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X-RAY TUBE

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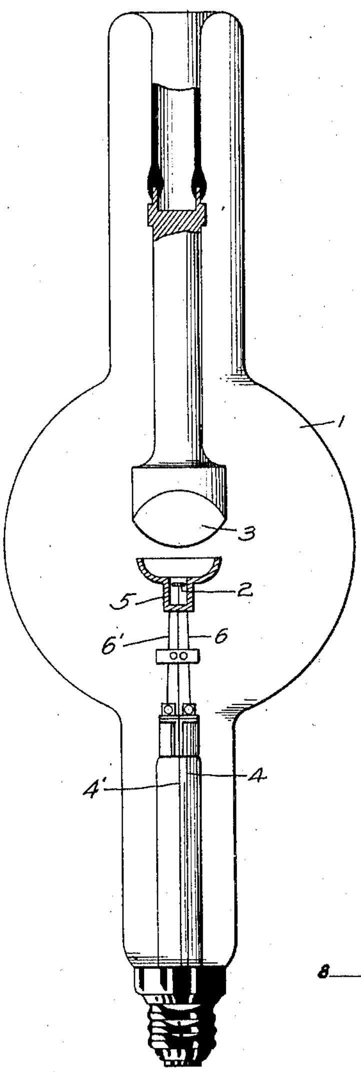

Fig. 1

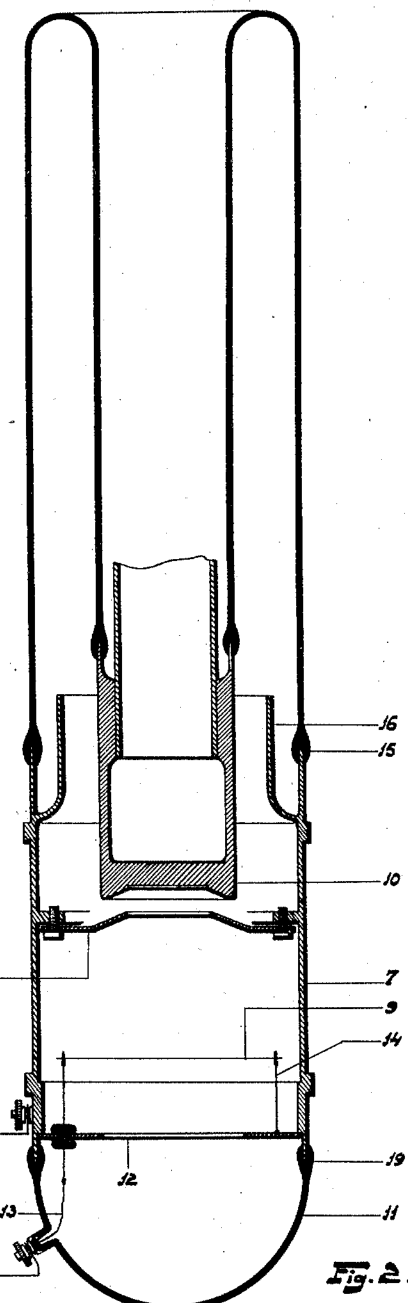

Fig. 2.

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UNITED STATES PATENT OFFICE.

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X-RAY TUBE.

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The present invention relates to improvements in incandescent cathode X-ray tubes. Known tubes of this type are for example those constructed by Wehnelt and Trenkle (Sitzungsberichte der physikalisch medizinischen Sozietät, Erlangen 37,312 (1905)) and those constructed by Coolidge.

In contradistinction to the X-ray tube of Wehnelt and Trenkle in which the vacuum was not extremely high, the vacuum in the X-ray tube of Coolidge according to his description, is to be as high as possible in order to avoid ionization. For this latter purpose the gas pressure in Coolidge's tubes is about 0.00005 millimetres of mercury, the upper limit of pressure being fixed at 0.0006 millimetres, thus much lower than the gas pressure in X-ray tubes the operation of which is based on gas ionization and in which the gas pressure varies between 0.001 and 0.01 millimetres of mercury. In order to ensure as far as possible the removal of the very last gas residues it has even been proposed to introduce into the X-ray tubes of the Coolidge type suitable substances, for example thorium or zirconium, which upon heating, will combine with the said gas residues.

It has been found that the objectionable influence of gas ionization can be suppressed in another way than by exhausting the X-ray tube to a high vacuum and it is possible to obtain very satisfactory incandescent cathode X-ray tubes with a properly chosen gaseous filling.

Incandescent cathode X-ray tubes according to the present invention are characterized by a gaseous filling of hydrogen, helium, or a mixture of the said gases, said filling having a pressure such that no appreciable gas ionization occurs and the production of positive ions is practically eliminated.

As a rule the gaseous pressure will be chosen higher than 0.0006 millimetres of mercury. Very good results have been obtained with X-ray tubes in which during operation, the field at the anticathode was very intensive. The more intensive the field at the anticathode in such X-ray tubes, the higher is the gas pressure at which gas ionization begins to have an appreciable influence.

Consequently the invention also comprises X-ray tubes in which, owing to their construction and geometric dimensions, the field adjacent the focal spot is very intensive when the tubes are connected to a source of high voltage current.

Probably ionization is due principally to secondary electrons generated at the anticathode. Therefore by providing a large field at the focal spot, the said secondary electrons will be drawn back to the anticathode before having an opportunity of ionizing molecules of the gaseous filling.

In order to ensure an intensive field at the anticathode, the X-ray tube may be so proportioned that the distance between the cathode and the anticathode is very small. The X-ray tube may also be so constructed that when connected to a high voltage circuit, the field is quite intensively concentrated before the anticathode and the entire potential difference between the cathode and anticathode is substantially before the anticathode and even very close before it.

X-ray tubes according to the invention will satisfy the condition that on supplying the high voltage between the cold cathode and the anticathode, no current will pass through the tube. In case such a current should flow, phenomena of ionization might be produced during the operation of the tube with the incandescent cathode, which phenomena would have a detrimental effect on the operation of the X-ray tube. It will be possible to prevent such phenomena of ionization by taking care that the distances between all parts between which a high difference of potential exists are very small and by constructing the tube in such a manner that all lines of force pass over a minimum distance in the interior of the X-ray tube. It will be essential in that case also that those parts of the X-ray tube, surrounded by walls of insulating material, should be so constructed and proportioned that the lines of force strike the said walls as far as possible in a normal or perpendicular direction and that the distance between said walls is small.

The present invention also comprises an incandescent cathode X-ray tube having a gaseous filling of hydrogen, helium, or a mixture of said gases, the cathode being arranged within a metal vessel the walls of which form partly or wholly part of the outer envelope of the tube and from which the anticathode is separated by an insulation capable of resisting the operating voltage to be supplied between the incandescent cathode and the anticathode, the metal vessel and the anticathode being so shaped and so arranged in relation to each other that the cathode rays can strike only a small area of the anticathode. Preferably the metal vessel will be locally constricted to form a small aperture and the portion of the surface of the anticathode to be struck by the cathode rays will be placed in or adjacent the said aperture.

X-ray tubes according to the invention have the advantage that they are better adapted than high vacuum X-ray tubes to be operated with alternating current without the anticathode being heated by the bombardment of electrons to such a temperature that a counter-current is produced.

Moreover the cooling of the anticathode in X-ray tubes according to the present invention will be assisted by the heat-conduction of the gaseous filling. Particularly when hydrogen is used as a gaseous filling, the anticathode will reach a less high temperature during the operation of the tube than has heretofore been the case in the usual high vacuum X-ray tubes and thus the probability of the anticathode being burnt or pitted by the intensively concentrated beam of cathode rays will be very small.

The invention will be more clearly understood by reference to the accompanying drawings, in which Figures 1 and 2 illustrate by way of example two constructions of X-ray tubes embodying the invention.

Figure 1 shows an X-ray tube having a bulb 1, an incandescent cathode 2 and an anticathode 3. The incandescent cathode may be of tungsten and is connected to leading-in wires 4, 4′ sealed in the bulb. The cathode 2 is surrounded by a focussing device 5 for cathode rays; said device being in electrical conductive connection to the cathode and supported by supporting wires 6, 6′. The said focussing device comprises a metal cylinder to which a metal hemispherical element is fixed. The anticathode may be of tungsten fixed in copper which may be sealed in the bulb by means of platinum. It is so arranged that the cathode rays can strike the anticathode only over part of its surface. As there is no objection to a relatively high gas pressure within the X-ray tube according to the present invention, it is not necessary that the air enclosed within the tube be removed by means of a high vacuum pump; a properly operating oil-pump is quite sufficient for the object of the invention. While using such pump, the tube should be continuously washed with the gas with which the X-ray tube is to be filled.

Furthermore it is necessary that the glass of the bulb and the anti-cathode be freed from gases as the gases they generally contain, might injuriously influence the operation of the X-ray tube. As soon as the objectionable gases have as far as possible been removed by the continuously flowing gas which is intended to fill the X-ray tube, the gaseous filling is given the desired pressure. By operating the X-ray tube thereupon for some time some gas may disappear from the tube, thereby reducing the gas pressure. By subsequently supplying gas to the tube and repeating this operation several times, the desired gas pressure can be restored, and thus a state of affairs can be ensured in which the gas pressure no longer varies objectionably. When the said state of affairs is reached, the X-ray tube is sealed off from the pump.

It is possible to obtain excellent results with a tube of the construction described, in which the distance from cathode to anticathode is only 0.8 centimetres, so that when connected to a circuit supplying 100,000 volts a very intensive field is obtained before the anticathode, the tube having a hydrogen filling under a pressure of 0.01 millimetres of mercury. The current passing through the tube remains perfectly constant during a radiographic exposure of several minutes and even after several hundreds of exposures no impairment of the good properties of the X-ray tube is perceptible. The gas pressure of 0.01 millimetres used in this tube is even higher than is the practice in X-ray tubes the operation of which is based on gas ionization. According to the present invention it is however, possible to supply X-ray tubes with a gaseous filling of a materially higher pressure than 0.01 millimetres of mercury, for instance one millimetre. In any event, the gas pressure will be above 0.0006 millimetres of mercury, and lies preferably between 0.0006 and 0.02, within which range a pressure of from 0.001 to 0.01 generally yields the best results.

Figure 2 shows an X-ray tube with a metal envelope. In this highly suitable construction, the incandescent cathode 9 is arranged within a metal vessel 7 to the wall of which is fixed a metal cover 8 provided with an aperture before which part of the surface of the anticathode 10 is located. Opposite the said anticathode, the metal vessel is provided with a window for the passage of the X-rays generated. The said window comprises a glass cap 11 hermetically sealed to the metal vessel at 19, and in addition an annular metal plate 12 for example of iron is provided screening the X-rays and having the leading-in wires for the incandescent cathode fixed to it. The X-ray tube is filled with hydrogen or helium of a pressure between 0.01 and 1 millimetres of mercury. One leading-in wire 13 for the incandescent cathode passes through the metal plate 12 from which it is insulated and is sealed in the glass cap 11. The other leading-in wire is constituted by the conductive connection of the terminal 14, the metal plate 12 and the metal envelope 7. The cathode is made incandescent by the passage of an electric current supplied by a battery 17 with which a regulating resistance 18 is connected in series. A metal cylinder 16 disposed before the weld 15 is sealed to the metal envelope 7 and serves to protect the weld 15 against bombarding electrons and thus against electrostatic charges. The distance from the anticathode to the metal envelope 7, the metal cover 8 and the metal cylinder 16 is so small throughout that at the gas pressure used there is no risk of a discharge occurring between the said metal parts when the tube is connected to a source of high voltage.

The cathode rays emitted by the cathode can strike only a small area of the anticathode, owing to the particular shape of wall and cover of the metal vessel and to the arrangement of the anticathode in relation to the said cover. In the case of the cover being provided with an aperture having a diameter of 20 millimetres, the focal spot is found to have a diameter of some 2 millimetres only.

When supplying a high voltage between the cathode and anticathode the whole field between the cathode and anticathode will be concentrated in a small space before the anticathode, as the metal vessel 7 has a potential which is approximately equal to or lower than that of the cathode and an X-ray tube according to the present invention and constructed as described is found to operate in an excellent manner.

It is obvious that in addition to the constructions hereinbefore described there are many other constructions of X-ray tubes which fall within the scope of the invention. Moreover if the geometric dimensions of the X-ray tube are so chosen that the field before the anticathode is concentrated to a higher extent than in the construction shown in Figure 2, it is possible to use higher pressures than 1 millimetre of mercury.

In many cases it may be desirable to introduce a drying-medium for example into the bulb of the X-ray tube.

While in the appended claims we refer specifically to a hydrogen filling, we desire it to be understood that for the purposes of our present invention helium, or a mixture of helium and hydrogen, are to be considered equivalents of hydrogen, and that such claims are to be interpreted accordingly.

What we claim is:

1. An X-ray tube comprising an envelope, cooperating electrodes therein one of which has connections for heating it independently of the other, the space within said envelope being provided with a gaseous filling of at least one of the two elements of smallest atomic number having a pressure higher than 0.0006 mm. of mercury such that there does not occur appreciable ionization by collision during the operation of the tube.

2. In an X-ray tube operating by substantially pure electron conduction independently of positive gas ionization, the combination of a cathode, an anode and an inclosing envelope provided with a gaseous filling of at least one of the two elements of smallest atomic number having a pressure between 0.0006 and 0.02 mm. of mercury.

3. An incandescent cathode X-ray tube containing a gaseous filling of at least one of the two elements of smallest atomic number having a pressure higher than 0.0006 mm. of mercury such that no appreciable gas ionization occurs, and including an incandescent cathode and an anticathode, the distance between the anticathode and the incandescent cathode being very small.

4. An incandescent cathode X-ray tube containing a gaseous filling of at least one of the two elements of smallest atomic number having a pressure higher than 0.0006 mm. of mercury such that no appreciable gas ionization occurs, and including a metal vessel having a wall which forms part of the outer envelope of the tube, an incandescent cathode mounted within the metal vessel, and an anticathode separate from said vessel by an insulation capable of resisting the operating voltage to be supplied between the incandescent cathode and the anticathode.

5. An incandescent cathode X-ray tube containing a gaseous filling of at least one of the two elements of smallest atomic number having a pressure higher than 0.0006 mm. of mercury such that the hydrogen is not appreciably ionized, and including a metal vessel having a wall which forms part of the outer envelope of the tube, a cathode mounted within the metal vessel, and an anticathode separated from said vessel by an insulation capable of resisting the operating voltage to be supplied between the cathode and the anticathode, said metal vessel being locally constricted to form a small aperture for focusing the electrons passing therethrough and a portion of the surface of the anticathode designed to be struck by the cathode rays being placed adjacent the said aperture, whereby the cathode rays can strike only a small area of the anticathode.

6. An X-ray tube comprising an evacuated envelope, an anticathode and a double terminal cathode located in said envelope, and a gaseous filling of at least one of the two elements of smallest atomic number in said envelope under a pressure greater than 0.0006 mm. of mercury.

7. An X-ray tube of the incandescent cathode type, having an envelope the outer

wall of which is partly of metal, and comprising a gaseous filling of at least one of the two elements of smallest atomic number under a pressure higher than 0.0006 mm. of mercury such that no appreciable gas ionization will occur, an incandescent cathode, and an anticathode in the tube, the distance between the anticathode and parts of the tube which are electrically connected with the incandescent cathode being very small.

In testimony whereof we affix our signatures, at the city of Eindhoven, this 19th day of January, 1924.

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