W. D. COOLIDGE.

X-RAY APPARATUS.

APPLICATION FILED JAN. 24, 1919.

1,408,989. Patented Mar. 7, 1922.

Fig. 1.

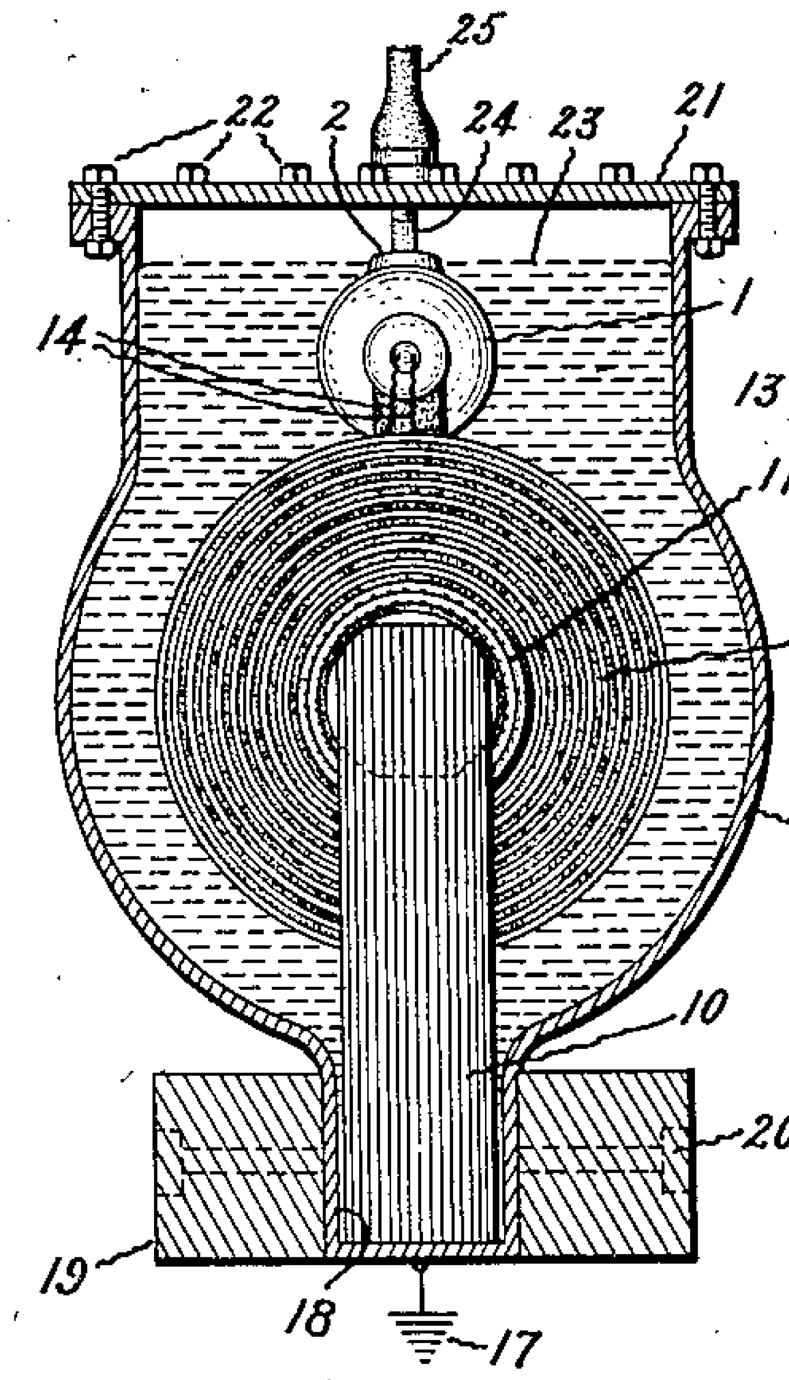


Fig. 2.

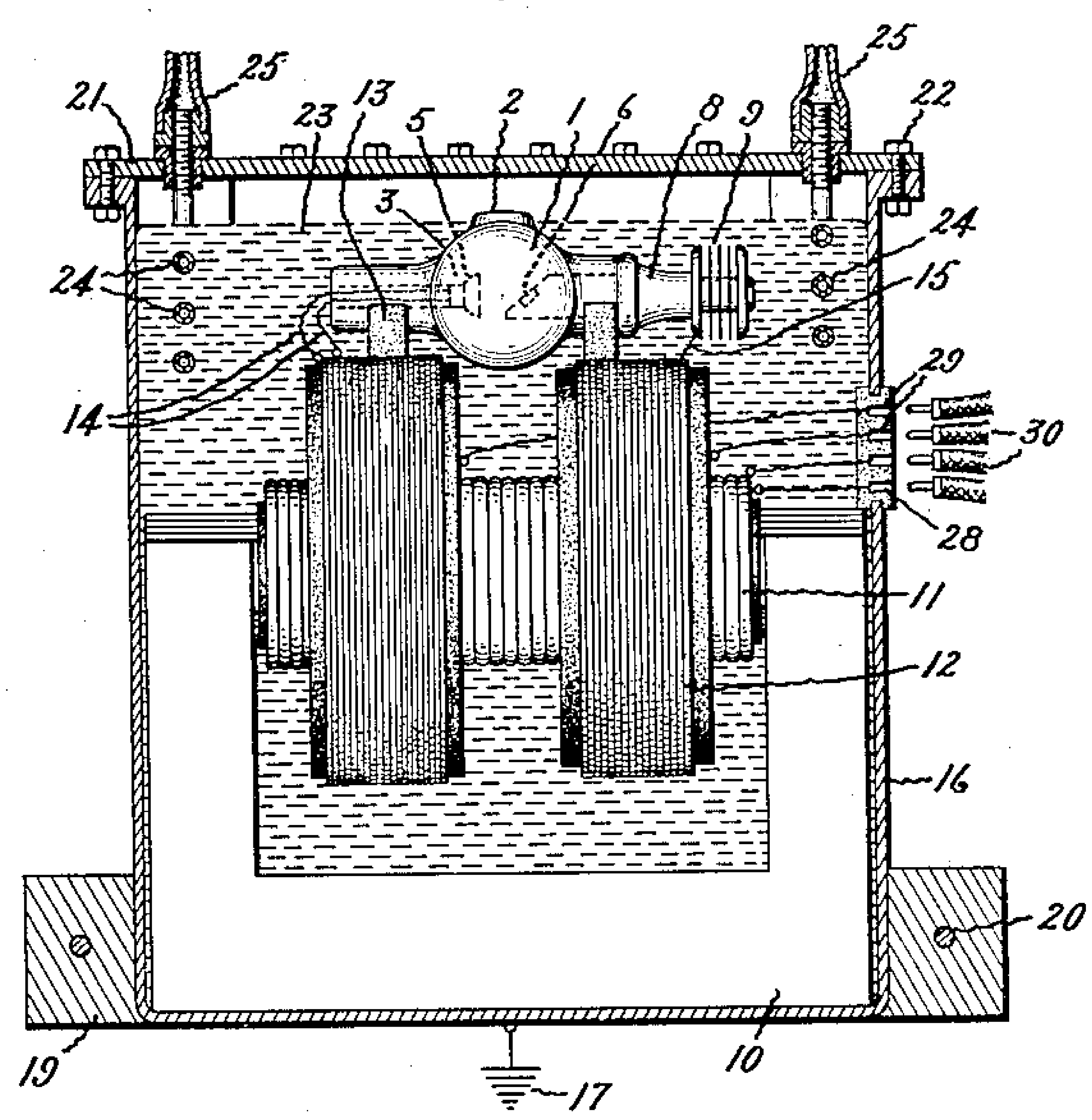


Fig. 3.

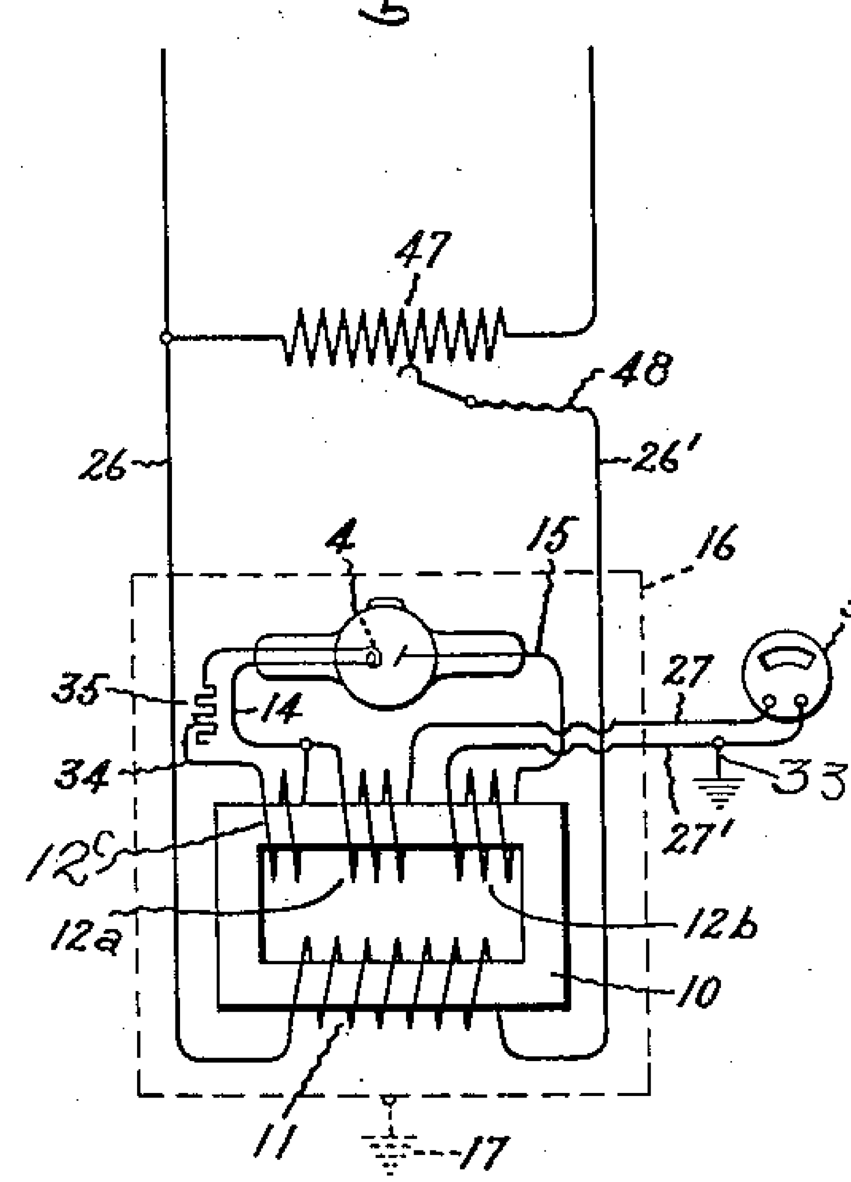


Fig. 4.

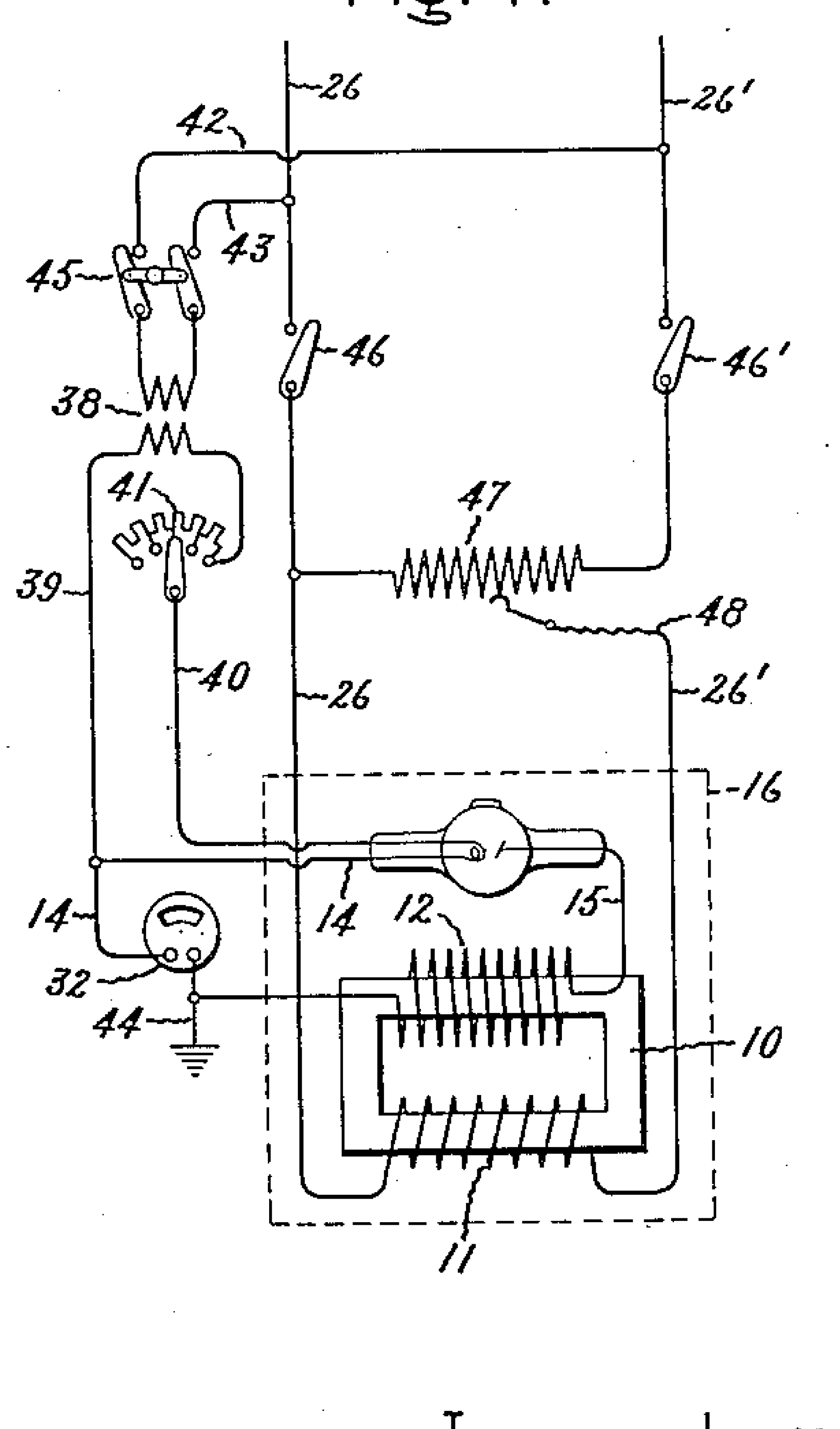
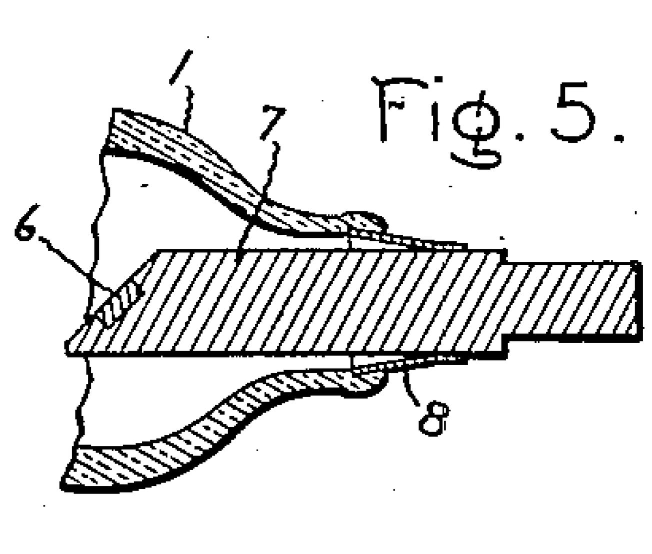


Fig. 5.



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UNITED STATES PATENT OFFICE.

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X-RAY APPARATUS.

1,408,989. Specification of Letters Patent. Patented Mar. 7, 1922.

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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, 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.

It is the object of my present invention to provide for generating X-rays an improved and simplified apparatus which will be safe and suitable for general use without requiring specialized skill.

My invention, in one of its aspects, relates to a self-contained X-ray apparatus comprising a transformer, an X-ray tube connected directly to its high tension terminals, and a body of oil enveloping both the transformer and X-ray tube for insulating and cooling purposes.

It is the object of my invention to provide a rugged, portable X-ray generator, which can be handled freely without danger of electrical shock and is adapted for connection to ordinary sources of alternating current. My invention in one of its aspects comprises an X-ray tube of small size having an anode adapted for external cooling which is operated in a body of oil to secure energetic heat dissipation at the anode and to enable higher impressed voltages to be used than permitted by the separation of the tube terminals in air. These and other aspects of my invention will be pointed out with greater particularity in the appended claims and explained in the following specification taken in connection with the accompanying drawings.

An apparatus embodying my invention is shown in Fig. 1 in cross-section, and Fig. 2 in a longitudinal section; Figs. 3 and 4 are diagrams of electrical connections embodying certain aspects of my invention; and Fig. 5 is a detail sectional view of the anode end of a tube forming part of my new apparatus.

It has been suggested as early as 1896 to operate X-ray tubes in oil in order to reduce the corona effect at the terminals of the tube when operated at very high potentials and to cool the bulb. It was observed that energetic external cooling of the tube walls, such as afforded by a liquid, maintained a higher vacuum within the tube than could be obtained by operation of the tube in air and as the passage of the discharge in the tubes thus operated was dependent entirely on residual gases, the behavior of the tube was greatly modified by the oil cooling. No advantage was taken in these prior experiments of the cooling action of the oil upon the anode in order to carry away effectively heat generated by the impact of the cathode stream on the anode. Nor, as far as I am aware, has any advantage been taken of the insulating property of a non-gaseous medium having a high heat conductivity such as oil to reduce the size of the tube, that is, to enable the anode terminal to be shortened to increase its heat conductivity, without lowering the permissible operating voltages.

In accordance with my present invention I have provided an X-ray apparatus in which the anode is connected to an external heat-dissipating member by means of a thermal path of high heat conductivity. Referring to Fig. 2, the X-ray tube comprises a bulb 1 consisting preferably of lead glass which is relatively impermeable to X-rays and as having a window 2 consisting of glass highly permeable to X-rays. Into this tube are sealed a cathode 3 comprising a filament of tungsten, or other suitable refractory material 4, which is rendered incandescent by passage of current during the operation of the tube. Surrounding the cathode is a conductive focusing member 5. The discharge receiving face of the anode (see Fig. 5) preferably consists of a disc 6 of tungsten, or other suitable refractory metal, backed by a cylindrical member 7 of copper, or other good heat-conducting metal, communicating with the exterior of the tube and sealed into the glass envelope 1 by means of an intermediate conical tube 8 consisting of platinum, or a suitable platinum substitute. The copper rod 7 as shown in the drawing, has a length not materially greater than several times its diameter and affords a path of high heat conductivity, permitting the effective carrying away of heat from the charge-receiving face of the anode to a body 23 of oil, for example, a heavy mineral oil, such as Transil oil. In some cases external fins 9 may be provided, as shown in Fig. 2, although this is not essential in all cases.

Electrical energy for operating the tube is derived from a transformer comprising a core 10, a primary winding 11 and a secondary winding 12, which in some cases may consist of two sections (12^a and 12^b, Fig. 3), connected in series. The X-ray tube is mounted by insulating supports 13 upon the transformer. The terminals of the tube are connected by conductors 14 and 15 directly to the secondary terminals of the transformer, as more clearly shown in Figs. 3 and 4. On account of the high dielectric strength of oil the high tension terminals 14 and 15 may be placed closer together than the air gap equivalent of the working voltage of the tube, hence the anode rod 7 may be correspondingly short with a proportionate gain in thermal conductivity. The transformer and the tube are contained within a receptacle 16 consisting preferably of metal, such, for example, as galvanized iron. The container 16 preferably has a ground connection 17. A receptacle 16 is preferably shaped so as to receive in a pocket 18, at its lower end, the transformer core in order to hold the transformer in a fixed position. A wooden base 19 may be fastened by bolts 20 to both sides of the pocket 18 in order to enable the apparatus to be placed upright upon its base. The container 16 may be provided with a removable cover 21 permeable to X-rays which makes an oil-tight seal by being drawn into close contact with a flange on the container by means of bolts 22, suitable gaskets being provided. The oil 23 may be cooled by means of pipes 24 conveying a cooling liquid, the terminals of the pipes 24 being tightly sealed through the cover and provided with flexible connections 25. Conductors 26, 26′, conveying current to the primary winding and the conductors 27, 27′, connecting in series the two sections of the secondary winding (Fig. 3), are brought respectively to suitably insulated terminals 28, 29 affixed in the wall of the container (Fig. 2) and to which external electrical connections may be made by means of connecting plugs 30.

The conductors 27, 27′, as shown in Fig. 3, are connected to a current-measuring device, such, for example, as milliammeter 32, and provided with a ground connection 33. The current-measuring device will indicate the energy passing through the tube and will enable the operator to determine the X-ray emissivity during operation.

The cathode of the device shown in Figs. 1, 2 and 3, is heated by a winding 12^c, mounted on the transformer core 10 and connected to the cathode filament 4 by the conductors 14 and 14, one of the conductors preferably containing an adjustable resistor 35 in order to enable the resistance of the cathode circuit to be varied at will. It will be noted that the high potential windings 12^a, 12^b, as well as the winding 12^c, which is connected to the high potential conductor 14, are electrically insulated from the primary winding 11. As the enclosing tank 16 and the conductors 27, 27′, leading to the milliammeter 32 are grounded, and as the high potential windings are immersed in oil and therefore are inaccessible during the operation of the tube, the apparatus presents no possibility of electric shock.

In the alternative system of connections shown in Fig. 4, the cathode filament is provided with heating current from a separate transformer 38 having a secondary winding connected to the cathode by conductors 39, 40, containing an adjustable resistance 41. The primary winding of the cathode heating transformer 38 is connected by conductors 42, 43, to the conductors 26, 26′, conveying the main operating current to the primary winding 11 of the main transformer. The secondary winding 12 in the system shown in Fig. 4 consists of a single coil, the terminal 14 of which is connected to ground by a conductor 44. The grounded conductor 14 connecting the primary 12 to the cathode of the X-ray tube contains in circuit a milliammeter 32. Suitable switches 45, 46, 46′ are provided respectively for closing the circuit of the cathode heating transformer and the main operating transformer. The transformer 38 may be immersed in oil in the container 16 in common with the tube operating transformer, but more conveniently it may be mounted outside the tank say, on the same support with the milliammeter.

In both of the systems of connections shown respectively by Figs. 3 and 4, the electron emissivity of the cathode may be varied by varying the voltage impressed upon the primary of the main operating transformer without sufficiently altering the voltage of the secondary winding of the main transformer, to materially alter the hardness of the X-rays. With this end in view the resistance of the cathode filament circuit is so proportioned with respect to the electrical characteristics of the transformer winding connected to the cathode circuit that the temperature and hence also the electron emission of the cathode is somewhere midway the desired operating range. As a small change in the temperature of the cathode produces a relatively great change in the electron emissivity of the cathode, a relatively small change in voltage of the windings supplying heating current to the cathode is effective to vary the electron emissivity of the cathode over the entire range desired in the operation of the apparatus. This change in voltage impressed upon the cathode filament heating circuit may be produced by a variation in the voltage of the primary circuit of the transformer. Voltage variations sufficient to produce desired variations in cathode temperature are too small to materially alter the hardness of the X-rays. Hence, by providing some device for adjusting the operating voltage impressed upon the apparatus, for example, by means of an auto-transformer 47, having a movable terminal 48, the energy through the tube may be varied at will without injuriously affecting the penetrability of the X-rays. In the device shown in Fig. 4 having an independent cathode transformer, the temperature of the cathode can be regulated by the resistance 41, independently of the voltage impressed on the X-ray transformer by the adjustable auto-transformer 47.

While I have described the preferred embodiment of my invention, it will be evident to those skilled in this art that modifications may be made without departing from the spirit of my invention. For example, in place of oil for cooling and insulating purposes, other dense media of high dielectric strength may be used. I intend by the appended claims to cover modifications falling within the scope of my invention.

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

1. An X-ray apparatus comprising a step-up transformer, an X-ray tube having terminals separated by a distance less than the air-gap equivalent of the working voltage of said tube, conductors directly connecting the high tension winding of said transformer to the terminals of said tube, a container for said transformer and tube and a body of oil in said container insulating said conductors and terminals from each other.

2. An X-ray apparatus comprising an X-ray tube having a cathode operable at incandescence, a transformer having primary and secondary windings electrically insulated from each other, direct conductive connections from the secondary winding of said transformer to the terminals of said tube, a winding on the core of said transformer electrically insulated from said primary winding and connected to deliver heating current to said cathode, a metal container enclosing said tube and transformer, and a body of oil therein cooling and insulating the tube and transformer.

3. An X-ray apparatus comprising an X-ray tube having a cathode operable at incandescence, a transformer having primary and secondary windings electrically insulated from each other, direct conductive connections from the secondary of said transformer to the terminals of said tube, connections for delivering a heating current to the cathode of said tube from a secondary winding of said transformer, a conducting container for said tube and transformer, a connection to ground from said container, conductors for the primary of said transformer insulated from said container, a current-measuring device external to said container, conductors from the main secondary winding to said measuring device, a connection to ground from said measuring device circuit, and voltage-varying means operatively connected to the primary circuit of said transformer.

4. An X-ray apparatus comprising an X-ray tube having a cathode operable at incandescence, a transformer winding connected to furnish a heating current to said cathode, a transformer secondary winding connected to the terminals of said tube to generate X-rays, means insulated from said windings for inductively exciting said windings, a container for said apparatus, a connection from said container to ground, and a connection from said secondary winding to ground.

5. The combination of an electron discharge device having an incandescent cathode, an anode, and a member having a heat conductivity sufficient to effectively cool said anode extending from said anode to the exterior of said device, and a body of oil surrounding said device and in contact with said member, the distance between the terminals of said device being less than is required for a tube operating in the air with the same applied voltage.

6. The combination of an electron discharge device having an incadescent cathode, an anode and a member extending from said anode to the exterior of said device having a mass and length adapted to effectively cool said anode, whereby the distance between the terminals of said device is reduced to less than the air-gap equivalent of a desired working voltage, a source of high potential electric energy connected to said device, and a body of oil enveloping said device and said source.

In witness whereof, I have hereunto set my hand this 23rd day of January, 1919.

WILLIAM D. COOLIDGE.