Sept. 6, 1938. C. T. ULREY 2,129,383

X-RAY SYSTEM FOR TAKING SHORT EXPOSURE X-RAY PHOTOGRAPHS

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Fig. 1.

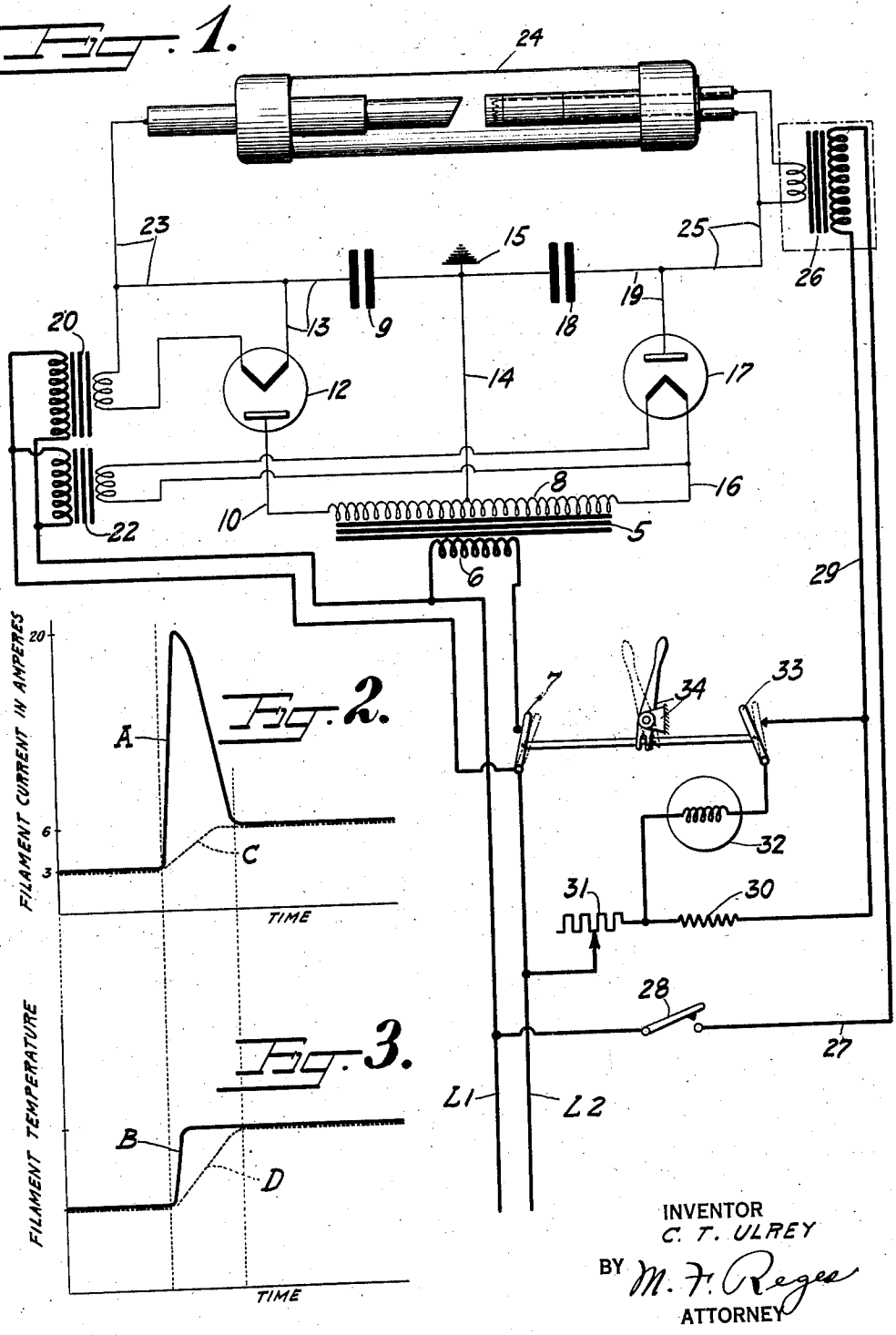

Fig. 2.

Fig. 3.

INVENTOR
C. T. ULREY
BY M. F. Regan
ATTORNEY

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X-RAY SYSTEM FOR TAKING SHORT EXPOSURE X-RAY PHOTOGRAPHS

Clayton Tridle Ulrey, East Orange, N. J., assignor, by mesne assignments, to Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

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9 Claims. (Cl. 250—34)

My invention relates to the method and system for the taking of X-ray photographs in a short interval of time.

In systems of this general type the energy for the X-ray tube is usually taken from an energy storage device, such as a condenser, which is stored with all the energy required for the taking of the radiographic exposure and is suddenly allowed to discharge through the X-ray tube. The utilization of an energy storage means for the X-ray tube excitation has not only the advantage of enabling the exposure to be of extremely short duration, but also the further advantage of not subjecting the supply lines to a heavy load during the exposure. This is obviated by charging the energy storage means over a period of time which is relatively long in comparison with the time of exposure thus preventing heavy surges through the network to the supply lines and affecting other users of the same.

A usual method of causing excitation of the X-ray tube is to maintain the cathode heating temperature below that required for electron emissivity by utilization of a resistance in series with the cathode heating source which is short circuited when it is desired to take a radiographic exposure. Inasmuch as the discharge of the condenser starts and rises to maximum as the cathode heating temperature rises there is not only an appreciable time lapse before the cathode reaches its desired temperature, which is lost from the actual exposure time, but the intensity of the generated X-rays varies with discharge of the condenser. Moreover, in such systems of the prior art the rectified alternating current source is not disconnected from the condenser during the discharge thereof which imposes a sinusoidal ripple upon the X-ray tube excitation energy with a still further variance in the intensity of the X-rays.

It is accordingly an object of my present invention to provide a system for the taking of X-ray photographs in a short interval of time wherein an energy storage device is employed for the X-ray tube excitation energy which is discharged through the X-ray tube by causing substantially an instantaneous rise in the cathode heating temperature.

Another object of my present invention is the provision of an X-ray system for the taking of short exposure X-ray photographs wherein the X-ray tube excitation energy is taken directly from a condenser device and the energization of the tube is controlled by raising the temperature of the cathode to the point of desired emissivity with an absence of appreciable time lag.

Another object of my present invention is the provision of an X-ray system wherein the X-ray tube excitation energy is taken directly from a condenser device, and in which the cathode of the tube is momentarily supplied with heating current in excess of that required for maximum electron emissivity after which it automatically decreases to a constant value, in order to cause substantially an instantaneous rise in cathode heating temperature to the point of desired emissivity with an attendant energization of the X-ray tube.

A further object of my present invention is the provision of an X-ray system wherein the X-ray tube is energized by the discharge of a condenser device which is controlled by raising the temperature of the cathode to the point of desired emissivity with an absence of appreciable time lag, and in which the condenser is disconnected from its charging circuit simultaneously with raising of the cathode heating temperature to prevent a sinusoidal ripple from being imposed upon the X-ray tube excitation energy.

Still further objects of my present invention will become obvious to those skilled in the art by reference to the accompanying drawing wherein

Figure 1 is a diagrammatic illustration of an X-ray system for the taking of short exposure X-ray photographs in accordance with my novel method and showing one form which my invention may take,

Figure 2 is a graphic illustration of the current wave form applied to the cathode, and

Figure 3 graphically illustrates the rise in cathode heating temperature as a result of applying a current to the cathode of the X-ray tube having a wave of the form depicted in Figure 2.

Referring now to the drawing in detail I have shown in Fig. 1 a high tension transformer 5, the primary winding 6 of which, is connected to the usual alternating current source of commercial potential, such as the conductors L1 and L2, through a suitable switch arm 7. The secondary winding 8 of the high tension transformer 5 is adapted to accumulate a charge of high potential electrical energy of one sign only in an energy storage device, such as a condenser 9, by having one of its ends connected, by means of a conductor 10 to the anode of a rectifying valve 12. The cathode of this valve is in turn connected by means of a conductor 13 to one plate of the condenser 9 and the remaining plate of the condenser 9 is connected to the midpoint of the secondary

winding 8 through a conductor 14 which is suitably grounded as at 15.

In a similar manner the remaining end of the secondary winding 8 is connected, by means of a conductor 16, to the cathode of a second rectifying valve tube 17. The anode of this latter valve is in turn connected to a second condenser device 18 through a conductor 19 and the remaining plate of this condenser 18 is likewise connected to the mid-point of the secondary winding 8 by means of the common conductor 14. The cathodes of the rectifying valves 12 and 17 receive heating current from a suitable source, such for example as low tension transformers 20 and 22, the primary windings of which may be connected to the commercial source of supply L1, L2. Accordingly upon the cathodes of these valve tubes being heated to electron emissivity and the switch 7 closed, as hereinafter more fully explained, the condensers 9 and 18 will be charged during alternate half waves of the alternating current cycle with unidirectional high potential energy from the high tension transformer 5, as is well understood in the art. It should also be understood that although I have shown, for the sake of simplicity, half wave rectification for accumulating a charge in a pair of condensers, full wave rectification might just as readily be employed and a single condenser of suitable capacity utilized.

The positive plate of condenser 9 is connected by means of a conductor 23 to the anode terminal of an X-ray tube 24 and in a similar manner the negative plate of condenser 18 is connected, by means of a conductor 25, to the cathode of the X-ray tube 24, thus forming an output or discharge circuit for these condensers which discharge in series through the X-ray tube. The cathode of the X-ray tube receives heating current from a source of electrical energy which includes a low tension transformer 26 of relatively large current capacity in order that current in excess of that required for maximum emissivity of the cathode may be generated.

The primary winding of this transformer 26 has one of its ends connected, by means of a conductor 27 and a suitable switch 28, to one of the supply conductors L1, while its remaining end is connected by means of a conductor 29 through a fixed resistance element 30 and a variable resistance element 31 to the other supply conductor L2. A second resistance element, such as a tungsten filament lamp 32, the ohmic resistance of which varies rapidly with temperature changes, is adapted to be connected in electrical shunt relationship with the resistance element 30 by closure of a suitable switch arm 33. This switch arm 33 is connected, by any suitable actuating mechanism, such as a link bar and lever 34 constituting substantially a unitary double pole switch, with the switch arm 7 in the source of supply for the primary of the transformer 5 in order that upon opening of the switch arm 7 simultaneous closure of the switch arm 33 follows and vice versa.

Upon closure of the switch 28 the variable resistance 31 together with the resistance element 30 limits the current supplied by the source L1, L2, to the primary winding of the transformer 26 which in turn maintains the cathode at a temperature where no appreciable electron emissivity occurs. Moreover, adjustment of the variable resistance 31, while altering the maximum ohmic resistance included in the primary circuit of the transformer 26, nevertheless maintains the current at a value which prevents any appreciable electron emissivity, as previously mentioned, and during excitation of the X-ray tube functions as a timing device as hereinafter more fully explained.

In the operation of my system the switch 28 is closed which energizes the transformer 26 and heats the cathode of the X-ray tube 24 to a comparatively low temperature where no appreciable electron emissivity occurs. The switch mechanism 34, which prior to closure of the switch 28 is in a neutral position with both switch arms 7 and 33 open, is then moved to the left as shown in Fig. 1 to cause closure of the switch arm 7 and a further opening of switch arm 33. The high tension transformer 5 is accordingly energized from the source L1, L2 and a high tension charge of unidirectional energy will be accumulated in the condensers 9 and 18 as before explained, over a period of time which is relatively long in comparison with the time of discharge thus prohibiting heavy surges upon the supply lines L1, L2. This charge may be regulated by means of a suitable auto-transformer (not shown) in the primary circuit of the transformer 5 and is also naturally dependent upon the capacity of the condensers 9 and 18. During the accumulation of this charge any leakage thereof, which would cause energization of the X-ray tube with attendant generation of X-rays, is prevented by the cathode being at a temperature insufficient for appreciable electron emissivity.

Assuming now that the condensers 9 and 18 have been charged and it is desired to take a radiographic exposure the switch 34 is moved to the extreme right, as viewed from Fig. 1, which simultaneously opens the switch arm 7 and closes the switch arm 33 thus connecting the resistance element 32 in shunt relationship with the resistance element 30.

The resistance element 32, having an initial low ohmic resistance due to its inherent characteristics because constructed of tungsten or similar metal, causes a momentary decrease in the ohmic resistance of the fixed resistance element 30, which may also be a tungsten filament lamp similar to the resistance element 32 and having identical characteristics if desired, thus changing the total ohmic resistance in the primary circuit of transformer 26.

Upon this momentary decrease in the total ohmic resistance the heating current supplied to the cathode rises substantially instantaneously during this interval to a value in excess of that required for maximum emissivity of the cathode thus necessitating a heating transformer capable of generating current considerably higher than is usually employed.

This phenomenon may be better appreciated by reference to Fig. 2 wherein for the sake of simplicity the curves shown indicate current values when a direct current is applied to the cathode, and by assuming arbitrary values. It is to be understood, however, that these values may or may not be correct and that if the cathode is heated with alternating current, as shown in Fig. 1, the heating current wave will have a sinusoidal form and there will be a difference in the time interval during the change in cathode heating current from one value to another. Assuming, therefore, that with switch 28 closed and switch arm 33 open the resistance of element 30 equals 100 ohms and that of resistance element 32, at room temperature, is 5 ohms, and the variable resistance element 31 is of such value, re-

gardless of its particular setting, that a maximum of only 3 amperes of heating current is supplied to the cathode which maintains it at a temperature insufficient for electron emissivity.

Accordingly during the time of accumulating a charge in the condensers 9 and 18, where time is represented by the abscissa line in Fig. 2, the cathode heating current will remain at the assumed value, namely 3 amperes, as shown by the line A of Fig. 2 with the ordinate representative of cathode heating current. Upon closure of the switch arm 33 (with simultaneous opening of switch arm 7) the resistance element 32 having an initial ohmic resistance assumed as 5 ohms is connected in a shunt circuit to the resistance element 30 assumed to have an ohmic resistance of 100 ohms.

This causes a momentary decrease in the total ohmic resistance in the primary circuit of the transformer 26 with an attendant increase in cathode heating current in excess of that required for maximum emissivity or approximately 20 amperes. However, the resistance element 32 being of tungsten or similar metal, having an initial low resistance value when cold, changes its ohmic resistance as it becomes heated until it automatically reaches a state of equilibrium with that of resistance element 30 which is still at 100 ohms while that of element 32 has risen from 5 to 50 ohms during this short interval. After the lapse of this momentary decrease of total resistance with attendant increase of current the resistance elements 30 and 32, upon reaching equilibrium nevertheless automatically decrease the total ohmic resistance in the primary circuit below its initial value, with the result that the cathode heating current is raised from 3 amperes, which was insufficient for appreciable electron emissivity, to a constant value of 6 amperes or that desired for the radiographic exposure.

During the interim of the momentary increase of current in excess of that required for maximum emissivity and its automatic decrease to a constant value the temperature of the cathode rises in the manner shown in Fig. 3 wherein the abscissa again represents time in the same manner as in Fig. 1. The ordinate represents cathode heating temperature but no particular temperature value therefor has been assumed. Suffice is to say that the line B indicates the temperature of the cathode which is maintained at that temperature to which 3 amperes of current will raise the same, and upon the aforementioned momentary rise in heating current to a value in excess of that required to produce maximum emissivity, the temperature likewise rises substantially instantaneously to a constant temperature to which 6 amperes of current will raise the cathode. However, while there is a substantially abrupt rise in current from approximately 3 amperes to 20 amperes which automatically falls after the lapse of a brief moment to 6 amperes, and the cathode heating temperature likewise rises abruptly as does the current, to that temperature at which 6 amperes will raise the same, but in a shorter interval of time than it takes for the current to reach its equilibrium value of approximately 6 amperes. However, under certain conditions there may be a slight momentary "overshooting" of the cathode temperature to a value slightly higher than that temperature at which 6 amperes will raise the same, which nevertheless automatically falls to its constant value after the lapse of this brief period of time.

This results in a substantially instantaneous rise in cathode heating temperature with an attendant discharge of the energy accumulated in the condensers through the X-ray tube. As a consequence X-ray exposures of extremely short duration can be taken wherein there is substantially no appreciable time lapse, as in such systems of the prior art, which must be taken from the actual exposure time. In these prior art systems, where a resistance connected in series with the primary of the heating transformer is short circuited, the current supplied thereto rises in the manner designated by the curve C of Fig. 2 and the cathode heating temperature rises in proportion thereto as is shown by the curve D of Fig. 3. This results, as before stated, in a gradual rise in the discharge current through the X-ray tube with the generation of X-rays of varying intensity.

On the other hand by the employment of my novel system the temperature of the cathode is raised substantially instantaneously to the point of desired emissivity and the initial surge of current through the X-ray tube is at its maximum which gradually decreases to its minimum thus generating X-rays having characteristics depending upon the nature of this particular type of discharge. The time required to completely discharge the condensers and consequently energize the X-ray tube may be regulated, as before stated, by the variable resistance element 31. This may be empirically determined and when set for any given exposure need not be further disturbed.

In order to increase the time of exposure this resistance need only be increased which maintains the temperature at one desired emissivity value. Also by decreasing this resistance the temperature of the cathode, following operation of the switch arm 33 with the resulting phenomenon increases the temperature, for example, slightly greater than the assumed 6 amperes thus causing discharge of the condensers in a shorter time than at the temperature resulting from excitation by a current of 6 amperes.

Moreover, by interrupting the source of supply or charging circuit for the condensers 9 and 18 simultaneously with operation of the cathode heating circuit to cause discharge of these condensers with attendant excitation of the X-ray tube, the alternating current source is divorced from the system during the discharge thus preventing a sinusoidal ripple, such as in the pulsating charging circuit from being imposed upon the X-ray tube excitation energy.

It thus becomes obvious to those skilled in the art that I have provided an X-ray system for the taking of short exposure X-ray photographs in which control of the energization of the X-ray tube is accomplished by maintaining the temperature of the cathode below that required for electron emissivity which is raised substantially instantaneously to that necessary for the desired emissivity with an absence of appreciable time lapse.

Although I have shown and described one specific embodiment of my invention I do not desire to be limited thereto as various other modifications may be made without departing from the spirit and scope of the appended claims.

What is claimed:

1. In an X-ray system for taking X-ray photographs in a short interval of time, the combination of means for accumulating a charge of high potential electrical energy, an X-ray tube provided with a thermionic cathode and adapted to be energized by said means, means normally op-

erative to supply heating current to the cathode of said X-ray tube to maintain the same at a temperature insufficient for electron emission to prevent said first mentioned means from energizing said X-ray tube, and means adapted to be connected to said last mentioned means to cause the same to momentarily supply a heating current to said cathode in excess of that required for maximum emissivity and then automatically decrease to a constant value, for the purpose of raising the cathode heating temperature substantially instantaneously to the point of desired electron emissivity and to simultaneously cause energization of said X-ray tube by said first mentioned means.

2. In an X-ray system for taking X-ray photographs in a short interval of time, the combination of energy storage means, a source of rectified alternating current energy for accumulating a charge in said energy storage means, an X-ray tube provided with a thermionic cathode and connected to said energy storage means for energization by the charge accumulated therein, means normally operative to supply heating current to the cathode of said X-ray tube to maintain the same at a temperature insufficient for electron emission to prevent energization of said X-ray tube during the accumulation of the charge in said energy storage means, means adapted to be connected to said last mentioned means to cause the same to momentarily supply a heating current to said cathode in excess of that required for maximum emissivity and then automatically decrease the current to a constant value, for the purpose of causing a substantially instantaneous rise in the cathode heating temperature to the point of desired electron emissivity with an attendant simultaneous energization of said X-ray tube, and means operable to simultaneously render said last mentioned means operable and to interrupt the source of rectified alternating current in order to prevent the same from imposing a sinusoidal wave form upon the X-ray tube excitation energy.

3. In an X-ray system for taking X-ray photographs in a short interval of time the combination of an energy storage means adapted to accumulate a high potential charge of electrical energy, a source of rectified alternating current for charging said energy storage means, a discharge circuit for said energy storage means including an X-ray tube provided with a thermionic cathode, a source of heating current for the cathode of said X-ray tube including means normally operative to maintain said cathode at a temperature below that required for thermionic emission; and means adapted to be connected to said cathode heating source and operable to cause a momentary increase in the current supplied to said cathode in excess of that necessary for maximum emissivity, in order to cause a substantially instantaneous rise in the cathode heating temperature to the point of desired electron emissivity with attendant energization of said X-ray tube by the discharge of said energy storage means.

4. In an X-ray system for taking X-ray photographs in a short interval of time, the combination of energy storage means, a source of pulsating electrical energy for accumulating a charge in said energy storage means, an X-ray tube provided with a thermionic cathode and connected to said energy storage means for energization by the charge accumulated therein, a source of heating current for the cathode of said X-ray tube including a resistance element normally operative to cause the heating current to maintain the cathode at a temperature insufficient for electron emission to prevent energization of said X-ray tube during the accumulation of the charge in said energy storage means; and a resistance element adapted to be connected to said cathode heating source to cause a large momentary variation in the effect of said first mentioned resistance element and an increase in the current supplied to said cathode in excess of that required for maximum emissivity with an automatic decrease of current to a constant value after the lapse of a brief instant, for the purpose of causing a substantially instantaneous rise in cathode heating temperature to the point of desired electron emissivity with an attendant simultaneous energization of said X-ray tube.

5. In an X-ray system for taking X-ray photographs in a short interval of time the combination with an X-ray tube provided with a thermionic cathode and a source of high potential electrical energy for energizing said X-ray tube, of means for controlling the energization of said X-ray tube comprising a source of electrical energy for supplying heating current to the cathode of said tube, a resistance element included in said cathode heating source and normally operative to cause the same to supply a heating current to said cathode and maintain the latter at a temperature insufficient for electron emission; and a second resistance element adapted to be connected to said source having an initial low resistance which rapidly increases upon connection thereof to said cathode heating source, for the purpose of momentarily causing said cathode heating source to supply a current to said cathode in excess of that required for maximum emissivity, and both of said resistance elements reaching a state of equilibrium after the lapse of a brief instant to automatically reduce said current and maintain it at a constant value, in order to cause substantially an instantaneous rise in cathode heating temperature to the point of desired electron emissivity with an attendant energization of said X-ray tube by said high potential source.

6. In an X-ray system for taking X-ray photographs in a short interval of time the combination with an X-ray tube provided with a thermionic cathode and a source of high potential electrical energy for energizing said X-ray tube comprising an energy storage means adapted to accumulate a high potential charge from a source of rectified alternating current, of means for controlling the energization of said X-ray tube comprising a source of electrical energy for supplying heating current to the cathode of said tube, a resistance element included in said source and normally operable to cause the same to supply a heating current to said cathode and maintain the latter at a temperature insufficient for electron emission; a second resistance element adapted to be connected to said cathode heating source having an initial low resistance which rapidly increases upon connection to said source, to momentarily cause said cathode heating source to supply a current to said cathode in excess of that required for maximum emissivity, said second resistance element being adapted to reach a state of equilibrium with said first mentioned resistance upon an increase in its resistance, to automatically reduce said cathode heating current and maintain it at a constant value, in order to cause substantially an instantaneous rise in cathode heating temperature to the point of

desired electron emissivity and a resultant energization of said X-ray tube by said energy storage means; and a switch connected to said cathode heating source and operable to simultaneously connect said second resistance thereto and to render said rectified alternating current source ineffective to accumulate a charge in said energy storage means, to prevent a sinusoidal wave form from being imposed upon the X-ray tube excitation energy supplied by said energy storage means.

7. The method of taking short exposure X-ray photographs in a predetermined short interval of time with an X-ray tube having a thermionic cathode which consists in accumulating a charge of high potential electrical energy of a predetermined maximum value, maintaining the cathode of the X-ray tube at a temperature below that required for thermionic emission to prevent any excitation of the X-ray tube until the accumulated charge has attained its predetermined maximum value, raising the temperature of the cathode of the X-ray tube substantially instantaneously to that required for desired electron emissivity by momentarily supplying the cathode with current in excess of that required for maximum emissivity and then automatically reducing the current to a constant value necessary to maintain the cathode temperature at the desired electron emissivity, in order to cause the accumulated charge to be supplied to the X-ray tube with a rise in current flow therethrough corresponding to the rise in cathode heating temperature, and the initial surge of current to be substantially at its maximum value.

8. The method of taking short exposure photographs in a short interval of time with an X-ray tube having a thermionic cathode which consists in accumulating a charge of high potential electrical energy of a predetermined value, maintaining the cathode of the X-ray tube at a temperature insufficient for electron emission during the period of accumulating the charge, interrupting the accumulation of the charge, and raising the temperature of the cathode of the X-ray tube substantially instantaneously to that required for desired electron emissivity by momentarily supplying the cathode with current in excess of that required for maximum emissivity and automatically reducing the current after the lapse of a brief instant of time and maintaining it a constant value necessary to heat the cathode to the desired electron emissivity, in order to cause energization of the X-ray tube by the accumulated charge.

9. The method of taking short exposure X-ray photographs in a short interval of time with an X-ray tube having a thermionic cathode which consists in accumulating a charge of high potential electrical energy of a predetermined maximum value, maintaining the cathode of the X-ray tube at a temperature below that required for thermionic emission to prevent any excitation of the X-ray tube until the accumulated charge has attained its predetermined maximum value, interrupting the accumulation of the charge and simultaneously raising the temperature of the cathode substantially instantaneously to that required for desired electron emissivity by momentarily supplying the cathode with current in excess of that required for maximum emissivity and then automatically reducing the current to a constant value necessary to maintain the cathode temperature at the desired emissivity, in order to cause the accumulated charge to be supplied to the X-ray tube with a rise in current flow therethrough corresponding to the rise in cathode heating temperature and the initial surge of current to be substantially at its maximum value with an absence of sinusoidal wave form.

CLAYTON TRIDLE ULREY.