May 25, 1954 R. L. WRIGHT ET AL 2,679,598

X-RAY APPARATUS

Filed Dec. 4, 1950 2 Sheets-Sheet 1

Fig. 1A.

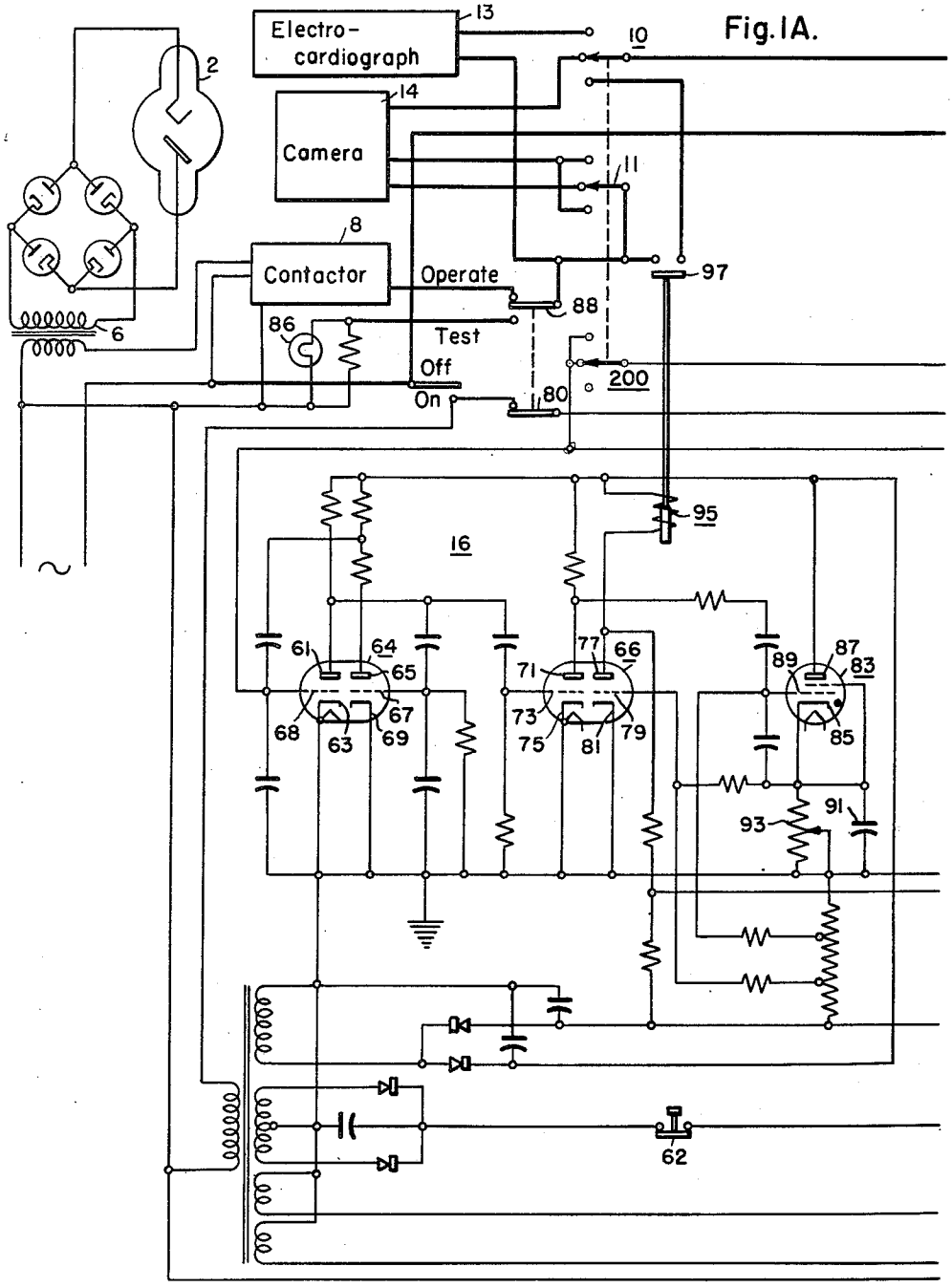

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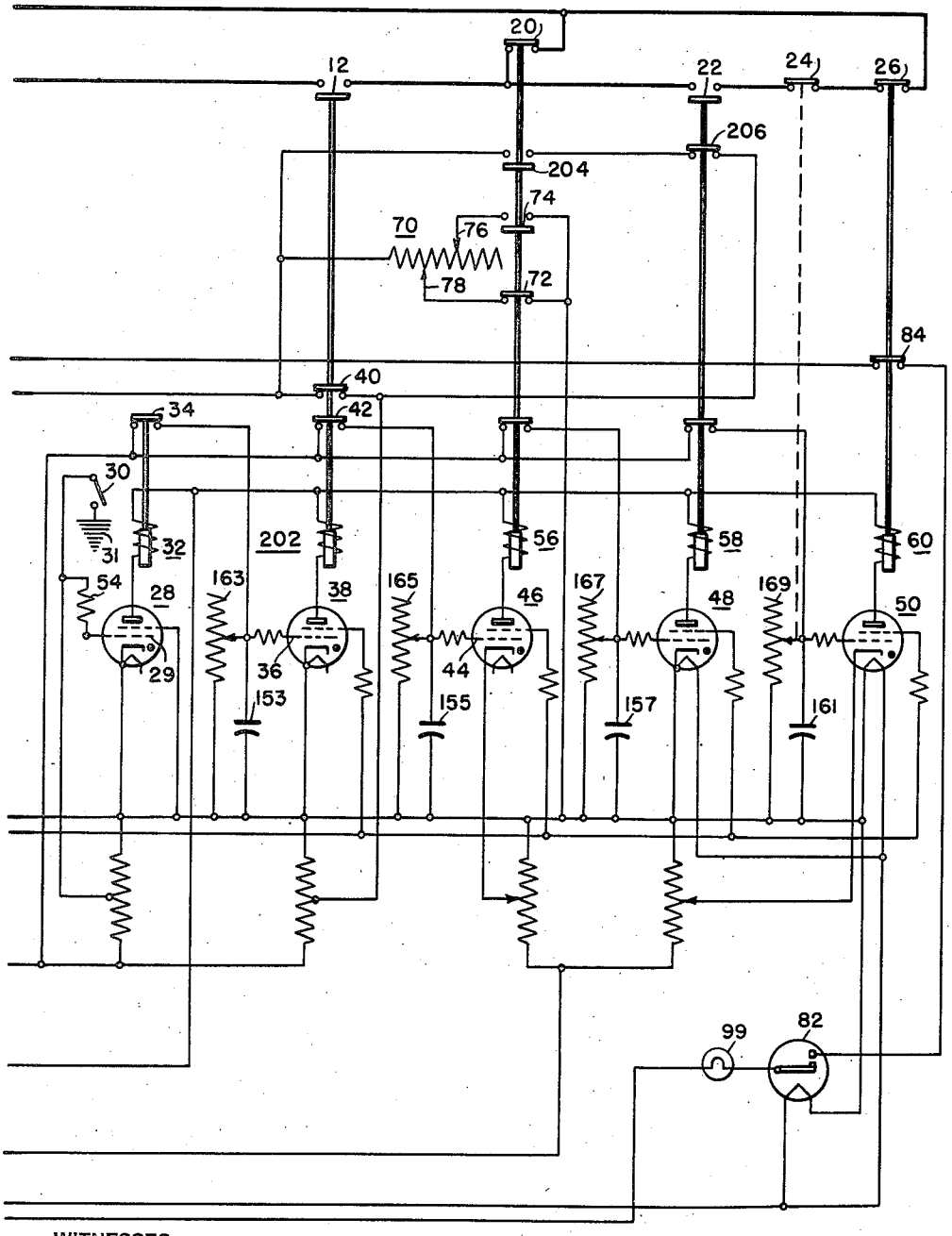
Fig.1B.



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X-RAY APPARATUS

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12 Claims. (Cl. 250—66)

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Our invention relates to X-ray apparatus, and more particularly to X-ray apparatus for use in angiocardiography.

In medical studies of the heart, known as the science of angiocardiography, a material opaque to X-radiation is injected into the veins of a patient and photographs are taken of the patient's heart by means of X-rays, as the opaque material passes through the heart. For some purposes, it is desirable that repeated pictures be taken at equal time intervals. For other purposes, it is desirable that repeated pictures be taken with the heart in the same position. For these latter purposes it is desirable that the photographing process begin at the time that the opaque material first enters an auricle of the heart, that it continue during the time that the opaque material is in that auricle, and cease when the opaque material leaves that auricle. While some types of apparatus have been devised whereby pictures are taken in coordination with the heart beats so that successive pictures are taken while the heart is in the same position, there has been no apparatus built, to our knowledge, that will ensure that the X-ray film will be exposed only while the opaque material is in the heart.

It is, therefore, an object of our invention to provide X-ray apparatus for use in angiocardiography wherein the photographic process is so controlled that the taking of pictures will begin as soon as the opaque material enters an auricle of the heart, and stopped as soon as the opaque material leaves that auricle.

It is an ancillary object of our invention to provide a control circuit for an X-ray apparatus whereby exposures may be made at predetermined repetition rates for predetermined intervals of time, which intervals are separated by other predetermined intervals of time.

Another object of our invention is to provide a circuit whereby the output from an electrocardiograph is applied to an X-ray control apparatus at predetermined intervals of time.

An ancillary object of our invention is to provide X-ray apparatus for angiocardiography wherein the apparatus must be manually reset for each successive cycle of operation.

Another object of our invention is to provide X-ray apparatus for use in angiocardiography wherein X-ray exposures are made, responsive to signals from an electrocardiograph; or alternatively signals from a camera; or alternatively signals from a multivibrator.

Still another ancillary object of our invention

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is to provide testing means for an angiocardiography sequencing timing control circuit wherein the responses of the control circuit may be viewed visually by an operator so that he may check the timing of the circuit prior to operation of the X-ray apparatus.

In accordance with our invention we provide an angiocardiography sequencing apparatus for the control of an X-ray apparatus. Included in this sequencing apparatus are connections for receiving the output from an electrocardiograph; or alternatively, for receiving the output from a camera control circuit in which an electrical pulse is produced each time a film is in place; or alternatively, a multivibrator circuit for producing periodic electrical pulses. Switches are provided for controlling the contactor, which controls the X-ray tube, responsive to the electrocardiograph, or alternatively to the camera, or alternatively to the multivibrator. A timing circuit is provided comprising a plurality of electric discharge devices, such as thyratron tubes, connected so that the first one is triggered by external means and each succeeding tube is rendered conductive in response to the conduction of the tubes immediately preceding. A time delay is provided between the conduction of each thyratron tube and conduction of the immediately succeeding thyratron tube. The thyratron tubes are connected to a plurality of respective switching means, whereby their outputs cause the operation of the respective switching means. These switching means control the contactor which in turn controls the firing of the X-ray tube.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood when read in connection with the accompanying drawings, in which the Figures 1A and 1B constitute a schematic showing of an apparatus embodying our invention.

Referring now to Fig. 1A, we provide an X-ray tube 2 connected to the secondary winding of a transformer 6. The primary winding of the transformer 6 is connected through a contactor 8 to a suitable source of alternating current, not shown.

A pulse generator selector switch 10 is connected electrically to an electrocardiograph 13, a camera 14, and by means of mechanical and electrical connections, to a multivibrator 16. Connected mechanically to the pulse generator

selector switch 10 is a camera switch 11 for providing a different connection to the camera 14 when the original pulse is received from the camera 14 than when the original pulse is received from the electrocardiograph 13 or the multivibrator 16.

Connected in series with the switch 10 are a plurality of relay actuated switches for determining the periods during which the pulses produced by either the electrocardiograph 13, the camera 14, or the multivibrator 16 are allowed to reach the contactor 8 which controls the X-ray tube 2. These latter relay actuated switches are operated by a series of time delay circuits, with which are associated a plurality of electric discharge devices, such as thyratrons.

A first control thyratron tube 28 is provided with a control grid 29 connected through apparatus 30 to ground at 31. This apparatus 30 may be a switch which the physician pushes at the time that he injects the opaque material into the blood of the patient, or may be a connection of the syringe which will ground that grid to the patient when the syringe discharges the opaque material into the patient's veins. When the grid 29 is grounded, the negative bias which is normally impressed thereon is removed and the first control thyratron 28 is immediately rendered conductive. This starts the operation of the timing cycle.

Connected to the anode circuit of the first thyratron 28 is a relay 32 which operates a normally closed switch 34. When the tube 28 conducts, the switch 34 is opened, disconnecting the negative bias supply from the grid 36. After a predetermined time the negative bias on grid 36 leaks off so as to render the second thyratron 38 conductive. Connected to the output of the second thyratron 38 is a relay which operates three switches, 12, 40 and 42. When the second thyratron 38 conducts and causes the switch 42 to open, the negative bias supply is removed from the control grid 44 of the third thyratron 46, and the negative bias is allowed to leak off, thereby allowing the tube 46 to conduct. This process continues through the fourth and fifth control thyratron tubes 48 and 50.

Connected to the grid of each of the control thyratrons 38, 46, 48, 50, is a condenser 153, 155, 157, 161, and a variable resistance 163, 165, 167, 169. The resistor 163, 165, 167, 169 and the condenser 153, 155, 157, 161 are connected to the control grids of the control thyratrons 38, 46, 48, 50 to provide a time delay circuit so that substantial time is required for the negative bias on the control grid of the respective thyratron tube to leak off. Since the resistances 163, 165, 167, 169 are variable, the period of time between the time of firing of each tube and the time of firing of the succeeding tube, may be adjusted. Thus, when the opaque material is first injected into the patient's body, a substantial time delay is provided before the second control thyratron tube 38 conducts and causes operation of the switch 12. If the apparatus has been properly adjusted this time delay is equal to the period of time which is required for the opaque material to reach the right auricle of the heart. The time between the firing of the second control thyratron 38 and the firing of the third control thyratron 46 is equal to the period of time required for the opaque material to pass through the right auricle. The period of time between the firing of the third control tube 46 and the firing of the fourth control tube 48 is equal to the period of time between

the time when the opaque material leaves the right auricle, and the time it enters the left auricle after traversing the lungs. The period of time between the firing of the fourth control thyratron 48 and the firing of the fifth control thyratron 50 is equal to the length of time during which the opaque material is passing through the left auricle.

Thus, when the second thyratron 38 fires, it operates a relay in its output circuit, closing the switch 12 in the contactor control circuit. This allows the X-ray control contactor to operate and cause the X-ray tube to conduct. The operation of the contactor 8 will continue in response to electric pulses from the electrocardiograph 13, or alternatively the camera 14 or alternatively the multivibrator 16, until the third thyratron 46 fires. When the third thyratron fires it operates a relay 56 which opens the switch 20 in the control circuit of the contactor 8. Thus, when the third thyratron 46 fires, which, if the apparatus has been properly adjusted is at the time that the opaque material leaves the right auricle, the train of pulses entering the contactor is stopped, and will remain stopped until the fourth thyratron 48 fires. When the fourth thyratron 48 fires, which, if the apparatus has been properly adjusted, is at the time that the opaque material reaches the left auricle, the switch 22 is closed by the action of relay 58 and pulses are again allowed to enter contactor 8. When the opaque material leaves the left auricle, the fifth thyratron 50 fires and causes the relay 60 to open the switch 26, thereby preventing pulses from entering the contactor 8.

Since a thyratron once triggered will continue to fire until the anode voltage is removed, each of the tubes, after having once been triggered, continues to fire, and when the fifth thyratron commences firing, all five thyratrons will be firing. Thus, until some external operation is done to remove the anode potential from the thyratrons, the apparatus cannot repeat because the fifth thyratron 50, while firing, causes the relay 60 to keep the switch 26 open. A reset switch 62 is provided in the common anode circuit of the five control thyratrons. When it is desired to prepare the apparatus for another cycle of operation, the switch 62 connected between the anodes of the control thyratrons and their source of anode potential is opened, and then allowed to close. When the reset switch 62 is opened manually by the operator, the anode potential is removed from the control thyratrons and they cease to conduct. When the reset switch 62 is closed again, none of the control thyratrons are firing, and the apparatus is ready to repeat the cycle when it is again triggered by grounding the control grid 29 of the first control thyratron tube 28.

The multivibrator 16 employed in a preferred embodiment of our invention is a double multivibrator comprising three tubes. These tubes are, a master vacuum tube 64 having two anode circuits, namely, an originally non-conducting master circuit comprising an anode 61, a cathode 63 and a grid 68, and an originally conducting master circuit comprising an anode 65, a cathode 69 and a grid 67; a slave vacuum tube 66 having therein two anode circuits, namely, an originally conducting slave circuit comprising an anode 71, a cathode 75, and a grid 73, and an originally non-conducting slave circuit comprising an anode 77, a cathode 81 and a grid 79; and a multivibrator control thyratron tube 83 com-

prising a cathode 85, an anode 87 and a control grid 89. The master, and the slave vacuum tubes 64, 66 of the multivibrator 16 are connected together in such a manner that the two circuits of the master tube 64 have the grid of each connected so as to be responsive to the plate current of the other, and the grid 73 of the originally conducting slave circuit connected so as to be responsive to the current through the originally non-conducting master circuits 61, 63, 68 of the master tube 64. Connected to the originally conducting section 71, 73, 75 of the slave tube 66, so as to be responsive to the current thereof is a first control grid of the multivibrator control thyratron 83. Connected in series with the cathode 85 of this control thyratron 83 is a condenser 91 and a variable resistance 93 in parallel. Connections are also provided between the cathode 85 of the multivibrator control thyratron 83 and the grid 79 of the originally non-conducting slave circuit 77, 79, 81. Connected in the latter circuit so as to be responsive to the current therethrough is a relay 95 and a switch 97 responsive thereto. This switch 97 constitutes the output of the multivibrator 16 for control of the X-ray contactor 8 and the camera.

When the multivibrator control thyratron 83 fires in response to the originally conducting slave circuit 71, 73, 75 becoming non-conductive, the control condenser 91 in series with the cathode 85 of the control thyratron becomes charged. When the control condenser 91 becomes charged, there is no longer sufficient plate voltage on the control thyratron 83, to maintain conduction. At the same time the charge on the condenser 91, which is applied to the grid 79 of the originally non-conducting slave circuit, causes that circuit to become conducting to cause the operation of the multivibrator relay 95. When the charge on the control condenser 91 leaks off through the variable resistance 93 in parallel therewith, the grid 79 of the originally non-conducting slave circuit becomes negative again and that circuit becomes non-conducting. Thus, by adjusting the variable resistance 93, an operator is able to control the length of time the originally non-conducting slave circuit 77, 79, 81 conducts and, thereby to control the length of time the multivibrator relay 95 is activated.

Connected between the grid 68 of the master tube 64 and ground is a variable resistor 70 with two movable contacts 76, 78. Each of these contacts 76, 78 is connected through a respective pulse control switch 74, 72 of relay 56 to ground. Switch 74 is open when switch 72 is closed. The magnitude of the resistance between the grid 68 and ground determines the time constant of the multivibrator. Thus, by changing the setting of the variable resistor 70, the frequency of the pulses produced by the multivibrator may be controlled. The pulse control switches 72 and 74 are operated by the relay 56 in response to firing of the third thyratron 46. Thus, when the apparatus starts to operate, during the period before the third control tube 46 fires, the first pulse control switch 72 is closed and the second pulse control switch 74 is opened. Therefore, the frequency of firing of the multivibrator is determined by the setting of contact 78 on the variable resistor 70. When the third control thyratron tube 46 fires and actuates relay 56, the first switch 72 is opened and the second switch 74 is closed. When the second switch 74 is closed, the time constant of the multivibrator is determined by the position of contact 76. Thus, when the first switch 72 is opened and the second switch 74 is closed in response to the firing of the third thyratron 46, the time constant of the multivibrator 16 is changed and thereby the rate of firing of the multivibrator is changed.

It is, therefore, possible with our apparatus to cause pictures to be taken at one frequency when the opaque material passes through the first auricle of the heart, and to be taken at another frequency when same opaque material passes through the second auricle.

It may be desirable, though not essential, to prevent the multivibrator circuit from operating when the pulse generator selector switch 10 is in the electrocardiograph, or camera, position. For this purpose a multivibrator control switch 200 is provided. This switch has three contact positions and is ganged to the selector switch 10 and connected so that when the selector switch is not in the multivibrator position, the switch 40 on relay 202, which is operated by the second discharge device 38, is shunted. When the selector switch 10 is on the multivibrator position, then switch 40 is effective to remove the negative bias from the grid 68 to start multivibrator operation when relay 202 is operated responsive to conduction of the second discharge device. When the third discharge device 46 conducts, switch 204 on relay 56 closes to shunt switch 40 and stop multivibrator operation. When the fourth discharge device 48 conducts, switch 206 on relay 58 opens to remove the shunt on switch 40, and multivibrator operation again starts.

An electrical connection is provided between the anode 77 of the originally non-conducting slave circuit and a second grid of each of the control thyratrons 38, 46, 48, 50. Thus, when the originally non-conducting slave circuit is conducting and thereby activating the multivibrator relay 95, a negative potential is applied to the second grids of the control thyratrons. The negative potential thus applied to the second grids of the control thyratrons prevents these thyratrons from conducting when the originally non-conducting slave circuit is conducting. We have thus provided a means of preventing any of the control switches 12, 20, 22, 26 from operating while an X-ray photograph is being taken in response to the action of the multivibrator output switch 97.

A time delay device, which may be a thermally actuated device 82, is energized from suitable connections to the power supply. The contacts of this device 82 are connected in series with a lamp 99, a switch 80 and an "on-off" switch, when in the "on" position, to the main power supply. The delay device 82 therefore provides a time delay which begins when power is first applied to the apparatus. Therefore, when the lamp 99 is lighted, it is an indication that the apparatus is in condition for operation.

The switch 84 is actuated by the relay 60 so as to be responsive to the output current of the fifth thyratron 50. Thus, when the fifth thyratron 50 fires, it causes the switch 84 to open which causes the lamp 99 to go out, indicating that the apparatus is not ready for operation. When the reset switch 62 is opened, and the potential is thereby removed from the anodes of the control thyratrons causing them to cease firing, the relay 60 connected to the fifth thyratron 50 is no longer energized and the switch 84 is allowed to close, allowing current to be again supplied to the lamp

99, thereby indicating to an operator that the apparatus is again ready for operation.

The switch 24 is ganged to the variable resistance 169 in the time constant network of the fifth discharge device 59 in a manner such that the switch 24 will be opened when the variable resistance is set to zero. Thus, when there is to be no time interval for the taking of exposures of the second auricle, then the switch 24 is open and the contactor cannot be energized after the third discharge device 46 conducts.

A test circuit is provided for showing to an operator by the flashing of a light, the timing sequence for which the apparatus has been set. The test circuit comprises a lamp 86 connected to one side of the main power supply and connected through a test switch 88 to which is applied the output electric pulses which would normally go to the X-ray contactor 8 if the switch 88 were in the operate position as shown, instead of in the test position. The test switch 88 is ganged with the switch 80 and it follows therefore that when the switch 88 is in the test position, the switch 80 is open, thereby breaking the circuit to the lamp 99.

Since numerous changes may be made in the above-described construction and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. In combination, an X-ray generating apparatus, a multivibrator, a relay connected to said multivibrator so as to be responsive to the current therethrough, a first switch adapted to be operated by said relay, electrical connections between one side of said switch and said apparatus, current supply connections connected to the other side of said switch for supplying current to said switch, a plurality of electric discharge devices so connected that each succeeding discharge device is rendered conductive in response to conduction of the discharge device immediately preceding, a terminal for applying a negative bias potential, connections between the grid of a first of said electric discharge devices and said terminal, said last-mentioned connections including a resistor, connections for grounding said grid so as to cause said first electric discharge device to fire; connections between the output of a second of said plurality of discharge devices and a second relay so that said relay is responsive to the output current of said second discharge device, a switch energized by said second relay, said switch being connected on one side to ground and on the other side through one of a first resistance, or alternatively through a second resistance, to a grid of said multivibrator, whereby said switch is capable of selecting the frequency of operation of said multivibrator.

2. In combination, an X-ray generating apparatus, a multivibrator, a relay connected to said multivibrator so as to be responsive to the current therethrough, a first switch adapted to be operated by said relay, electrical connections between one side of said switch and said apparatus, current supply connections connected to the other side of said switch for supplying current to said switch, a plurality of electric discharge devices so connected that each succeeding discharge device is rendered conductive in response to conduction of the discharge device immediately preceding, a terminal for applying a negative bias potential, connections between the grid of a first of said electric discharge devices and said terminal, said last-mentioned connections including a resistor, connections for grounding said grid so as to cause said first electric discharge device to fire; connections between the output of a second of said plurality of discharge devices and a second relay so that said relay is responsive to the output current of said second discharge device, a switch connected to said second relay so as to operate in response thereto, said switch being connected on one side through a first resistance, or alternatively through a second resistance to ground, and also to a grid of said multivibrator and on the other side to a terminal which is negative with respect to ground, connections for applying a positive potential to the anodes of said electric discharge devices, a reset switch in series with said connections for disconnecting the source of said positive potential from said anodes.

3. In combination, an X-ray generating apparatus, a multivibrator, a relay connected to said multivibrator so as to be responsive to the current therethrough, a first switch adapted to be operated by said relay, electrical connections between one side of said switch and said apparatus, current supply connections connected to the other side of said switch for supplying current to said switch, a plurality of electric discharge devices so connected that each succeeding discharge device is rendered conductive in response to conduction of the discharge device immediately preceding, a terminal for applying a negative bias potential; connections between the grid of a first of said electric discharge device and said terminal, said last-mentioned connections including a resistor, connections for grounding said grid so as to cause said first electric discharge device to fire; connections between the output of a second of said plurality of discharge devices and a second relay so that said relay is responsive to the output current of said second discharge device, a switch connected to said second relay so as to operate in response thereto, said switch being connected on one side through a first resistance, or alternatively through a second resistance to ground, and also to a grid of said multivibrator, connections for supplying a current to the filament of at least one of said discharge device, said last-mentioned connections including apparatus for indicating when a current has flowed through the filament of said last-mentioned discharge device for a predetermined period of time.

4. In combination, an X-ray generating apparatus, a multivibrator, a relay connected to said multivibrator so as to be responsive to the current therethrough, a first switch adapted to be operated by said relay, electrical connections between one side of said switch and said apparatus, current supply connections connected to the other side of said switch for supplying current to said switch, a plurality of electric discharge devices connected together so that each succeeding discharge device is caused to conduct in response to the current flowing through the preceding discharge device, a terminal for applying a negative bias potential, connections between the grid of a first of said electric discharge devices and said terminal, said last-mentioned connections including a resistance, connections for grounding said grid so as to cause said first electric discharge device to become conductive; connections between the output of a

second of said plurality of thyratrons and a second relay so that said relay is responsive to the output current of said second thyratron, a pair of switches connected to said second relay so as to operate in response thereto one of said switches being open when the other is closed, said switches being connected on one side to ground and on the other side through first and second resistances respectively, to a grid of said multivibrator, connections between said grid of said multivibrator to a source of negative potential, whereby said switch is capable of selecting the frequency of operation of said multivibrator, a test light, a switch connected to said test light and connected in the circuit of said first-mentioned connections for allowing the current from said source to pass through said apparatus, or alternatively to pass through said light.

5. In combination, an electrocardiograph, apparatus for producing X-rays, a plurality of electric discharge devices, connections to a first of said electric discharge devices for triggering said first device, connections between said first device and a second of said electric discharge devices for rendering said second device conductive in response to conduction of said first device, said last-mentioned connections including a capacitor and a resistor for effecting a time delay between the firing of said first device and the firing of said second device, switching means connected to said second electric discharge device so as to be responsive thereto, electrical connections between said electrocardiograph and said switching means, electrical connections between said switching means and said apparatus.

6. In combination, an electrocardiograph, apparatus for producing X-rays, a plurality of electric discharge devices, connections to a first of said electric discharge devices for triggering said first device, connections between said first device and a second of said electric discharge devices for triggering said second device, said last-mentioned connections including a capacitor and a resistor for effecting a time delay between the firing of said first device and the firing of said second device, switching means connected to said second electric discharge device so as to be responsive thereto, electrical connections between said electrocardiograph and said switching means, electrical connections between said switching means and said apparatus, said switching means being operable responsive to conduction of said second device so that the circuit through said switching means is closed and current from said electrocardiograph is allowed to flow through said switching means to said apparatus, means for operating said camera in response to an electric current, connections between said switching means and said means for operating said camera so that at least part of the current through said switching means passes through said means for operating said camera.

7. Apparatus as is described in claim 6 wherein a third of said plurality of electric discharge devices is connected to said second device so as to be rendered conductive in response to the conduction of said second device, a second switching means connected to said second device so as to be responsive thereto, said second switching means being connected in the circuit between said electrocardiograph and said apparatus for generating X-rays so that said second switching means opens that circuit when activated by said third electric discharge device.

8. An X-ray apparatus comprising an X-ray generator control contactor, connections for applying a potential to said control contactor so as to activate said contactor, a first switching means, a first time delay circuit connected to said first switching means so as to be responsive thereto, a second switching means connected to said first time delay circuit so as to be responsive to the current therethrough, a second time delay circuit connected to said second switching means so as to be responsive thereto, a third switching means connected to said second time delay circuit so as to be responsive to the current therethrough, a third time delay circuit connected to said third switching means so as to be responsive thereto, a fourth switching means connected to said third time delay circuit so as to be responsive to the current therethrough, a fourth time delay circuit connected to said fourth switching means so as to be responsive to the current therethrough, a fifth switching means connected to said fourth time delay circuit so as to be responsive to the current therethrough, said second switching means being connected to said connections for applying a potential so as to close the circuit of said connections when said second switching means is activated, said third switching means being connected to said connections so as to open the circuit of said connections when said third switching means is activated, said fourth switching means being connected to said connections so as to close the circuit of said connections when said fourth switching means is activated, said fifth switching means being connected to said connections so as to open the circuit of said connections when said fifth switching means is activated.

9. In apparatus of the type wherein an X-ray generator is operated responsive to operation of a contactor having an energizing circuit, and a control circuit controls the condition of said energizing circuit, the combination with said control circuit of a multivibrator, a relay connected to be operated responsive to the action of said multivibrator, a switch controlled by said relay, said switch being connected in series with said contactor energizing circuit, a plurality of electric discharge devices, means for causing said discharge devices to become conductive in succession, a relay associated with each of said discharge devices so as to be operated responsive to conduction of its associated discharge device, a switch controlled by each of said relays, each said switch being connected in series with said contactor energizing circuit, and means for preventing said discharge devices from becoming conductive when said switch which is responsive to the action of said multivibrator is in the closed position.

10. In apparatus of the type wherein an X-ray generator is operated responsive to operation of a contactor having an energizing circuit, and a control circuit controls the condition of said energizing circuit, the combination with said energizing circuit comprising a multivibrator having two predetermined operating frequencies, a switch device to be operated responsive to the action of said multivibrator, said switch device being connected in series with said contactor energizing circuit, a plurality of electric discharge devices, means for causing said discharge devices to become conductive in delayed succession, a switch device associated with each of said discharge devices so as to be operated responsive to a change in the state of conduction of its associated discharge device, each said switch device being con-

nected in series with said contactor energizing circuit, and a further switch device associated with one of said discharge devices and operative to change said multivibrator operating frequency when said discharge device changes its conductive state.

11. In apparatus of the type wherein an X-ray generator is operated responsive to operation of a contactor having an energizing circuit, and a control circuit controls the condition of said energizing circuit, the combination with said energizing circuit comprising a multivibrator, a switch device to be operated responsive to the action of said multivibrator, said switch device being connected in series with said contactor energizing circuit, a plurality of electric discharge devices, means for causing said discharge devices to become conductive in delayed succession, a switch device associated with each of said discharge devices so as to be operated responsive to a change in the state of conduction of its associated discharge device, each said switch device being connected in series with said contactor energizing circuit, and a further switch device associated with each of the first, second and third discharge devices of said succession, said further switch devices being connected to control the starting and stopping of said multivibrator.

12. In apparatus of the type wherein an X-ray generator is operated responsive to operation of a contactor having an energizing circuit, and a control circuit controls the condition of said energizing circuit, the combination with said energizing circuit comprising an electrocardiograph having output terminals connected in series with said contactor energizing circuit, a plurality of electric discharge devices, means for causing said discharge devices to become conductive in delayed succession, a switch device associated with each of said discharge devices so as to be operated responsive to a change in the state of conduction of its associated discharge device, each said switch device being connected in series with said contactor energizing circuit.

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