May 20, 1947. C. M. SLACK 2,420,844

SHORT EXPOSURE X-RAY APPARATUS

Filed June 15, 1944

Fig. 1.

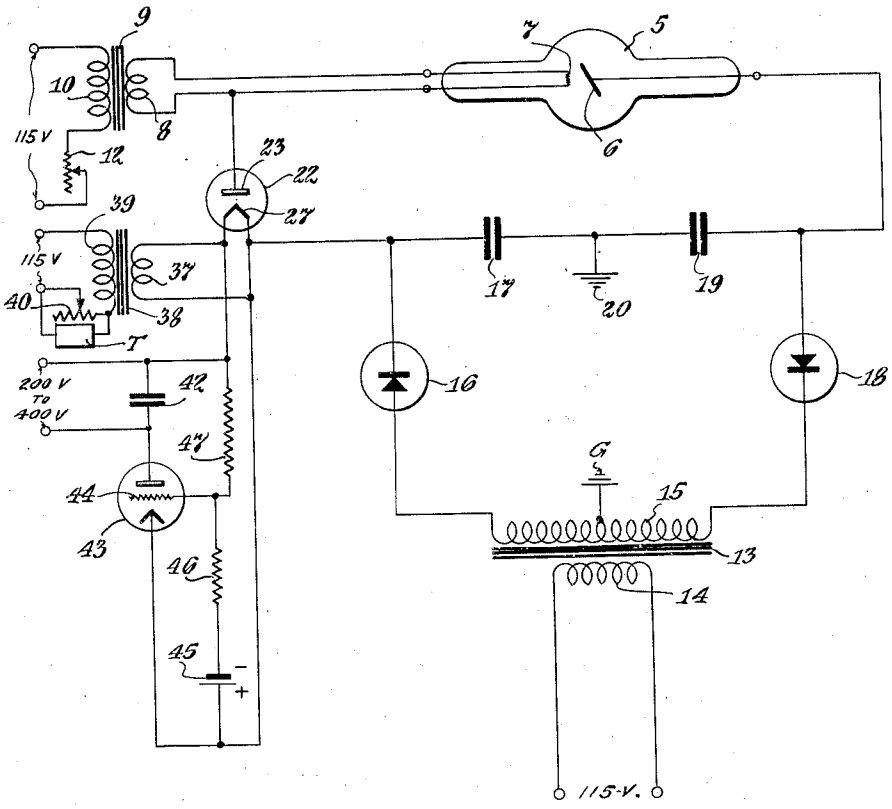


Fig. 2.

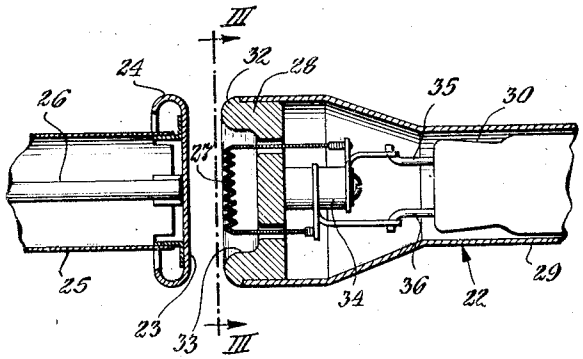
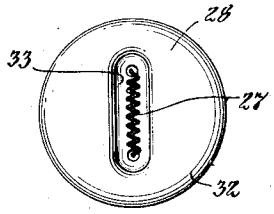


Fig. 3.



INVENTOR
C. M. SLACK.
BY J. W. Mellowes
ATTORNEY

Patented May 20, 1947 2,420,844

UNITED STATES PATENT OFFICE

2,420,844

SHORT EXPOSURE X-RAY APPARATUS

Charles M. Slack, Glen Ridge, N. J., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporatoin of Pennsylvania

Application June 15, 1944, Serial No. 540,382

6 Claims. (Cl. 250—98)

1

The present invention relates to X-ray apparatus and especially to such apparatus for the making of X-ray exposures of short duration.

Apparatus of this general type is now familiar in the art and customarily comprises high voltage condensers which are first charged to the desired high potential. Discharge of these condensers through the X-ray tube is effected either by changing the bias on the grid of a control tube serially connected with the X-ray tube, as shown in Morrison Patent No. 2,101,152, issued December 7, 1937, by charging the condensers until the potential breaks down a spark-gap as shown in Bouwers Patent No. 1,901,865, issued March 21, 1933; or by changing the bias on a grid forming an integral element of the X-ray tube itself, such as shown in Bouwers Patent No. 1,954,612, issued April 10, 1934.

The apparatus of these various types have been subject to certain disadvantages. For example, the employment of a spark-gap produces considerable noise during discharge of the condensers, which has a detrimental psychological effect on a patient. An X-ray tube provided with a control grid not only increases the cost of the tube but should the grid become defective, the entire tube loses its effectiveness. A serially connected control tube of the grid control type is subject to the disadvantage that not only does it require extreme care in manufacturing, but it is bulky and requires a very high wattage to heat the filamentary electrode. Also its complicated structure makes it difficult to avoid high potential gradients, and as a result extensive seasoning is required during fabrication to make the tube capable of withstanding the necessary D. C. voltage to which it must be subjected during operation. Moreover, a complicated and expensive mechanism is required to swing grid from blocking to conducting potential.

It is accordingly the primary object of the present invention to provide an X-ray apparatus which eliminates the objections of prior art types of short exposure X-ray apparatus.

Another object of the present invention is the provision of an X-ray apparatus for the taking of short exposure X-ray photographs wherein energization of the X-ray tube is under the control of a two element tube of simple construction having a low wattage filamentary cathode and in which difficulties of operation due to high voltage gradients is eliminated.

A further object of the present invention is the provision of an X-ray apparatus for the making of short exposure radiographs and wherein very little energy is dissipated in the control tube, thus allowing most of the available energy to be supplied to the X-ray tubes.

2

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

Figure 1 is a schematic diagram of the electrical system of the X-ray apparatus of the present invention;

Figure 2 is a fragmentary cross-sectional view of the control tube forming a part of the X-ray apparatus of the present invention, and

Figure 3 is a cross-sectional view taken on the line III—III of Fig. 2.

Referring now to the drawing in detail, the X-ray apparatus of the present invention is shown as comprising an X-ray tube 5 provided with the customary anode 6 and filamentary cathode 7. The cathode receives heating current from the secondary winding 8 of a low-voltage transformer 9, the primary winding 10 of which is connected, through a variable resistance 12, to a source of supply of the customary domestic potential as noted by the legend 115V.

High voltage electrical energy for the X-ray tube is supplied by a high voltage transformer 13 having its primary winding 14 connected to the customary domestic source of potential. The high voltage secondary winding 15 of this latter transformer is grounded in the center at G and has one end connected through a rectifying valve tube 16 to one plate of a high voltage condenser 17, while the remaining end of this secondary winding is connected through an oppositely connected rectifying valve 18 to one plate of another high voltage condenser 19. The remaining plates of the condensers 17 and 19 are grounded at 20 so that each condenser is charged through its respective rectifying valve during one half-wave of the alternating current cycle to one half the total voltage of the secondary winding 15.

The X-ray tube 5 is in turn connected across the discharge circuit of these condensers 17 and 19 so as to receive the full potential of the energy accumulated in these series connected condensers upon their discharge. Included in the discharge circuit for the condensers and thus in series with the X-ray tube 5 is a control tube in the form of a discharge device 22 which simulates the rectifying valves 16 and 18, but differs therefrom in that it is designed to withstand voltage in the forward direction when the cathode is negative.

By reference more particularly to Figs. 2 and

3, it will be noted that this control device 22 comprises an anode 23 having any desired shape but shown as a disc provided with a rounded edge 24 and supported by a sleeve or collar 25, to which a leading-in conductor 26 is connected. Spaced a short distance from the anode sufficiently to avoid excessive space charge loss is a low wattage filamentary cathode 27 surrounded by a smooth shield 28 for the purpose of eliminating as much as possible voltage difficulties. This shield 28 is supported by a collar or the like 29 clamped to the re-entrant press 30 of the enclosing envelope. As shown, this shield is also provided with a rounded edge 32 similar to that of the anode to avoid local field concentrations and the cathode 27 is disposed in a recess 33 provided in the surface of the shield 28. Immediately in back of the shield 28 and secured thereto is an insulating support 34 to which the ends of the filamentary cathode 27 are connected as are the leading-in conductors 35 and 36 extending through the press 30.

This low wattage filamentary cathode is arranged to receive heating energy from a low voltage secondary winding 37 of a transformer 38 having its primary winding 39 connected, through a variable resistance 40, to the same commercial source of potential as that of the heating transformer 9 for the X-ray tube cathode. Normally the rheostat 40 is set so that a low voltage of approximately 3 volts is supplied to the filamentary cathode 27, which maintains the latter at a temperature where no appreciable electron emission occurs.

For the purpose of energizing the X-ray tube to take a radiograph by discharging of the condensers 17 and 19, a triggering arrangement is provided for rapidly raising the temperature of the cathode 27 of control tube 22. As shown, such arrangement comprises an energy storage means or condenser 42 charged from any suitable D. C. source to a potential which may vary from 200 to 400 volts. Such D. C. source may, for example, comprise a transformer and rectifying circuit similar to that for charging the high voltage condensers 17 and 19. The discharge circuit of the condenser 42 includes the filamentary cathode 27 and a series connected three electrode trigger tube 43 of the thyratron type provided with a control grid 44.

Discharge of the condenser 42 is prevented by the application of a negative bias to the grid 44 from a source, such as a battery 45 and resistance 46, which thus makes the grid more negative than the filament of the trigger tube 43. When it is desired to take a radiograph, a suitable relay or timer T is operated which short-circuits the variable resistance or rheostat 40, thus applying about 10 volts to the filamentary cathode 27. Ordinarily this would require a substantial lapse of time to bring the cathode up to an electron emitting temperature which would be lost from the actual exposure time, as well as the slow heating of cathode 27 causing excessive energy loss in the control tube 22. In accordance with the present invention, however, this increased voltage from the secondary winding 37 is simultaneously applied between the cathode and grid 44 of the trigger tube 43 through a high resistance 47, which thus changes the grid bias to a potential more positive than the cathode. This makes the plate circuit of the tube 43 instantaneously conductive resulting in the discharge of condenser 42 through the filamentary cathode 27 of control tube 22 in about one-thousandth of a second, thus raising the temperature of the latter to a very high value.

When the temperature of the cathode 27 is thus suddenly raised, the energy stored in the high voltage condensers 17 and 19 is then discharged through the X-ray tube energizing the latter for the taking of a radiographic exposure, which may vary in duration from about one-half to one-hundredth of a second. It is to be noted that the sudden raising of the temperature of the low wattage filamentary cathode 27 produces no deleterious effects because of the extremely short period of time of about one-thousandth of a second that the voltage from the condenser 42 is applied thereto. Moreover, a total useful life of only a few hours corresponds to many thousands of radiographic exposures. By suddenly raising the temperature of the cathode 27 very little energy is dissipated in the tube 22, thus allowing practically complete dissipation in the X-ray tube, with avoidance of a steep wave-front in the X-ray tube excitation energy due to a gradual increase in the discharge of the high voltage condensers, despite the sudden discharge of the condenser 42 through the cathode 27, since there is naturally a slight time lag before the cathode 27 reaches full electron emission.

As thus far described, the duration of the exposure has been assumed to be at least no longer than the time required for the condenser 42 to discharge through the filamentary cathode 27, after which the timer T will reduce the cathode heating voltage to approximately 3 volts, allowing the cathode 27 to cool with attendant recharging of condenser 42, as well as the high voltage condensers 17 and 19. There are many occasions, however, when it is desired to take exposures of longer duration of about $\frac{1}{10}$ of a second, which is considerably longer than the discharge time of condenser 42. In these instances once the temperature is initially raised by discharge of condenser 42, the timer T merely maintains the filament heating voltage at that required to heat the filament to an electron emitting temperature, or about 10 volts, until the expiration of the desired exposure period.

Although this is sufficient voltage to make the trigger tube 43 conductive, the condenser 42 no longer influences the cathode 27 once it has discharged its energy because the time required to again recharge condenser 42 is quite long in comparison with its discharge time. The control tube 22 thus remains conductive so long as the voltage applied to the cathode is sufficient to maintain the latter at an electron emitting temperature.

It thus becomes obvious to those skilled in the art that an X-ray apparatus is herein provided for the taking of short exposure radiographs. Moreover, a control tube is utilized, which is of simple and relatively inexpensive construction simulating a conventional high voltage rectifier and wherein substantially no energy is dissipated in the control tube, thus allowing the energy to be supplied to the X-ray tube. By very rapidly raising the temperature of the control tube, a steep wave-front in the X-ray tube excitation energy is avoided, which promotes longevity of the X-ray tube. Also a low wattage filamentary cathode is employed in the control tube, thus greatly contributing to the over-all efficiency of the arrangement without impairment in the useful life of the control tube. A further advantage of the apparatus of the present invention resides in the fact that the X-ray tube is not subjected

to the high voltage until the exposure is actually desired, which thus eliminates the possibility of auto-emission of electrons with undesired generation of incipient X-rays.

Although one specific embodiment of the present invention has been shown and described, it is to be understood that other modifications thereof may be made without departing from the spirit and scope of the appended claims.

I claim:

1. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube to a temperature where no appreciable electron emission occurs, and energy storage means connected to the cathode of said control tube and operable to suddenly and momentarily raise the temperature of said cathode to a value higher than that required for electron emission to cause discharge of said high potential energy storage means and attendant energization of said X-ray tube with substantially no dissipation of energy from said source in said control tube.

2. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube to a temperature where no apperciable electron emission occurs, a condenser connected to the cathode of said control tube and adapted to discharge its energy through said cathode to suddently and momentarily raise the temperature thereof to a value in excess of that required for electron emission to cause discharge of said energy storage means and attendant energization of said X-ray tube with substantially no dissipation of energy from said high voltage source in said control tube, and triggering means operable to cause discharge of said condenser through said control tube cathode when a radiographic exposure is desired.

3. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube

to a temperature where no appreciable electron emission occurs, a condenser connected to the cathode of said control tube and adapted to discharge its energy through said cathode to suddenly and momentarily raise the temperature thereof to a value in excess of that required for electron emission to cause discharge of said energy storage means and attendant energization of said X-ray tube with substantially no dissipation of energy from said high voltage source in said control tube, and triggering means including a thermionic discharge device and operable to cause discharge of said condenser through said control tube cathode when a radiographic exposure is desired.

4. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube to a temperature where no appreciable electron emission occurs, a condenser connected to the cathode of said control tube, a thermionic discharge device connected to said condenser and to said control tube cathode and normally operable to prevent discharge of said condenser, and a switch operable to cause said thermionic discharge device to become ineffective to prevent discharge of said condenser with attendant simultaneous discharge of its accumulated energy through said control tube cathode, to suddenly and momentarily raise the temperature thereof to a value in excess of that required for electron emission to cause discharge of said energy storage means and attendant energization of said X-ray tube with substantially no dissipation of energy from said high voltage source in said control tube.

5. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube to a temperature where no appreciable electron emission occurs, a condenser connected to the cathode of said control tube and adapted to discharge its energy through said cathode to suddenly and momentarily raise the temperature thereof to a value in excess of that required for electron emission to cause discharge of said energy storage means and attendant energization of said X-ray tube with substantially no dissipation of energy from said high voltage source in said control tube, and a triggering arrangement for causing discharge of said condenser comprising a thermionic discharge device interposed between said condenser and said control tube cath-

ode, a source of electrical energy connected to a control electrode of said thermionic discharge device for applying a voltage thereto to render the latter normally non-conductive, and a switch operable to cause an increase in the voltage supplied by said low voltage source of heating energy to said control tube cathode and a simultaneous change in the voltage applied to the control electrode of said thermionic discharge device to cause the latter to become conductive with attendant discharge of said condenser through said control tube cathode when a radiographic exposure is desired.

6. An X-ray apparatus for the taking of short exposure radiographs comprising an X-ray tube, a source of high potential electrical energy including energy storage means for energizing said X-ray tube upon the discharge of the energy accumulated in said energy storage means, a control tube connected in series with said energy storage means and said X-ray tube for controlling the discharge of said energy storage means and provided with a filamentary cathode adapted to be heated to an electron emitting temperature prior to said control tube becoming conductive, a source of low voltage electrical energy for normally heating the cathode of said control tube to a temperature where no appreciable electron emission occurs, a condenser connected to the cathode of said control tube, a thermionic discharge device connected to said condenser and to said control tube cathode and normally operable to prevent discharge of said condenser, and a time switch operable to cause said low voltage heating source to heat said control tube cathode to an electron emitting temperature for a preselected period of time and to simultaneously render said thermionic discharge device ineffective to prevent discharge of said condenser with attendant discharge of its accumulated energy through said control tube cathode to suddenly and momentarily raise the temperature thereof to a value substantially in excess of that attainable from said low voltage source, to cause discharge of said energy storage means and energization of said X-ray tube with substantially no dissipation of energy from said high voltage source in said control tube.

CHARLES M. SLACK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,264,051	Niemann	Nov. 25, 1941
2,222,536	Kuntke	Nov. 19, 1940
2,227,353	Kuntke	Dec. 31, 1940
2,113,696	Kuntke	Apr. 12, 1938