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F. REINIGER

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LIQUID COOLING OF ANODES IN VACUUM DISCHARGE TUBES, MORE PARTICULARLY X-RAY TUBES

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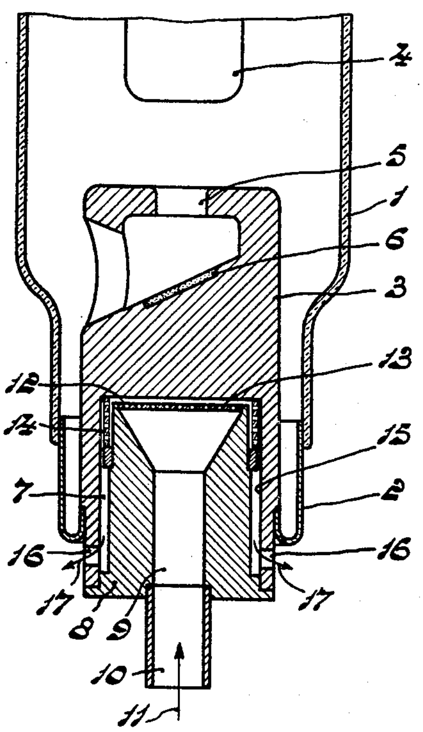

Fig. 1

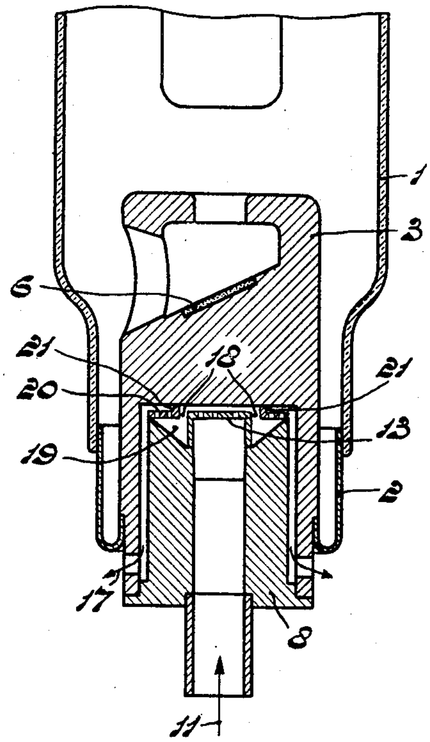

Fig. 2

INVENTOR.
FRIEDRICH REINIGER
BY Fred M Vogel
AGENT

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LIQUID COOLING OF ANODES IN VACUUM DISCHARGE TUBES, MORE PARTICULARLY X-RAY TUBES

Friedrich Reiniger, Hamburg-Wellingsbuttel, Germany, assignor to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

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4 Claims. (Cl. 313—32)

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The invention relates to an X-ray tube comprising a liquid-cooled anode. This method is adapted more particularly with X-ray tubes which are heavily loaded and are in use continuously for some time. Examples of such uses are therapeutic irradiations and examination of materials.

The heat produced in the anode is preferably transmitted to the liquid at an area closely behind the focus. It is common practice to supply the liquid in a space recessed in the anode body, the liquid flowing at high speed along the surface to be cooled.

In a further construction the liquid is passed through a channel which is provided in the material of the anode in order to increase the surface area to be cooled, the pressure on the liquid becoming very high, when the liquid is also required to flow at high speed.

Intense cooling is obtained, when the liquid is projected through a nozzle at high speed against the heated surface. The advantage thereof is that a greatly turbulent flow is produced and that the formation of a laminary layer which involves material increase in thermal resistance is substantially avoided. However, owing to the quantity of heat to be conducted away, the surface area to be cooled may assume such great dimensions that the liquid from the space between the nozzle and the surface to be cooled cannot be drained at sufficient high speed, so that the pressure difference at the front and at the back of the nozzle decreases and is no longer uniform throughout the surface area. In this case the spacing between the nozzle apertures will have to be increased or the speed of the liquid flow will have to be decreased. In this case the use of a nozzle for the liquid supply is not particularly advantageous over the use of a liquid flowing along the surface.

According to the invention, in an X-ray tube having a liquid-cooled anode, the liquid is passed in succession through two or more nozzles, which are arranged opposite different parts of the surface to be cooled. With a view to securing the required quantity of liquid, the dimensions and the distance from the surface to be cooled may be such for each nozzle that the pressure on the liquid supplied is distributed among the nozzles and only low losses of pressure occur along the course still to be traversed by the liquid.

In order that the invention may be more clearly understood and readily carried into effect, it will now be described more fully with reference to the accompanying drawing, in which Figs. 1 and 2 show part of an X-ray tube in which the invention is embodied.

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In the two figures similar elements are designated by identical reference numerals.

The glass wall 1 of the X-ray tube is united by a metal ring 2 with the anode 3, which extends in the space embraced by the wall 1; 4 designates the cathode, which is arranged at a small distance opposite the anode. When the tube is in use, a flow of electrons moves from the cathode 4 through the aperture 5 in the front of the anode 3 to a plate of impact 6, which is made of tungsten and is secured to the metal anode body. The anode 3 is made of copper and is provided with a hollow space 7. This space contains a metal plug 8, which closes the space 7 to the outside and which is provided with a bore 9, which communicates with a supply pipe 10 for the cooling liquid, the direction of flow of which is indicated by an arrow 11. The plug 8 extends to near the bottom 12 of the space 7. Referring to Fig. 1 the bore 9 is widened at its end so as to have approximately the same diameter as the plug and in front of the aperture provision is made of a nozzle 13 constituted by a flat plate having small apertures. The cooling liquid is projected from these apertures at a high speed against the surface 12, from which is withdrawn the heat produced in the impact plate 6 by the electron flow and supplied by conduction of the anode material. The liquid escapes from the space between the nozzle 13 and the surface 12 along the edge and passes through a second nozzle 14, arranged opposite another part of the surface to be cooled and constituted by a cylindrical shell, which is provided with small apertures. The liquid is projected through the apertures, again in a finely divided state but energetically against part of the cylindrical wall 15 of the hollow space 7 into the anode and then flows through the space between the plug 8 and this wall to the outside through apertures 16 in the wall portion 15 of the anode 3 in the direction of arrows 17.

Referring to Fig. 2 the bore 9 is less widened, so that the nozzle 13 covers a smaller portion of the surface 12. The liquid escapes from the space between the nozzle 13 and the surface 12 through an aperture 18 to a space 19, which is recessed in the plug 8. A nozzle 20, which then allows the liquid to pass, is constituted by an annular plate with small apertures which is flush with the nozzle 13 and which is connected to the plug along the outer circumference, whereas along the inner circumference provision is made of an upright edge 21 which bears on the bottom of the space 7. The liquid escapes from the space between the nozzle 20 and the bottom 12 and is then drained. Provision may be made of a third nozzle the construction of which is similar to the nozzle 14 of Fig. 1.

Owing to the successive disturbances produced in the liquid flow, since the latter passes in succession through two or more nozzles, the heat transfer to the liquid contacting with the surface to be cooled is not affected when the surface area exceeds the size for which a single nozzle is sufficient. It is true that with an increase of the surface to be cooled the required quantity of liquid increases, but the higher pressure required therefor is distributed among the various nozzles without incurring any loss of pressure owing to the increase in resistance of the liquid flow due to less favourable properties in the case of a single nozzle and of increasing surface to be cooled.

What I claim is:

1. An X-ray tube comprising an envelope, a cathode, an anode comprising a target of heat refractory metal facing the cathode, a body of good heat conducting material backing said target and having a hollow recessed portion to the rear of the target, a hollow plug fitting into said recessed portion, means to circulate a cooling medium over a maximum surface area of said recessed portion of said body comprising a first perforated member having a plurality of openings therein forming with said plug a first chamber directly in back of the surface area of the recessed portion and forming a plurality of passages perpendicular to a first portion of the surface area of said recessed portion whereby the cooling medium will flow with high turbulence over the first portion of the surface area to be cooled without forming a laminar layer to effect maximum heat transfer from said body to said cooling medium, a second perforated member having a plurality of openings therein and forming with said first surface portion and said first perforated member a second chamber directly in back of a second portion of the surface of said recessed portion, said second perforated member providing a plurality of passages perpendicular to the second portion of the surface area of said recessed portion whereby the cooling medium after striking said first surface portion is recovered and flows with high turbulence over said second surface portion without forming a laminar layer to effect further heat transfer from said body to said cooling medium.

2. An X-ray tube comprising an envelope, a cathode, an anode comprising a target of heat refractory metal facing the cathode, a body of good heat conducting material backing said target and having a hollow recessed portion to the rear of the target, a hollow plug fitting into said recessed portion, means to circulate a cooling medium over a maximum surface area of said recessed portion of said body comprising a first perforated member having a plurality of openings therein forming with said plug a first chamber directly in back of the surface area of the recessed portion and forming a plurality of passages perpendicular to a central portion of the surface area of said recessed portion whereby the cooling medium will flow with high turbulence over the central surface portion of area to be cooled without forming a laminar layer to effect maximum heat transfer from said body to said cooling medium, a second perforated member having a plurality of openings therein and forming with said first surface portion and said first perforated member a second chamber directly in back of a side portion of said surface area and forming a plurality of passages perpendicular to the side portion of the surface area of said recessed portion whereby the cooling medium after striking said first surface portion is recovered and flows with high turbulence over said second surface portion without forming a laminar layer to effect further heat transfer from said body to said cooling medium.

3. An X-ray tube comprising an envelope, a cathode, an anode comprising a target of heat refractory metal facing the cathode, a body of good heat conducting material backing said target and having a hollow recessed portion to the rear of the target, a hollow plug fitting into said recessed portion, means to circulate a cooling medium over a maximum surface area of said recessed portion of said body comprising a first perforated member having a plurality of openings therein over the end of the plug and forming with said plug a first chamber directly in back of central portion of the surface area, said perforated member forming a plurality of passages perpendicular to the central portion of the surface area of said recessed portion whereby the cooling medium will flow with high turbulence over the surface of said central surface portion without forming a laminar layer to effect maximum heat transfer from said body to said cooling medium, a second perforated member having a plurality of openings therein forming with said portion and said plug member a second chamber communicating with said first chamber and which is directly in back of a side portion of the said surface area to be cooled adjacent said central surface portion, said second perforated member forming a plurality of passages perpendicular to the side surface portion of the surface area of said recessed portion whereby the cooling medium after striking said central surface portion is recovered and flows with high turbulence over said side surface portion without forming a laminar layer to effect further heat transfer from said body to said cooling medium.

4. An X-ray tube comprising an envelope, a cathode, an anode comprising a target of heat refractory metal facing the cathode, a body of good heat conducting material backing said target and having a recessed portion to the rear of the target, a hollow plug fitting into the recessed portion of the body, the hollow plug having a conical internal taper diverging towards the surface area of the recessed portion, means to circulate a cooling medium over a maximum surface area of the recessed portion comprising a first perforated member having a plurality of openings therein over the end of the plug and forming with said plug a first chamber directly in back of the surface area of the end of said recessed portion, said perforated member forming a plurality of passages perpendicular to surface area of said recessed portion whereby the cooling medium will flow with the high turbulence over the surface of said end surface portion without forming a laminal layer to effect maximum heat transfer from said body to said cooling medium, a second perforated member having a plurality of openings therein and forming with the walls of the plug and the side surface portions of the recessed portion of said body a second chamber directly in back of the

side surface portion which communicates with said first chamber, said second perforated member forming a plurality of passages perpendicular to the side surface portion of the recessed portion whereby the cooling medium after striking said end surface portion is recovered and flows with high turbulence over the side surface portion without forming a laminar layer to effect further heat transfer from said body to said cooling medium.

FRIEDRICH REINIGER.

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