

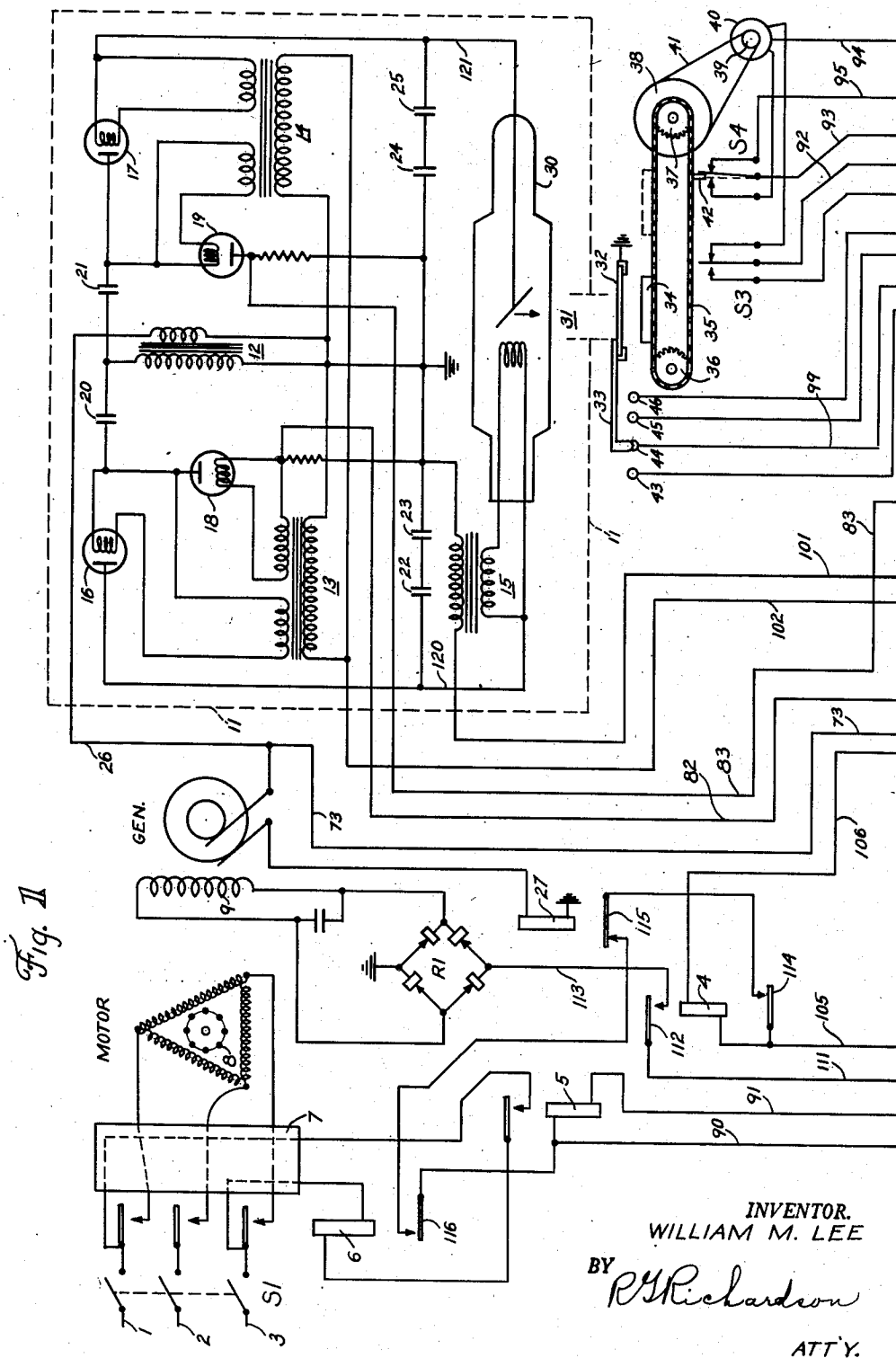
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W. M. LEE
X-RAY APPARATUS

2,659,015

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2 Sheets-Sheet 1



INVENTOR.
WILLIAM M. LEE
BY *R. Richardson*
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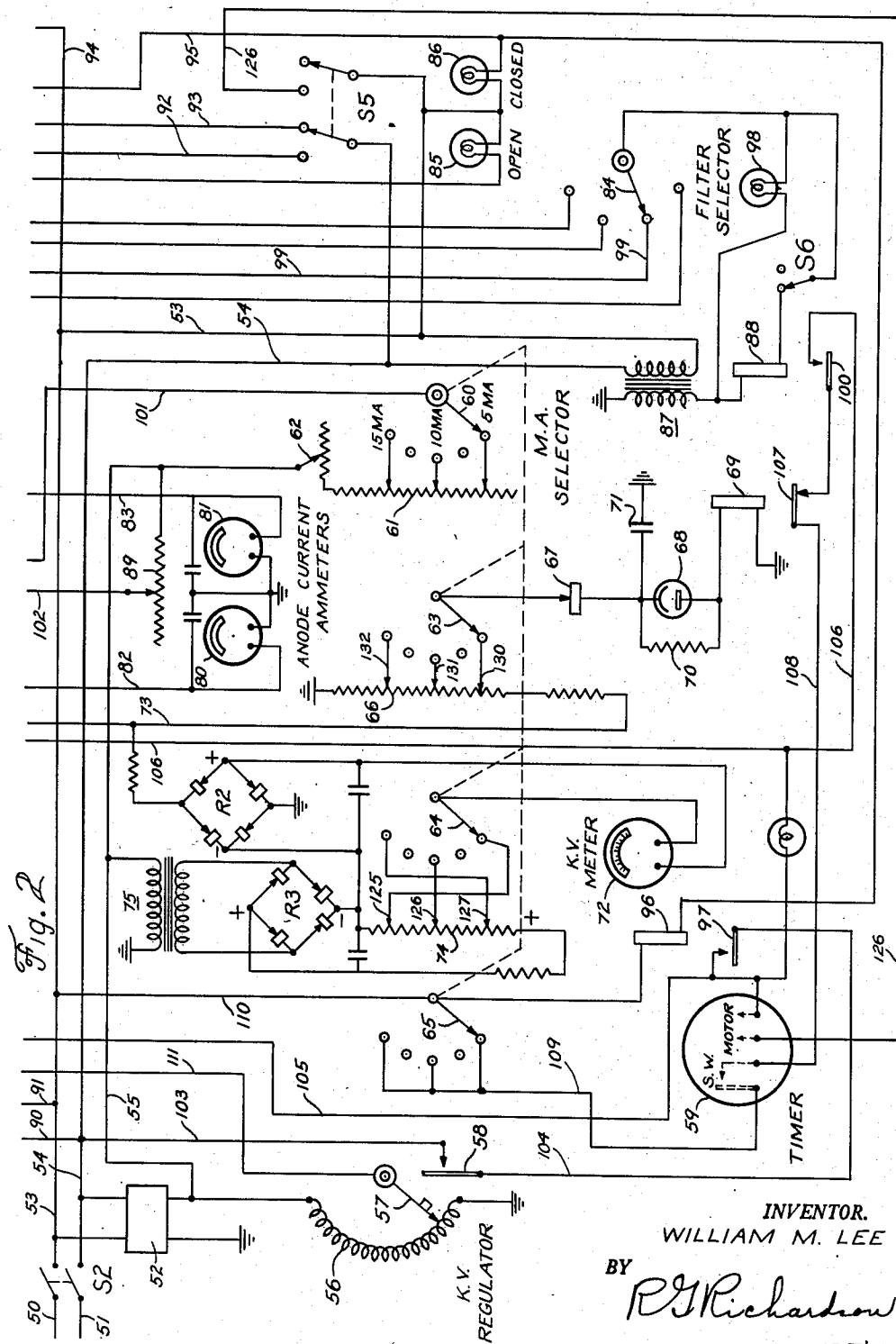
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UNITED STATES PATENT OFFICE

2,659,015

X-RAY APPARATUS

William M. Lee, Delavan, Wis., assignor to The George W. Borg Corporation, Chicago, Ill., a corporation of Delaware

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16 Claims. (Cl. 250-86)

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The present invention relates in general to X-ray apparatus, but more in particular to X-ray apparatus for use in deep therapy; and the object of the invention is the provision of new and improved control circuits for apparatus of this character.

The control circuits are adapted for use with X-ray apparatus in which the X-ray tube, the high tension transformer, and the valves and condensers for the voltage multiplying circuit are installed together in an oil-cooled adjustable head, and in which the primary winding of the transformer is energized by alternating current of rather high frequency, on the order of 2000 cycles per second. The use of 2000 cycle current enables smaller condensers to be used and makes a more compact arrangement in the head. Certain features of the circuits are, however, useful with other types of X-ray apparatus.

A feature of the invention is concerned with the regulation or adjustment of the anode voltage at the X-ray tube and comprises an arrangement whereby a D. C. voltmeter calibrated in kilovolts is connected to the output of the alternator through a rectifier and is caused to show correct readings in kilovolts notwithstanding changes in the load on the tube which take place responsive to adjustment of the milli-ampere selector.

Another feature is an overvoltage protective circuit which responds to a small predetermined rise in the voltage of the alternator.

Still another feature relates to circuit arrangements which make it impossible to start a treatment unless certain necessary preliminary operations are performed in a predetermined order.

The foregoing and other features will be described more in detail hereinafter with reference to the accompanying drawing, comprising Figs. 1 and 2, which show by means of a conventional circuit diagram the apparatus and electrical circuits involved in the invention.

Referring to Fig. 1 of the drawing, the reference characters 1, 2 and 3 indicate a three-phase power line, and S1 is a switch for connecting the line through to the three-phase induction motor 8, also labeled "Motor" in the drawing. The relay 6 and associated parts which are included in the rectangle 7 constitute a motor starting and overload cutout device of known type and construction.

The generator GEN is preferably a single-phase alternator directly coupled to the motor. It may have a frequency of 2000 cycles per second, for example, and a variable output voltage the maximum value of which may be on the order of 250 volts.

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The X-ray tube is indicated at 30 and may be enclosed in an oil cooled housing or head indicated by dotted line rectangle 11. The head 11 also encloses the transformer 15 for supplying filament current to the X-ray tube, the high tension transformer 12 for supplying anode potential to the X-ray tube, and a voltage multiplying circuit comprising the diodes 16-19, the condensers 20-25 and the transformers 13 and 14 for supplying filament current to the diodes. The generator GEN supplies 2000 cycle alternating current to the primary winding of the high tension transformer 12 over a grounded circuit as shown. The reference character 27 indicates an overload circuit breaker which is included in the circuit.

The opening or outlet in the housing 11 through which the X-rays are projected is indicated diagrammatically at 31. The filter 32 and the shutter 34 are located in front of this opening.

The shutter 34 may be of any suitable type, of which several are known. As indicated in the drawing, it comprises a thick lead plate 34 which is slidable on supports (not shown) through the medium of a chain such as 35. This chain passes over sprockets such as 36 and 37, the latter of which may be driven by an electric motor 40 to which it is coupled by the pulleys 38 and 39 and the belt 41. The shutter is shown in closed position in the drawing, that is, the lead plate 34 is interposed in front of the outlet 31. In open position, the lead plate is at the right, where it is indicated by dotted lines. The motor 40 is a reversible motor and affords means for opening or closing the shutter at will.

The switches S3 and S4 are associated with the shutter and are operated by an actuating member 42 carried on the chain 35. When the shutter is in closed position, as it is shown in the drawing, the switch S4 is held operated by actuating member 42, while switch S3 is in normal or unoperated position. When the shutter is opened, the actuator 42 moves to the left, permitting switch S4 to restore and operating switch S3 as the shutter reaches open position.

The filter 32 is slidable in guides as indicated and may be a sheet of aluminum, for example, or a compound sheet composed of a layer of aluminum and a layer of copper, for example. The filters are interchangeable and a number of them are provided, all different as regards their penetrability by X-rays. Each filter has a contact arm such as 33, and a row of contacts 43-46 is provided in which there is a contact individual to each filter.

Referring to Fig. 2 of the drawing, the conductors 50 and 51 represent a single-phase 60

cycle commercial power line. Switch S2 is the main switch through which 60 cycle current is supplied to the various relays and other pieces of equipment by way of the conductors 53 and 54. The reference character 52 indicates a voltage stabilizer by means of which current at substantially constant voltage may be supplied to certain grounded circuits which include conductor 55.

The K. V. regulator comprises a winding 56 connected between the conductor 55 and a ground and a movable contact arm 57. It is used to regulate the anode voltage at the X-ray tube, as will be described shortly. The switch 58 is closed by the contact arm 57 when it is restored to zero position.

The reference character 59 indicates a timer of known construction. It is adapted to be set by the operator to predetermine the duration of an exposure or treatment.

The reference character 72 indicates a D. C. voltmeter which is connected to the output of the alternator GEN through the rectifier R2 and is calibrated in kilovolts. This voltmeter, referred to as the K. V. meter and so labeled in the drawing, indicates the anode potential at the X-ray tube 30.

The load on the tube is indicated by the two anode current ammeters 80 and 81. These meters are connected to the voltage multiplying circuit over conductors 82 and 83, respectively, and are included in the respective charging circuits of the condensers 20 and 21.

The milli-ampere selector, labeled "M. A. selector" in the drawing, is a manually adjustable rotary switch which is used for regulating the supply of current to the filament circuit of the X-ray tube 30, which is one factor in determining the load on the tube, or the current in the anode circuit. The selector includes a contact arm 60 and may have three working positions or contacts corresponding to loads of 5, 10, and 15 milli-amperes, respectively. These contacts are connected to adjustable taps on the resistor 61. A vernier rheostat 62 is connected in series with the resistor 61.

The contact arms 63, 64, and 65 are mounted on the same shaft with the contact arm 60, so that whenever contact arm 60 is adjusted the other contact arms receive a corresponding adjustment. Each contact arm has three active or working contacts, like contact arm 60.

The contact arm 63 is included in the over-voltage protective circuit, said circuit also including the potentiometer 66, the rectifier 67, voltage regulating tube 68, and the relay 69. The tube 68 may be a Type VR105-30 tube, made by Sylvania Electric Products Co. The tube 68 is shunted by a resistor 70 which is preferably about 47M ohms. The condenser 71 may have a capacity of 1 mf. The operation of the circuit will be explained presently.

The contact arm 64 is operative to select a portion of the winding of the potentiometer 74 for inclusion in the circuit of the K. V. meter 72 in series with the output of rectifier R2. Current is supplied to the potentiometer 74 by means of the transformer 75 and the rectifier R3 and the direction of current flow is such that the voltage developed across the potentiometer opposes the voltage of rectifier R2 in the circuit of the K. V. meter.

The contact arm 65 is included in the circuit of relay 4, Fig. 1, for a purpose to be described hereinafter.

The filter selector switch, labeled "Filter Selector" in the drawing, is a manually operable rotary switch and comprises a contact arm 84 and a plurality of contacts which are connected by individual conductors to the contacts 43-46 Fig. 1.

The switch S5 is a manually operable double pole switch which is provided for the purpose of controlling the shutter 34, Fig. 1. The switch S5 has two positions, corresponding respectively to the open and closed positions of the shutter. The associated signal lamps 85 and 86 are controlled from the shutter and indicate the open or closed position thereof as the case may be.

The operation of the equipment will now be explained, it being assumed for this purpose that the equipment is to be used for administering deep therapy to a patient. The explanation will be confined to the operation of the circuits and apparatus.

The switch S1 is closed to connect up the three-phase power line. The switch may be left in closed position, unless the equipment is to be taken out of service for a period, or in case the power has to be cut off to enable repairs to be made. Closure of switch S1 does not start the motor, since the power circuit is open at contacts of the starting relay 6.

When the main switch S2 is closed, the power line conductors 50 and 51 are connected through to the conductors 53 and 54 and 60 cycle alternating current is supplied to the equipment, thereby energizing certain circuits with results which will be pointed out.

The first operation to which attention may be directed is the energization of relay 5, Fig. 1, which is supplied with current over conductors 90 and 91. Upon energizing, relay 5 closes a circuit for the motor start relay 6. The latter relay accordingly energizes and closes the three-phase power circuit through to the motor 8. The motor accordingly starts to run and drives the generator GEN. The generator has no power output at this time, however, for its field is not supplied with current.

The operator should now see to it that the shutter 34 is closed. Assuming that the shutter is open, switch S5 will be in its left hand position and the signal lamp 85 will be lighted. When the switch is moved to its right hand position, the lamp 85 is extinguished and a circuit is completed for the motor 40 which may be traced from conductor 54 by way of switch S5, conductor 93, switch S4 in normal position, motor 40, and conductor 94 to conductor 53. The motor 40 is accordingly operated to move the shutter 34 to its closed position. The movement of the actuating member 42 which takes place incident to the closing of the shutter restores switch S3, thereby preparing a circuit for driving the motor to open the shutter, and operates switch S4, which opens the motor circuit and stops the motor 40. The operation of switch S4 also closes circuits for lamp 86 and relay 96 which may be traced from conductor 54 by way of switch S5, conductor 93, and switch S4, in operated position, to conductor 95, and thence through lamp 86 and relay 96 in parallel to conductor 53. Lamp 86 indicates that the shutter is now closed. Relay 96, upon energizing, prepares a circuit at contact 97 for energizing relay 4.

The operator may now adjust the filter selector switch to select the filter which is to be used. In this connection it will be understood that the several positions of the contact arm 84 are

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marked by numbers, letters, or other means for identifying the different filters to which they correspond and the selecting operation consists in setting the switch to the position which corresponds to the desired filter. The positions may even be marked with descriptions of the filters, as 2MM. AL, 1MM. AL—1MM. CU, etc.

The second position of the filter selector switch corresponds to the filter 32 and the second position contact of the switch is connected to contact 44, Fig. 1, by means of conductor 99. Assuming that the operator desires to use filter 32, he will set the switch to its second position, where it is shown in the drawing, thereby closing a circuit which includes the grounded filter; contact arm 33 and contact 44, conductor 99, contact arm 84, switch S6 (normally closed), relay 88; and the secondary winding of transformer 87. This is a low voltage circuit, preferably about 6-10 volts, to avoid any danger to the operator when changing filters. Upon energizing, relay 88 closes a point in the circuit of relay 4 at contact 100. The circuit is still open, however, at the timer 59. The lamp 98 has a circuit in parallel with relay 88 and lights at this time to indicate to the operator that the desired filter is in position.

If there is no filter in position on the shutter when the operator sets the filter selecting switch, or if a non-selected filter is in position, the relay 88 will not energize and the lamp 98 will not light. The failure of the lamp to light notifies the operator of the situation and he will insert the correct filter before attempting to proceed further.

The operator may now adjust the milli-ampere selector to preselect the desired value of anode current. Assuming that a current of 5 milliamperes is to be used, the switch is rotated, if necessary, to set the contact arm 60 on the first contact in its bank, labeled 5MA in the drawing. The adjustment of contact arm 60 simultaneously adjusts the contact arms 63, 64, and 65 to corresponding positions. Current is now flowing over a circuit which includes the primary winding of the filament transformer 15, conductor 101, contact arm 60 of the milli-ampere selector, potentiometer 61, vernier rheostat 62, conductor 55, and voltage stabilizer 52. The secondary winding of transformer 15 supplies current to the filament of the X-ray tube at a potential which will produce the emission required for an anode current of 5 milliamperes. It will be understood that the 5MA tap on the potentiometer 61 has been preadjusted to bring about this result and that the other two taps have been preadjusted in accordance with the indicated current values.

The primary windings of the transformers 13 and 14 are supplied with current through the rheostat 89 by way of conductor 102. The secondary windings of these transformers supply current to the filaments of the diodes 16 to 19, inclusive, Fig. 1.

The operator may now set the timer 59 in accordance with the length of the treatment to be administered to the patient. Setting of the timer closes the switch SW, but without immediate result. It closes another point in the circuit of relay 4.

The next operation is the restoration of the K. V. regulator to its zero or normal position, the circuit arrangement being such that this must be done before power can be supplied to the X-ray tube. When the operator restores the

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K. V. regulator to zero, the contact arm 57 closes the switch 58, thereby establishing a circuit for relay 4 which extends from conductor 54 by way of conductor 103, switch 58, conductor 104, contact 97 of relay 96, conductor 105, winding of relay 4, conductor 106, contact 100 of relay 88, contact 107 of relay 69, conductor 108, switch SW in the timer, conductor 109, contact arm 85, and conductor 110 to conductor 53. Upon energizing, relay 4 establishes a locking circuit for itself which extends by way of contact 114, contact 115 of circuit breaker 27, contact 116 of motor start relay 6, and conductor 90 to conductor 54. This locking circuit makes the continued energization of relay 4 independent of switch 58 on the K. V. regulator and contact 97 of relay 96, since the branch 114, 115, 116, and 90 is in parallel with that part of the original energizing circuit which includes 105, 97, 58, and 103.

When the relay 4 energizes it closes a grounded circuit over which alternating current is supplied to the rectifier R1 for energizing the field 9 of the alternator GEN. This grounded circuit includes the rectifier R1, conductor 113, contact 112, conductor 111, and the contact arm 57 of the K. V. regulator. The contact arm 57 having been moved to its zero position, it is in engagement with the grounded end of the resistor and no current flow takes place in the circuit.

The operator will now rotate the contact arm 57 in a clockwise direction, thereby opening switch 58 and including a part of the winding of the resistor 56 in the grounded rectifier circuit. The opening of switch 58 has no effect at this time, since relay 4 is held energized over its locking circuit. But it does insure that whenever relay 4 is deenergized it cannot again be energized except by restoring the K. V. regulator to zero position.

The operation of the K. V. regulator supplies alternating current to rectifier R1, which supplies direct current to the field 9 of the alternator. The alternator voltage builds up quickly and 2000 cycle alternating current is supplied to the primary winding of the high tension transformer 12 in the voltage multiplying circuit. The operation of the latter circuit will not be discussed in detail since it is known and is not involved in the invention. Suffice it to say that the voltage generated in the secondary winding of transformer 12 is multiplied approximately four times and is applied to the anode circuit of the X-ray tube. This circuit includes the conductors 120 and 121, leading to the cathode and anode, respectively, of the X-ray tube.

The alternator also supplies current over conductor 73 to the rectifier R2 and to the potentiometer 66, Fig. 2. The direct current output of the rectifier R2 is connected to the K. V. meter in series with the contact arm 64 and a part of the winding of the potentiometer 74. The potentiometer is supplied with current at this time by the transformer 75 and rectifier R3, and the direction of current flow is such that the upper and lower ends of the potentiometer are negative and positive, respectively. Rectifier R2 having the polarities as shown, it follows that the voltage developed across that portion of the potentiometer which is in series with the K. V. meter will oppose the voltage of the rectifier R2. This opposing voltage is small as compared to the voltage of the alternator. The voltage across the entire potentiometer may be on the order of about 20 volts, for example.

As previously mentioned, the alternator supplies current over conductor 73 to the potentiometer 66, which is connected in parallel with the rectifier R2. There will accordingly be a potential at the tap 130 of the potentiometer which causes an intermittent current flow by way of said tap, the contact arm 63, rectifier 67, resistor 70, and the relay 69 to ground. Due to the high resistance of resistor 70, the relay 69 is not energized. The condenser 71 becomes charged, however, and the tap 130 is so adjusted that the potential at the condenser is only a few volts lower than the breakdown or firing potential of the tube 68. If the breakdown potential is 105 volts, the potential at the condenser may be 100 volts, so that a rise in potential of 5 volts will cause the tube to fire.

It will be seen that the K. V. meter will respond directly to changes in the voltage of the alternator, being connected to the alternator output in the manner explained. The anode voltage at the X-ray tube is a function of the alternator voltage, however, and hence the meter may be calibrated in kilovolts, to show directly the voltage at the tube, or between conductors 120 and 121. The calibration is carried out by known methods which need not be explained herein. In case the calibration is affected subsequently by replacement of parts in the head it can be corrected by adjusting the movable tap 125.

The operator observes the K. V. meter and notes the reading thereof. It may be assumed by way of example that the maximum anode voltage that can be used is 250 kilovolts and that the treatment is to be given at the maximum voltage. The operator accordingly will rotate the contact arm 57 of the K. V. regulator until the K. V. meter indicates 250 kilovolts.

The operator should also observe the anode current ammeters 80 and 81 at this time, to see if the readings correspond to the setting of the milli-ampere selector switch. This switch has been set for 5 milli-amperes and the reading of the K. V. meter will not be correct unless the current actually has this value. If the current is more or less than 5 milli-amperes, therefore, the necessary correction is made by adjusting the rheostat 62.

It may be noted at this point that resetting of the milli-ampere selector at this stage is not permissible. If the operator should forget this, and adjust the selector to some different load than the load for which it was previously set, the movement of contact arm 65 will break the circuit of relay 4. This relay will then deenergize and stop the supply of current to the field of the alternator. The operation can proceed at the new setting but in order to do so the operator has to start over again by restoring the K. V. regulator to zero.

The equipment is now ready, and the next operation is to open the shutter and start the treatment. This is accomplished by moving the switch S5 to its left hand or "Open" position.

The operation of switch S5 opens the circuit for lamp 86 and the relay 96. The lamp is accordingly extinguished and relay 96 is deenergized. Contact 97 of relay 96 is thus opened but relay 4 remains energized over its locking circuit.

The operation of switch S5 also closes a circuit for the motor 40 which can be traced from conductor 54 by way of left hand contact arm of the switch, conductor 92, switch S3, motor 40, and conductor 94 to conductor 53. The motor 40 accordingly starts to run and moves the shutter 34 to its open position, shown in dotted lines

in the drawing. The opening of the shutter is accompanied by the movement of actuator 42, which permits switch S4 to restore and operates switch S3. The latter switch opens the motor circuit to stop the motor and closes a circuit for the lamp 85. The lighting of lamp 85 indicates to the operator that the shutter is open and that the treatment has begun.

The movement of switch S5 to its left hand position also closes a circuit for the motor in the timer 59, said circuit extending from conductor 53 by way of right hand contact arm of switch S5, conductor 126, timer motor to conductor 105, and thence by way of the locking circuit of relay 4 to conductor 54. The timer is now in operation and starts to measure off the time interval for which it has been set.

Upon the expiration of the time interval, the timer opens the switch SW, thereby breaking the circuit of relay 4, Fig. 1. Upon deenergizing, relay 4 breaks its locking circuit at contact 114 and at contact 112 breaks the circuit over which current is supplied to rectifier R1 for energizing the field of the alternator GEN. The generator output then falls to zero and the generation of X-rays ceases.

In case of an emergency occurring during the treatment, the operator can stop the treatment instantly by momentarily opening the switch S6. This switch opens the circuit of relay 88, which falls back and opens the circuit of relay 4. It will be noted that if the relay 4 is deenergized in the course of a treatment, it cannot be energized again without first closing the shutter 34 and energizing relay 96 to prepare the initial energizing circuit of relay 4 by way of switch 53 at the K. V. regulator.

It will be assumed now that another treatment is to be given, with the voltage the same as before, that is, 250 kilovolts, and with an anode current of 10 milli-amperes.

The operator will proceed as before, first moving switch S5 to its right hand position to close the shutter, then adjusting the filter selector, if necessary, resetting the M. A. selector, and setting the timer. The resetting of the M. A. selector moves the contact arm 60 to the contact labeled 10 MA and at the same time the contact arms 63 and 64 are moved to contacts 131 and 126, respectively.

The restoration of the K. V. regulator to zero closes switch 58 to energize relay 4, which locks itself and prepares the circuit for supplying current to the field of the alternator. Rotation of the contact arm 57 of the K. V. regulator closes this circuit, whereupon the alternator builds up voltage promptly and begins to supply current to the X-ray tube. As in the case previously described, the operator will rotate the arm 57 of the K. V. regulator in a clockwise direction, increasing the field current at the alternator until the K. V. meter shows the desired anode voltage, or 250 kilovolts.

The operator can rely on the voltage at the X-ray tube being 250 kilovolts, as indicated by the K. V. meter, notwithstanding the increase in the load from 5 milli-amperes to 10 milli-amperes, because the voltage of the alternator has been increased sufficiently to compensate for the losses resulting from the increase in the load.

Explaining this further, the opposing voltage in the circuit of the K. V. meter is greater now than it was in the former case, due to the movement of contact arm 64 from the contact connected to the tap 125 to the contact connected

to the tap 126, and consequently the voltage of the alternator must be raised to a higher value than before in order to bring the reading of the K. V. meter up to 250 kilovolts. The tap 126 is so adjusted that when the load on the tube is 10 milliamperes the value of the opposing voltage at the tap is sufficient to effect the necessary compensation and make the calibration of the K. V. meter correct for that load.

The tap 127 is adjusted so as to make the necessary compensation for a load of 15 milliamperes.

It will be recalled now that tap 130 on potentiometer 66 is so adjusted that when the load on the X-ray tube is 5 milli-amperes the potential at the condenser 71 is preferably about 100 volts, assuming that the breakdown potential of the tube 68 is 105 volts. When the load is changed to 10 milli-amperes and the anode potential is brought up to 250 kilovolts, the alternator voltage is higher than before, for the reasons explained, which raises the potential at tap 130 close to or above the breakdown potential of tube 68, or 105 volts. However, the contact arm 63 is now in engagement with the contact which is connected to tap 131, which is so adjusted that the voltage at the condenser 71 is still only 100 volts, notwithstanding the increase in the alternator voltage.

The tap 132 is so adjusted that when the milli-ampere selector is adjusted for a current of 15 milliamperes, and the voltage at the tube is brought up to 250 kilovolts, the potential at the condenser 71 will be 100 volts.

The overvoltage protective circuit makes it possible to maintain a close supervision of the equipment when the maximum voltage of 250,000 kilovolts is employed, in spite of the variations in the alternator voltage which are required in order to maintain the tube voltage at the desired value under different load conditions.

In case the voltage at the condenser 71 should rise to a value equal to the breakdown potential of tube 68, the tube will fire and the condenser 71 will discharge through relay 69. Upon energizing, relay 69 breaks the circuit of relay 4 at contact 107 and the latter relay deenergizes to interrupt the supply of field current to the alternator in the manner already explained.

The invention having been described that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

I claim:

1. In combination, an X-ray tube, means including an alternator for supplying power to said tube, a circuit for supplying current to the field of said alternator, a regulator for adjusting the current flow in said circuit to regulate the voltage of said alternator, said regulator including a normally open switch which is closed responsive to an operation of said regulator which would reduce the current flow in said circuit, if current were flowing therein, a control relay for closing said circuit, an initial energizing circuit for said relay including said switch, and a locking circuit for said relay independent of said switch, said locking circuit including contacts closed by said relay on energizing.

2. The combination as claimed in claim 1, including a shutter for the X-ray tube, a relay energized responsive to closure of said shutter, and contacts on said relay which are included in the initial energizing circuit of the control relay in series with the said switch at the regulator.

3. The combination as claimed in claim 1, including a milli-ampere selector switch for controlling the load on said tube, and means for opening the relay locking circuit in response to adjustment of said selector switch to change the load, said means comprising a switch actuated by said selector switch during said adjustment.

4. In combination, an X-ray tube, a relay for controlling the supply of power to the anode circuit of said tube, a milli-ampere selector for controlling the load on said tube, means including a circuit and switch therein for energizing said relay, a locking circuit for maintaining said relay energized independent of said switch, said locking circuit including normally open contacts on said relay, and means for opening said locking circuit to deenergize said relay in response to any change in the setting of said selector switch, said last means comprising a contact arm of said switch and spaced contacts engaged thereby which are included in said locking circuit.

5. In combination, an X-ray tube, a control relay controlling the supply of power to the anode circuit of said tube, a circuit including said relay, a power voltage regulator, a switch actuated responsive to adjustment of said regulator to a starting position to close said circuit and energize said relay, a locking circuit including contacts of said relay to maintain the same energized when said regulator is moved to various working positions to increase the voltage, a timer having a switch and means for opening it after a predetermined time interval, said timer switch being included in said locking circuit, and means for starting said timer.

6. The combination claimed in claim 5, including an emergency switch for opening said locking circuit independent of said timer.

7. The combination claimed in claim 5, including a circuit breaker for opening said locking circuit responsive to an excessive consumption of power by said tube.

8. The combination claimed in claim 5, including a shutter for the X-ray tube, and means for preventing the energization of said relay unless said shutter is closed, said last means comprising a second relay energized by closure of said shutter, and normally open contacts on said second relay connected in the circuit of said first relay.

9. The combination as claimed in claim 5, including a motor for driving the timer, and a circuit for said motor extending through contacts in the locking circuit closed by said relay when energized.

10. In combination, an X-ray tube, a shutter for said tube, a first relay energized responsive to closing said shutter, a filter selector, a second relay energized responsive to placing a selected filter in position adjacent said shutter, a third relay controlling the supply of power to said tube, an initial energizing circuit for said third relay including contacts of said first and second relays in series, and a locking circuit for maintaining said third relay energized when said shutter is open and said first relay is deenergized, said locking circuit including the said contacts on said second relay but not the contacts on said first relay.

11. In combination, an X-ray tube, means including a transformer for supplying a high voltage to the anode circuit of said tube, an alternator for supplying current to the primary winding of said transformer, a rectifier, a direct current voltmeter connected to the output of said alternator through said rectifier, said voltmeter

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being calibrated in kilovolts to indicate the anode voltage at said tube, a milli-ampere selector switch having a contact arm and associated bank of contacts for controlling the load on said tube, a source of direct current supplying a variable voltage in the circuit of said voltmeter in opposition to the voltage supplied by said alternator, means included in said milli-ampere selector switch for changing the value of said variable voltage in accordance with changes in the load, said last means including a second contact arm and associated bank of contacts, and means for regulating the voltage of said alternator.

12. The combination as claimed in claim 11, together with independently adjustable means for changing the value of said variable voltage, said means comprising a potentiometer having adjustable taps which are connected to contacts in the second bank of contacts in said selector switch.

13. In combination, an X-ray tube, means including a transformer for supplying a high voltage to the anode circuit of said tube, an alternator for supplying current to the primary winding of said transformer, a rectifier, a direct current voltmeter connected to the output of said alternator through said rectifier, said voltmeter being calibrated in kilovolts to indicate the anode voltage at said tube, a milli-ampere selector switch for controlling the load on said tube, a source of alternating current differing in frequency from the frequency of said alternator, means including said source and a second rectifier for introducing a variable voltage in the circuit of said voltmeter in opposition to the voltage supplied through the first said rectifier by said alternator, a switch mechanically coupled to said milli-ampere selector switch, means including said second switch for effecting predetermined changes in the value of said variable voltage responsive to the operation of said milli-ampere selector switch to effect changes in the load on said tube, and means for regulating the voltage of said alternator.

14. The combination as claimed in claim 13, wherein the means for effecting predetermined changes in the value of the variable voltage includes a potentiometer and independently adjustable taps which are selectable by the second switch.

15. In combination, an X-ray tube, means including a transformer and a source of alternating current for supplying a high voltage to the anode circuit of said tube, a milli-ampere selector switch for controlling the load on said tube, means for changing the voltage of said source in accordance with changes in the load, a diode space discharge tube having a fixed breakdown

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potential, a protective circuit including a relay connected across said source in series with said discharge tube, said relay having means for controlling the supply of current to the anode circuit of said X-ray tube, a variable resistance in said protective circuit, means including said resistance for regulating the voltage between the cathode and anode of said discharge tube to a selected value which is less than said breakdown potential, switching means responsive to adjustment of said selector switch for maintaining the voltage at said discharge tube substantially constant at said selected value notwithstanding changes in the voltage of said source made pursuant to changes in the load, and connections between said resistance and said switch whereby said switch adjusts the amount of said resistance in said protective circuit to control the voltage at said discharge tube as set forth.

16. In combination, an X-ray tube, means including a transformer and a source of alternating current for supplying a high voltage to the anode circuit of said tube, a milli-ampere selector switch for controlling the load on said tube, means for changing the voltage of said source in accordance with changes in the load, a potentiometer connected across the terminals of said source, said potentiometer having a plurality of adjustable taps, a second switch having bank contacts connected to said taps, respectively, a diode space discharge tube having a fixed breakdown potential, a protective circuit including said switch and said discharge tube connected in series between said potentiometer and one terminal of said source, the voltage at said discharge tube being regulated to a selected value less than said breakdown potential by adjustment of said potentiometer, a mechanical connection to operate said second switch responsive to operation of said milli-ampere selector switch, a relay in said protective circuit energized by breakdown of said discharge tube, and means controlled by said relay to interrupt the supply of current to the anode circuit of said X-ray tube.

WILLIAM M. LEE.

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