W. D. COOLIDGE.

X-RAY APPARATUS.

APPLICATION FILED JULY 15, 1918.

1,328,495. Patented Jan. 20, 1920.

Fig. 1.

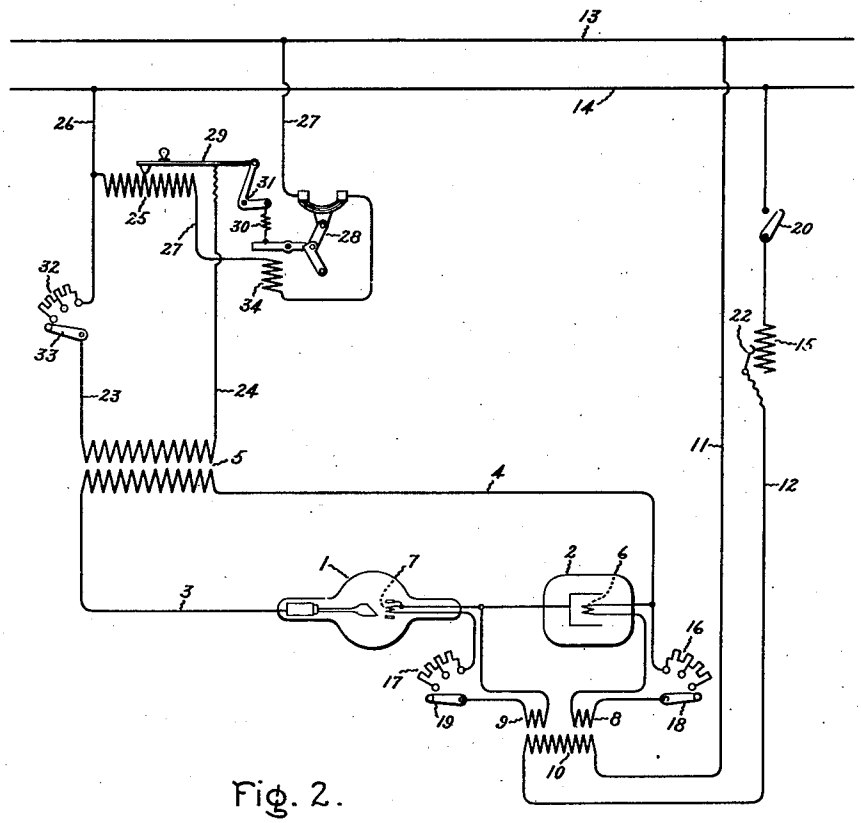
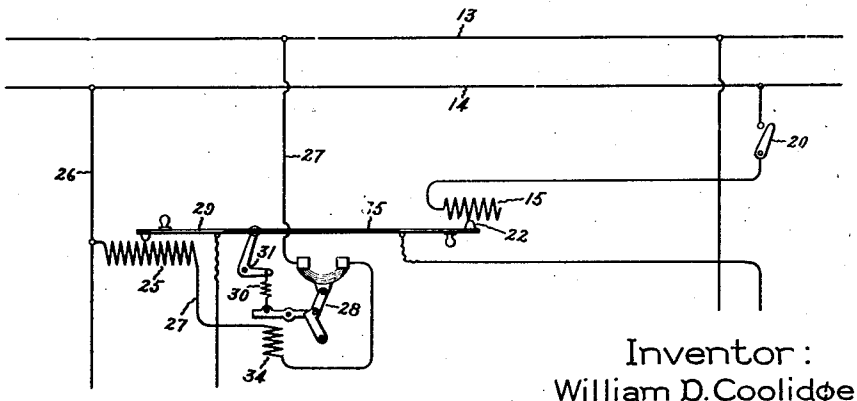


Fig. 2.



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UNITED STATES PATENT OFFICE.

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X-RAY APPARATUS.

1,328,495. Specification of Letters Patent. Patented Jan. 20, 1920.

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To all whom it may concern:

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

The present invention comprises a new X-ray apparatus or system of connections which is free from complicated moving parts and adapted for the varying conditions encountered both in diagnostic X-ray work, requiring high currents and relatively low voltages, and in therapeutic X-ray work requiring materially lower currents, but higher voltages.

It is the object of my invention to provide an apparatus for these purposes which is largely automatic in its operation and which is provided with safety devices for reducing the danger of electric shock to the operator and to the patient.

My invention comprises a combination of an X-ray tube of the incandescent cathode type with an incandescent cathode rectifier, as for example, a kenetron, these two devices being connected in series to a source of alternating current and being provided with automatic devices for preventing the accidental passage of a high current at the upper range of the voltages at which the system is operable.

The novel features of these safety devices will be enumerated with greater particularity in the appended claims, including an arrangement for changing the electron emissivity of the kenetron cathode, coincident with the electron emissivity of the X-ray tube cathode, and switching devices for changing the setting of a circuit breaker simultaneously with the change in the setting of the voltage of the operating current for the X-ray device.

In the accompanying drawings, Figure 1 is a diagram illustrating the preferred form of my invention, and Fig. 2 is a diagram illustrating a modification of the system.

The X-ray tube 1 illustrated somewhat diagrammatically in Fig. 1, is of the incandescent cathode type operating substantially by pure electron conduction, as described in my paper in the *Physical Review* for December, 1913. This tube 1 is connected in series with a kenetron 2 by conductors 3, 4 to the secondary of a transformer 5. The kenetron as described in a paper by Dr. Saul Dushman, *General Electric Review*, for March, 1915; also in Dushman Patent 1,172,961 is a device somewhat similar to the X-ray tube and has an incandescent cathode and operates substantially by pure electron conduction, but unlike the X-ray tube the kenetron is designed to have a low potential drop between cathode and anode so that there is a minimum of energy consumption in the device. The kenetron not only assists the X-ray tube in the rectification of current, but acts as a current limiting device to prevent any greater passage of current through the X-ray tube than is provided for by the electron emissivity of the kenetron cathode 6, which is controllable by the heating current passed through the same.

As described in my above referred to paper in the *Physical Review*, an X-ray tube operating with a pure electron discharge will rectify its own current unless the temperature of the focal spot on the anode becomes excessively high, but in some cases, particularly when using an anode of tungsten, or other refractory metal, or when operating a tube for protracted periods, there is danger of an inverse discharge in the tube, in other words, a possibility of undesired half wave impulses of an alternating current supply passing through the tube. The voltage consumption between the anode and cathode in the kenetron in general is maintained low by locating the cathode and anode close together. Because of this fact and other features of design of the kenetron, a very much larger amount of energy may be transmitted by the kenetron with a suitable cathode temperature, without loss of its rectifying property than is possible in an X-ray tube.

The cathode 6 of the kenetron and the cathode 7 of the X-ray tube are respectively provided with heating current from the secondaries 8 and 9 of a transformer having a primary 10. This transformer is connected by conductors 11 and 12 to a suitable source of alternating current, for example, to the mains 13 and 14 supplying operating current to the X-ray supply transformer 5. Included in series with the conductor 12 is a regulating device 15 such, for example, as an adjustable resistance. In circuit respectively with the heating circuits of the cath-

odes 6 and 7 are regulating resistances 16 and 17, whereby the value of the heating currents through these respective cathodes may be adjusted to a desired relation by movement of the switches 18 and 19. Upon closure of the switch 20 in the supply circuit of the transformer the cathodes of the X-ray tube and the kenetron will be each heated to a predetermined temperature by moving the contact arm 22 over the resistance 15. The current in the heating circuits for each of the cathodes is changed in proportionate measure so that when it is desired to set the electron emissivity of the X-ray tube cathode from a higher to a lower value (the electron emissivity of the kenetron cathode likewise will be lowered.

Diagnostic X-ray work usually is carried out at relatively high currents, for example, 100 milliamperes whereas therapeutic work is carried out at very much lower currents, say, for example, 5 milliamperes, but at higher voltages. As the current drawn by an X-ray tube depends upon the electron emission of the cathode and this in turn upon the temperature of the cathode, the regulation effected by the operator when turning from diagnostic work at high current to therapeutic work at lower current, incidentally effects the same change in the current-carrying capacity of the kenetron and hence prevents an accidental electric shock to the patient at the high voltage of therapeutic work from assuming a destructively high current value.

The terminals of the primary windings of the transformer 5 are connected by conductors 23, 24, to the terminals of a compensator or auto-transformer 25, which is in turn connected by conductors 26 and 27 to the supply mains 13, 14. In circuit with the conductor 27 is a circuit breaker 28 which constitutes an aditional current limiting device to prevent the drawing of an excessive current from the X-ray transformer. By shifting a lever 29 and thus varying the relation between the primary and secondary turns of the auto-transformer 25, the voltage impressed on the primary of the transformer 5 may be varied. As the lever is shifted to the right, the number of secondary turns is increased and the voltage is raised. At the same time, the tension of the spring 30 connected to the armature of the circuit breaker is decreased, thereby setting the circuit breaker to trip at a lower current value. The connection between the lever 29 and spring 30 may be made in any convenient manner. As shown diagrammatically in the drawing, the two may be connected to a bell crank lever 31, but it is obvious that other connecting means may be used to accomplish the same purpose.

In series with the conductor 23 is a starting resistance 32 and a switch 33, the starting resistance preventing shock to the apparatus by the excess voltages which would be produced in the transformer secondary, if it should happen that the circuit were closed at or near the peak of a voltage wave with a consequent rapid change of current in the primary.

The operation of this safety device will be clear from the foregoing description. For example, should it be desired to use the tube for diagnostic work, say, at 100 milliamperes, and at a voltage, say, of 50,000 volts, the circuit breaker may be set to open the circuit at a milliamperage exceeding 100, but if it is desired to operate for therapeutic work at a current of only 5 milliamperes, say, at 100,000 volts, the movement of the lever 29 to the right will decrease the tension upon the spring 30, thereby enabling the circuit breaker winding 34 to open the circuit if the operating current for any reason should exceed the value of five milliamperes.

In some instances, as shown in Fig. 2, the setting of the resistance 15 in the circuit of the transformer cathodes of the X-ray tube and the kenetron, may be arranged to occur simultaneously with the setting of the operating voltage and the setting of the current value at which the circuit breaker will trip. For this purpose, the movable contact 22 is connected by a rod or link 35 to the lever 29 so that as the lever 29 is moved to the right increasing the operating voltage for the X-ray tube the value of the resistance in circuit with the primary winding 10 of the heating transformer is simultaneously increased, thereby decreasing the temperatures of the cathode. This decrease of temperature decreases the electron emissivity of both cathodes and prevents passage of an excessive current through the tube.

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

1. An X-ray system comprising the combination of an X-ray tube, a current limiting device in circuit with said tube, means for varying the X-ray output of said tube and automatic means for simultaneously changing the setting of said current-limiting device.

2. An X-ray system comprising the combination of an X-ray tube, a current limiting device connected in circuit with said tube, a regulator for changing the operating voltage of said tube, and means for changing the setting of said current limiting device in accordance with the setting of said voltage regulator.

3. An X-ray system comprising an X-ray tube, an electrical supply circuit therefor, a kenetron rectifier connected in series with said X-ray tube, a circuit breaker connected in said supply circuit, means for varying

the voltage of the operating current, and means for changing the setting of said circuit breaker by and in accordance with the operation of said voltage-varying means.

4. An X-ray system comprising an X-ray tube, a current supply circuit therefor, a circuit-breaker for opening said circuit, means for varying the operating voltage for said tube, and means for changing the setting of said circuit breaker by the movement of said voltage-varying means.

5. An X-ray system comprising an X-ray tube, a current supply circuit therefor, a circuit-breaker for opening said circuit, an adjustable transformer connected to vary the voltage impressed on said X-ray tube, and a mechanical link connected to said transformer and to said circuit breaker to lower the current setting of said circuit breaker as said transformer is adjusted to furnish a higher voltage.

6. An X-ray system comprising the combination of an incandescent cathode X-ray tube, an incandescent cathode rectifier connected in series therewith, heating means for the cathodes of said X-ray tube and said rectifier and common means for changing the heating currents for said cathodes in proportionate measure.

7. An X-ray system comprising the combination of an incandescent cathode X-ray tube, an incandescent cathode rectifier connected in series therewith, a supply of alternating current connected to said devices, a transformer having two secondary windings connected respectively to the cathode of said X-ray tube and the cathode of said rectifier, a common primary winding, and means for regulating the energy supply of said primary winding to simultaneously vary the heating currents of said cathodes in proportionate measure.

8. An X-ray system comprising the combination of an incandescent cathode X-ray tube, a kenetron rectifier connected in series therewith, a source of current in common for heating the cathodes of said X-ray tube and said kenetron, means for individually setting the current supply of said X-ray tube and said kenetron, and means for simultaneously changing said heating currents.

9. An X-ray system comprising the combination of an incandescent cathode X-ray tube, a kenetron rectifier connected thereto, a circuit supplying alternating current connected to said devices, a circuit-breaker in said supply circuit, means for controlling the voltage of said alternating current and means responsive to the operation of said voltage control for changing the setting of said circuit breaker.

In witness whereof, I have hereunto set my hand this 12th day of July 1918.

WILLIAM D. COOLIDGE.