Nov. 9, 1937. D. G. SHARP 2,098,315

X-RAY TUBE

Filed July 14, 1934

Fig. 1.

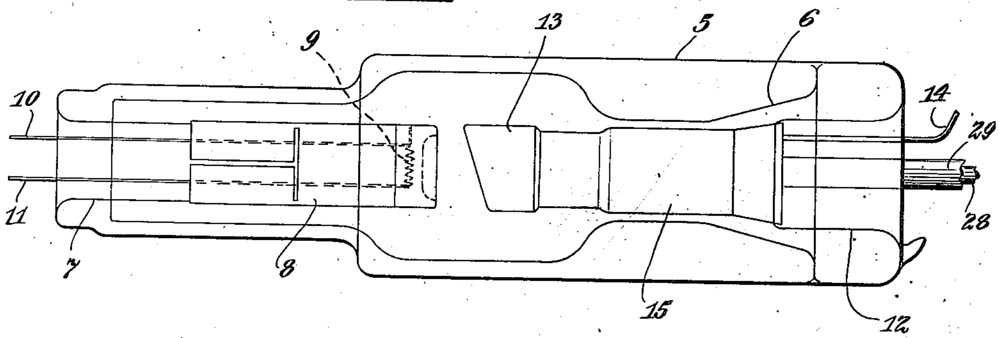


Fig. 2.

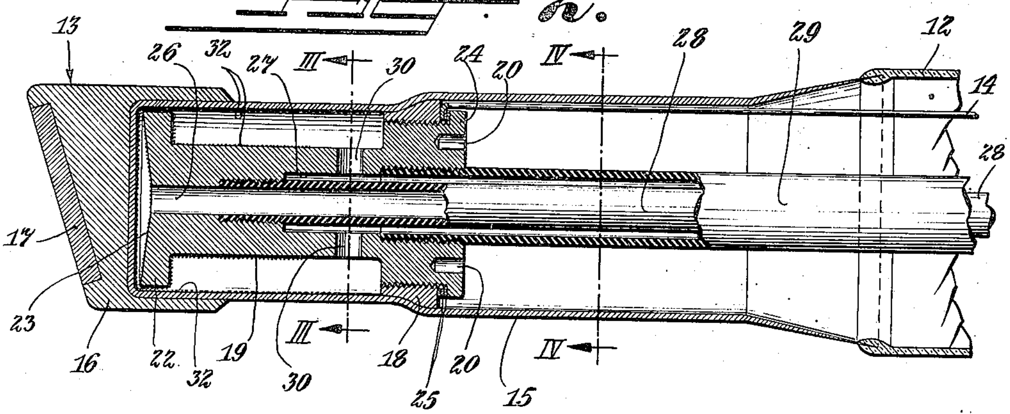


Fig. 3.

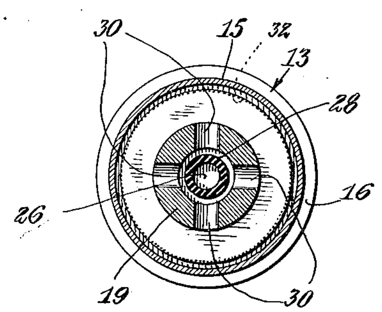
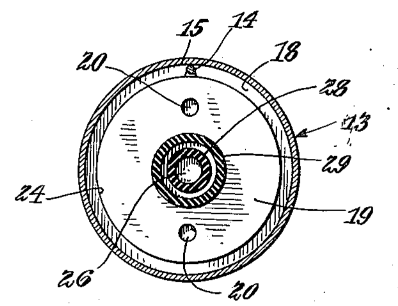


Fig. 4.



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UNITED STATES PATENT OFFICE

2,098,315

X-RAY TUBE

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Application July 14, 1934, Serial No. 735,181

6 Claims. (Cl. 250—35)

My invention relates to X-ray devices and comprises in particular a new X-ray anode or target which is particularly adapted for use in connection with the continuous generation of X-rays, for example, in the administration of therapeutical treatments.

It is usual in the construction of X-rays tubes to provide a surface of refractory metal, such as tungsten or the like, molecularly secured to a stem of good heat conducting metal, such as copper. During operation of the tube the electron stream is more or less concentrated upon the refractory metal surface resulting in the generation of considerable heat, which is transmitted to the stem. The energy for the tube is supplied from a high tension source to be rectified by the tube itself or by intermittent direct current when a separate rectifier is employed. Under either of these conditions the anode surface or target is subject to severe mechanical shocks caused by the intermittent bombardment thereof accompanied by periods of intense heating followed by like intervals of cooling. This has a tendency to cause cracking and tearing of the refractory metal surface as well as a buckling away from the back plate.

For the purpose of preventing undue heating of the anode in X-ray tubes when employed for therapeutical treatments or other conditions requiring a heavy load, it is common to circulate a cooling and insulating material through the anode in an endeavor to maintain an even temperature. If water is employed the device cannot be advantageously rendered shockproof because of the high voltages to which the tube is subjected and the fact that water is not dependable as a dielectric medium. As a consequence a high dielectric fluid is normally utilized, such as hydrocarbon oils, but even such fluid requires special treatment to properly adapt them for anode cooling purposes.

In the utilization of any cooling medium one of the most important factors is turbulent or hydraulic flow, which is absolutely necessary to efficient heat exchange in that there is always a film of the medium in contact with the walls of the passage through which it flows. The heat from the body to be cooled must be transmitted through this film to the turbulent body of a well mixed cooling fluid. When cooling and insulating materials, such as hydrocarbon oils and the like, are employed for cooling purposes there is a greater tendency for the same to "film" over the surface due to its high viscosity and, because of its low thermal conductivity, about 99% of the temperature drop between a surface to be cooled occurs at the point of contact of the film with the heated surface as compared with about 75% of the temperature drop occurring at this point with water.

Also consideration of the factors of density and specific heat makes it essential that at least twice the flow of oil is necessary to dissipate a given amount of heat as would be required in water cooling assuming identical conditions of transfer which, as above noted, do not exist. Moreover, this necessity for increased flow when utilizing oil is made still more difficult by the greater viscosity thereof at all temperatures, which difference is very marked in the cooler parts of the circulating system.

Of all the aforenoted factors those of density, thermal conductivity and specific heat remain constant for a given medium, but I have found the factors of "filming" and viscosity can be advantageously dealt with. By increasing the turbulence of flow the thickness of the "film" at the surfaces of greatest heat may be reduced, which it should be noted, is augmented by the fact that the viscosity of the oil is lowest because of the high temperature at this point thus reducing the resistance to flow.

Furthermore, by increasing the velocity of flow of the medium not only is the thickness of the film reduced, but the tendency of hydrocarbon oils to "carbonize" at the points of high temperature is also substantially eliminated, due to the fact that the oil is in contact with the highly heated surface but a very brief instant owing to the high turbulence and velocity thereof.

It is accordingly an object of my present invention to provide an X-ray tube suitable for continuous operation wherein an anode is provided through which a cooling and insulating material, such as oil circulates, at high velocity thereby increasing the efficiency of heat transfer from the heated surfaces to the medium.

Another object of my invention is the provision of an X-ray tube having an anode which becomes heated during operation of the tube and wherein a cooling and insulating medium of higher viscosity than water is caused to circulate therethrough at a high velocity thus reducing the tendency of the medium to film.

A further object of my present invention is the provision of an X-ray tube having an anode which becomes heated during operation of the tube and wherein a cooling and insulating material of comparatively high viscosity circulates therethrough at high velocity and turbulence thus increasing the efficiency of heat transfer and substantially eliminating the probability of carbonizing of the medium at points of greatest heat.

Still further objects of my present invention will become obvious to those skilled in the art by reference to the accompanying drawing wherein:

Figure 1 is a side view of an X-ray tube constructed in accordance with my present invention,

Fig. 2 is a longitudinal sectional view of the anode construction of my tube,

Fig. 3 is a sectional view taken on the line III—III of Fig. 2 looking in the direction of the arrows, and

Fig. 4 is a sectional view taken on the line IV—IV of Fig. 2 looking in the direction indicated by the arrows.

Referring now to the drawing in detail I have shown in Fig. 1 an X-ray tube comprising an evacuated envelope **5** having a reentrant sleeve **6** forming an inner fold extending a substantial distance longitudinally of the envelope to well beyond each of the electrodes, for the purpose of preventing sputtered metal particles or electron bombardment from striking the walls of the envelope and puncturing the same. Another reentrant sleeve **7** extends inwardly of the envelope **5** to which is sealed a suitable focusing cup or shield **8** having a thermionic cathode **9** recessed therein and adapted to receive electrical energy through a pair of conductors **10** and **11** extending through and suitably sealed to the glass wall of this reentrant sleeve **7**.

A further reentrant stem **12** extends inwardly of the envelope and has sealed thereto the anode electrode **13** which receives energy through a conductor **14**. By reference more particularly to Fig. 2 this anode comprises a hollow metallic member **15**, such as spun copper or the like, sealed to this reentrant portion of the envelope.

A head or back plate **16** of good heat conducting material, such as copper or the like, is molecularly secured to the member **15** and this head in turn is provided with a target face **17** of a refractory metal, such as tungsten, secured thereto adjacent the cathode which receives the electron bombardment during operation of the tube.

This electron bombardment being more or less concentrated upon the target **17**, causes the generation of considerable heat particularly when the tube is continuously operated for long periods of time as in the administration of therapeutic treatments. This heat is in turn transmitted to the copper head or back plate **16** and in order to transfer this heat and maintain the temperature of the entire anode substantially uniform I provide a structure for circulating an insulating and cooling medium through the anode stem.

The interior of the hollow member or anode stem **15** has suitably secured thereto an annular threaded ring or the like **18** and an elongated thimble like member **19** is arranged to threadedly engage this ring **18** being screwed in place by a suitable tool engaging recesses **20** provided in the thimble. The thimble **19** is provided with a shoulder portion **22** of increased diameter with its outer periphery spaced closely to the interior of the member **15** and the end of this thimble **19** is provided with a concave surface or face **23** spaced a short distance from the end of the member **15** to which the copper head **16** is secured. While I have shown the member **15** as having a closed end to provide more surface area for the purpose of molecularly securing the back plate **16** thereto and to facilitate ease of construction, it is to be understood that this may be open ended thus allowing the face **23** to be spaced a short distance directly in the rear of the back plate **16**.

Moreover, this end of the member **15** is more or less integrally united with the back plate **16** and for all intents and purposes may be considered as a part thereof. Accordingly throughout my specification and claims I shall refer to the back plate as being spaced directly from the face **23** of the thimble **19** and directly contacted by the cooling and insulating material. The opposite end of the thimble is likewise provided with a shoulder portion **24** and a series of spacer washers **25** are disposed between this shoulder portion **24** and the annular ring **18** for the purpose of adjusting the spacing between the concave end surface of the thimble and the adjacent surface of the back plate **16**.

A longitudinal opening having a reduced diameter portion **26** and a portion **27** of larger diameter extends through the thimble **19** from the center of the concave face **23**. An inlet conduit **28** of suitable insulating material, such as hard rubber or a phenolic condensation product, threadedly engages the reduced diameter portion **26** and projects beyond the envelope for connection to a suitable oil reservoir.

In a similar manner a concentrically disposed outlet conduit **29** surrounds the inlet conduit which is formed of the same insulating material and threadedly engages the thimble **19** at its increased diameter portion **27**. A plurality of radially disposed passages **30**, as shown more clearly in Figs. 2 and 3, interconnect the annular spacing between the shoulder portions **22** and **24** and the inner increased diameter portion **27** of the thimble passage, for the purpose of completing the return passage for the cooling and insulating material. A coating of a metal, such as nickel, rhodium, platinum, and the like **32**, may be applied to the inner surface of the member **15** as shown and claimed in the copending application of Louis F. Ehrke, Serial No. 754,231 filed November 22, 1934 and assigned to the same assignee as the present invention, and also to the thimble **19** to prevent clinging of the cooling and insulating material with the formation of an undesirable deposit as hereinafter more fully described.

In the operation of the tube a cooling and insulating material, such as a high grade hydrocarbon oil, is caused to flow from a suitable reservoir through the inlet conduit **28** to the concave face **23** of the thimble **19**. Due to the spacing between this end of the thimble and the rear surface of the back plate **16**, which is the point of greatest heat, as well as the configuration of the thimble surface **23** a high turbulence of the oil results with an attendant high velocity in the flow thereof. This accordingly prevents too great a filming of the oil at the point or surface of greatest heat with a rapid flow of sufficient volume of the fluid to transfer the generated heat thereto. The oil then circulates around the periphery of the shoulder portion **22** into the annular passage formed by the latter and the ring **18** after which it enters the outlet conduit **29** through the radial openings **30** and returns to the reservoir for cooling.

Moreover, the high velocity of flow not only prevents too great a filming of the oil with a concentration of heat transfer at the surface of greatest heat, but likewise eliminates the possibility of the oil carbonizing by leaving deposits which would ordinarily occur offering an impediment to the flow thereof, as well as acting as a heat insulator. This is further augmented by the coating of nickel or other metal upon the greater portion of the surface of the copper thimble 19 and the adjacent surface of the member 15, which is contacted by the oil when at its highest temperature. The possibility of the oil forming a chemical deposit with the copper is eliminated by this metallic coating which has a polished surface offering less resistance to the flow of the heated oil as well as the fact that the particular metal employed has a less affinity for the various elements composing the oil than would copper. This latter feature of providing the coating 32 upon the inner surface of the hollow anode stem 15, however, forms no part per se of my present invention but is specifically shown and claimed in the aforenoted copending application.

It thus becomes obvious to those skilled in the art that I have provided an X-ray tube suitable for continuous operation for therapeutical purposes wherein an anode is provided through which a cooling and insulating material circulates for transferring the heat generated during operation of the tube. By increasing the turbulence and maintaining a constant velocity of flow at the surface of greatest heat an increase in the efficiency of heat transfer is obtained. Moreover, by increasing the velocity of flow at the critical area or region where high turbulence is needed and low viscosity is available through high temperature, resistance to the flow of oil in this region is reduced to a minimum, and the maximum amount of oil surface is presented in the path of heat flow immediately in back of the target without possibility of resulting carbonization of the oil.

Although I have shown and described one specific embodiment of my invention I do not desire to be limited thereto as various other modifications thereof may be made without departing from the spirit and scope of the appended claims.

What is claimed:

1. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment, a back plate of good heat conducting material for supporting said target and a hollow anode stem for supporting said back plate, and means for uniformly circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target including a member disposed interiorly of said anode stem having passages for the ingress and egress of a cooling and insulating material, and said member being of such size relative to said back plate and having a concave surface spaced a short distance from the adjacent rear surface of said back plate so as to impart a high turbulence and high velocity to said cooling and insulating material at all points of greatest heat to enable said material to flow over the surface of said back plate without filming and to effect maximum heat transfer from said anode to said cooling and insulating material.

2. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment, a back plate of good heat conducting material for supporting said target and a hollow anode stem for supporting said back plate; and means for uniformly circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target including a member threadedly engaging the interior of said anode stem provided with a concave surface spaced from the adjacent rear surface of said back plate and having a smooth polished coating of a metal offering a negligible resistance to the flow of a cooling and insulating material, and inlet and outlet passages provided in said member for the circulation of a cooling and insulating material interiorly of said anode stem and in contact with said back plate, said inlet passage terminating coaxially with the concave surface of said member whereby a high turbulence and high velocity is imparted by said concave surface to said cooling and insulating material at points of greatest heat to cause flow thereof over the maximum surface area of said back plate with substantially no resistance thereto and maximum heat exchange is effected between said anode and said cooling and insulating material.

3. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment, and means disposed interiorly of said anode for circulating a cooling and insulating material at a high constant velocity interiorly of said anode, said means being spaced in close proximity to the rear surface of said anode immediately in back of said target and having a surface of a diameter slightly less than the internal diameter of said anode, and said surface being angularly disposed relative to the rear surface of said anode so as to impart a high turbulence to said material to cause a rapid flow thereof over the maximum surface of greatest concentration and to effect efficient heat transfer from said anode to said material without the formation of a heat-absorbing film impeding the uniform flow of said material.

4. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment and a back plate of good heat conducting material for supporting said target, and means disposed interiorly of said anode for circulating a cooling and insulating material at a high constant velocity immediately in back of said back plate, said means being spaced in close proximity to the surface of said back plate and having a surface of a diameter slightly less than the internal diameter of said anode, and said surface being angularly disposed relative to the surface of said back plate so as to impart a high turbulence to said material to cause a rapid flow thereof over the maximum surface of greatest heat concentration of said back plate and to effect efficient heat transfer from said anode to said material without the formation of a heat-absorbing film impeding the uniform flow of said material.

5. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment and a back plate of good heat conducting material for supporting said target, and means for uniformly circulating a cooling and insulating medium over the maximum surface area of said back plate including a member spaced from said back plate having passages for the ingress and the egress of a cooling and insulating material, and said member having a surface adjacent to said back plate spaced in close proximity thereto and of a diameter slight-

ly less than the internal diameter of said anode in order to impart a high turbulence and a high velocity to said cooling and insulating material immediately in back of said back plate to enable the material to flow uniformly over the entire surface of said back plate of greatest heat concentration and to effect maximum heat transfer from said anode to said cooling and insulating material.

6. An X-ray tube comprising an envelope, a cathode, an anode including a refractory metal target which becomes heated during operation by electron bombardment and a back plate of good heat conducting material for supporting said target, and means for uniformly circulating a cooling and insulating material of comparatively high viscosity over the maximum surface area of said back plate rearwardly of said target including a member spaced from said back plate having passages for the ingress and the egress of a cooling and insulating material, said member having a surface adjacent to said back plate in close proximity thereto and of a diameter slightly less than the internal diameter of said anode in order to impart a high turbulence and a high velocity to said cooling and insulating material immediately in back of said back plate and to cause the material to flow uniformly over the entire surface of said back plate without forming an impediment to the flow thereof, to present maximum amount of cooling and insulating material surface in the path of greatest heat flow to effect maximum heat exchange between said anode and said cooling and insulating material.

D. GORDON SHARP.