Aug. 18, 1925. 1,550,506

W. D. COOLIDGE

X-RAY APPARATUS AND METHOD

Filed July 9, 1920

Fig. 1.

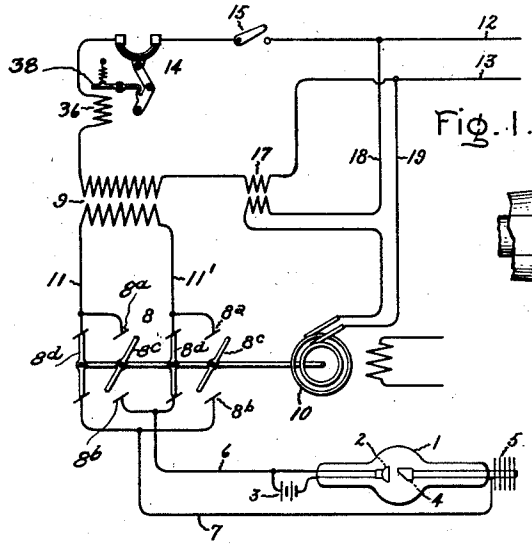


Fig. 3.

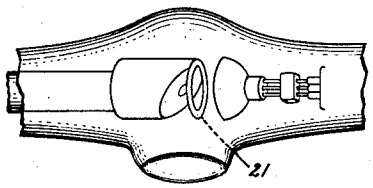


Fig. 4.

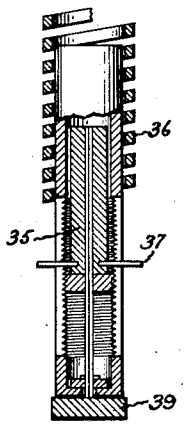
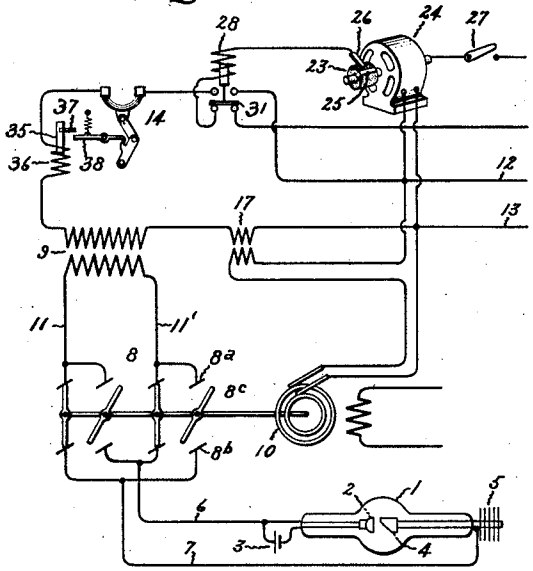


Fig. 2.



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UNITED STATES PATENT OFFICE.

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X-RAY APPARATUS AND METHOD.

Application filed July 9, 1920. Serial No. 395,087.

To all whom it may concern:

Be it known that I, WILLIAM D. COOLIDGE, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in X-Ray Apparatus and Methods, of which the following is a specification.

The present invention relates to the production of X-rays and particularly X-rays for the taking of short exposure radiographs. In order to obtain X-ray pictures of the greatest fidelity of moving objects, such, for example, as the lungs, heart or stomach of a living body, it is desirable to reduce the time of exposure to a short fraction of a second. In the ordinary operation of an X-ray tube the generation of X-rays is not of sufficient intensity to permit of such short exposures.

I have discovered that a sufficiently powerful X-ray discharge may be obtained by applying to the cathode of a tube adapted to independently generate electrons, a voltage which will produce a discharge of sufficient energy to evolve gas or vapor, thereby producing an ionization discharge of materially greater current value than would be obtained without gaseous ionization. This high current discharge may be automatically interrupted at the end of an exposure interval of a fraction of a second. According to one of the novel features of my invention the X-ray producing discharge is interrupted by a circuit breaker and the length of exposure interval is regulated by the inertia of a moving part of the circuit-breaker.

As the focal spot on the anode of the X-ray tube operated in accordance with my invention is heated to a temperature so high that it is capable of itself acting as cathode, and therefore the tube is not capable of acting as a rectifier, I have provided a new system of connections for carrying out my invention, the novel features of which will be hereinafter more fully described and pointed out in the appended claims.

In the appended drawings, Fig. 1 illustrates an apparatus and system of connections for carrying out my invention; Fig. 2 illustrates a modification; Fig. 3 is a detail view showing a modified form of X-ray tube for carrying out my invention; and Fig. 4 illustrates the time regulating mechanism of the circuit breaker.

Referring to Fig. 1, the X-ray tube 1, in connection with which my invention is practiced, may be a hot cathode tube of the Coolidge type containing a cathode 2 adapted to have some part heated independently of the discharge through the tube, for example, by means of a battery 3. The cathode structure has not been shown in detail in the drawing as it is now well understood by those skilled in the art. A tube of the type here shown is described in detail in an article on page 56 of the General Electric Review for January, 1918.

The anode has a discharge receiving tip or head 4 which consists in part at least of metallic tungsten and which is in good thermal relation with an external radiator 5. The terminals of the tube are connected by conductors 6, 7 to a mechanical rectifier 8 which is in turn connected to the secondary winding of a transformer 9. The mechanical rectifier is of a well known type comprising a plurality of stationary contacts 8^a and 8^b adapted to be bridged by rotating contact arms 8^c carried by a synchronous motor 10. For example, in the position of the rectifier shown in the drawing, a complete circuit is established through the tube to the conductors 11, 11′, by the arms 8^d which lead to the transformer by two of the rotating contact arms and when the current reverses the transformer circuit will be established in a reverse direction by the two remaining contact arms 8^c which will then have been brought into conducting relation to the corresponding contacts 8^a and 8^b.

The primary of the transformer 9 is connected to the supply conductors 12, 13, containing a circuit breaker 14 and a manually operated switch 15. The booster transformer 17, the primary of which is connected in circuit with conductor 13, has a secondary winding in series with the supply conductors 18, 19 of the motor 10, which receives current from the main supply conductors 12, 13. When the switch 15 is closed, the motor 10, being in operation, rectified current is applied to the X-ray tube. It is the function of the booster 17 to compensate for the drop in voltage due to the load upon the supply conductors 12,

13, from throwing the synchronous motor 10 out of step when the load comes on the tube which would interfere with the proper action of the mechanical rectifier 8.

The voltage impressed upon the X-ray tube and the setting of the cathode temperature are so chosen with respect to each other that a sufficiently high energy input is received by the tube to produce ionizable vapor which immediately increases the current-carrying capacity of the tube to a materially higher value, that is, produces an arc-like or "run-away" discharge. For example, assuming an X-ray tube to be used which is normally operated with an impressed voltage of about 50,000 volts at a cathode filament temperature causing about thirty milliamperes to flow through the tube, the operation of such an X-ray tube in accordance with my invention occurs as follows:

The filament temperature is chosen somewhat above the normal value by setting the heating current to give about double the normal electron emission and the impressed voltage is raised to about 80,000 or 100,000 volts. The resulting high energy discharge immediately causes the evolution of tungsten vapor at the focal spot and the ionization of this vapor increases the current-carrying capacity of the tube to something like 500 to 1000 milliamperes. A heavy discharge of negative or runaway characteristics consequently occurs with a progressive increase of current. This change in current immediately causes the opening of circuit breaker 14 and the interruption of the supply circuit 12, 13. The energy of this discharge during the short interval the tube is in operation, which may be of the order of 1/10th to 1/60th of a second, is many times the normal rating of the tube. If this high energy discharge were continued for a greater length of time, say for two or three seconds, it would result in the destruction of the X-ray tube.

The circuit breaker 14 acts as a time switch and the length of time of exposure may be regulated by varying the inertia of the circuit breaker. For example, in order to increase the working or time interval of the circuit breaker, the weight of the moving parts of the circuit breaker may be increased; or as shown in Fig. 2, the distance through which the movable core 35 of the circuit breaker travels when attracted by the coil 36 before the circuit breaker is tripped by the contact 37 striking the latch 38 may be adjusted. The structure of this part of the circuit breaker is shown in greater detail in Fig. 4. The armature 35 of the circuit breaker moves up and down within the solenoid winding 36. By turning the thumb screw 39, the solenoid 35 may be raised into the coil 36 so that the dog 37 has a shorter distance to travel before unlatching the circuit breaker.

In some cases it is desirable to provide a ring 21, as shown in Fig. 3, connected to the anode and located between the cathode and anode in a plane at right angles to the discharge to guide the cathode beam to a desired area upon the anode face.

In some cases, particularly when employing very high energy discharges, it is desirable that conduction of current through the X-ray tube should begin at or near the zero point of the half wave of current in order to avoid the deleterious high voltage impulse which occurs when the contact is established at or near the peak of a current wave. To insure the making of contact at or near the zero point of the current wave, I employ a synchronous contact maker 23. The motor 24 driving this switch is driven from the same source of current as the motor 10, for example, by being connected across the supply conductors 12, 13. The revolving contact-making element 23 carried by the synchronous motor 24 contains a conductive segment 25. The brush 26 makes contact with this segment when the contact maker 23 is revolved and the contact segment 25 is so located upon a revolving insulating cylinder that contact is made at or near a zero point of the alternating current in the supply conductors 12, 13. In series with the segment 25 and brush 26, is a suitable source of direct current (not shown); also a manually operated switch 27, and the winding of a trip switch 28. When the synchronous motor 24 is in operation a current is impressed upon the solenoid 28 timed in synchronism with the alternating current in the circuit 12, 13. Assuming the switch 27 to be closed, the electro-magnetic switch 28 operates at or near a zero point of the current wave in the alternating current supply conductors 12, 13, to energize the X-ray tube by the switch 31 closing the circuit of the conductor 12. Current flows through the tube, and immediately builds up to a high value as already described, thereby operating the circuit breaker 14 to open the supply circuit 12, 13 at the end of a desired fraction of a second.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The method of operating an X-ray tube for instantaneous photography which consists in initially producing a thermionic discharge in said tube substantially independently of gas ionization and at a sufficiently high voltage to generate X-rays, the current value of said discharge being so chosen with respect to heat dissipated at the anode that some of the anode material is vaporized thereby producing an increase of current value by the ionization of said vapor and interrupting said discharge at the end of a

predetermined interval which is chosen to prevent destruction of said tube.

2. The method of operating an X-ray tube having an incandescent cathode which consists in starting said tube with a thermionic discharge substantially independently of gas ionization, vaporizing metal by said discharge, thereupon conducting current through said tube by the ionization of said vapor to produce an ionization discharge of progressively increasing current value and interrupting said discharge in response to an increase of current value above a predetermined value.

3. The method of operating an X-ray tube which consists in heating the cathode of said tube to incandescence, initiating from said cathode a thermionic discharge of stable volt-ampere characteristic, producing by said discharge ionizable vapor to cause said thermionic discharge to be converted to an ionization discharge of negative volt-ampere characteristic and automatically interrupting said ionization discharge in response to an increase in current value thereof.

4. An apparatus for making substantially instantaneous X-ray exposures comprising an X-ray tube having a cathode capable of emitting electrons by incandescence, a source of current having a voltage so high that metal is vaporized at the anode of said tube, thereby producing an ionization discharge in said tube of materially higher current value than conditioned by the normal current-carrying capacity of the device, and means for timing the duration of said discharge.

5. An X-ray apparatus comprising the combination of a transformer, an X-ray tube having a cathode adapted to emit electrons independently of the impressed voltage, a synchronous mechanical rectifier connected to deliver rectified current to said X-ray tube, a mechanical circuit breaker having a winding in circuit with the primary of said transformer, and operative to open the supply circuit of said tube, means for varying the time interval required for said circuit breaker to open the circuit, and a source of current for said transformer having a voltage sufficiently high to produce in said X-ray tube an arc-like discharge of higher current value than conditioned by the normal current carrying capacity of said tube.

6. An apparatus for taking substantially instantaneous X-ray pictures comprising an X-ray tube which is operable independently of positive ionization, means for delivering electric energy to said tube at a rate materially in excess of the continuous operating capacity of said tube, and electro-mechanical means for limiting the duration of said discharge, said means being responsive to an increase of operating energy of said tube to a value characteristic of ionization discharge, said means having a regulable time period.

7. An apparatus for taking substantially instantaneous X-ray pictures comprising a source of alternating current, an X-ray tube supplied with energy by said source, means for predetermining the length of the period during which said tube is energized, and means for timing the start of said discharge to occur at substantially zero value of alternating current.

8. The method of generating X-rays of high intensity for a pre-determined short period which consists in producing an electron discharge substantially independent of gas ionization with energy sufficiently high to generate X-rays, volatilizing by said discharge a highly refractory metal, thereby permitting the discharge to attain a high current value by the ionization of the resulting vapor, and interrupting said discharge through the intermediary of the rise of current before injury occurs to said X-ray device.

9. The method of generating X-rays of high intensity for short time radiography in an X-ray device which is evacuated so highly that positive ionization of residual gas is substantially excluded up to a predetermined current value and which is provided with an anode consisting in part at least of refractory metal which consists in producing therein an electron discharge of such high current value that some of said refractory metal is vaporized, thereby producing a rise of current by ionization and interrupting the discharge through the intermediary of said current before said device is injured.

10. An X-ray apparatus for taking short exposure X-ray pictures comprising the combination of an X-ray tube of the Coolidge type, means for supplying said tube with current falling periodically to zero and being at a voltage so high that the energy input so materially exceeds the normal operating capacity of said tube that vaporization of anode material occurs accompanied by positive ionization, means for connecting said tube in circuit with said supply means when the current value is substantially zero, and circuit breaking means operatively connected to deenergize said tube at the end of a predetermined period of a small fraction of a second.

In witness whereof, I have hereunto set my hand this 1st day of July, 1920.

WILLIAM D. COOLIDGE.