

[54] **LIQUID COOLED X-RAY TUBE ANODE**

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[58] Field of Search **313/60, 34, 32**

[56] **References Cited**

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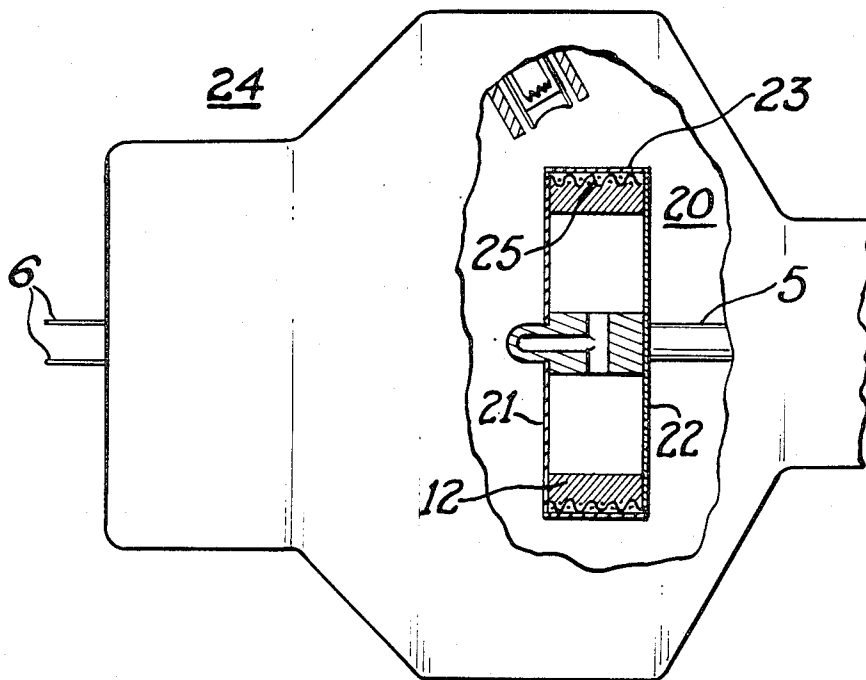
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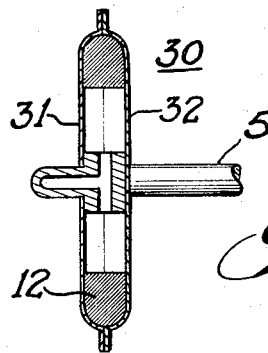
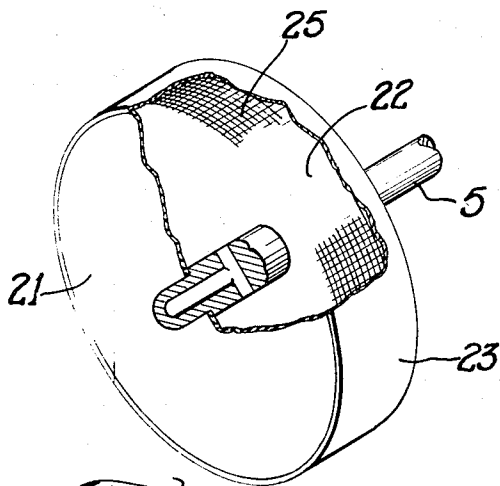
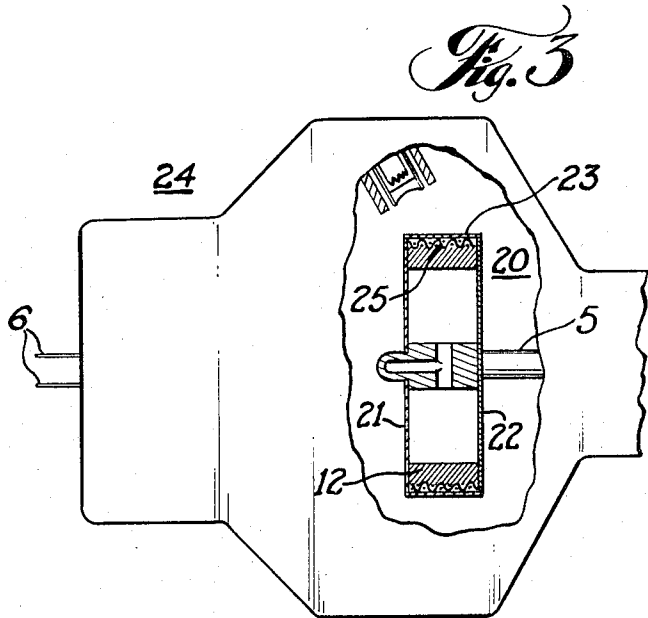
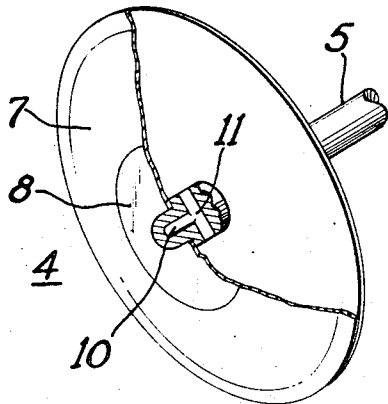
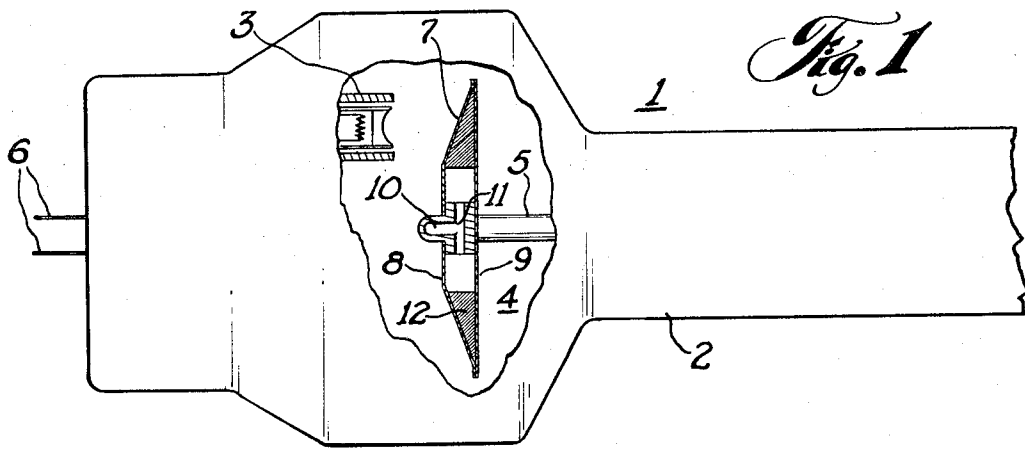
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[57] **ABSTRACT**

The rotating anode of an X-ray tube used for medical examination is formed as a hollow member having a portion of its outer surface formed by an X-ray emitting metal and filled with liquid metal which evaporates to provide rapid cooling of the anode and permits operation with larger electron beam powers. The liquid metal is returned to the hot spot by centrifugal force. In one form of the anode a metal mesh is attached to the inner surface of the hollow member to retain liquid metal next to the target metal while the tube is cooling below the melting point of the liquid metal.

12 Claims, 5 Drawing Figures





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LIQUID COOLED X-RAY TUBE ANODE

My invention relates to rotating anode type X-ray tubes and in particular to a rotating anode which is cooled by internally contained liquid metal.

The high X-ray intensities needed for medical X-rays require the use of large electron beam powers striking the tube anode. Such large power densities of bombarding electron beams tend to melt the anode at the focal spot within a short time. In the past, melting has been prevented by rapidly rotating the anode to bring cooler metal surfaces into the focal spot area, thus providing a high thermal conductivity by physically moving the heated anode to cooler regions. Heat fluxes in the focal spot of an X-ray tube even larger than those in the present tube would be used if conduction of heat away from that region could be increased. Such a structure would permit the use of larger X-ray fluxes than presently used and at the same time make possible shorter exposures when movies of various organs of the body are being made. Efforts to solve this problem in the past have been in the direction of increasing the size of the anode and, consequently, its rotational inertia. This has resulted in larger, more complex X-ray tubes.

It is a primary object of my invention to provide a new and improved rotating anode for an X-ray tube which permits the use of larger electron beam power while still reducing the total rotational inertia of the anode.

It is still another object of my invention to provide a new and improved rotating anode for X-ray tubes which permits the use of increased electron beam powers while reducing the thickness of the metal target surface.

In its broadest aspect, my invention obtains high thermal conductivity from the focal spot of a rotating anode in an X-ray tube by using the evaporation of a liquid metal contained within the anode to provide cooling of the target surface. One of the features of the invention consists in providing a hollow anode in which is contained a liquid metal which vaporizes when heated and which is returned to a hot spot by centrifugal force to provide rapid cooling of the spot. Another feature consists in the use in the hollow anode of a metal mesh attached to the inner surface of the anode to retain liquid metal next to the anode target while the tube is cooling below the melting point of the liquid metal.

These and other important objects and advantages of the invention will become apparent as the invention is understood from the following description which, taken in connection with the accompanying drawings, discloses preferred embodiments of the invention. In the drawings,

FIG. 1 is a side view, partly in section, of an X-ray tube embodying the invention;

FIG. 2 is a perspective view, partly in section, of the rotating anode employed in the X-ray tube of FIG. 1;

FIG. 3 is a side view, partly in section, of an X-ray tube embodying another form of the invention;

FIG. 4 is a perspective view, partly in section, of the rotating anode employed in the X-ray tube of FIG. 3, and

FIG. 5 illustrates another form of an anode for an X-ray tube embodying my invention.

The X-ray tube 1 comprises a glass envelope 2 which encloses a cathode assembly 3 and an anode 4. Anode 4 is of the rotating type and is supported on a shaft 5 driven by a conventional armature and field structure (not shown) in a manner well known. Cathode 3 is heated by means of externally extending leads 6 and operating potentials are supplied to leads 6 and an anode lead (not shown). The axis of cathode 3 is displaced from the axis of shaft 5 so that the beam of electrons from cathode 3 strikes the slanted target wall 7 of anode 4.

Anode 4, shown in enlarged, partly sectional view in FIG. 2, is in the form of a hollow metal member having a pair of parallel flat circular end walls 8, 9 and a connecting peripheral slanting wall 7 which forms the target for electrons from cathode 3. The slanted target wall 7 is welded to end walls 8, 9 to form a sealed box or hollow member. Shaft 5 extends through end walls 8, 9 and is provided near its outer extremity with a longitudinally extending duct 10 which connects with a transverse duct 11. The ducts 10, 11 thus provide means for introducing a liquid metal 12 into the sealed anode after the latter has been vacuum-processed to clean the inside of the sealed box and remove gases which might contaminate the liquid metal. The liquid metal is introduced into the sealed box through longitudinally extending duct 10 after which the end of shaft 5 is pinched off and sealed in a conventional manner. Preferably, the hollow member which forms anode 4 is supported within a vacuum during the processing operation and the introduction of the liquid metal to prevent oxidation of the exterior surfaces of the anode.

End walls 8, 9 of anode 4 preferably are formed of a refractory metal, such as tantalum or niobium, while slanting target wall 7, as well as the end walls, may be formed of a good X-ray target material of one of the heavy metals, for example, tantalum, tungsten, rhenium, or alloys of these metals which have a high melting point. One alloy particularly suitable for such target material consists of 75 percent tungsten and 25 percent rhenium. Shaft 5 is likewise formed of a refractory material, such as, for example, niobium or tantalum.

The liquid target used for cooling the target wall surface may comprise a metal selected from the group consisting of sodium, lithium, cesium and potassium. While lithium has the highest heat of vaporization of these liquid metals, I prefer to employ sodium because, in many respects, it is easier to work with than the other liquid metals mentioned.

In constructing the rotating anode, I prefer to use a thin tungsten or tungsten rhenium alloy sheet or foil for slanting target wall 7 to maximize heat conduction between the outside surface of wall 7 and the liquid metal in contact with the inner surface of that wall. If the target wall 7 is too thick, the surface of the wall may still melt when an intense electron beam is projected on it because of the large temperature drop across the wall. Thus, to obtain full advantage of the liquid metal cooling, target wall 7 should be as thin as possible, consistent with retaining requisite mechanical strength, to avoid any melting of the wall and maximize thermal conduction through the wall to the liquid metal within the anode.

In operation, the cathode beam striking target wall 7 vaporizes the liquid metal in contact with the inner sur-

face of wall 7 at the point where the beam strikes that wall. As the anode is rotated, the vaporized metal is returned by centrifugal force into contact with an condenses on the inner surface of wall 7. Using a typical anode size and rotation speed, the centrifugal force is strong enough to return any liquid metal lost from the heated hot spot in about 1/30th of a revolution.

FIGS. 3 and 4 illustrate a modified form of the X-ray anode of my invention in which anode 20 is cylindrical in form and comprises spaced, parallel end walls 21, 22 and a connecting peripheral target wall 23. Cathode 3 is so positioned in X-ray tube 24 that its electron beam strikes target wall 23.

The hollow member comprising anode 20 is formed similarly to anode 4 of FIGS. 1 and 2 and includes a similar structure for introducing a liquid metal into the hollow anode structure. I may also provide means to maintain the liquid metal in close contact with the peripheral, or target wall 23 which means comprises a metal mesh 25 attached to the inside surface of target wall 23. Mesh thus attached to the inside of wall 23 functions somewhat as a wick to keep the liquid metal next to the inner surface of the target wall while the tube is cooling below the melting point of the liquid metal. Mesh 25 may comprise a suitable metal such as tantalum or niobium.

FIG. 5 illustrates another configuration of an X-ray anode embodying my invention. In this construction the hollow anode 30 is formed by two opposed dish-shaped metal spinnings 31, 32 which are welded along their outer edges. Spinning 31 functions as a target for the electron beam. The liquid metal 12 is carried by centrifugal force to the outer portion of the anode as it is rotated.

An important advantage of my invention is that it permits increasing the intensity of the cathode ray beam to provide larger X-ray fluxes than presently obtainable. Alternatively, if the same intensity cathode ray beam is used as presently employed in conventional X-ray tubes, the life of the X-ray target is increased considerably over that of conventional rotating anodes.

Certain changes may be made in the structure of the rotating anode illustrated without departing from my invention. Thus, mesh 25 usually will not be necessary if the anode is operated in a manner such that the cathode ray beam is turned on at freezing low power level until the liquid metal is heated and melted. However, if the full beam power and rotor power are turned on at the same time, it is desirable to use the mesh since such mesh prevents freezing of the liquid metal in a lump on the inner surface of the target wall and ob-

viates the need for a warm-up period.

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

1. In an X-ray tube of the type having an enclosing envelope and an electron emitting cathode, an anode cooperating with said cathode comprising a hollow metal member, a metallic mesh interiorly disposed thereon, an axially extending shaft supporting said member and adapted for rotation in the envelope, and means for cooling said anode comprising a liquid metal contained within said hollow member, said liquid metal contacting the inner surface of said member as the anode is rotated and being evaporated when electrons from said cathode heat the outer surface of said member, said liquid metal being returned by centrifugal force into contact with the inner surface of said member.

2. The combination of claim 1 in which said metal member comprises a thin tungsten foil.

3. The combination of claim 1 in which said metal member comprises an alloy of tungsten and rhenium.

4. The combination of claim 2 in which said liquid metal is selected from the group consisting of sodium, and lithium.

5. The combination of claim 2 in which said liquid metal comprises sodium.

6. The combination of claim 2 in which said liquid metal comprises lithium.

7. A rotatable anode for an X-ray tube comprising a hollow metal member having a pair of spaced, parallel flat circular end walls and a connecting target wall, a metallic mesh interiorly disposed thereon, an axially extending shaft connected to one end wall, and a liquid metal contained within said member, said liquid metal contacting the inner surface of said target wall upon rotation of the anode whereby when said target wall is heated the liquid metal evaporates to effect cooling of the target wall, the liquid metal being returned by centrifugal force into contact with said inner surface.

8. The anode of claim 7 in which the liquid metal is selected from the group consisting of sodium, and lithium.

9. The anode of claim 7 in which the liquid metal is sodium.

10. The anode of claim 7 in which the liquid metal is lithium.

11. The anode of claim 7 in which said end walls comprise tantalum and said shaft comprises niobium.

12. The anode of claim 7 in which said metal mesh comprises a metal selected from the group consisting of tantalum and niobium.

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