Jan. 10, 1928. 1,655,455

W. D. COOLIDGE

X-RAY APPARATUS

Filed Sept. 29, 1923

Fig. 1.

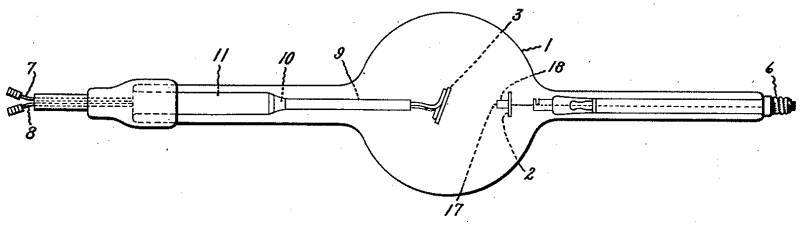


Fig. 2.

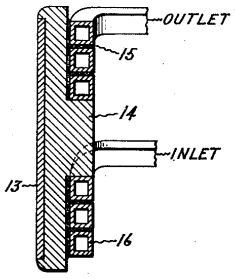


Fig. 3.

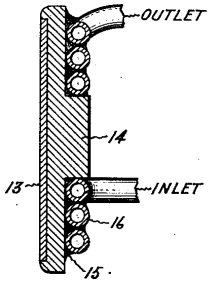


Fig. 5.

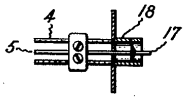
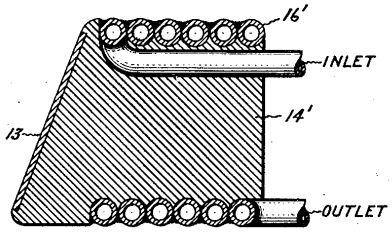


Fig. 4.



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His Attorney.

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UNITED STATES PATENT OFFICE.

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X-RAY APPARATUS.

Application filed September 29, 1923. Serial No. 665,693.

The present invention relates to X-ray devices and comprises in particular a new X-ray anode or target which is particularly adapted for use in connection with the continuous generation of X-rays.

In my prior Patent 1,253,156, of January 8, 1918, I have described a water-cooled X-ray target which is adapted for continuous operation with currents of the order of magnitude of 100 milliamperes and voltages as high as 140,000 volts. These relatively large amounts of high voltage electric energy are conveniently obtained from transformers and delivered to the X-ray tube either as alternating current to be rectified by the X-ray tube itself or as intermittent direct current when a separate rectifier is provided. In either case the target is subjected to severe mechanical shocks by the expansion and contraction accompanying the intermittent heat input so that cracks or tears gradually develop in the metal which finally permit water to leak into the interior of the X-ray tube which, of course, ends its usefulness. For example, on sixty cycle operation, the target face plate is subjected sixty times per second to short periods of intense heating causing expansion and a tendency to buckle away from the back plate, these periods being separated by intermediate periods of cooling and contraction.

As described in my prior patent, this destructive effect may be reduced by making the face plate relatively thick. Further investigation has demonstrated that the tearing action of the discharge is intimately related to the temperature gradient in the target. A thick face plate reduces the temperature gradient but also reduces the rate of heat removal from the target face and hence reduces the permissible power input.

In accordance with my present invention, I have provided an X-ray tube in which the tearing effect by an intermittent discharge of commercial frequency has been substantially eliminated. This is accomplished by improving the efficiency of heat transfer from the focal spot to the cooling fluid. In a preferred embodiment of my invention the cooling fluid is conveyed by a seamless tube of copper in good thermal relation to a relatively large area of the target. In accordance with another feature of my invention I have provided a construction for increasing the size of the focal spot on the target.

The invention will be best understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 is an outline drawing of an X-ray tube provided with a target embodying my invention and having a cathode constructed to increase the area of the focal spot, Figs. 2, 3 and 4 are cross-sectional views of different modifications of anodes embodying my invention, and Fig. 5 is a view partly in section and partly in elevation of the cathode.

Referring to Fig. 1, the X-ray tube which is assumed to be a pure electron type, as described in my Patent 1,203,495, of October 31, 1916, comprises in the main a highly exhausted bulb 1 into the arms of which are sealed a cathode 2, and an anode 3. The cathode comprises a filament of tungsten or other refractory metal ordinarily wound in spiral form (see Fig. 5) adapted to be heated by electric current supplied by conductors 4, 5 connected to an external base 6. The anode 3 is provided, as will be explained in connection with Figs. 2, 3 and 4, with a cooling fluid supplied through the tubes 7, 8, which pass from the exterior directly into close contact with the anode. The tubes 7, 8, are silver soldered into the plugged end of a copper tube 9, which is joined to a cone 10 consisting of thin platinum, or other metal of suitable expansion coefficient which in turn is sealed to the reentrant portion 11 of the glass anode arm.

As shown in Figs. 2, 3 and 4, the anode comprises a face plate 13 of refractory metal, preferably wrought tungsten, and a back plate 14 of metal of good heat conductivity, preferably copper, which is welded to the face plate, as described for example in my prior Patent 1,162,341, of November 30, 1915. In the type of target shown in Figs. 2 and 3, the tubes 7 and 8 which carry the water or other cooling fluid, are shaped in the form of a spiral with closely adjacent turns, and are then brought into close thermal relation with back plate 14 by a layer of silver solder 15. The water cooling duct, which is of square section in Fig. 2 and round section in Fig. 3, preferably consists of seamless drawn copper. A union of good heat conductivity may be made by placing the tubing into close contact with the back plate together with silver solder, and then heating in a vacuum to a temperature high

enough to melt the silver solder. The solder which may consist of an alloy of 72 parts of silver and 28 parts of copper intimately unites with the copper plate 14 and the cooling spiral 16 to make a unitary structure. This silver solder has a heat conductivity only a little less than that of pure copper.

In the modification shown in Fig. 4, the back plate 14 has been shown of cylindrical form and the cooling duct has been coiled in the form of a helix 16', which is silver soldered into intimate contact with the exterior of the copper cylinder 14'.

In order to operate the tube with a high energy input, it is desirable to broaden the focal spot on the anode, particularly when the X-ray output of the tube is to be used for therapy or sterilization purposes. With this end in view the cathode is provided with a projecting point, as shown at 17 in Figs. 1 and 5. It is the function of this point to modify the electric field about the cathode so as to expand the beam of cathode rays falling upon the anode. In the particular form of cathode shown, the field produced by the joint effect of the focusing collar 18 and the pin 17 will cause the focal spot to assume the form of an annulus on the target. The focal spot and the sinuous cooling duct both being of substantially the same annular shape and being separated only by the thickness of the target, efficient heat removal is facilitated.

X-ray targets constructed as described herein have been operated for hundreds of hours with an alternating current input of about nine kilowatts without developing any fissures in the target face receiving the discharge.

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

1. An X-ray target comprising a face plate of highly refractory metal, a backing member of copper provided with a sinuous duct for circulating a cooling fluid, through said member, the turns of said duct being fused to said member and to one another whereby the walls of the duct are in such good heat conducting relation to said member, that flow of heat to a cooling fluid may occur at a rate capable of maintaining the temperature gradient in said target sufficiently low to prevent fissuring of the face plate when operated with a rectified, sixty cycle current supply of sufficient energy to fissure a target cooled by the projection of a cooling fluid thereon.

2. An X-ray target comprising a face plate of refractory metal, a back plate of greater mass joined thereto, said back plate being constituted of a metal of high heat conductivity and a metal tube having a plurality of turns integrally united with said back plate said tube being proportioned and arranged to permit a current of water therein to carry heat away from said anode at a sufficiently high rate to maintain the temperature gradient in said target with a variable energy input below a value at which fissures would form in said target.

3. An X-ray target comprising a face plate of refractory metal, a back plate of metal of higher heat conductivity than said refractory metal, said back plate being provided with a coiled duct for the circulation of a cooling fluid, the turns of said duct being fused to said plate and to one another whereby the heat conducting capacity of the walls of said duct is sufficiently great to enable a circulating fluid therein to carry away heat with sufficient rapidity to maintain the temperature gradient in said target with an intermittent energy supply below the value at which fissures develop therein.

4. An X-ray tube comprising an envelope, a cathode, an anode, an electric current conveying terminals therefor sealed into said envelope, the anode terminal comprising a continuous walled metal tube bent upon itself, and joined in good thermal relation to a relatively large area of said anode, to afford cooling at a sufficiently high rate to prevent destructive expansion and contraction of said anode with an intermittent energy input.

5. An X-ray tube comprising an envelope, a cathode, an anode or target, means for focusing electrons emitted by said cathode as an annular beam upon one face of said anode and a duct for conveying a cooling fluid coiled in an annular band and intimately united with said anode in a plane substantially parallel to the charge-receiving face of said anode.

6. In combination, an X-ray target comprising a metal plate of high heat conductivity, one face of said plate having a recessed portion and the other face an integral central extension, a plate of refractory material mounted in the recessed portion, and a metal cooling coil surrounding said central portion, the turns of said coil being arranged in a plane parallel to said metal plate and fused to the metal plate and to one another.

In witness whereof, I have hereunto set my hand this 28th day of September, 1923.

WILLIAM D. COOLIDGE.