustment for radiography and photofluorography is maintained by means of the potentiometers 48 and 49 respectively. The dot-dash line connecting switches 52 and 63 indicates that these switches are ganged to move in unison so that they engage 52a and 63a simultaneously in one position and engage 52b and 63b simultaneously in the other position. Means is provided for terminating an exposure after a predetermined interval in case the photo timer should fail. This means includes a trigger tube 64 of the Thyratron type having an anode 64a, a screen grid 64b, a control grid 64c and a cathode 64d. The filament 64e is energized through lines 65 and 66 which are connected with the secondary 13f of the power transformer 13. A condenser 67 normally floats across the line L1, L2 in charged condition. This charging circuit comprises line 68, resistor 69, cathode 64d, grid 64c, resistor 70, line 71, variable resistor 72, line 66, transformer winding 13f, line 65 and lines 73 and 74. The switch 20b between lines 68 and 74 is normally in open position as indicated in the drawing. At the start of an exposure, switch 20b is moved to connect lines 68 and 74. This stops the charge of condenser 67 while connecting the cathode 64d to L2 and the plate 64a to L1. The condenser 67 then discharges slowly through a resistance bank indicated at 75. A rough time adjustment may be obtained in that portion of the bank indicated at 75a while a finer adjustment may be provided at 75b. The negative plate of the condenser 67 is connected to the control grid 64c and no current will pass tube 64 until the charge has leaked off condenser 67 to the threshold of tube 64. When control grid 64c passes this point, the tube 64 fires and current passes through line 76 and relay 77. This will terminate the X-ray exposure if it has not previously been terminated by the phototube as will presently appear. If the phototube fires first, then the relay 33 opens the switch 33a which is in line 76 just described and this opens the interval timer circuit and resets the tube 64 for the next operation.

The variable resistor 72 might be connected directly to the line 73 but it is connected through the transformer winding 13f as just described for the purpose of correcting the interval timer for variations in line voltage. The winding 13f is so connected in the circuit for charging condenser 67 that its voltage bucks the charge voltage and therefore an increase in the line voltage will automatically decrease the charge on condenser 67 which will decrease the time interval necessary to fire tube 64.

For the purpose of indicating the general control of the X-ray exposure a number of switches have been assembled in the wiring diagram at one end thereof so as to illustrate the various ways in which the exposure may be made or broken. This series of connections beginning at L1 comprises the relay winding 24 which controls the contacts 25 which energize the X-ray transformer during an exposure. Next comes the switch 20a which is energized by the relay 20 previously described. The switch 80a is normally open but is closed immediately upon the energization of the winding 13f of the power transformer 13. Upon failure of this power supply, relay 80 would be deenergized and switch 80 would open. Line 81 connects switch 80a to switch 77a which is normally closed against the contact 82 as shown in the drawing when relay 77 is deenergized. If the interval timer operates so as to energize relay 77 in the manner described above, the switch 77a engages contact 83 which will light a lamp 84 or other signal to indicate that the interval timer has terminated the exposure rather than the photo timer. At the same time that switch 77a engages contact 83 it completes a circuit through lines 85, 86 and 87 to energize relay 88 which is in line 85. This relay has an armature 88a which is normally open as shown in the drawing but which closes upon energization of relay 88 so as to lock the relay in through lines 89 and 87. The signal 84 therefore remains energized so that the operator will make the necessary corrections to return to the control of the photo timer. The line 86 connects switch 77a to switch 32a which is normally closed but is opened by energization of relay 32 when trigger tube 31 fires upon operation of the photo timer to terminate the X-ray exposure. The line 87 leads to a switch 91 which is ganged with switches 52 and 63 as indicated by the dot-dash line connecting them. For radiography the switch engages contact 91a and for photofluorography it engages contact 91b. The broken line 55 indicates that this swtich is inside the photo timer assembly. Outside of this assembly is a manual switch 92 having positions 92a and 92b corresponding respectively to the circuits through 91a and 91b inside the phototube assembly. The purpose of this manual switch is to insure that the operator definitely selects the circuits either for radiography or photofluorography.

The operation of our improved apparatus will now be apparent. After properly setting the selection switches 92, 91, 52 and 63, the operator closes button 11 which energizes relay 12. This closes switch 12a in line 28 to energize the trigger tube 31. It also closes switch 12b in line 15 to energize the peaking transformer 14. It also closes switch 12c in line 19 so as to place the relay 20 in circuit with tube 17. Upon occurrence of the first positive peak in transformer winding 16b, tube 17 passes current and energizes relay 20. This closes switch 20a which energizes relay 24 to close the X-ray transformer contacts 25 a predetermined time after the potential peak from transformer 14 and, as previously mentioned, this is so adjusted as to close the X-ray transformer contacts at zero potential. As previously mentioned, the switch 80a is closed when power transformer 13 is energized providing the winding 13f is in proper condition. Relay 20 also closes switch 20b connecting lines 74 and 68 so as to cause the interval timer to begin its operation as previously described. Relay 20 also opens switch 20c in line 59 so that capacitor 56 (or 56 plus 60) begins to collect a charge for the operation of the photo timer as previously described. If the photo timer terminates the exposure by firing of the tube 31, relays 33 and 32 are energized. Relay 33 when energized will open switch 33a in line 76 of the interval timer circuit so as to reset that timer for the next operation. Relay 32 will open switch 32a to deenergize relay 24, permitting contacts 35 to open and terminate the X-ray exposure. Upon the release of button 11 relay 12 is deenergized and the circuit switches 12a, 12b and 12c are returned to their original positions so as to set the parts for another operation.

What we claim is:

1. In apparatus for timing the exposure of a film to record X-rays which have passed through

a body and are incident upon a fluorescent screen, the combination of a phototube having an anode and a light sensitive cathode and multiplying electrodes, a trigger tube having an anode and a cathode and a control grid, switch means operatively connected with an electrical circuit sensitive to firing of said trigger tube for terminating said X-ray exposure, an electrical circuit normally biasing said trigger tube beyond cutoff, and an electrical connection from said anode of said phototube to said cathode of said trigger tube, whereby electrons from said phototube anode may charge said trigger tube cathode negatively to cause said trigger tube to fire.

2. In apparatus for timing the exposure of a film to record X-rays which have passed through a body and are incident upon a fluorescent screen, the combination of a phototube having an anode and a light sensitive cathode and multiplying electrodes, a trigger tube having an anode and a cathode and a control grid, switch means operatively connected with an electrical circuit sensitive to firing of said trigger tube for terminating said X-ray exposure, an electrical circuit normally biasing said trigger tube beyond cutoff, a capacitor in circuit with said phototube and said trigger tube, and an electrical connection from said anode of said phototube to said cathode of said trigger tube, whereby electrons from said phototube anode may charge said capacitor to a potential sufficient to charge said trigger tube cathode negatively to cause said trigger tube to fire.

3. In apparatus for timing the exposure of a film to record X-rays which have passed through a body and are incident upon a fluorescent screen, the combination of a phototube having an anode and a light sensitive cathode and multiplying electrodes, a trigger tube having an anode and a cathode and a control grid, switch means operatively connected with an electrical circuit sensitive to firing of said trigger tube for terminating said X-ray exposure, an electrical circuit applying a positive potential in the plate circuit of said trigger tube, an electrical circuit normally maintaining said control grid at a relatively fixed potential below the threshold of said trigger tube, and a capacitor in circuit with said phototube anode and said trigger tube cathode and so arranged that electrons collecting on said phototube anode may charge said capacitor to a potential sufficient to charge said trigger tube cathode negatively and to cause said trigger tube to fire.

4. In apparatus for timing the exposure of a film to record X-rays which have passed through a body and are incident upon a fluorescent screen, the combination of a phototube having an anode and a light sensitive cathode and multiplying electrodes, a trigger tube having an anode and a cathode and a control grid, switch means operatively connected with an electrical circuit sensitive to firing of said trigger tube for terminating said X-ray exposure, an electrical circuit applying a positive potential in the plate circuit of said trigger tube, an electrical connection from said control grid to ground, an electrical connection from said phototube anode to said trigger tube cathode, and a capacitor connected between said last named means and ground.

5. The combination of claim 1 including a resistor for varying the potential of that multiplying electrode in circuit nearest said anode of said phototube, and a separate resistor having spaced taps connected consecutively to the other multiplying electrodes of said phototube to render them consecutively more positive, whereby said electrode nearest said anode is used to vary the sensitivity of said phototube.

6. In a phototube for timing the exposure of a film to record X-rays which have passed through a body, said phototube being of the type having an anode and a light sensitive cathode and multiplying electrodes, the provision of a resistor having spaced taps connected consecutively to all but one of said multiplying electrodes to render them consecutively more positive, and separate means for varying the potential of said one of said multiplying electrodes to vary the sensitivity of said phototube.

7. In a phototube for timing the exposure of a film to record X-rays which have passed through a body, said phototube being of the type having an anode and a light sensitive cathode and multiplying electrodes, the provision of a resistor having spaced taps connected consecutively to all of said multiplying electrodes except that one of said electrodes in circuit nearest said anode of said photo tube to render said electrodes consecutively more positive, and separate means for varying the potential of that one of said multiplying electrodes in circuit nearest said anode of said phototube, whereby to vary the sensitivity of said phototube.

8. The combination of claim 3 including an interval timer having a second trigger tube, means biasing a control grid of said second trigger tube beyond its firing threshold and including a second capacitor in charged condition, means normally charging said second capacitor to a predetermined potential, resistor means in circuit with said second capacitor to provide a controlled leaking off of its charge to a point where said second trigger tube will fire, means responsive to firing of said second trigger tube for terminating said X-ray exposure, switch means normally short-circuiting said first named capacitor, and means operable by initiation of an X-ray exposure for opening said short-circuiting means of said first named capacitor and for synchronously interrupting said second capacitor charging means, whereby two alternative timing circuits are available for terminating said X-ray exposure.

9. The combination of claim 1 including two separate fixed resistors adapted to be placed alternatively in circuit with one only of said multiplying electrodes for varying the potential of said one of said multiplying electrodes, and switch means for connecting a selected one of said fixed resistors in said last named circuit whereby to provide two alternatively selected fixed sensitivities for said phototube.

JACK BALL.
EDWARD B. GRAVES.

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