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X-RAY INSTALLATION COMPRISING A MOVABLE ANODE X-RAY TUBE

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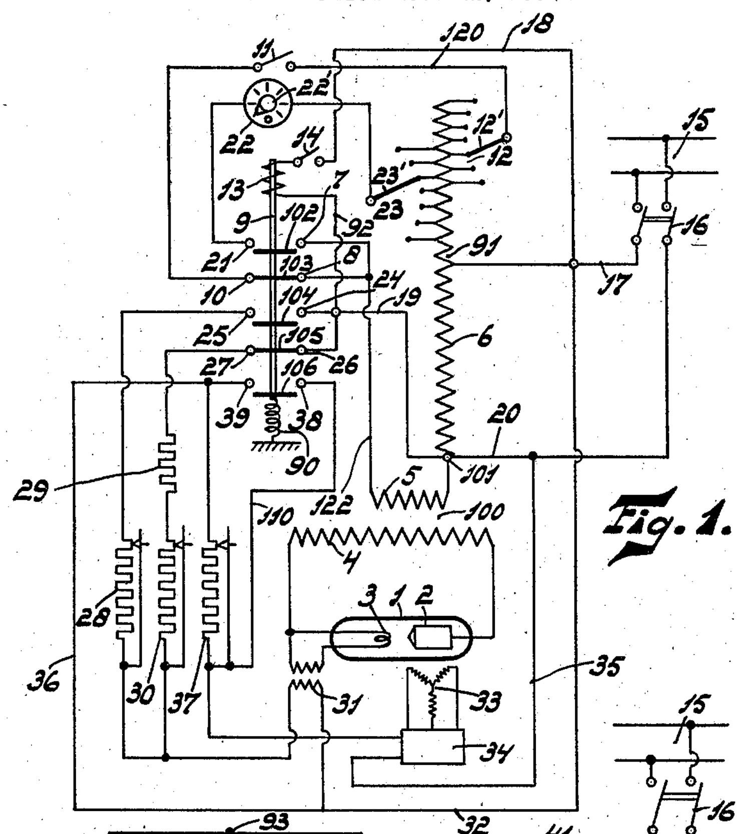

Fig. 1.

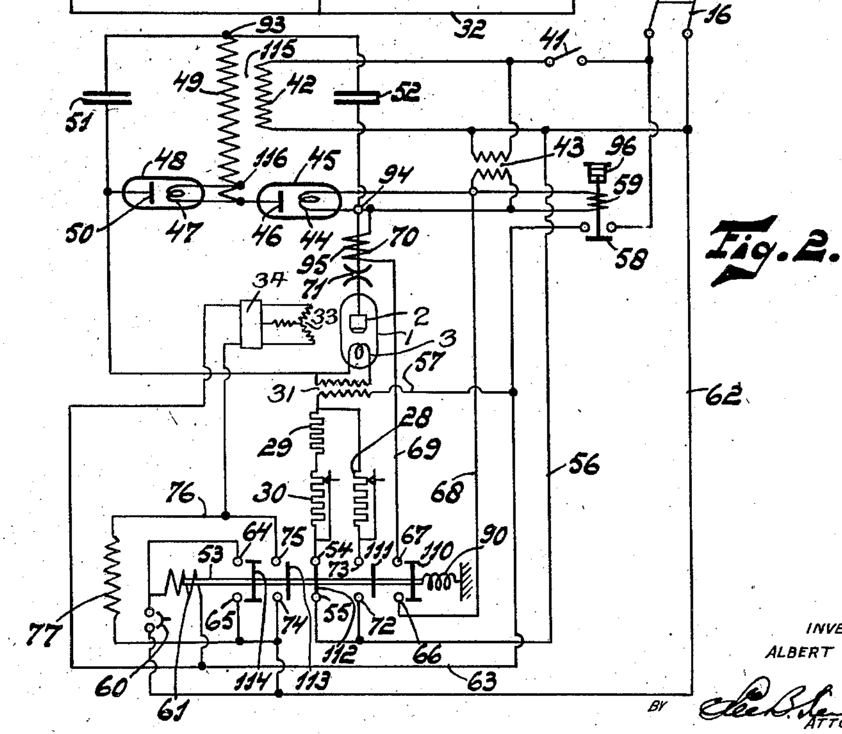

Fig. 2.

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X-RAY INSTALLATION COMPRISING A MOVABLE ANODE X-RAY TUBE

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The present invention relates to an X-ray installation and circuits therefor, which installation comprises an X-ray tube having a movable anode, and to methods of operating such installations.

My invention will be described in connection with a rotating anode type of X-ray tube as described in my U. S. Patent No. 1,893,759, but is not limited thereto.

In X-ray work, especially for taking instantaneous X-ray exposures, it is desirable, prior to taking the exposure, to radioscopically locate the part to be radiographed. In the past, as a rule two individual tubes of different type and capacity were used for such purpose, the one for radioscopy being a small capacity and lower voltage tube, whereas for exposures, a larger capacity, higher-voltage tube was used. For the second tube, especially for taking instantaneous radiographs requiring a very high instantaneous load, rotatable anode tubes were advantageously used.

The present invention relates to an installation in which instead of two separate tubes, a single tube is used for both the radioscopic work and for the exposure, the tube being of the rotatable anode type.

Rotatable anode tubes are comparatively expensive, and because of the high rotating speeds required for their use at the high instantaneous loads, and the difficulty of providing bearings within the high vacuum container of the tube which can stand such speeds, the useful life of such tubes is limited, even if lightly loaded, because of the gradual wearing of the bearings.

Thus, while such a tube could stand the high load required in radioscopic work without injury, even for the prolonged times required for radioscopic work, the corresponding prolonged rotation of the anode would very considerably shorten the life of the tube. Thus, whatever advantage there might be in the use of a single tube instead of two tubes is more than offset by the fact that for radioscopy a considerably more expensive tube than is required for such work is "used up".

I have found that a rotating anode tube can be advantageously used for both radioscopy and radiography without the radioscopic work markedly shortening the life of the tube.

According to the invention, the rotational speed of the anode for radioscopic work is considerably reduced below the value required for exposure work, or the anode may be kept altogether stationary during radioscopy. Simultaneously with the changing of the rotational speed of the anode for radioscopy and for exposure work, the voltage applied to the tube, and the current passing through the tube (the latter for instance by changing of the heating current of the cathode) are simultaneously, preferably automatically, adjusted to meet the requirements of the respective type of work.

While by the proper dimensioning of the target surface, the specific power applied to a stationary target portion during radioscopy will not be excessive, nevertheless I prefer to rotate the anode at a comparatively low speed during the radioscopy, partly to provide a more uniform wearing on the target during the radioscopic work, and partly because, the anode already having a slow rotation, it is possible to switch over from radioscopic work to exposure work without much time delay. As such small rotating speeds do not markedly affect the bearings, the rotation of the anode during radioscopy does not markedly shorten the life of the tube. For instance, while in exposure work with say 10 kw. the anode may have a speed of 2500 to 3000 R. P. M. and for very high loads e. g. with 20 kw. a speed of even 5000 to 6000 R. P. M., during radioscopy with 250 watts for example a very low speed may be used, for instance 100 to 200 R. P. M. or even less.

In practicing my invention, as will be shown in some examples hereafter described, the adjustments of the operating voltage, of the operating current (for instance by means of the heating current), and of the speed of rotation, are done simultaneously and automatically (or semi-automatically) so that the establishing of the proper operating conditions for either radioscopy or for taking the exposures are obtained by the operation of a single switch or button. The varying adjustments are thereby preferably effected by a single multiple contact switching device having two positions, one for radioscopy and the other for radiography.

The variations in the speed of rotation of the anode may be effected in various manners, for instance the stator may be supplied with different voltages or the frequency of the alternating current supplied to the stator may be changed. A simple manner of changing the speed is by means of an impedance in the circuit of the stator current, which, for radioscopy, sufficiently reduces the current and thus the torque, as to rotate the anode at the desired low speed. This impedance can be then short-circuited for exposure work, permitting the anode to rotate at its high speed.

Various other novel features of my invention will appear as the specification progresses:

In order that my invention may be clearly understood and readily carried into effect, I shall describe same more fully with reference to the accompanying drawing, in which:

Figure 1 is a schematic wiring diagram in which the operating voltage of the X-ray tube is supplied from a transformer.

Fig. 2 is a schematic wiring diagram in which the operating voltage of the X-ray tube is supplied by condensers during the exposure.

Referring to Figure 1, the X-ray tube 1 has its rotary anode 2 and its cathode 3 connected respectively to the two ends of the secondary winding 4 of a high-tension transformer 100 having a primary winding 5, and the cathode 3 is also connected across the secondary winding of a heating transformer 31.

To establish the necessary circuits for the operating current and the heating current of the X-ray tube, and for the rotation of the anode, for the conditions required for radioscopy and for taking the exposure respectively, there is provided a two-position multiple contact switch 9, which is spring-biased in its lower position by spring 99 and electromagnetically raised into its upper position by actuating coil 13 which acts on a plunger rod.

As shown in the drawing, the plunger rod of the switch 9 is provided with five contact arms 102, 103, 104, 105 and 106, insulated from each other and adapted to connect contact pairs 7—21, 8—10, 24—25, 26—27 and 38—39 respectively. When the switch is in its lower position, which is the position for radioscopy, the contact arms 103 and 105 bridge their respective contact pairs and the remaining contact arms are open, whereas when the switch 9 is in its upper position, which is the position for taking the exposure, the contact arms 102, 104 and 106 bridge their respective contact pairs and the arms 103 and 105 are open.

For rotating the anode 2, a three-phase stator 33 is provided, and for supplying a three-phase current to the stator from a single-phase supply 15, a current supply device 34 is provided, which device may be a transformer or a frequency alternator; such constructions being well known need not be shown in detail.

To use the X-ray tube for radioscopy, the switch 16 is first closed, which causes the anode to rotate by energizing the device 34 from the supply 15 through a circuit including the conductors 17, 32 and 36, adjustable resistance 37, device 34, conductors 35 and 20, back to the other pole of the switch 16. The adjustable resistance 37 can be adjusted so that the anode 2 will rotate at a slow speed during the radioscopy.

The heating of the cathode 3 is effected by energizing the transformer 31 from alternating network 15 through a circuit passing through one pole of switch 16, conductors 20 and 19, contact point 26, contact arm 105, contact point 27, fixed resistance 29, adjustable resistance 30, primary winding of heating transformer 31, and back through conductors 32 and 17 to the other pole of the switch 16. The adjustable resistance 30 regulates the current through the incandescent cathode to the desired value for the radioscopy.

When the anode 2 is thus rotated at a slow speed and the heating current is supplied to the incandescent cathode, the operating voltage required is applied to the tube by energizing the primary winding 5 of high-tension transformer 100 from autotransformer 6, as follows:

The autotransformer 6 is fixedly connected with one of its ends 101 to one end of the winding 5, this junction point being also connected to one pole of the switch 16. The other pole of switch 16 is connected through conductors 17 to a fixed tap 91 of the autotransformer 6. Beyond the tap 91 the autotransformer 6 is provided with a plurality of taps forming two groups, the first group, cooperates with a voltage regulating device 12 having a movable contact arm 12′ by means of which successive taps of the transformer can be connected to a conductor 120. Autotransformer 6 is also provided with additional taps which—possibly together with some of the upper taps also cooperating with arm 12′—cooperate with a contact arm 23′ of a voltage regulator 23.

To energize the winding 5 (the switch 16 having been closed for the rotation of the anode and the heating of the cathode, as well as the energization of the autotransformer 6) a hand switch 11 is closed, establishing the energizing circuit of the winding 5 as follows:

From the energized autotransformer 6 through winding 5, conductor 122, contact 8, contact arm 103, contact 10, closed switch 11, conductor 120, contact arm 12′ and corresponding tap of autotransformer 6. By varying the position of contact arm 12′ a smaller or larger voltage can be applied to the winding 5 and thus a smaller or larger voltage is applied to the X-ray tube.

To use the tube for taking an exposure a hand switch 14 is closed, which energizes the coil 13 of switch 9 through a circuit passing through one pole of switch 16, conductors 20, 19 and 92, coil 13, switch 14, conductors 18 and 17, back to the other pole of switch 16. The switch 9 being thus raised against the tension of spring 99 into its upper position, breaks connections at contact arms 103 and 105 and establishes connections at contact arms 102, 104 and 106.

With the switch 9 in this position the anode 2 is caused to rotate at a higher speed as resistance 37 is short-circuited by contact arm 106 and conductor 110, and thereby the full supply voltage is applied across the device 34.

The heating current is increased through the heating transformer 31 and adjusted to a value suitable for taking the exposure by interrupting its circuit through the higher resistance series combination of fixed resistor 29 and adjustable resistor 30 and establishing its circuit through a lower resistance adjustable resistor 28.

This circuit can be traced as follows: From one pole of switch 16, conductors 20 and 19, contact 24, contact arm 104, contact 25, adjustable resistance 28, primary winding of heating transformer 31, conductors 32 and 17 back to the other side of supply 15. The adjustable resistance 28 serves to adjust the heating current of cathode 3 to its proper value for taking the exposure.

The apparatus is now in condition for taking an exposure as the anode is rotating at a high speed and cathode 3 is being supplied with the proper heating current for this purpose.

The application of the operating voltage of the tube for the exposure is initiated and terminated by a time switch 22, which also regulates the time of exposure.

The energizing circuit of the high voltage transformer winding 5 is established by the actuation of the handle 22′, which in its normal inactive position intercepts this circuit. This energizing circuit can be traced as follows: From end 101 of autotransformer 6 through winding 5, conductor 122, contact 7, contact arm 102, contact 21, time-switch 22, arm 23′ of voltage regulator 23, to the selected tap of autotransformer 6.

Adjustment of device 23 permits decrease or increase of the voltage applied to primary winding 5, and thus across the X-ray tube for the exposure.

At the end of the selected exposure time the time-switch 22, in known manner, interrupts the energizing circuit of primary winding 5, after which by opening switch 14 the apparatus can be returned to its proper condition for radioscopy.

Fig. 2 shows a modification of the arrangement shown in Figure 1, similar parts being designated by similar reference numerals. In the modification of Fig. 2 the operating current of the tube during the exposure is obtained by utilizing the discharge current of previously charged condensers. Also the timing of the exposure is obtained without a time switch.

Similarly to Figure 1, a multiple contact switch 53 is provided to establish the desired circuits for the operating current and heating current of the X-ray tube, and for the rotation of the anode for the conditions required for radioscopy, and for taking the exposure respectively. Switch 53 is a two-position switch, being, as shown, biased in its right-hand position by a tension spring 90 and being moved into its left-hand position by an actuating magnet coil 61, acting on a plunger rod which carries contact arms 110, 111, 112, 113 and 114, which arms are insulated from each other and are adapted to connect contact pairs 66—67, 72—73, 55—54, 74—75, and 65—64 respectively.

When the switch is in its right-hand position, which is the position for radioscopy, contact arm 112 bridges its respective contacts, and all of the other contact arms are open, and when the switch is in its left-hand position, which is the position for taking the exposure, contact arms 110, 111, 113 and 114 bridge their respective contacts, while contact arm 112 is open. The three-phase stator 33 and control device 34 are assumed to be similar to those of Figure 1.

The operating current of the X-ray tube 1 is obtained from the condenser battery consisting of two series-connected condensers 51 and 52. The condensers 51 and 52 are first charged through separate rectifiers 45 and 48 by complementary half-waves of the alternating current supplied from common high-tension transformer 115. The rectifiers 45 and 48 are shown as being cathode rectifier tubes having anodes 46 and 50, and cathodes 44 and 47 respectively. One end of the cathode 3 of X-ray tube 1 is connected to the anode 50 and to one terminal of condenser 51, the other terminal of condenser 51 being connected to the end 93 of secondary winding 49 of high-voltage transformer 115 having a primary winding 42. To the other end of secondary winding 49 is connected the anode 46 and one end of the cathode 47, the other end of cathode 47 being connected to a tap 116 of the winding 49 for the supply of its heating current.

The anode 2 of the X-ray tube 1 is connected through the switch member 71, for example a switch as is described in U. S. Patent 1,946,324, of an electromagnetic switch 95—having an actuating coil 70—to the end 94 of the cathode 44, and also to one terminal of condenser 52. The other terminal of condenser 52 is connected to the end 93 of secondary winding 49. Across the ends of cathode 3 is connected the secondary winding of heating transformer 31.

With the apparatus in the position shown, all of the parts are currentless, and if it is desired to use the tube for radioscopy, first the main switch 16 and then a hand switch 41 are closed. Upon closure of switch 41 the primary winding 42 is energized, as well as the primary winding of transformer 43, from the current supply source 15. The secondary winding of transformer 43 supplies heating current to cathode 44 and also energizes coil 59 of a time delay switch 96. Energization of transformer 115 causes the heating of cathode 47 and also applies across the X-ray tube 1 the operating voltage required for radioscopy, as the switch member 71 is closed due to its coil 70 being de-energized.

The device 34 is only slightly energized as the contact arm 113 is in its open position and the current to the device 34 must pass through an impedance 77, and conductor 62 from the source 15; the other side of device 34 being connected through conductor 63 and closed time contact 58 to the other pole of source 15. Thus the anode 2 rotates at a slow speed during radioscopy, which not only conserves the bearings but also maintains the advantage of anode rotation.

The closure of contact 58 also energizes the heating transformer 31 from the supply source 15 through a circuit passing through one pole of switch 16, contact 58, conductor 57, primary winding of transformer 31, fixed resistance 29, variable resistance 30, contact 54, contact arm 112, contact 55, conductor 56, back to the other pole of switch 16. The variable resistance 30 serves to regulate the heating current of cathode 3 to its proper value required for the radioscopy.

Thus for radioscopy, the anode 2 is rotated at a slow speed, the incandescent cathode 3 is heated to the proper value desired for radioscopy, and the proper operating voltage of the tube is supplied from the secondary winding 49.

To take an exposure a push button 60 is closed, which energizes coil 61 of switch 53 from the supply 15 through the following circuit: Through one pole of switch 16, conductor 62, push button 60, coil 61, conductor 63, closed contact 58, and back through the other pole of switch 16. This causes switch 53 to move against tension of spring 90 into its left-hand position, whereby contact arm 114 shunts push button 60, which retains the coil 61 energized even if the button 60 is released.

With the switch 53 in its left-hand position contact arm 110 bridges contacts 67 and 66 and energizes coil 70 of switch 95 from the secondary winding of transformer 43 through the following circuit: conductor 68, contact 66, contact arm 110, contact 67, conductor 69, coil 70, and back to the other side of the secondary winding of transformer 43.

Opening of switch 71 interrupts the operating circuit of the X-ray tube. Thereby the condensers 51 and 52 are charged up at a rate depending on the constants in their charging circuits and to a voltage approximating the maximum voltage existing at the terminals of the secondary winding 49.

The movement of switch 53 into its left-hand position also removes the resistances 29 and 30 from the energizing circuit of transformer 31 by disconnecting points 55 and 54 due to the opening of contact arm 112, and establishes the energizing circuit of this transformer through resistance 28 by bridging contacts 72 and 73 through contact arm 111. The heating current is thereby increased and can be adjusted to the proper value required for the exposure, by adjusting resistance 28.

The connection through contact arm 110 is established prior to the closure of the heating current circuit through contact arm 111, so that the contact at 71 is interrupted before the contact arm 111 touches contacts 72 and 73. The current through coil 70 must remain flowing during the further movement of switch 53 and for this purpose contact arm 110 is designed to keep contacts 66 and 67 connected. This has been indicated in the drawing by a small line at each end of the contact arm. Contact arm 114 is of the same shape in order to prevent that switch 53 is drawn backward by spring 90 when the push button 60 is released before switch 53 has reached its left-hand position.

The switch 53 is provided with a time delay in its movement from right to left to establish a time interval between the interruption of the energizing circuit of the cathode 3 through contact arm 112 and the re-establishing of this energizing circuit through contact arm 111; thereby the cathode will be permitted to cool down before switch 95 is opened and thus switch 95 will not be required to interrupt a current in the high tension anode circuit.

The closure of contact arm 113 causes the full supply voltage of the network 15 to be applied to the device 34 through the following circuit: Through one pole of switch 16, conductor 62, contact 74, contact arm 113, contact 75, conductor 76, device 34, conductor 63, contact 58, back through the other pole of switch 16. The anode 2 is thus caused to rotate at the desired high speed.

The above establishes the proper conditions for taking the exposure. To take the exposure, switch 41 is opened, which de-energizes transformers 115 and 43. De-energization of transformer 115 interrupts further charging of condensers 51 and 52 and also the heating of cathode 47 of rectifier tube 48. De-energization of transformer 43 causes de-energization of coils 70 and 59 and of the cathode 44 of rectifier tube 45.

The de-energization of the cathodes of rectifiers 45 and 48 interrupts the circuits through same, whereas deenergization of coil 70 permits the closure of contact member 71, thus establishing a discharge circuit for condensers 51 and 52 through the X-ray tube 1.

The de-energization of coil 59 ultimately breaks the circuit of device 34 and the heating circuit of the cathode 3 and thus causing the stoppage of the rotation of the anode after the exposure has been completed.

What I claim is:

1. An X-ray installation comprising an X-ray tube having a movable anode, an electric power supply system for said tube comprising a source of power and adjusting means to adjust the amount of power supplied to the tube, a second electric system for moving said anode comprising control means to control the rate of movement thereof, and means for interlocking said adjusting means and said control means to cause simultaneous operation thereof and to cause the anode to move at a higher rate for a larger amount of power supplied to the tube and to move at a lower rate for a smaller amount of power supplied to the tube.

2. An X-ray installation comprising an X-ray tube having a rotatable anode, an electric power supply system for said tube comprising a source of power and adjusting means to adjust the amount of power supplied to the tube, a second electric system for rotating said anode, comprising control means to control the rotational speed of the anode, and means for interlocking said adjusting means and said control means to cause simultaneous operation thereof and to cause the rotational speed of the anode to be higher for a larger amount of power supplied to the tube and lower for a smaller amount of power supplied to the tube.

3. An X-ray installation comprising an X-ray tube having a rotatable anode, an electric supply system for said tube comprising a source of power and adjusting means to adjust the operating current and operating voltage of the X-ray tube to values suitable for radiography and to values suitable for radioscopy, a second electric system for rotating said anode comprising control means to control the rotational speed of the anode to a high value and to a low value, and switching means connected with said adjusting means and said control means to cause the rotational speed of the anode to have the low value when the operating current and voltage of the X-ray tubes are adjusted to the radioscopic values, and to have the high value when the operating current and voltage of the tube are adjusted to the radiographic values.

4. An X-ray installation comprising an X-ray tube having an incandescible cathode and a rotatable anode, an electric system for rotating said anode comprising an electromagnetic stator and a device for energizing said stator, an electric power supply system for said tube comprising means for energizing said cathode and means for applying an electromotive force across said anode and cathode, and a two-position switching device having a set of contacts for controlling said energizing means and said means for applying electromotive force, and a second set of contacts for controlling said device, said switching device in one position conditioning said electric power supply system for supplying the power required for radioscopic work and conditioning said device to give the rotational speed of said anode a low value, and in its second position conditioning said electric power supply system for supplying the power required for radiographic exposures and conditioning said device to give the rotational speed of the anode a high value.

5. In an X-ray installation for making fluoroscopic examinations and radiographic exposures with a single X-ray tube having a rotatable anode, a two-position switching device for controlling the operating current to the tube and the rotational speed of the anode, said device comprising a set of contacts which when closed conduct current for radioscopic examination and for slowly rotating the anode, and a second set of contacts which when closed conduct current for radiographic exposures and for rapidly rotating the anode, one set of contacts being closed in each position of the device.

6. An X-ray installation comprising an X-ray tube having an incandescible cathode and a rotatable anode, an electric system for supplying power to said tube comprising means for applying an electromotive force across said anode and cathode, and means for energizing said cathode, said energizing means comprising a transformer having a secondary winding connected across said cathode and a primary winding, and an electric circuit including said secondary winding, two re-

sistances, a stator for rotating said anode and a second electric supply system connected therewith to provide for a high speed of rotation and a low speed of rotation of said anode, and a two-position switching device which in one position establishes in said second supply system the conditions for providing the higher speed of rotation and connects one of said resistances in said circuit, and in its other position establishes in said second supply system the conditions for providing for the lower speed of rotation and connects the other of said resistances in said circuit.

7. An X-ray installation comprising an X-ray tube having an incandescible cathode and a rotatable anode, an electric system for supplying power to said X-ray tube including a heating current transformer having a secondary winding connected across said cathode and a primary winding, a second electric system for rotating said anode comprising an electromagnetic stator, leads for supplying electric current to said stator and an impedance in one of said leads, a resistance, a second resistance having a considerably lower value than said first resistance, and a two-position multi-contact switching device, said device in one position connecting said first resistance in series with said primary winding, said device in its other position connecting in place of said first resistance said second resistance in series with said primary winding and short-circuiting said impedance.

8. In an X-ray installation for making radioscopic examinations and radiographic exposures with a single X-ray tube having a rotatable anode, an electric system for rotating said anode comprising an electromagnetic stator, means for supplying power to the stator, and means to automatically change the amount of power supplied to the stator in accordance with the power supplied to the tube so that the anode rotates at about 100 R. P. M. during radioscopy and at several thousand R. P. M. during radiography.

9. In an X-ray installation comprising a rotatable anode X-ray tube, an electric system for rotating said anode comprising an electromagnetic stator, an alternating current supply for said stator to produce a revolving flux and a corresponding rotational speed of said anode, a frequency alternating device connected to said stator for changing the rate of revolution of the flux and the rotational speed of the anode, means to adjust the amount of power supplied to the tube to a low value for radioscopy and to a high value for radiography, and means cooperating with said adjusting means to vary the amount of power supplied to said device to cause the anode to rotate at a high speed during radiography and at a relatively low speed during radioscopy.

10. An X-ray installation comprising an X-ray tube having a movable anode, an electric power supply system for said tube comprising a source of power and adjusting means to adjust the power input to the tube to a high value suitable for radiography and to a low value suitable for fluoroscopy, said low value being less than the permissible input to the tube with said anode stationary, and a second electric system for moving said anode at a high speed during the application of said high input including means to maintain the speed of the anode at a low value during application of the low power input.

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