May 25, 1937. A. BOUWERS 2,081,789

X-RAY TUBE HAVING A ROTARY ANODE

Filed May 31, 1933

Fig. 1.

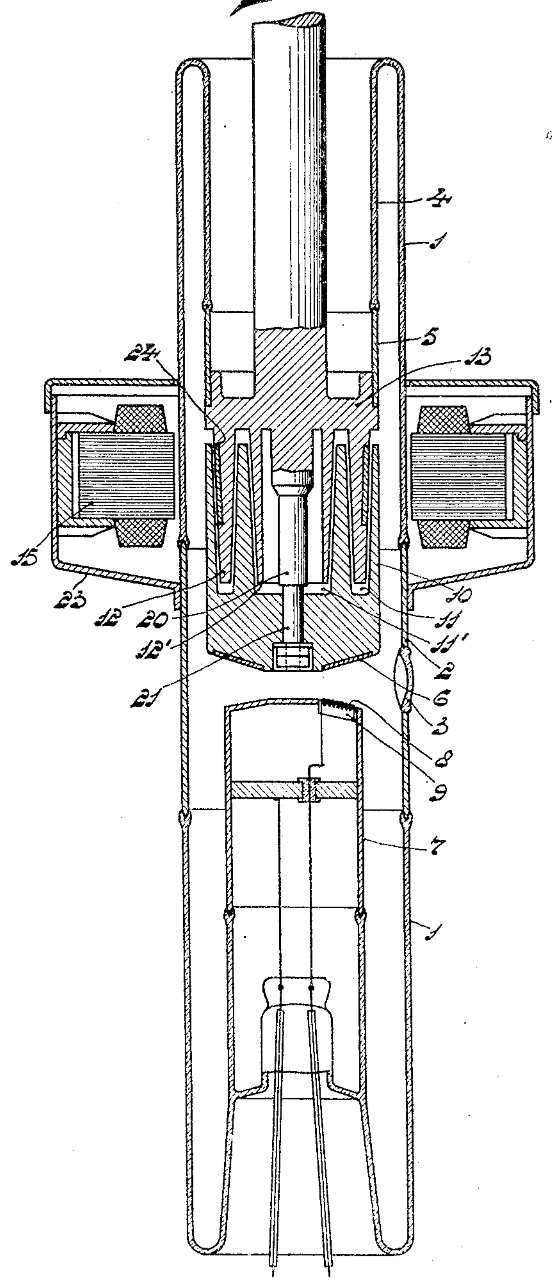
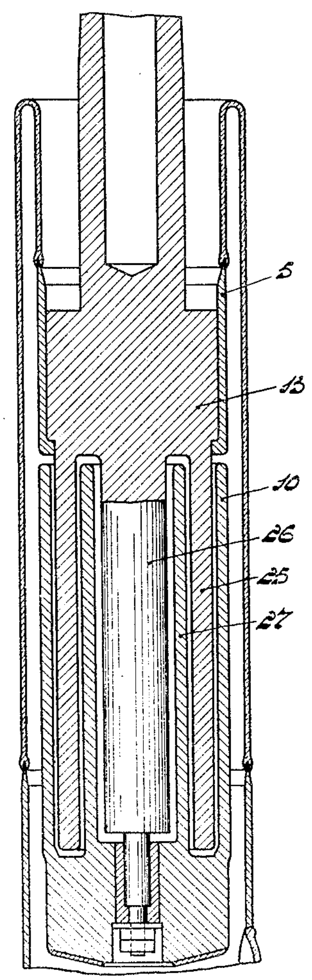


Fig. 2.



Inventor

ALBERT BOUWERS

Attorney

Patented May 25, 1937 2,081,789

UNITED STATES PATENT OFFICE

2,081,789

X-RAY TUBE HAVING A ROTARY ANODE

Albert Bouwers, Eindhoven, Netherlands, assignor, by mesne assignments, to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, a Dutch company

Application May 31, 1933, Serial No. 673,782
In Germany May 30, 1932

11 Claims. (Cl. 250—35)

(Granted under the provisions of sec. 14, act of March 2, 1927; 357 O. G. 5)

My invention relates to discharge tubes having movable electrodes and more particularly to X-ray tubes having rotary anodes, and I shall describe my invention in connection with the latter devices.

X-ray tubes having rotary anodes of the construction described in my U. S. Patent No. 1,893,759 are—due to the fact that the heat produced at the anode is distributed over a large surface—particularly well adapted to carry heavy instantaneous loads. However, difficulties are encountered in transferring the heat developed at the anode to the outside, as the connection of the rotary anode with the outer parts of the discharge tube is through bearings, and the low-friction bearings, suited for this purpose, offer a high resistance in the heat conduction path. Thus the dissipation of the heat developed in the anode can not efficiently take place by the cooling means usually employed for stationary anodes. The lack of proper cooling of the rotary anode required considerable time intervals of rest, between the taking of successive exposures, and in addition such tubes were unsuited for long-time exposures.

In my co-pending application, Ser. No. 464,067, filed June 26, 1930, now Patent No. 1,962,275, I have described constructions by means of which efficient cooling of the rotary anode could be obtained during periods of idleness of the tube with the result that the time interval for the cooling of the anode between two successive exposures could be greatly reduced.

According to the above referred to patent, there is provided a body of good heat conductivity, with which, while the tube is inoperative, a portion of the anode body is brought into contact. Thus the heat from the anode is transferred to the heat conducting body and from there, by means of a cooling rod or cooling medium, as a liquid or gas, conducted to the outside.

The above construction, however, does not provide for an efficient cooling of the rotary anticathode during the taking of the exposure, and the purpose of my present invention is to provide means for the efficient heat dissipation from the anode and cooling of the anode not only in time intervals between exposures, but also during the exposures.

My novel construction thereby renders rotary anode tubes adapted for longer exposures and even for continuous loading, as is required, for instance, in screening work.

According to the invention, I provide a highly efficient cooling of the anode during operation by means of heat radiation in such a manner that large surfaces of the anode are disposed in closely spaced relationship with corresponding surfaces of a body of good heat conducting properties, whereby the heat developed in the anode is transferred by heat radiation to said heat conductive body and from there conducted to the outside of the tube by the usual cooling means.

Preferably, a material portion of the anode surrounds said heat conducting body. For instance, one of these members, i. e. either the anode or the heat conducting body, is provided with one or more axially extending cylindrical recesses or grooves, and the other member is provided with corresponding cylindrical ribs which extend into said grooves, with only so much play left between these correlated parts as is required for the unobstructed rotation of the anode.

The heat conducting body may extend from the tube and may be directly cooled in a known manner by a liquid or gaseous medium, or it may be connected to an intermediate cooling body, which in its turn is hermetically led out from the tube.

It is preferable to limit the heat radiation of the anode toward the tube wall by special means, so as to direct substantially the whole heat radiation of the anode towards the heat conducting body. For this purpose, the heat radiating capacity of the entire outer surface of the anode body, except for its frontal target portion opposing the cathode, is reduced, for instance, by providing this surface with a high polish. Preferably, this surface is coated with a metal which is highly reflecting for heat rays, for instance, with chromium or silver. To further improve the reflecting capacity of this coating, it is preferably given a high polish.

On the other hand, the heat radiating capacity of the anode surfaces opposing the heat conducting body, is preferably increased, for instance, by providing these surfaces with a suitable black coating. This can be obtained by making these radiating surfaces of iron, ferro-chromium, sesqui-oxide of chromium, platinum-black, soot, nickel-carbide, etc.

As a result, there is very little heat radiation from the anode towards the tube wall and substantially the whole heat developed in the anode is dissipated by radiation towards the heat-conducting body.

Although reduction of the heat radiating capacity of the outer anode face slightly increases the anode temperature, this is more than compensated by the increased heat radiation from the anode towards the heat-conducting body.

The heat-conducting body preferably also carries the bearing for the rotating anode.

The connection between the vitreous envelope of the tube and the heat-conducting body, or between the envelope and other metal portions leading to the outside of the tube are preferably made by providing a ferro-chromium sleeve sealed to a reentrant portion of the envelope. The ferro-chromium sleeve may be filled out with a metal of good heat conducting properties. The heat-conducting body may be cooled by a cooling rod, or by making it hollow and providing a fluid or gaseous cooling medium.

Preferably, the opposing surfaces of the anode and of the heat-conducting body are uniformly spaced from each other, by making these surfaces parallel to each other. This provides for a uniform heat radiation of the anode and for a uniform heat-absorption of the heat-conducting body, and thereby provides for a substantially uniform temperature distribution.

The construction according to the present invention can also provide for a further increased cooling effect while the tube is out of operation, by eliminating the interspace between the opposing surfaces of the anode body and of the heat-conducting body and bringing these members in direct and intimate contact with each other along said surface, so as to provide for the heat dissipation of the anode by thermal conduction.

For instance, the cooperating recesses and ribs of the anode and of the conducting body respectively, may be tapered in opposite directions, and these members so disposed with regard to each other that by the axial displacement of one of the members the play existing between the recesses and ribs, as well as between the frontal surfaces, while the tube is in operation, is eliminated when the tube is placed out of operation, and the members are brought into direct contact with each other along these surfaces. This can be achieved in the manner described in my above referred to Patent #1,962,275, for instance, by turning the tube upside down, or by magnetically approaching these members to each other.

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

Fig. 1 is a sectionized view of an X-ray tube having a rotatable anode;

Fig. 2 is a sectionized view of a portion of a rotatable anode X-ray tube and shows another embodiment of the invention.

The X-ray tube comprises a cylindrical vitreous envelope 1, which is provided with a metallic sleeve portion 2 which surrounds the discharge path and the operating portions of the electrodes and which is preferably of ferro-chromium, an alloy well adapted to be fused to the glass to form an air-tight joint therewith. The sleeve 2 is provided with a window 3 through which the X-rays can emerge and which may be a glass window sealed to the sleeve 2.

The re-entrant glass portion 4 of the envelope on the anode side is provided with a hollow metal body 5, sealed to the glass and preferably also consisting of ferro-chromium. Supported from the body 5 is a metal body 13 of good heat-conducting material, for instance copper, which body is surrounded by the anode 10. The anode is provided with a truncated conical end face, in which is provided a target insert 6 of tungsten or similar refractory metal. The anode body consists of a material of good heat conductivity, for instance copper, and is provided with two concentric cylindrical recesses 11 and 11' axially extending through the major portion of the body 10, the recesses being slightly upwardly tapered.

The body 13 has two cylindrical ribs or skirt-shaped portions 12 and 12' slightly tapering downwardly and extending into the corresponding cylindrical recesses 11 and 11' of the anode body 10. Sufficient play is left between the side walls and bottom edge of the ribs and the opposing faces of the recesses, and similarly also between the bottom face of the body 13 and the upper end-face of the anode body, to permit unobstructed rotation of the anode 10 with respect to the body 13.

In the hollow cylinder formed by the rib 12' extends a shaft 20, the end 21 of which forms the bearing for the anode body 10.

The outer surface of the body 10, except for its conical end face, is preferably provided with a highly reflecting surface. For instance, this surface may be provided with a chromium or silver plating, which is given a high polish, whereas those surfaces of the anode which oppose the heat-conducting body, i. e. the surfaces of the recesses 11 and 11', are preferably provided with a highly heat radiating surface, for instance, by blackening these surfaces in the manner previously stated.

The cathode support 7 is provided with a conical end face on which the incandescible filament 8 is asymmetrically disposed, so as to be opposed during rotation of the anode by changing portions of the target 6. A focussing device 9 surrounds the cathode. The rotation of the anti-cathode or anode is obtained by means of a rotary magnetic field created by a stator 15 surrounding the anode. The stator housing 23 is preferably secured to the metal sleeve 2 of the tube.

It will be noted that in operation the anode 10 is free to rotate around the heat conductive body, and through the close spacing and the large area of the opposing surfaces of the anode and the heat-conducting body, a very efficient heat transmittal from the anode to the heat-conducting body takes place by means of heat radiation. From the body 13, the heat is conducted outside the tube by a suitable cooling medium in known manner.

In between operations the heat dissipation of the anode can be further improved by bringing the anode into direct contact with the body 13. This can be achieved, for instance, by turning the tube upside down, so that the anode body 10 comes to rest on the body 13 over the entire extent of the grooves as well as of the end face of the anode, or by axially lifting the anode, for instance, by magnetic means.

The rib 12 has an insert 24 of iron through which the magnetic circuit of the stator 15 is closed behind the outer cylinder of the anode 10.

In Fig. 2 the heat conductive body 13 has only one cylindrical rib or skirt-shaped portion 25 projecting into a recess of the anode 10. The shaft 20 and the rib 12 in Fig. 1 are here replaced by a solid rod 26 receiving heat from the inner side of the rib or skirt-shaped portion 27 of the anode. A further difference with the construction described above is that the ribs are not tapered, but the radiating surfaces are parallel to the axis of the tube. The surfaces of the anode

10 and the heat-conductive body 13 may be coated or treated to modify the heat-radiating properties thereof as described above in connection with the modification shown in Fig. 1, if desired.

While I have described my invention in connection with a specific construction and a specific application thereof, it should be well understood that I do not wish to be limited to such construction and application, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What I claim is:

1. An electric discharge tube comprising an evacuated envelope, electrodes within said envelope, one of said electrodes being movable during the operation of the tube, and a body of good heat conductivity, said movable electrode and body being provided with solid interlapping portions of large mass, said portions having large-area opposing surfaces closely spaced in good heat-radiating relationship.

2. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode, and a body of good heat conductivity cooperating with said anode, said anode and body being provided with solid annular interlapping portions of large mass, said portions having closely-spaced opposing surfaces of large area to increase the radiation of heat from said anode to said body.

3. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotary anode, and a body of good heat conductivity cooperating with said anode to remove the heat therefrom, said anode and body having solid complementary interlapping portions of large mass, said portions being skirt-shaped and having closely-spaced opposing surfaces of large area to increase the radiation of heat from said anode to said body.

4. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode, and a body of good heat conductivity, said anode and body having complementary interlapping skirt-shaped portions opposing each other with large surface areas and closely spaced in good heat-radiating relationship, said portions having a large cross-sectional area to provide a rapid conduction of heat from the anode during the operation of the tube.

5. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode provided with an annular cavity, and a body of good heat conductivity provided with a solid ring-shaped projection of large mass extending into said cavity with its surfaces closely spaced from the opposing surfaces of the cavity, said anode and body forming two members of a couple to transfer to said body by radiation the heat developed in said anode.

6. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode provided with a ring-shaped recess, and a body of good heat conductivity provided with a solid projection of large mass and corresponding in shape to the recess and extending therein with its surfaces closely spaced from the opposing surfaces of the recess, said anode and body forming two members of a couple to transfer to said body by radiation the heat developed in said anode.

7. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode provided with a plurality of concentric ring-shaped recesses, and a body of good heat conductivity provided with concentric massive ribs of annular cross section and extending into said recesses with their walls closely spaced to the walls of the recesses, said anode and body forming two members of a couple to transfer to said body by radiation the heat developed in said anode.

8. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode provided with a ring-shaped recess having tapered sides, and a body of good heat conductivity provided with a massive rib having sides tapered in a direction opposite to those of the recess, said rib extending into said recess with its sides in close spacial relationship to the sides thereof, said body and anode forming two members of a couple to transfer to said body by radiation the heat developed in said anode.

9. An X-ray tube comprising an evacuated envelope, an incandescible cathode, a rotatable anode provided with an annular recess, a body of good heat conductivity provided with a solid projection of large mass extending into said recess with its surfaces closely spaced from the opposing surfaces of the recess, said anode and body forming two members of a couple to transfer to said body by radiation the heat developed in said anode, and a coating having high heat-radiation properties provided on the opposing surfaces of said anode and said body.

10. An electric discharge tube comprising an evacuated envelope, electrodes within said envelope including an electrode which moves during the operation of the tube, a stationary body of good heat conductivity, and means for transferring to said body by radiation during the operation of the tube a major portion of the heat produced in said movable electrode, said means comprising interlapping portions of said body and said movable electrode, said portions being solid and of large mass and having large-area opposing surfaces in good heat-radiating relationship.

11. An electric discharge tube comprising an evacuated envelope, electrodes within said envelope and including an electrode which rotates during the operation of the tube, a stationary body of good heat conductivity, and means to transfer to said body by radiation during the operation of the tube a major portion of the heat developed in said rotatable electrode, said means comprising a solid annular projection of said stationary body, said projection surrounding a portion of said rotatable electrode and opposing same with a large area surface.

ALBERT BOUWERS.