Nov. 19, 1940. A. VERHOEFF 2,222,549

X-RAY TUBE

Filed Dec. 17, 1938 2 Sheets-Sheet 1

Fig. 1

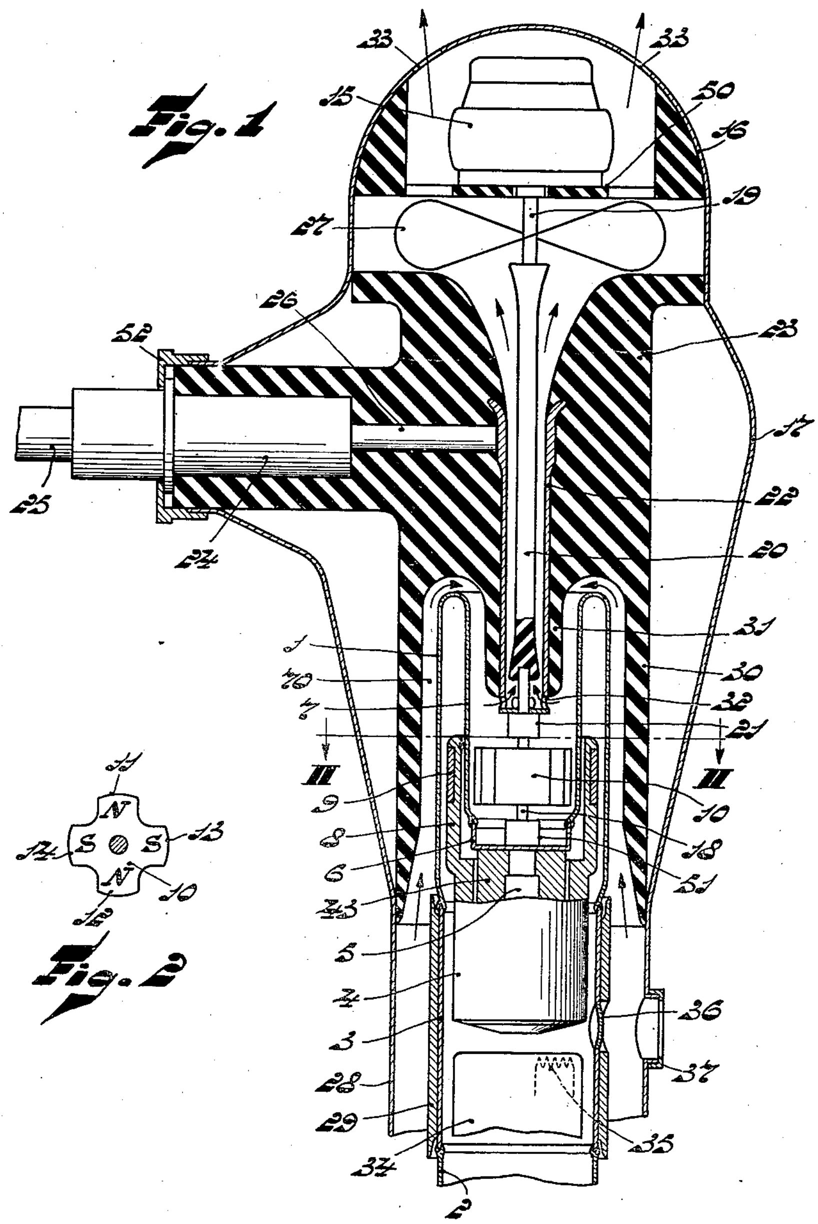

Fig. 2

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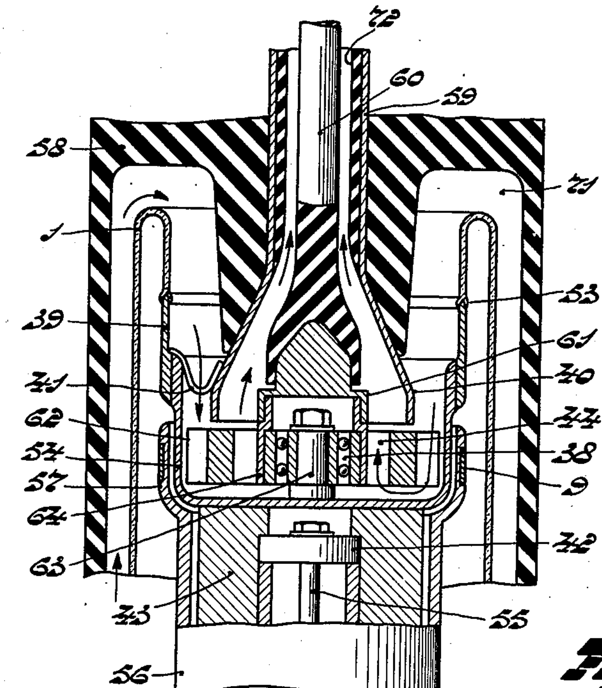


Fig. 3

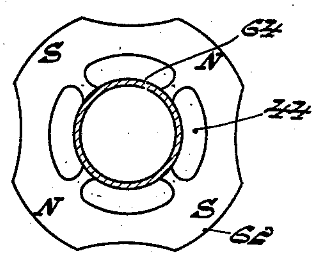


Fig. 4

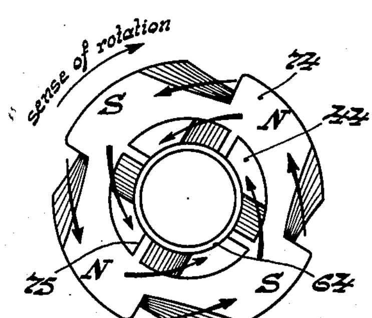
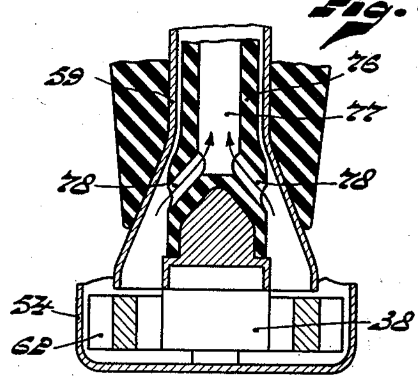


Fig. 5

Fig. 6



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Patented Nov. 19, 1940 **2,222,549**

UNITED STATES PATENT OFFICE

2,222,549

X-RAY TUBE

Adrianus Verhoeff, Eindhoven, Netherlands, assignor, by mesne assignments, to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

Application December 17, 1938, Serial No. 246,451
In Germany December 22, 1937

11 Claims. (Cl. 250—148)

My invention relates to X-ray tubes having a rotary anode and particularly to tubes of this type which are enclosed within a protective housing.

In practice the rotation of the anode of an X-ray tube is usually effected by means of a rotating magnetic field set up by a stationary, and preferably three-phase, stator which surrounds the tube. Although this method is very simple and satisfactory it is difficult to insulate the stator, which must be located close to the tube, against a high voltage with respect to the anode. Furthermore the stator increases the diameter of the protective housing of the tube, and if it is desired to control the speed of rotation of the anode a frequency changer must be used. In addition, if three-phase current is not available, it is necessary to provide phase-displacement means for starting the rotation of the anode.

The object of my invention is to overcome the above difficulties and for this purpose I rotate the anode by means of a driving rotor which is located outside the vacuum space of the X-ray tube and which may be either an electro-magnet or a permanent magnet. Alternatively the rotatable anode may carry a permanent magnet cooperating with a driving rotor consisting of a body of ferromagnetic material, which body may be provided with poles. I drive this rotor from an electric motor, and effect this drive through a shaft of insulating material so that the rotor can have the potential of the anode.

The motor is located at one end of the tube so that it does not cause any increase in the diameter of the protective housing, and may be of a variable speed type, for instance a single-phase commutator motor.

According to one embodiment of the invention, I locate the driving rotor within a glass or metallic reentrant portion of the tube envelope, and provide the anode with a cylindrical extension which extends into the annular space formed between this reentrant portion and the outer wall of the tube envelope. This cylindrical extension forms the point of application of the driving torque and is provided with a cylinder of magnetic material of high permeability or with a cylindrical permanent magnet. With such a construction no part of the anode actuating means surrounds the tube, and as a result the protective housing may be given a small cross-section which is determined only by the value of the voltage.

In cases in which a fan for circulating a cooling medium, such as air, or a stirrer for a cooling liquid, such as oil, is provided within the protective housing, I prefer to connect the driving rotor to the means for driving the fan or stirrer. This gives a simple construction and at the same time an increase in the speed of rotation of the anode will be accompanied by an increase in the cooling capacity, which is very desirable.

The driving rotor may also serve to circulate a cooling fluid and for this purpose may be formed as an impeller of a fan or as a rotor of a pump, or an impeller or pump rotor can be arranged adjacent the driving rotor so that they are also at high potential. The driving shaft may be made hollow so that it can serve as a passageway for the cooling fluid, and under some conditions this improves the cooling of parts of the tube in the vicinity of the anode.

In order that the invention may be clearly understood and readily carried into effect, I shall describe the same in more detail with reference to the accompanying drawings in which:

Figure 1 is a sectionized view of a portion of an X-ray tube embodying the invention,

Fig. 2 is a sectional view along line II—II of Figure 1,

Fig. 3 is a sectionized view of a portion of an X-ray tube according to another embodiment of the invention, and

Fig. 4 is a plan view of the driving rotor of Fig. 3.

Fig. 5 is a plan view of a driving rotor in a modified form.

Fig. 6 shows a modification of the construction represented by Fig. 3.

The X-ray tube partly shown in Figure 1 has an envelope comprising a central metal cylinder **3**, for instance of chrome iron, to the ends of which are hermetically sealed two vitreous members **1** and **2**. Member **1** has a reentrant portion **7** whose lower end is hermetically sealed to a cup-shaped member **6** of metal, for instance of chrome iron. Supported by member **6** is a shaft **5** upon which is rotatably mounted a cylindrical anode **4** having an annular portion **8** extending into the annular space formed by vitreous member **1** and carrying an iron cylinder **9**. Instead of being solid, the cylinder **9** may be made up of axially-extending sections each forming a separate magnetisable body. A cylindrical body **43** is fixedly secured to member **6** and has a large surface closely spaced from the inner surface of anode **4** so as to facilitate the removal of heat from the anode.

Metal cylinder **3** is provided with a window **36** for the exit of the X-rays, and is surrounded, except at window 36, with a lead sheath 29. A cathode 35 located within a concentrating device 34 is shown near the target surface of anode 4.

The X-ray tube is enclosed within a protective housing 17 of metal, or of insulating material having a metal coating, provided with a filter holder 37, and having a cup-shaped end portion 16 provided with several apertures 33. Supported in a suitable manner from housing 17 is a moulded body 23 of insulating material which serves to prevent flash-over between the parts of the tube which are at high potential and the housing 17 which is usually grounded. Body 23 surrounds the vitreous member 1 with an intermediate annular space 70 and is provided with a central bore in which is moulded a metal tube 22 provided at its lower end with a plurality of apertures 32.

Supported from an apertured portion 50 of body 23 is a motor 15, preferably of the variable speed type, having a shaft 19 carrying a fan 27. A rod 20 of insulating material is secured at one end to shaft 19. During operation the housing and the windings of motor 15 have substantially the potential of housing 17.

Within the space formed by reentrant portion 7 and aligned with ring 9 is a driving rotor 10 in the form of a permanent magnet which, as shown in Figure 2, has four poles 11 to 14 of which poles 11 and 12 may be north poles and poles 13 and 14 may be south poles, as indicated. Rotor 10 is fixedly mounted on a metal shaft 18 which shaft has one end supported in a bearing 51 secured to member 6, and its other end extending through a bearing 21 secured to tube 22, and connected to the lower end of insulating rod 20. Thus, because of its metallic connection to member 6, rotor 10 is at a very high potential with respect to the housing 17 and the motor 15. However, the use of the insulating rod 20 completely insulates the motor and housing against this high voltage.

As rotor 10 and portion 8 are at the same potential, the intervening part of glass portion 7 will not be electrostatically loaded, and consequently the spacing between the peripheral surface of rotor 10 and the inner surface of portion 8 can be as small as is possible from a mechanical standpoint. In view of this small spacing there will be very little slip between rotor 10 and anode 4, and the anode can be rapidly accelerated to the desired rotational velocity.

Tube 22, to which rotor 10 and thus anode 4 is electrically connected, is engaged by a contact rod 26 forming part of a terminal piece 24 of insulating material secured to housing 17 by a nut 52. An insulated cable 25 for the supply of anode current is secured to terminal piece 24 with its conductor connected to rod 26.

To eliminate the passage of current through bearing 51, member 6 may be made longer so as to extend between rotor 10 and portion 8 and form a direct metallic connection with tube 22. Such a construction is illustrated by Figure 3.

During operation the cooling air travels a course indicated by the arrows. More particularly the air passes from the cathode end of the tube through the annular passageway formed between cylinder 29 and the central portion 28 of housing 17. The air then passes upwardly through the space 70, downwardly through the space formed between the portion 7 and an extending portion 31 of member 23, through apertures 32, through the annular passageway formed between tube 22 and shaft 20, and out of the tube through apertures 33. With such a circulation of air the vitreous member 1 as well as the metal to glass seals of the tube envelope are effectively cooled.

Figure 3 is a sectionized view of a portion of an X-ray tube which, in other respects, is similar to that shown in Figure 1. In Figure 3 the reentrant part of member 1 terminates at a point 53 at which it is hermetically fused to a ring 39 of chrome iron. Secured to the lower end of ring 39, for instance by solder, is a cup-shaped metal member 54, hereinafter more fully described, to which is fixedly secured the metal member 43 of Figure 1.

Mounted in member 43 is a bearing 42 carrying a shaft 55 to which is secured an anode 56 similar to the anode 4 of Figure 1 and having an extending portion 57 surrounding a portion of member 54 and provided with an iron ring 9.

A moulded member 58 of insulating material, whose upper portion (not shown) is similar to that of member 23 of Figure 1, surrounds the tube envelope with an intermediate space 71. Moulded within the central part of member 58 is a metal tube 59 having a flared end portion 40 extending into the space enclosed within the cup-shaped member 54.

Tube 59 has an inner coating 72 of insulating material to prevent flashing-over from the inner surface of the metal tube through the space between this tube and shaft 60 to grounded parts at the end of the housing.

Within the bore of tube 59 is a shaft 60 which is similar to rod 20 of Figure 1 and is driven in a similar manner by the motor 15 of this figure. Fixedly secured to the lower end of rod 60 is a coupling 61 connected to a bushing 64 secured to a driving rotor 62. Rotor 62 rotates on a ball bearing 38 mounted on a shaft 63 carried by member 54. As shown more clearly in Figure 4, rotor 62 is similar to rotor 10 of Figure 1 except that it has a grooved inner surface which forms with the bushing 64, four openings 44.

A metal spring 41 has one end secured to member 54 and its other end bearing the flared end of tube 59 to form a direct electrical connection therebetween.

The anode 56 is rotated in the same manner as in Figure 1, by the rotating magnetic field produced by rotating the driving rotor 62. I have found that eddy currents produced in metal member 54, through which the magnetic lines of force pass, greatly reduce the speed of rotation of the anode, and to avoid this, I make this member of a non-magnetic material which has a high resistivity, for example more than 0.4 ohm per cubic centimeter (100 cm. length and 0.01 $cm.^2$ section). By using such metals the reaction caused by the eddy currents is extremely small, because these currents will be much smaller than in the case of a metal of high conductivity. As a result the anode will be readily carried along. I have found that particularly good results are obtained by using constantan, which is an alloy consisting of equal parts of nickel and copper and has a specific resistivity of about 0.5, but other non-magnetic alloys of high resistivity can be used.

During operation the cooling air is circulated by means of the fan 27 of Figure 1 and follows a course which is somewhat similar to that described in connection with Figure 1. However, in Figure 3 the air flows downwardly around the periphery of rotor 62, along the bottom of member 54, and upwardly through the openings 44 to the annular space formed between tube 59 and rod 60. Due to the passage of air along the bottom of member 54 a very effective cooling of the anode is obtained.

Instead of using the fan 27 of Figure 1, the rotor 62 can be formed as an impeller as shown in Fig. 5 or a fan can be mounted above this rotor on member 61. With the rotor shown in Fig. 5 the magnet poles 74 form the wings of a fan and are so positioned as to draw the air from the rear side to the side from which the rotor is shown, which is the side facing the bottom of member 54 of Fig. 3. Again the spokes 75 are disposed with a reversed inclination, so that they form a blower propelling the air from the space between the rotor and member 54 to the space enclosed between shaft 60 and tube 59.

Fig. 6 shows a portion of the arrangement of Fig. 3 with a modified construction of the shaft. In this construction the shaft 76 is hollow.

Through holes 78 provided in the thickened end portion of the shaft the air is permitted to penetrate into the duct 77 by which it is be sucked away. Because the space between the shaft and the tube 59 does no longer serve as an air conduit, it may be narrower than in the structure of Fig. 3. The insulating coating of the inner side of tube 59 is omitted, as there is no danger for flashing-over across the long narrow gap between the metal tube 59 and the insulating shaft 76.

While I have described my invention in connection with specific examples and constructions, I do not wish to be limited thereto but desire the appended claims to be construed as broadly as is permissible in view of the prior art.

What I claim is:

1. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, a protective metallic housing enclosing said tube, and means for magnetically rotating said anode including a driving rotor, a motor supported from said housing, and a shaft of insulating material connected between said motor and rotor, said rotor being in magnetic relationship with said anode.

2. An X-ray apparatus comprising a protective housing, and an X-ray tube within said housing and comprising an envelope having a reentrant portion forming an annular space with the envelope, a cathode, and a rotatable anode supported from the reentrant portion and having a portion extending into said annular space, and means to magnetically rotate said anode including a driving rotor within said reentrant portion, said rotor being in magnetic relationship with the extending portion of said anode.

3. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, and protective housing enclosing said tube, a fan, a motor for driving said fan and supported from said housing, and means to magnetically rotate said anode including a driving rotor in magnetic relationship with said anode, and a shaft of insulating material connecting said rotor to said motor.

4. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, a protective housing enclosing said tube, means for magnetically rotating said anode including a motor supported from said housing, a driving rotor and a shaft of insulating material connecting said rotor and motor, said rotor being in magnetic relationship with said anode, and means for circulating a fluid around the X-ray tube including a member arranged adjacent said rotor.

5. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, a protective housing enclosing said tube, and means for rotating said anode and for circulating a fluid around said tube including a motor supported from said housing, a driving rotor, and a shaft of insulating material connecting said rotor and motor, said rotor being in magnetic relationship with said anode and being shaped as an impeller.

6. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, a protective housing enclosing said tube, and means for rotating said anode and for circulating a fluid around said tube including a motor supported from said housing, a driving rotor, and a hollow shaft of insulating material connecting said rotor and motor, said rotor being in magnetic relationship with said anode and being shaped as an impeller.

7. An X-ray apparatus comprising an X-ray tube having a cathode and a rotatable anode, a protective metallic housing enclosing said tube, and means for rotating said anode including a driving rotor in magnetic relationship with said anode, a variable speed motor supported from said housing, and a shaft of insulating material connected between said motor and rotor.

8. An X-ray apparatus comprising an X-ray tube having an envelope, a cathode, and a rotatable anode, a protective housing enclosing said tube, and means to rotate said anode including a driving rotor in magnetic relationship with said anode, a motor, and a shaft of insulating material connecting said motor and rotor, said envelope having a non-magnetic metal portion of a resistivity at least .04 ohm per cubic centimeter extending between said rotor and a portion of said anode.

9. An X-ray apparatus comprising an X-ray tube having an envelope, a cathode and a rotatable anode, a protective housing enclosing said tube, and means to rotate said anode also enclosed by said housing, said means including an electric motor, a rotor and a shaft of insulating material connecting said motor and rotor, said rotor comprising radially extending magnet poles and said anode comprising a ring of ferromagnetic material, surrounding said rotor, a reentrant portion of said envelope extending between said rotor and ring, said shaft projecting from said reentrant portion.

10. An X-ray tube comprising an evacuated envelope having a reentrant portion, a cathode within said envelope, a rotatable anode within said envelope and at one end thereof, and means to magnetically rotate said anode including a driving rotor in magnetic relationship with the anode, and a driving device connected to said rotor, said rotor being located within said reentrant portion and outside the evacuated space of the tube.

11. An X-ray tube comprising an evacuated envelope having a reentrant portion, a cathode within said envelope, a rotatable anode near said reentrant portion, and means to magnetically rotate said anode, said means including a driving rotor in magnetic relation with the anode, and a motor connected to said rotor, said rotor being located within said reentrant portion and outside the evacuated space of the tube.

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