W. D. COOLIDGE.
INCANDESCENT CATHODE DEVICE.
APPLICATION FILED DEC. 4, 1917.

1,326,029.

Patented Dec. 23, 1919.

Fig. 1.

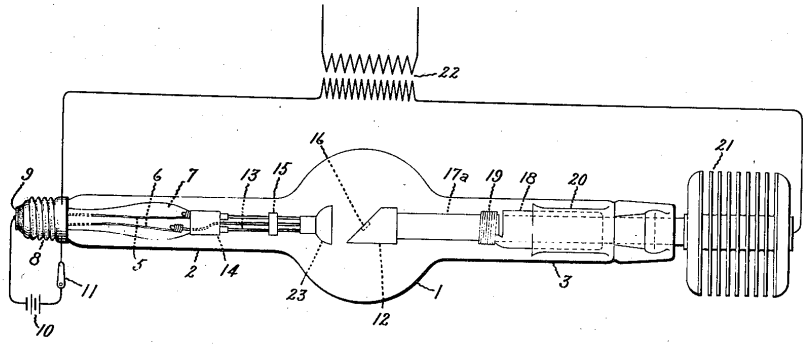
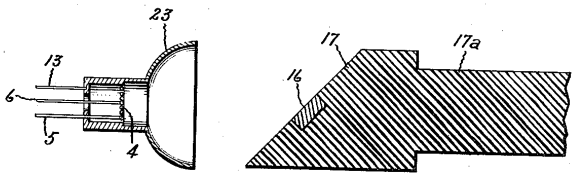


Fig. 2.



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UNITED STATES PATENT OFFICE.

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INCANDESCENT CATHODE DEVICE.

1,326,029. Specification of Letters Patent. Patented Dec. 23, 1919.

Application filed December 4, 1917. Serial No. 205,439.

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 Incandescent Cathode Devices, of which the following is a specification.

The present invention relates to thermionic devices, and particularly to X-ray tubes operating by an electron discharge generated substantially independently of gas ionization.

X-ray tubes operating without appreciable positive gas ionization have heretofore been provided with targets, or anodes, of refractory metal, such, for example, as tungsten. An X-ray tube thus provided is capable of operation with a source of alternating current for a short time, or more strictly speaking with an amount of energy input which will not heat the focal spot upon the anode receiving the cathode discharge to a temperature materially in excess of about 750° C., at which temperature the electron emission from heated metals begins to be appreciable. As soon as any part of the anode at the focal spot is heated to a sufficiently high temperature to emit electrons copiously, a so-called inverse electron stream is emitted from the heated part of the anode and strikes the opposite part of the tube, usually the glass wall of the bulb. The result is local heating, cracking of the glass and destruction of the tube.

I have discovered that an anode consisting of a refractory metal, such as tungsten, backed by copper, may be freed sufficiently from gas to be used in a tube operating with a substantially pure electron discharge and that such an anode has a substantially negligible electron emissivity, even when the tungsten at the focal spot is heated to bright incandescence or in fact up to its melting point. My invention includes both a new process of preparing an electron discharge tube and a new tube which will continue to rectify its own current even when the anode becomes in part highly heated.

In the accompanying drawings Figure 1 is a somewhat diagrammatic perspective view of the X-ray tube as a whole; Fig. 2 is an enlarged sectional view of the electrodes.

The tube as shown in Fig. 1 comprises a glass bulb 1 having oppositely extending arms 2 and 3 into which the electrodes are sealed. The cathode as shown more clearly in Fig. 2 comprises a spiral filament 4 of tungsten, or other suitable refractory metal, connected to leading-in conductors 5 and 6, which are sealed into a glass stem 7 and joined respectively to external contacts 8 and 9. The cathode spiral may be heated by any suitable source of low voltage current, as for example a battery 10, in circuit with a switch 11.

Surrounding the cathode 4 is a focusing device 23 comprising a cylindrical portion and a hemispherical portion. The object of this device is to cause the cathode rays to converge, the focus of the pencil of rays being directed upon a target or anode 12 located opposite the cathode. The focusing device 23 is supported upon the wire 13 and together with one of the cathode conductors 5 is attached to a short iron tube 14 carried by the stem 7. The conductor 6 passes through a hole in the end of the tube 14. The three wires, 5, 6 and 13 are held in place by a bridge 15 suitably insulated with mica, or the like.

The anode comprises a tungsten button 15 and a mass of copper 17 molecularly joined to the tungsten. This copper mass is treated to remove dissolved gases, preferably by adding to the copper while molten a small quantity of oxidizable boron material, as for example, boron sub-oxid or boron carbid. The degasified copper is then melted in a vacuum in contact with the tungsten body and under these conditions thoroughly wets the surface of the tungsten and forms a perfect molecular union therewith. This form of anode is described in my prior Patent #1,162,339.

The anode stem may be mounted upon a split iron tube 18 by iron wire 19. This tube 18 is in turn inserted into a glass tube 20. The anode stem 17_a is joined to a short platinum ring which is sealed into the glass wall of the arm 3 of the tube. The body of copper carrying the button of tungsten projects outside of the tube. External to the X-ray tube the anode stem is in effective thermal relation with a radiator 21 comprising a series of plates spaced apart, consisting of copper, or other good heat conducting metal.

The object in making of considerable length the anode stem 17_a, which is continu-

ous with the copper backing member 17, is to provide without appreciable sacrifice of heat conductivity an extended narrow space within the evacuated bulb between the stem 17_a and the wall of the anode arm 3 to suppress the passage of electrons to the glass wall adjacent the anode seal. The narrowness of this space insures a high space charge for stray secondary cathode rays, that is, the impeding effect of the electrical charge of the electrons upon each other is relative high, thereby preventing the accumulation of high negative charges upon the glass wall adjacent the anode seal which would result in rupture of the glass at high impressed voltages.

The tube thus assembled is exhausted to a good vacuum and then dry hydrogen gas at a pressure of about an atmosphere is introduced, and is again exhausted. The tube is then again filled with hydrogen at about atmospheric pressure and heated to about 350° C. for about fifteen minutes. The tube thereupon is exhausted to the lowest pressure obtainable with a molecular pump, or condensation mercury vacuum pump, the conduit connecting the bulb to the pump having a liquid air trap. In my opinion the beneficial effect of this hydrogen treatment is due to the removal of oxygen from the target.

When the exhaust has been made as complete as possible and the tube has cooled, a discharge is cautiously started, while the cathode is heated to incandescence, thereby disengaging further amounts of gas from the anode, as well as incidentally from the cathode. This treatment is continued, the gas evolved being continuously removed, as described in my prior Patent 1,203,495 of October 31, 1916. When finally a discharge may be obtained between cathode and anode, substantially free from accompanying evidences of gas ionization, the tube is sealed off from the pump.

I have found that a tube thus prepared may be connected to an alternating source of current, such as the secondary of a transformer 22 and that the tube with the cathode heated to incandescence will conduct but such half waves of current as are negative with respect to the cathode and will not conduct waves of opposite polarity although the tungsten button upon which the cathode rays are focused is heated to bright incandescence. In fact, in some cases I have actually melted tungsten at the focal spot during the operation of the tube without obtaining an inverse discharge at the anode with its accompanying manifestation of bombardment of the wall near the cathode end of the tube by cathode rays.

In my opinion this surprising phenomenon can be explained by the fact that in spite of the great care exercised to remove dissolved gases from the copper, some gas, particularly a trace of oxygen, remains dissolved in the copper, or combined therewith, and that some of this oxygen acts upon the heated tungsten and produces some changes, chemical or physical, at the incandescent tungsten surface, suppressing or greatly inhibiting electron emission. Some of this oxygen may be evolved in the gaseous state from the incandescent tungsten, but is immediately absorbed again by the cooler copper in the vicinity and may then again diffuse through the copper to the tungsten button.

I have found that the bulb of a tube embodying my invention may be made very much smaller than for the former types of X-ray tubes. Because of its simplicity and ease of operation, an X-ray tube embodying my present invention is well adapted for portable X-ray outfits, particularly for field work in military operations. It is also well suited for bedside work in hospitals.

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

1. An electron discharge device comprising an envelop, a cathode, means for independently heating said cathode to incandescence, and an anode, the electron emissivity of which is negligible even when heated in part to incandescence.

2. An electron discharge device comprising an envelop, a cathode, means for independently heating said cathode to incandescence, and an anode, consisting of tungsten with a backing of copper, the electron emissivity of said anode being negligible even when said tungsten is heated to incandescence.

3. An X-ray tube comprising an envelop, a cathode, of refractory material, means for heating said cathode by passage of current, means for focusing an electron discharge from said cathode, an anode or target for receiving said discharge, the electron emissivity of the focal area of said target being negligible even when heated to incandescence.

4. The combination of a source of alternating current and an electron discharge device connected thereto, said device comprising an envelop, a cathode, means for independently heating said cathode to incandescence, and an anode the electron emissivity of which is negligible even when heated in part to incandescence.

5. The method of treating an anode of an X-ray tube to be operated with a substantially pure electron discharge of an X-ray tube which consists in filling said tube with hydrogen gas, heating the bulb to a temperature of several hundred degrees centigrade, evacuating said hydrogen filling to a pressure so low that the effects of gas ionization will be inappreciable when a dis-

charge is passed through said tube, then subjecting the tube to passage of current while continuing said evacuation and finally sealing said tube when the discharge is substantially unaccompanied by gas ionization.

6. An X-ray device comprising an inclosing evacuated envelop, a cathode operable at incandescence, an anode comprising a charge-receiving member of refractory metal and a backing member of copper, the electron emissivity of said anode being negligible at incandescence of said charge-receiving member, and a heat-conductive stem extending from said anode through the wall of said envelop, said envelop being shaped to provide an extended narrow space about said anode stem.

7. An X-ray device comprising a cathode operable at incandescence, an anode comprising a button of tungsten and a backing of copper molecularly joined to said tungsten, means for directing an electron discharge from said cathode upon said tungsten target, an anode stem adapted to effectively conduct heat away from said copper backing and an inclosing sealed envelop having an arm shaped to provide an extended narrow space about said anode stem, said device being freed from gas sufficiently to enable an electron discharge to occur therein without appreciable gas ionization.

In witness whereof I have hereunto set my hand this 3rd day of December 1917.

WILLIAM D. COOLIDGE.