# United States Patent

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[54] **AN ELECTRIC DRIVE MOTOR FOR ROTATABLY DRIVING THE ANODE OF AN X-RAY TUBE**
**9 Claims, 4 Drawing Figs.**


[52] **U.S. Cl.** ..... **313/149,** 310/268, 313/55, 313/60, 313/152, 313/160
[51] **Int. Cl.** ..... **H01j 1/44,** H01j 35/10
[50] **Field of Search** ..... 313/55, 60, 146, 149, 152, 160; 310/105, 108, 109, 237, 268



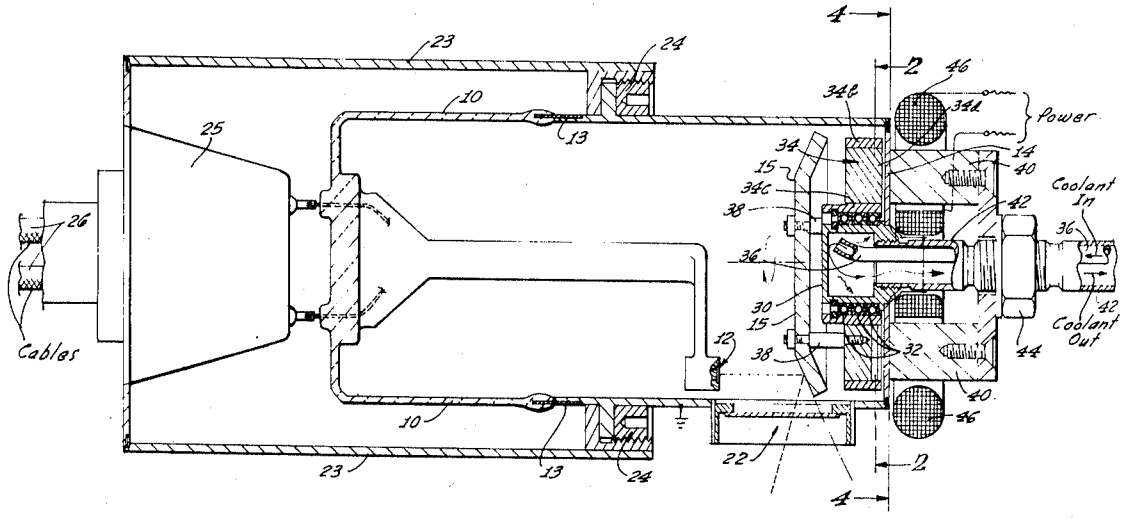
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**ABSTRACT:** A high-voltage, high-vacuum X-ray tube is provided which includes a rotating target electrode for increased target life, and which also includes a unique and improved electric motor for rotatably driving the target electrode, the motor having a flat, "pancake" configuration, with a rotor inside the evacuated envelope of the X-ray tube, and with an externally positioned stator.

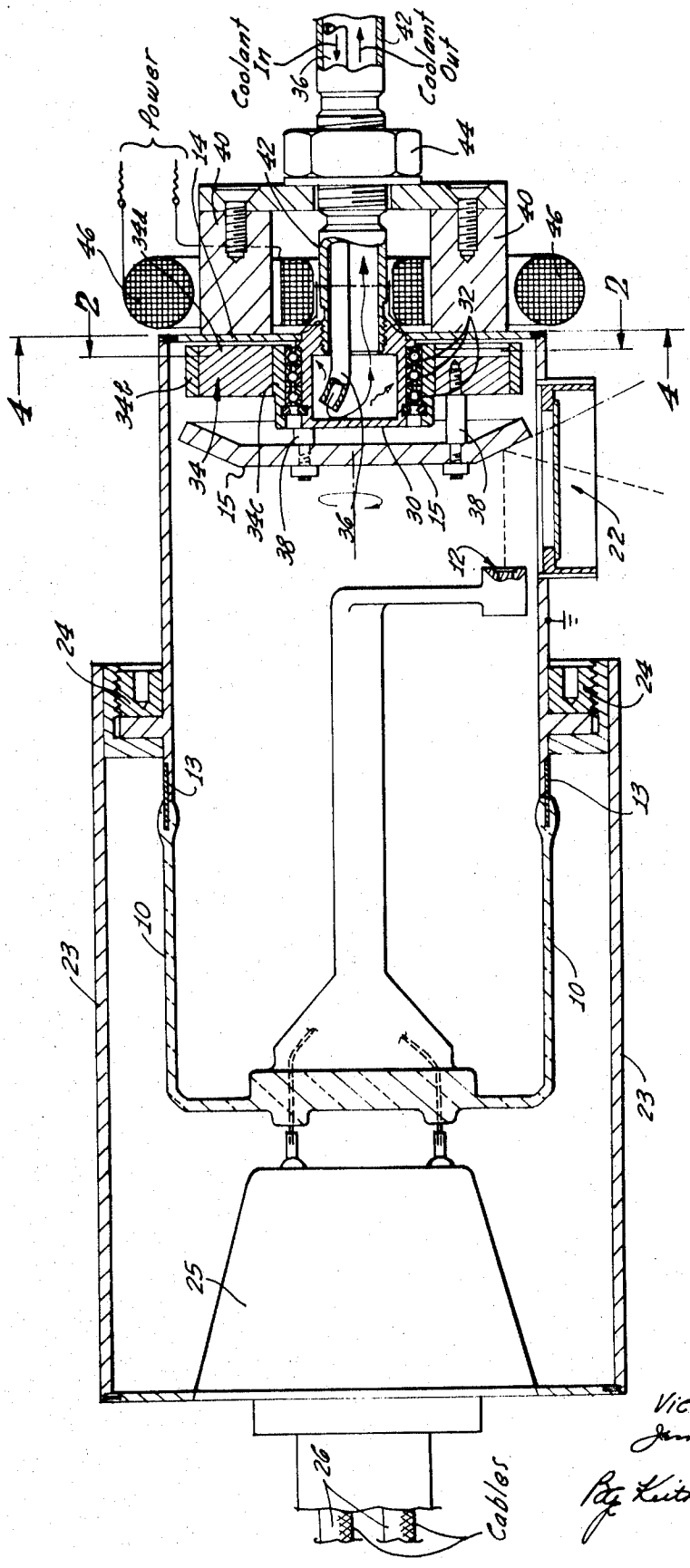



Fig. 1

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Fig. 2

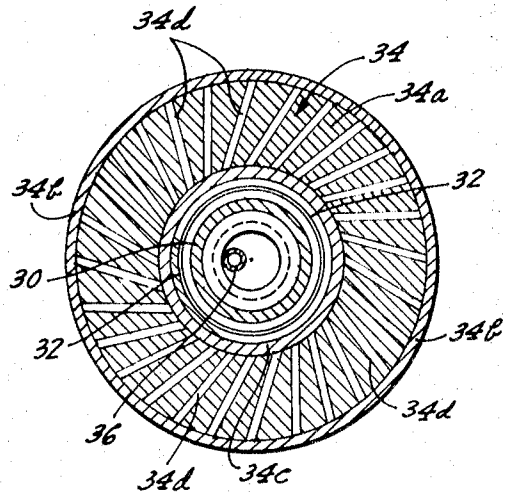



Fig. 3

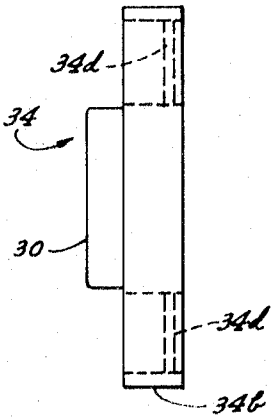
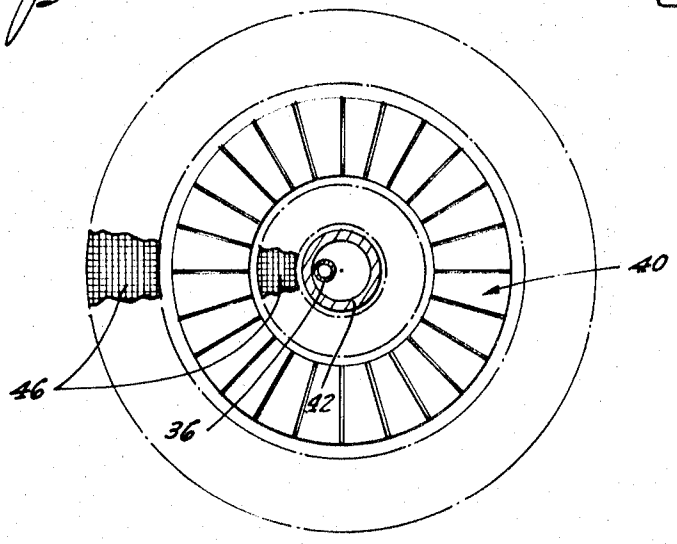



Fig. 4




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# AN ELECTRIC DRIVE MOTOR FOR ROTATABLY DRIVING THE ANODE OF AN X-RAY TUBE

## BACKGROUND OF THE INVENTION

X-ray tubes having rotating anode assemblies are known to the art. Generally, such an X-ray tube has its rotating anode assembly supported by bearings contained within the highly evacuated glass envelope of the tube. It is also usual to provide a drive motor for the rotating anode assembly within the envelope, since it is difficult to provide an adequate seal between the rotating drive shaft of an external motor and the wall of the envelope.

However, in the prior art, the provision of such drive motors within the envelope usually included a relatively long axial drive shaft for the rotating target assembly, and this drive shaft was susceptible to a wobbling motion after a period of wear. Such motion, however, produces blurring of the X-ray beam, and cannot be tolerated. The structure of the present invention is such that a portion only of the motor is inside the envelope, and that portion has a relatively short axial length, so that the target electrode may be rotatably supported for precise rotation about a particular axis and so that the aforesaid wobbling action is obviated.

The structure of the present invention, as will be described, includes an induction "squirrel cage" type of motor of a unique construction, which incorporates a disc-shaped rotor supported within the evacuated envelope, and a stator positioned outside of the envelope. The rotor is mechanically coupled to the target electrode of the aforesaid anode assembly, so that when the rotor is driven, the target electrode is rotated about a particular axis.

The rotor has a core which may be composed, for example, of a magnetizable material, such as soft iron. The core may have a solid rather than a laminated construction, since laminations are usually not compatible with the vacuum environment in which the rotor is positioned. However, a laminated rotor may be used if desired, with the laminations coated with an insulating oxide which is inert in vacuum environments. The rotor is formed, for example, of a conductive ring, such as copper, surrounding the rotor core, and of another conductive copper ring, for example, within the bore of the core, and with a plurality of radially extending copper rods interconnecting the two rings, so as to provide a squirrel cage type of induction winding required to develop torque in the rotor.

The rotor itself is supported on appropriate bearings for precise rotation about the axis of rotation of the target electrode. Since the bearings are used in a high degree of vacuum and at a relatively high temperature, for example, above 300° C., advanced techniques are required with respect to material selection, structure and lubrication for the bearings. For example, the bearing balls and races may be composed of stainless steel, with the balls silver plated for lubricating purposes. Alternately, the races and balls may be composed of a chrome iron cobalt alloy, with the balls silver plated, for an even more satisfactory structure. Practical bearings suitable for the purpose of the invention are presently available on the market.

In a typical construction, the rotor has a diameter of 2¼ inches and a width of ⅜ to ½ inches. These dimensions are set forth herein merely by way of example, and without any intention to limit the invention in any way.

As mentioned above, the stator of the motor of the present invention is positioned externally of the envelope of the X-ray tube. In the embodiment to be described, the stator is held directly against a nonmagnetic metallic end plate of the tube, formed, for example, of a nonmagnetic material, such as stainless steel. The stator, like the rotor, also has a disclike configuration, and it is positioned in coaxial relationship with the rotor, with the end plate separating the stator and rotor.

Appropriate field windings are provided on the external stator, and these windings set up a rotating magnetic field in the evacuated tube in response to an applied alternating current, so as to establish induction action with the squirrel cage rotor,



and thereby cause the rotor to exert a torque and drive the target electrode rotatably about the aforesaid axis. For example, when a 60-cycle alternating current voltage is introduced to the stator winding, the construction may be such that the rotor spins in the high-vacuum interior of the tube at a rate of 1,200 r.p.m.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a somewhat schematic representation of an X-ray tube which is constructed to incorporate the teachings of the present invention, and also illustrating the unique and improved drive motor for rotating the target electrode of the tube about a particular axis, the drive motor being constructed in accordance with the concepts of the present invention;

FIG. **2** is a cross-sectional view of the rotor of the motor of FIG. **1**, taken essentially along the line **2—2** of FIG. **1**;

FIG. **3** is a side view of the rotor of FIG. **2**; and

FIG. **4** is a view of the stator of the motor of FIG. **1**, taken essentially along the line **4—4** of FIG. **1**.

## DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

The X-ray tube illustrated in the drawing includes an envelope **10** formed of glass or other suitable vitreous or other material. The envelope **10** has a generally elongated configuration, and it includes a cathode assembly **12** supported on the left-hand end wall **10***a* of the envelope **10**, as shown in FIG. **1**. The envelope surrounding the X-ray tube is completed by a further tubular member **11** which is positioned coaxially with the envelope **10**, and which is sealed to the envelope **10** by means, for example, of a ring **13** of Kovar, or other appropriate material. The tubular member **11** may be formed, for example, of Monel, or other suitable nonmagnetic metal. An end wall **14** positioned at the right-hand end of the assembly in FIG. **1** is welded, by electrode beam welding techniques, or by other suitable processes, to the end of the tubular member **11**.

The anode assembly of the cathode-ray tube is supported within the evacuated interior of the tube, as formed by the envelope **10**, and by the tubular member **11** and end wall **14**, the anode assembly being supported on the end wall in a manner to be described. The anode assembly includes a target electrode **15** which is formed of tungsten, or other appropriate material. The target electrode is rotated about a particular axis, in a manner to be described, so that the beam developed within the tube by the cathode **12** may be concentrated into a small spot and directed to the target electrode **15**. This results in a high definition in the resulting X-ray beam being developed by the target electrode from the impingement of the electron beam from the cathode **12**.

The rotation of the target electrode **15** permits a high concentration of the electron beam from the cathode into a small spot, and yet obviates the tendency for the spot to burn itself through the target material. In this way, even though the electron beam developed by the cathode **12** is concentrated on a small area of the target electrode, the life of the target electrode is not unduly impaired, due to the fact that it is continually rotating during the operation of the tube.

The cathode and anode assemblies are supported within the evacuated interior of the X-ray tube in positions spaced from one another, as shown in FIG. **1**, and the electron beam developed by the cathode **12** is directed towards the rotating target electrode **15**. As is usual in the X-ray art, the target electrode is established at a relatively high voltage relative to the cathode assembly, so that the electron beam from the cathode **12** may be accelerated towards the anode assembly to strike the target **15** with a relatively high velocity. The aforesaid high voltage may be achieved, for example, by establishing the end plate **14**, the tubular member **11**, and the target electrode **15** at ground potential, and by establishing the cathode assembly **12** at a high negative potential.

The incidence of the electron beam from the cathode assembly 12 on the rotating target electrode 15 causes X-rays to be emitted from the target electrode, in accordance with known X-ray principles. These X-rays pass through a window assembly 22 which is mounted on the side of the tubular member 11, as shown. The window assembly 22, for example, may be similar to the window assembly described in copending application Ser. No. 781,143, which was filed Dec. 4, 1968, in the name of the present inventor.

For safety purposes, the envelope 10 may be surrounded by an external metallic housing 23, the housing 23 being mounted to the tubular member 11 and sealed thereto by an appropriate mounting and sealing assembly 24. An insulator 25 is mounted on the inner side of the end wall 23, and the high negative voltage leads 26 for the cathode may be brought in through the insulator 25. The spacing between the external housing 23 and the envelope 10 may be filled with a high-pressure gas, such as, for example, sulfur hexfluoride ($SF_6$).

A hub 30 formed of appropriate nonmagnetic material, such as stainless steel, is mounted on the inner face of the end wall 14, and it surrounds an opening in the end wall. The inner end of the hub 30 is closed, as shown. Three separate bearings 32 are mounted on the hub 30 adjacent one another, and these bearings rotatably support the rotor assembly 34. The bearings 32 have a relatively short axial overall length, and they assure that the rotor assembly will continue to rotate precisely about the particular axis of rotation without wobbling. The bearings 32, as mentioned above, may have their balls and races formed of stainless steel, and the balls may be silver plated for lubricating purposes. As is well known, conventional lubricants are not appropriate in a high vacuum. The relatively short rotor of the present invention, as shown in FIG. 3, is also advantageous as compared with the longer rotors of the prior art arrangements in that its mechanical resonant frequency is higher and less detrimental.

Cooling of the bearings is provided by means of a hose 36 which extends into the hub 30, and which introduces a coolant, such as water, to the interior of the hub which, in turn, cools the bearings. The target electrode 15 is supported on the rotor assembly 34 by means of posts 38. The posts 38, for example, may be composed of stainless steel or other relatively low heat conductivity material. In this way, the major heat emitted from the rotating target electrode 15 is by radiation, so as to avoid undue heating of the bearings 32. However, the selection of the posts 38, and the dimensions of the posts, may be selected so as to provide as much heat flow from the target through the bearings to the coolant in the hub 30 as possible, without unduly heating the bearings. Additional bearings may be provided, if desired, to increase the heat conduction away from the target.

The motor includes a stator 40 (FIG. 4) which is supported externally of the X-ray tube and directly against the end plate 14. The stator 40 is supported on a hollow shaft 42 which is threaded into the end of the hub 30, and which provides a passageway for the hose 36, as well as a return path for the coolant emitted from the hose. The stator is held directly against the end plate 14 by means of a nut 44 threaded onto the hollow shaft 42. The stator includes a usual stator winding 46, and an alternating current voltage of, for example, 60 cycles is introduced across the stator winding by way of terminals 48. The composition of the stator is shown, for example, in FIG. 4. The coolant introduced into the hub 30 also serves to cool the end plate 14 which in turn cools the stator which is in contact with the end plate.

As best shown in FIG. 2, the rotor 34 includes, for example, an annular core 34*a* formed of iron, or other appropriate magnetizable material, and it has a solid, rather than a laminated construction. A conductive ring 34*b* formed, for example, of copper is formed over the outer peripheral surface of the annular rotor 34, and a second conductive ring 34*c* which, likewise, may be formed of copper, is formed over the inner surface of the annular core. The rings 34*b* and 34*c* are interconnected by a plurality of copper rods 34*d*, for example, which establish a squirrel cage type of induction winding on the rotor. The rotor is rotatably mounted on the bearings 32 for rotation about the hub 30. As mentioned above, the target electrode 15 is mounted on the rotor by posts, such as the posts 38. The conductive parts of the rotor 34 may be silver plated.

Therefore, when the stator winding is energized by the aforesaid 60-cycle current, for example, the resulting rotating magnetic field, by induction action in the squirrel cage winding on the rotor 34 causes the rotor to rotate at a high speed about the bearings 32.

It might be pointed out that since the tubular member 11, as well as the end plate 14 and the rotating target electrode 15 are established at ground potential, there are no insulating problems insofar as the coolant introduced through the hose 36 is concerned, and it likewise may be established at ground potential.

An improved electric motor drive assembly for the rotating target of an X-ray tube is provided, therefore, in which the major part of the motor, and the part requiring electrical energization, is located outside of the envelope of the X-ray tube.

The external part of the motor is placed directly adjacent the end wall of the tube, which is composed of nonmagnetic material, and the magnetic field from the external stator passes to the adjacent rotor to set up, by induction forces, the desired torque on the rotor and on the rotating target of the assembly. This provides for cooling of the stator, as mentioned above. Also it tends to high efficiency in the motor due to the small magnetic gap between the stator and rotor. For example, power reductions of the order of 20 to 1 have been realized in constructed embodiments of the invention as compared with prior art motors of the same general type.

Since a relatively small part of the drive motor is inside the envelope, out-gassing problems are minimized. Also, there is no problem of bringing electrical leads into the envelope. Furthermore, the particular configuration of the drive motor is such that it is relatively flat in an axial direction, so that the tendency for the target electrode to wobble, and thereby blur the X-ray beam, is minimized. If desired, a small conical anode may be centrally mounted on the target 15, and a second cathode provided for directing an electron beam at the end of the conical anode. This results in a 360° X-ray beam being generated by the tube which is useful, for example, for X-raying the interior of pipes.

The improved drive motor of the invention is relatively simple and inexpensive to construct, and it constitutes an efficient drive for the target electrode of an X-ray tube.

The target may be driven at higher rotational speeds than the prior art arrangements because mechanical resonances occur at higher frequencies so that rotational speeds up to 10,000 for example, may be achieved without encountering resonance. The higher speeds permit higher X-ray tube currents without exceeding the critical target temperature.

The cooling of the stator, as mentioned above, permits higher stator power without excessive heating. Also, the small gap between the stator and rotor results in high magnetic efficiency.

What is claimed is:

1. A drive motor for driving an instrumentality within a sealed envelope said sealed envelope including an end wall formed of nonmagnetic material, a tubular hub member having a closed inner end extending through the end wall of said envelope, a rotor mounted within said envelope for rotation about a particular axis and mechanically coupled to said instrumentality; bearing means mounted on said tubular hub member within said envelope for rotatably supporting said rotor in coaxial relationship with said tubular hub member; and a stator mounted against the external surface of said end wall in coaxial relationship with said rotor externally of said envelope and adjacent said rotor to induce a torque-producing magnetic field in said rotor.

2. The drive motor defined in claim 1, in which said rotor and stator each have a disc-shaped configuration.

3. The drive motor defined in claim 1, which includes means mounting said stator directly against the external surface of said end wall and in coaxial relationship with said rotor.

4. The drive motor defined in claim 1, in which the instrumentality driven thereby comprises a target electrode for an X-ray tube.

5. The drive motor defined in claim 1, in which said rotor is formed of magnetizable material and has an annular configuration, and in which said rotor includes electrically conductive rings on the inner and outer peripheral surfaces thereof and a plurality of generally radial electrically conductive rods interconnecting said rings so as to impart induction-winding squirrel cage electrical characteristics to said rotor.

6. The drive motor defined in claim 5, in which said rotor is composed of iron and in which said rings and rods are composed of copper.

7. The drive motor defined in claim 1, in which said rotor is composed of a solid magnetizable material.

8. The drive motor defined in claim 1, and which includes conduit means extending into said tubular hub member for introducing a coolant into the interior of said drive motor to cool said bearing means.

9. The drive motor defined in claim 1, in which said bearing means includes balls and races formed of stainless steel, and in which said balls are silver plated for lubricating purposes.

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