W. D. COOLIDGE.

METHOD OF PRODUCING AND MAINTAINING VACUUMS.

APPLICATION FILED FEB. 5, 1916.

1,289,672. Patented Dec. 31, 1918.

Fig. 1.

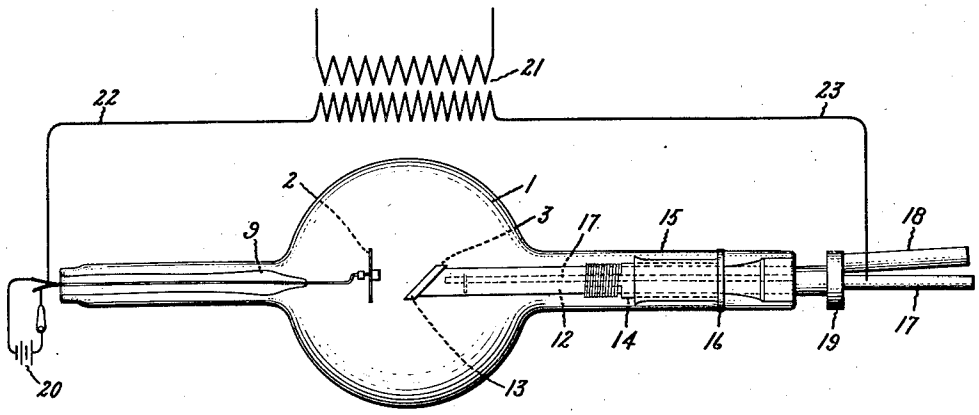


Fig. 2.

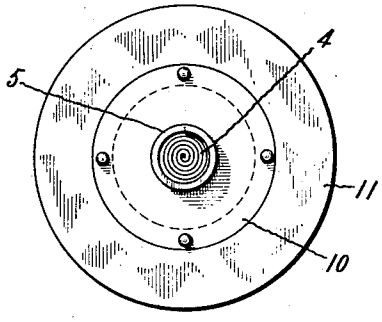


Fig. 3.

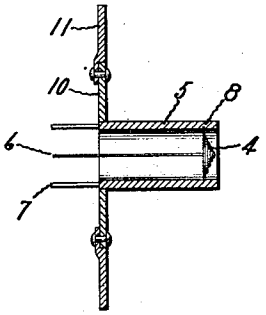
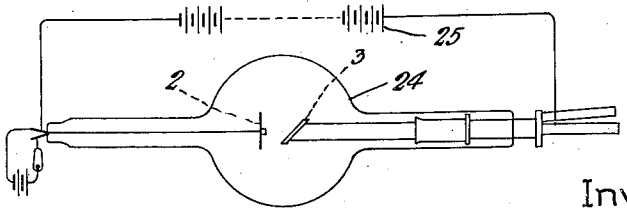


Fig. 4.



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UNITED STATES PATENT OFFICE.

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METHOD OF PRODUCING AND MAINTAINING VACUUMS.

1,289,672. Specification of Letters Patent. Patented Dec. 31, 1918.

Application filed February 5, 1916. Serial No. 76,349.

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 Methods of Producing and Maintaining Vacuums, of which the following is a specification.

The present invention relates to the automatic maintenance of a desired high vacuum in an electric apparatus operating with an electron discharge, such for example, as an X-ray tube, to prevent harmful positive ionization of gas.

In a device operating with a substantially pure electron discharge, such, for example, as the X-ray tube described in the *Physical Review* for December, 1913, it is necessary to maintain the pressure of residual gas below a low limiting value in order that positive ionization will be negligible. The complete removal of gas from the space within the envelop alone is not sufficient to insure freedom from gas ionization during the operation of the device, for as soon as the anode and other parts of the apparatus are subjected to electron bombardment gas is evolved. In some cases substantially all disengageable gas is removed during the evacuating process from parts of the apparatus subject to electron bombardment but the complete removal of gas is not always practicable.

In accordance with my invention the requisite vacuum is maintained during the operation of an electron discharge device by automatically disintegrating or sputtering electrically a metal within the container in response to incipient positive ionization of evolved gas, thereby fixing the gas before harm is done.

My invention in one of its aspects includes a cathode of novel construction comprising an incandescent filament and soft metal which is easily sputtered electrically.

In the accompanying drawing I have shown an X-ray device as illustrative of one form of apparatus to which my invention is applicable. Figure 1 is a somewhat diagrammatic perspective view of an X-ray tube; Figs. 2 and 3 are enlarged detail views taken at right angles to each other of a form of cathode construction, and Fig. 4 is a diagram showing an X-ray tube supplied with direct current.

The device which has been shown in connection with my invention is an X-ray tube with a water-cooled anode. Referring to the drawing, the X-ray tube comprises an evacuated glass envelop 1 in which are oppositely located a cathode 2 and an anode 3. The cathode, shown with greater detail in Figs. 2 and 3, comprises a spiral filament 4 consisting preferably of tungsten, and a surrounding tube 5 consisting of a refractory metal such as molybdenum. Electrical connections are made to the cathode filament by a tungsten wire 6 connected directly to the spiral, and a tungsten wire 7 connected to the ring 5 which is in turn welded to the opposite end of the cathode spiral 4, as indicated at 8. The wires 6 and 7 are sealed into a glass stem 9. Connected to the tube 5 is a flange 10 extending at right angles to the tube 5, and consisting preferably also of molybdenum or other highly refractory metal. To the outer periphery of the flange 10 in some cases is riveted, or otherwise fastened, a ring 11 of copper, silver, gold, or other metal which may be readily sputtered electrically by positive ion bombardment. It is the function of the tube 5 to so modify the electrostatic field about the cathode as to concentrate the cathode rays upon a small spot on the anode. The rings 10 and 11 intercept positive ions which are attracted to the negative terminal of the device. The impact of positive ions on the flange 11 sputters or vaporizes metal and improves the vacuum, as will be hereinafter more fully explained.

The anode of the X-ray tube comprises a tube 12 of copper to which is welded a disk 13 of tungsten. The tube 12 is fastened into a tube 14 of iron which is in turn sealed into the arm 15 of the X-ray bulb; the glass ring 16 serves to center and support the iron tube. A cooling fluid, such as water, may be introduced through a supply tube 17 and conducted away by a discharge tube 18 through a connection box 19. The location of the tube 17 is indicated by dotted lines.

The cathode filament is heated by any convenient means, such as a battery 20, and the main operating current is supplied by a high potential source of current, as for example, a transformer 21 connected to the terminals of the tube by the conductors 22, 23. As shown in Fig. 4, a source of unidirectional current may be used when the

cathode consists in part of electrically sputtering metal. In this figure an X-ray tube 24 is connected to a suitable source of high potential direct current as represented by a battery 25, the negative terminal of the battery being connected to the cathode 2, and the positive terminal to the anode 3.

The X-ray tube is exhausted to the highest attainable vacuum, the last stages of exhaust preferably being completed by the Gaede molecular pump, or any other exhausting device capable of producing a vacuum below about 0.00005 mm. of mercury. The tube is operated during the last stages of operation on the pump until the anode is heated to a just visible dull redness. The tube is then sealed off and may be operated without further treatment by a high potential current with the cathode at incandescence.

Assume the cathode to consist entirely of difficultly sputtering metal and the anode to consist in part of copper or other readily sputtering metal and gas to be evolved in some way in the tube and this gas to be ionized by the discharge. The target 3 in a device operated with alternating current as shown in Fig. 1, when negative in potential will attract the positive ions and some of the copper, silver, gold or the like, will be sputtered, thereby electrically precipitating the ionized gas, and restoring the high vacuum.

When the cathode consists in part of copper, or other electrically sputterable metal, the same effect will be obtained on direct current. Gas ionization will cause positive ions to be attracted to the negative terminal and the impact of the positive ions on the ring 11, or whatever part of the cathode consists of easily sputtered metal, will disintegrate some of the metal and thereby electrically precipitate or fix the gas.

Preferably both the cathode and the anode comprise in part a metal readily sputtered in devices intended for operation with alternating current, as the tube is then always ready to respond to incipient positive ionization with electrical vaporization of metal.

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

1. A cathode for an electrical discharge device comprising a conductor adapted to be heated by passage of current, and a member having the same polarity as the cathode and consisting of metal readily sputtered by positive ion bombardment.

2. An electrical discharge device comprising a filament of tungsten adapted to be heated, a member of metal readily sputtered by positive ion bombardment, an anode and an inclosing envelop, the space within said envelop being evacuated to a pressure so low that conduction of electricity may occur substantially independent of positive gas ionization.

3. A cathode for an electrical discharge device comprising a filament of highly refractory metal and a copper member located about said filament and electrically connected thereto.

4. A cathode for an X-ray tube comprising a filament of tungsten adapted to be independently heated, and a member of metal readily sputtered by positive ion bombardment connected to have the same polarity as said filament.

5. An electrical discharge device comprising an evacuated envelop, an electrode therein which is adapted to emit electrons independently of gas ionization, and a coöperating electrode, one of said electrodes consisting in part at least of metal readily sputtered by positive ion bombardment, and a source of energy connected to said device having a polarity negative during at least intervals of time with respect to the electrode containing sputterable metal, whereby gas may be electrically precipitated.

6. The process of fixing gas in an exhausted envelop containing a cathode comprising a member adapted to be heated independently to incandescence, and a coöperating anode, one of said electrodes consisting in part at least of metal readily sputtered electrically, which consists in producing a discharge between said electrodes while the member adapted to be heated is at incandescence, the polarity of the discharge being at least for intervals negative with respect to the electrode containing metal readily sputtered.

7. The process of completing the gas removal in an envelop containing an electrode comprising in part at least metallic copper, and a coöperating electrode of refractory material adapted to be heated by passage of current, which consists in producing an alternating current discharge between said electrodes while the copper electrode is maintained below the temperature of substantial thermal vaporization, and the cooperating electrode is heated to incandescence.

8. The process of creating and maintaining a high vacuum in an inclosed receptacle provided with electrodes, one of which is adapted to be independently heated to incandescence and one of which comprises a metal which may be electrically sputtered, which consists in subjecting said receptacle to a preliminary exhaust to a pressure at which a discharge occurs with difficulty from an unheated cathode, then sealing the receptacle, and finally impressing on the electrodes while the cathode is heated an alternating current of a potential high enough to sputter metal from the unheated electrode.

9. An electrical discharge device comprising a sealed envelop, the space within said envelop being evacuated to a pressure so low that an electron discharge can occur therein independently of gas ionization, a cathode therein adapted to emit electrons independently of gas ionization, and an anode, both of said electrodes consisting in part of metal readily sputtered electrically.

10. A thermionic device comprising a sealed envelop, the space within said envelop being evacuated to a pressure so low that a discharge may occur therein independently of gas ionization, a cathode comprising a filament of tungsten and a copper member, and an anode consisting in part at least of copper.

11. An X-ray tube comprising a sealed envelop, the space within said envelop being evacuated to a pressure so low that an electron discharge may occur therein without substantial gas ionization, a cathode comprising a filament of refractory metal, an anode, a plate of copper extending about said cathode substantially at right angles to an axis passing between cathode and anode.

12. An X-ray tube comprising the combination of an envelop, a cathode of refractory material adapted to be rendered incandescent, an anode, means for fluid-cooling said anode, and plate of copper within said tube connected to have the same polarity as said cathode.

13. An X-ray device comprising the combination of a filamentary cathode consisting of refractory material, means for heating said cathode, an anode comprising a copper member, and a discharge-receiving plate of refractory metal, means for circulating a cooling fluid in contact with said anode, a plate of copper electrically connected to said cathode, an inclosing evacuated envelop, and a source of alternating current connected to supply energy to said tube.

14. A cathode for an X-ray device operating by electron conduction comprising a filament of refractory metal adapted to be rendered incandescent by passage of current, a surrounding tube consisting of refractory metal and a flange of copper connected to and extending substantially at right angles to the tube of refractory metal.

15. A cathode for X-ray devices comprising a flanged tube of refractory metal, a spiral filament of refractory metal located near the mouth of said tube and a ring of metal, such as copper, which is readily sputtered by positive ion bombardment, fastened to the flange of said tube, and conductors for conveying a heating current to said spiral.

In witness whereof, I have hereunto set my hand this 2nd day of February 1916.

WILLIAM D. COOLIDGE.