

March 24, 1942.

J. H. FINDLAY ET AL

2,277,430

MULTIORIFICE ANODE

Filed Nov. 7, 1940

Fig. 1.

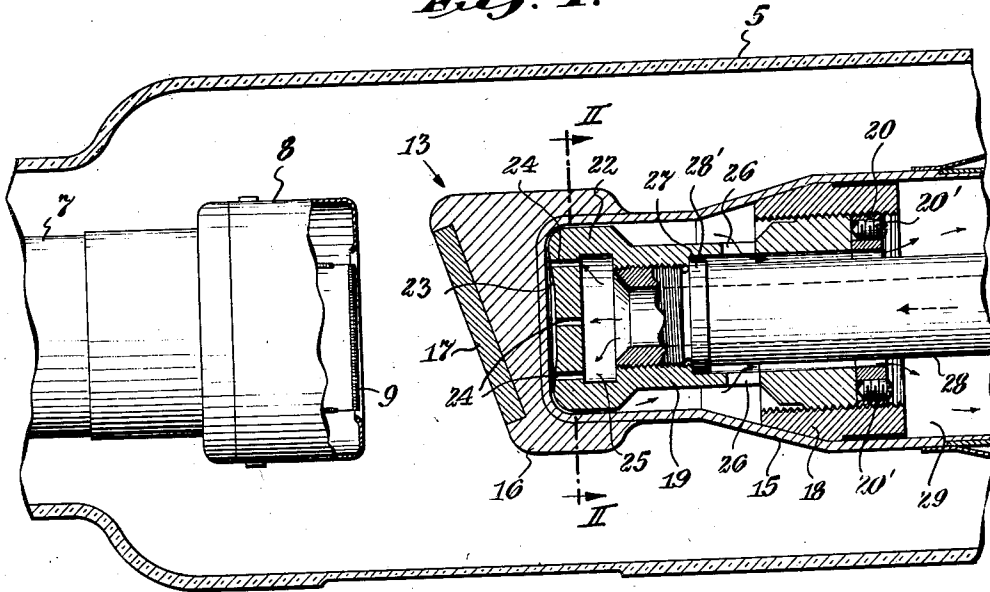


Fig. 3.

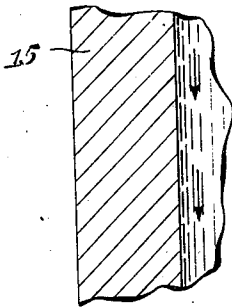


Fig. 2.

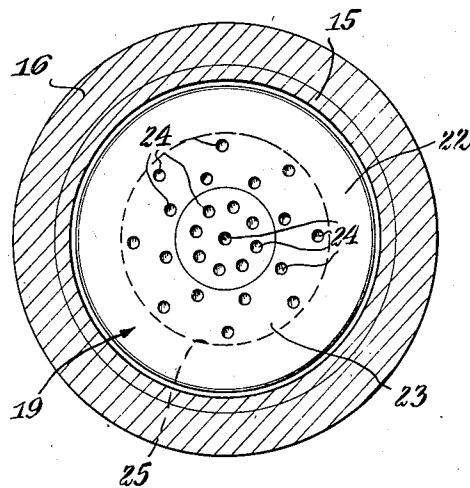
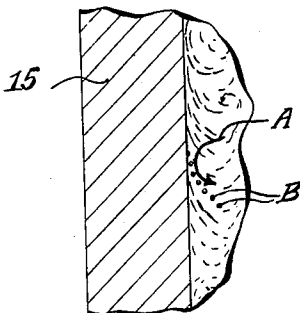


Fig. 4.



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2,277,430

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Application November 7, 1940, Serial No. 364,662

4 Claims. (Cl. 250-143)

Our 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 therapeutic treatments.

An object of our invention is to increase the turbulence of the cooling medium applied to the inner surface of an X-ray anode or target.

A more specific object of our invention is to bubble the cooling medium, such as oil, against the inner surface of the X-ray anode or target, whereby the film of oil tending to adhere thereto is replaced with fresh oil.

Other objects and advantages of the invention will be apparent from the following description and drawing wherein:

Fig. 1 is a view mainly in cross section of a preferred embodiment of the invention.

Fig. 2 is a view on lines II-II of Fig. 1.

Fig. 3 illustrates the flow of a cooling medium and devices of the prior art.

Fig. 4 illustrates the type of flow provided by our invention.

It is usual in the construction of X-ray 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, such as 3500 watts, 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 aforementioned factors those of density, thermal conductivity and specific heat remain constant for a given medium, but we 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 our 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 our 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 our 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.

In some respects our invention is an improvement over that disclosed in Patent #2,098,315, issued to D. G. Sharp, November 9, 1937, for an "X-ray tube."

Referring now to the drawing in detail, we have shown in Fig. 1 an X-ray tube comprising an evacuated envelope 5, having a sleeve 7 supported from one end of the envelope, and on this sleeve is sealed a suitable focusing cup or shield 8, having a thermionic cathode 9, recessed therein and adapted to receive electrical energy through a suitable pair of conductors sealed through the glass envelope. An anode electrode structure 13 is supported from the opposite end of the tube. Suitable electric energy is fed to this anode structure which comprises a hollow metallic member 15, such as spun copper or the like, sealed to this end 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 heat in turn is provided with a target face 17 of a refractory metal, such as tungsten, which receives the electron bombardment during operation of the tube and is secured thereto adjacent the cathode.

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 of back plate 16, and in order to transfer this heat and maintain the temperature of the entire anode substantially uniform, we provide a structure for circulating and insulating a 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 and secured in desired adjustment therewith by an annular ring 20 locked by expanding nuts 20'. 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 through thimble 19 is provided with a slightly concave surface or face 23 spaced a short distance from the end of the member 15 to which the copper head is secured.

While we 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 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, it shall be considered that the back plate is spaced directly from the face 23 of the thimble 19 and directly contacted by the cooling and insulating material. The slightly concave face 23 of the front end of the thimble has a plurality of small openings 24 extending through to an enlarged chamber 25 in the head of the thimble. These openings, as more clearly disclosed in Fig. 2, are preferably symmetrically arranged around the small central opening illustrated. Of course, any number of openings may be utilized, but we preferably utilize more in the central area. These openings are from .015 to .125 inch and preferably approximately .040 inch in diameter.

An inlet conduit 28 of suitable insulating material, such as hard rubber or a phenol condensation product, or a metal tube supported at the inlet end by such insulating material, is placed to open into the enlarged chamber 25 in the head of the thimble. This inlet conduit preferably has a shoulder 28' engaging a recess 27 on the inner diameter of the thimble. The thimble has annular openings 26 providing an entrance for the fluid from the space between the thimble and the inner wall of the member 15. This opening permits the cooling fluid to pass between the inner wall of the thimble and the conduit 28 out into the space 29 between the shaft of the inlet conduit and the outer wall of the member 15. The thimble 19 not only terminates rearwardly within ring member 18 to enable locking ring 20 to be applied, but to also afford a greatly enlarged passageway immediately to the rear of said ring member and thimble, materially reducing back pressure on the cooling medium flow from the front of the thimble. Any suitable exit from the tube may be utilized for this fluid.

The thimble 19 and the inner surface of the member 15 may be coated with metal, such as nickel, rhodium, platinum and the like, 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 high grade hydrocarbon oil is caused to flow from a suitable reservoir through the inlet conduit 28 to the chamber 25 in the head of the thimble. The rear surface of the back plate 16 is the point of greatest heat. The oil under high pressure bubbles through the openings 24 directly on this surface with an attendant high velocity. The holes 24 are shown perpendicular to the rear surface of the back plate, and disposed at various positions with respect thereto, so the high velocity streams propelled through said holes collide head-on with force disruptive to the streams against the surface. Each stream thus splashes vigorously against the surface and spreads and interferes with and suffers interference by the spreading splash of the other streams, so the several streams, individually and collectively, create chaotic turbulence in intimate contact with the surface. This turbulence and high velocity prevents an adherence of a film of the oil at the

point or surface of greatest heat and rapidly replaces any film with fresh oil.

In Fig. 3 we have disclosed the types of flow of the prior art wherein the fluid flows laterally across the inner surface of the metal wall 15. The flow of this oil is technically defined as laminar, because the films slide across one another. The inner film adjacent the wall 15 will be inclined to adhere thereto and the continued application of high heat to this film adhering to the wall will produce a film of carbon from the oil. However, the flow produced by our plurality of openings in the head of the thimble produces a bubbling of the oil against the wall with a consequent greater turbulence illustrated in Fig. 4. The effect of this turbulence will provide a current, for example, illustrated by the heavy curved arrow A driving directly against the wall and then curving back. The result of this flow directly against the wall will have the effect of dislodging particles B of the film, and replacement of these particles with fresh oil. The oil then circulates around the periphery of the shoulder portion 22 into the annular passage around the thimble. The oil then passes through the annularly spaced opening 26 to the space between the outlet conduit 28 and the ring 18 and returns to the cooling reservoir.

The high velocity of flow accompanied by the bubbling or turbulence from passing through the small openings 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 and offer an impediment to the flow thereof.

It thus becomes obvious to those skilled in the art that we have provided an X-ray tube suitable for continuous operation for therapeutic purposes wherein an anode is provided through which a cooling and insulating material circulates with greater turbulence for transferring the heat generated during operation of the tube. The increased velocity of flow at the critical area or region where there is high turbulence, low viscosity through high temperature reduces the resistance to the flow of oil to a minimum.

The maximum amount of oil surface is presented in the path of heat flow immediately in back of the target, without the possibility of resulting carbonization of the oil.

Although we have shown and described a specific embodiment of the invention, we 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.

We claim:

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 circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target, including a member forming a chamber within said anode stem directly back of said back plate, a conduit leading into said chamber, a plurality of comparatively small openings from said chamber through the wall of said member facing said back plate and forming a plurality of high velocity flow passages substantially perpendicular to said face at various positions with

respect thereto whereby said cooling and insulating material will flow through with high turbulence and high velocity into forceful concentrated stream engagement with and splashing spreading 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 circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target, including a member forming a chamber within said anode stem directly back of said back plate, a conduit leading into said chamber, a plurality of comparatively small openings from said chamber through the wall of said member facing said back plate and forming a plurality of high velocity flow passages substantially perpendicular to said face at various positions with respect thereto whereby said cooling and insulating material will flow through with high turbulence and high velocity into forceful concentrated stream engagement with and splashing spreading 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, the face of said member directly back of said back plate being concave.

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, 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 circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target, including a member forming a chamber within said anode stem directly back of said back plate, a conduit leading into said chamber, a plurality of comparatively small openings from said chamber through the wall of said member facing said back plate, said openings being disposed with maximum concentration thereof next to the middle and more distantly spaced from each other toward the periphery of the front end of said member whereby said cooling and insulating material will flow through with high turbulence and high velocity over the surface of said back plate without filming and to effect maximum heat transfer from said anode to said cooling and insulating material, said member directly back of said back plate having a head slightly less in diameter than the anode stem enclosing it.

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, 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 circulating a cooling and insulating material over the maximum surface area of said back plate rearwardly of said target, including a member forming a chamber within said anode stem directly back of said back plate, a conduit leading into said chamber, a plurality of comparatively small openings from said chamber through the wall of said member

facing said back plate whereby said cooling and insulating material will flow through with high turbulence and high velocity over the surface of said back plate without filming and to effect maximum heat transfer from said anode to said cooling and insulating material, said member directly back of said back plate comprising a thimble with a head slightly less in diameter than said anode stem surrounding it, said chamber being in the head of the thimble and having close contact with said conduit, a ring member supporting said thimble member from the inner surface of said anode stem, said ring member

being spaced from said conduit, the shaft of said thimble terminating rearwardly within said ring member and having a plurality of openings therein at a part thereof in front of the ring member, whereby said cooling and insulating material will have an exit passageway to and between said ring member and the outer surface of said conduit, and will have greatly enlarged exit passageway to the rear of said ring member and thimble.

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