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SYSTEM FOR COOLING CONDUCTIVE MEMBERS

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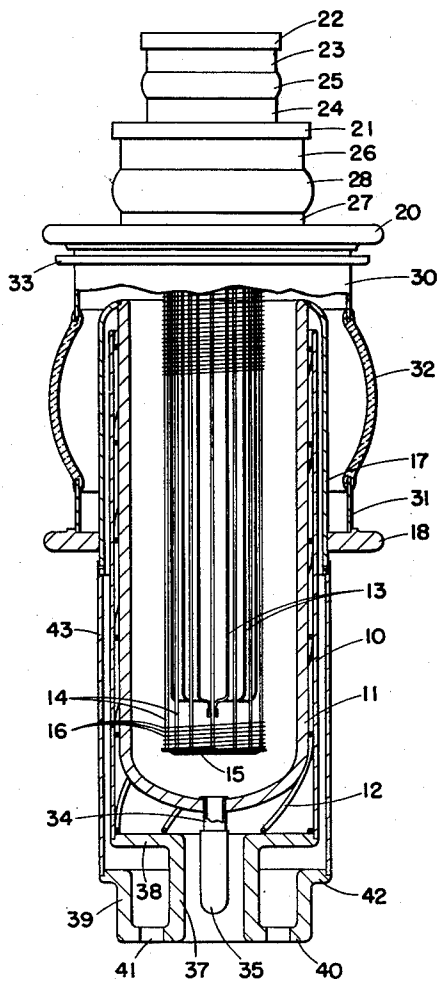


FIG. 1

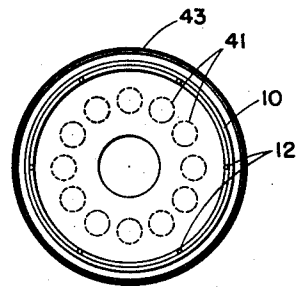


FIG. 3

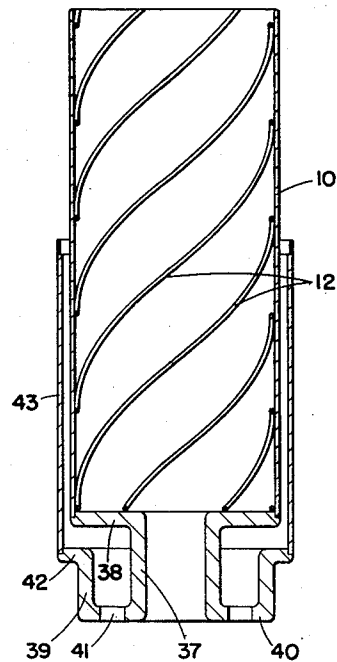


FIG. 2

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1

2,693,347

SYSTEM FOR COOLING CONDUCTIVE MEMBERS

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5 Claims. (Cl. 257—250)

This invention relates to a system for cooling conductive surfaces of electron tubes. In particular, it concerns a system for efficiently directing the flow of a coolant over the external surface of an electron tube anode.

It has become common practice to cool external anodes of electron tubes with relatively large volumes of water or other liquid coolants having high heat storage capacity. Increased cooling has been achieved by cutting grooves into the external surface of the anode or adding fins to the anode surface, thereby increasing the cooling area. In some instances the fins or grooves have been made spiral in an effort to increase the circulation of the coolant, thus increasing efficiency. These expedients have almost reached the limit of their effectiveness. A more efficient means of cooling has been needed for tubes of higher power level in order to avoid materially increasing anode sizes with consequent increases in tube sizes.

My invention provides an efficient compact structure for cooling a conductive electron tube surface, such as the external surface of the anode. The essential parts of my structure consist of a baffle means which is close spaced to the surface to be cooled and a plurality of walls or wall-like members defining channels. These walls are not cooling fins and, in fact, are advantageously affixed to the baffle member rather than to the anode. The walls in my preferred structure are advantageously made to extend the full distance between baffle and anode. Thus the walls may perform a spacing function. When so used, they permit very close spacing between anode and baffle while at the same time avoiding contact between these members at any point. In fact, it is possible to obtain uniform spacing at all points between the surface to be cooled and the baffle using the walls as spacing means.

The passage permitting flow of coolant past the surface to be cooled is kept small by the close spacing between the baffle and the surface to be cooled. The small passage produces a relatively large velocity of flow at any given pressure of coolant. Close spacing avoids laminar flow, wherein the layer of coolant midway between the anode and the jacket wall moves more rapidly than the layer adjacent the anode. In fact, all of the flow past the surface to be cooled is at the same rate and is sufficiently close to said surface to actively aid in the cooling. Likewise, close spacing leaves insufficient room between anode and baffle for eddy currents to be set up. Thus, despite the fact that a smaller total volume of water is used than in the prior art, almost all of the water molecules which flow past the surface contribute to its cooling.

The efficient use of the coolant in my cooling system is assured by turbulence, the constant redistribution of molecules within the body of the coolant. Turbulence is a by-product of high velocity. Tortuous channels between the walls will also tend to produce turbulence. Where the surface to be cooled gets hotter than the boiling point of coolant, turbulence is particularly important. Where there is no redistribution of molecules, a microscopic layer of coolant immediately adjacent the area to be cooled is transformed into an insulating layer of steam. In addition to the inefficient cooling resulting from this insulation of coolant from the area to be cooled, boiling at the surface to be cooled may produce scale and, in fact, may result in highly destructive mechanical vibrations. The effect of turbulence is constantly to remove heated molecules of coolant from the layer adjacent the surface to be cooled and to substitute cooler molecules of coolant.

2

Although the amount of turbulence is largely dependent upon velocity, it is not advisable to indefinitely decrease passage size in an effort to increase velocity. If the stream depth between the surface to be cooled and a baffle member is decreased until the super-heated layer adjacent the surface is no longer a negligible part of the total depth, turbulence will cease and the flow will become laminar. Accordingly, it is advantageous to keep the surface to be cooled spaced from the baffle at all points by the use of walls as previously described. In fact, the baffle and the surface may be spaced by the channel walls so that their spacing is optimum for maximum velocity of flow and maximum turbulence everywhere over the area to be cooled.

Water, the most frequently used liquid coolant, is usually available at relatively low pressures. In order to increase this pressure, additional equipment, which is subject to failure, is needed. Hence, in most instances, it is advisable to avoid high pressure systems. By the same token, it is advisable to take full advantage of the pressure available by obtaining a maximum velocity flow over the surface to be cooled. This is accomplished in my invention by keeping small the passages through which the coolant passes.

By use of my invention a relatively high velocity stream is maintained at uniform velocity over the whole area to be cooled because of uniformity in the size of the coolant passage. In my preferred construction the spacing between each pair of walls is made uniform over the whole length of the walls. Thus shallow paths highly uniform in cross sectional area throughout their length are provided so that the coolant pressure will produce high velocity streams having uniform velocity over the whole area to be cooled.

In my invention the walls are advantageously affixed to the baffle plate in order that the surface to be cooled may be maintained smooth and easily cleaned and in order that electron tubes may be replaced without replacing the baffle and the channel walls. Thus the tube is not complicated by the addition of vanes to the outer surface of its external anode. The channel walls affixed to the baffle also provide a self-positioning means which assures quick but highly accurate positioning of the baffle with respect to the surface to be cooled.

In electron tubes a particular problem arises which calls for solution by the use of a specially designed cooling system. This problem concerns the tendency for alternate stripes of heat and relative absence of heat to occur along the anode surface. It has been found that by making the anode wall extremely thick the increased conductive effect will smooth out the gradient between the stripes. However, it is costly to make thick anodes, and it is often inconvenient to do so. Thus in some instances tubes have been made with the knowledge that they will have a limited life, terminated by puncture of the anode wall due to overheating. The problem presented is one which calls either for redistribution of the heating effect or for adequate cooling of the extremely hot stripes.

My invention provides adequate cooling of the hot stripes. In the past, use of vanes along the vertical elements of an anode permitted the coolant to flow parallel to these stripes so that one channel of coolant had relatively more or less cooling to accomplish than another. It is my purpose to provide spiral paths or channels for the coolant so that every channel will cross some hot stripe. Thus the coolant contained in each channel will share nearly equally in the cooling of the hottest parts of the anode. Furthermore, the spiral walls will provide a tortuous path which will tend to increase turbulence, hence the cooling effect of the coolant.

For a better understanding of my invention a more detailed discussion of one of its preferred embodiments is included. This preferred embodiment concerns the cooling of a vacuum tube anode to which reference is made in the following drawings:

Fig. 1 illustrates in partial section an electron tube having an external anode which is positioned within the cooling means of my invention.

Fig. 2 illustrates in section the cooling means shown in Fig. 1 without a tube therein.

Fig. 3 illustrates in elevation this same cooling means from above.

Referring to Figures 1, 2 and 3, a cylindrical or tubular baffle member 10 is employed to direct the flow of coolant along the outer surface of cup-like anode 11. A plurality of helical walls 12 are arranged between anode 11 and baffle 10. These walls are preferably everywhere uniform in size and shape and may conveniently be made of wire. They are advantageously permanently affixed to the inside of baffle member 10, as by soft soldering, so that the distance between any adjacent pair of walls remains constant throughout their length. These walls are also advantageously made so that the anode, as well as the baffle member, is in contact with them substantially throughout its length.

The electron tube illustrated in Fig. 1 has an internal construction wherein are located an elongated free-hung filament 13 and a grid. The grid is composed of parallel struts 14 circularly arranged and terminated at their base in cap member 15. The active grid structure is provided by a helical winding 16 advantageously made of non-emissive material. These electrodes lie coaxially within the anode cup 11. Tubular member 17 is affixed to the lip of the anode cup 11 in such a way that it is effectively folded back over said cup, thereby forming a reentrant portion to said anode. Adjacent the opposite end of member 17 annular anode terminal ring 18 is placed. The grid is mounted on an annular grid ring 20 parallel to the anode terminal, and the filament is supported on members affixed to planar, circular filament terminals 21 and 22 at one end of the tube. The filament terminals are separated by a column composed of two Kovar rings 23 and 24 sealed to glass ring 25. A similar column separates cathode terminal 21 and grid terminal 20, namely Kovar collars 26 and 27 sealed to glass ring 28. The anode and the grid terminal rings are likewise separated by such a column having larger diameter Kovar rings 30 and 31 separated by large bowed glass member 32. The ring 30 may be made in two pieces flanged at the junction 33 at which is made the final seal as described in the application of George J. Agule, Serial No. 118,878. An exhaust tubulation 34 may be ported through the bottom of the anode 11. A cap 35 may be provided to cover and protect the tubulation. The tube structure, as a whole, thus briefly described, is also described in the application Serial No. 185,645 of George J. Agule.

The baffle 10 is the most important single part of the water jacket shown in Figs. 2 and 3. Water jackets may also be designed to cooperate with tubes of many shapes. Conformance of the baffle to the shape of the surface to be cooled is important in order to maintain the shallow stream required for high velocity. In this instance, the baffle extends into the reentrant portion of the anode formed by members 11 and 17 in order to parallel the surface to be cooled throughout its length. At its other end, baffle member 10 is affixed by means of radial flange 38 to a reduced diameter tubular member 37, which advantageously surrounds the cap 35 on exhaust duct 34. Tubular member 39 coaxially surrounds tubular member 37 to which it is joined at one end by radial member 40 which extends between the two tubular members and forms the bottom of an annular trough through which are made several holes 41. From the other end of tubular member 39 extends a short radially outward extending flange 42 to which is joined one end of tubular member 43 which is coaxial with and close spaced to baffle 10. As shown, it is possible to fabricate a single piece to provide all the members between baffle 10 and tubular member 43. The water jacket may be made an integral part of the tube as shown in Fig. 1 by soldering the other end of tubular member 43 to the adjacent end of anode member 17.

The use of a grid structure of the type shown in the tube of Fig. 1 produces some focusing of the electrons as they pass between the various grid supports 14 on the way to the anode. Thus the electrons will tend to bombard the anode in stripes around the anode thereby producing relatively hot stripes on the anode. This striping effect complicates the problem of adequately cooling the anode surface. However, if the coolant moved directly upward between the baffle and the anode in a direction parallel to the axis of the tube, the cooling effect of parallel streams of the water would be different. Accordingly, the preferred form of my invention employs spirals so that

each stream of coolant will be equally as effective in cooling the anode. In other words, the spiral channels formed by the spiral walls cause the coolant to cross alternately the hot and cold stripes on the anode. In order that each of these channels cross at least one stripe, I propose to use a pitch in the spiral such that each spiral crosses at least one hot stripe over the length of the anode. Otherwise expressed, I arranged the helical walls so that each of them will have a minimum pitch, in revolutions for a total length of anode surface, equal to the reciprocal of the number of hot stripes around the cylindrical surface. It is usually advisable to use a pitch equal to something less than a full turn per total length, although in some instances several turns per total length will not slow the stream too much, due to back pressure.

The functioning of the water-jacket is basically quite simple. The integral jacket may be made to fit a socket from which coolant is forced upward through tubular member 37 around the cap 35 on the exhaust tubulation. Thence the water moving upward takes the plurality of spiral channels formed by the walls 12 between the baffle 10 and the anode 11. Upon reaching the top of baffle 11, the coolant assumes a downward path between the outside of baffle 10 and anode member 17. This path continues on down between baffle 10 and tubular member 43, whence it flows into the channel formed by tubular members 39 and 37 and radial member 40. Thereafter, the coolant passes out through holes 41. Other means of access to and egress from the space between baffle 10 and anode 11 are possible and may be necessary with modified tube designs.

It is the purpose of the channels between the baffle and the anode to produce a high velocity stream of water adjacent the surface to be cooled. The high velocity is occasioned by minimizing the spacing between the anode and the baffle member. It is possible to successfully minimize this spacing because the wall-like members 12 act as spacers which keep the anode and the baffle everywhere separated. Thus, it is not possible for some portion of the anode to be inadequately cooled, due to insufficient flow of coolant over its surface where it is immediately next to or touching the baffle due to some eccentricity of its positioning. The reduction in this spacing reduces the area through which the coolant is able to flow. Since the velocity of the coolant is inversely proportional to the cross-sectional area of the channel through which it passes, the great reduction in the area of the channel afforded by my construction will permit a great increase in the velocity of the coolant stream. Since the rate of cooling is directly proportional to the .8 power of the velocity, this increase in velocity represents a material increase in the rate of cooling of the anode surface. It is my object to attain as high a stream velocity as possible by reducing the cross-sectional area of the stream path, specifically by reducing the distance between baffle and anode, without reducing this area to the point where turbulence will no longer occur or where efficiency is lost due to excessive friction.

In order to achieve uniform cooling over all the surface of the anode, not only is the depth of the channel maintained constant, but the spacing between the walls is also advantageously kept constant throughout their lengths so that the velocity of coolant in any given channel will remain constant throughout the whole length of that channel.

Several features of novelty are included in the preferred construction of my invention as described. It is not necessary that all of the novel features be used in conjunction with one another. Many advantages may be derived from use of one or more of these features without the others.

In the preferred form of my invention, the surface to be cooled is cylindrical. The shape of the channel walls may vary, but their use is essentially the same. In fact, should a complicated surface be chosen for cooling, the spacing function of my wall would prove invaluable.

I claim:

1. A system for cooling a cylindrical surface of a conductive electron tube member, said system comprising cylindrical baffle means uniformly spaced at all points from the cylindrical surface, a plurality of helical walls having a common axis and the same pitch and direction and located between the surface and the baffle and in contact with both, and means of access to and means of egress from the channels between the helical walls for the introduction and removal of a coolant.

5

2. A system for cooling a cylindrical surface of a conductive electron tube member, said system comprising cylindrical baffle means uniformly spaced at all points from the cylindrical surface, a plurality of helical walls fixed to the baffle means and contacting the cylindrical surface along the full length of said surface and means of access to and means of egress from the channels between the helical walls for the introduction and removal of a coolant.

3. A system for cooling a cylindrical surface of a conductive electron tube member, said system comprising cylindrical baffle means uniformly spaced at all points from the cylindrical surface, a plurality of helical walls having a common axis and the same pitch and direction, no wall making more than one revolution over the length of the cylindrical surface, said walls being located between the surface and the baffle and in contact with both, and means of access to and means of egress from the channels between the helical walls for the introduction and removal of the coolant.

4. A system for cooling a cylindrical surface of a conductive electron tube member, in which conductive surface there appear a plurality of alternate stripes of relatively hot and cold areas running generally parallel to the axis of the tube, said system comprising cylindrical baffle means uniformly spaced at all points from the cylindrical surface and a plurality of helical walls all of

6

which have the same pitch and direction, each wall making a turn over the length of the anode of at least that part of a revolution represented by the reciprocal of the number of hot stripes, said helical walls being located between the surface and the baffle and in contact with both, and means of access to and means of egress from the channels between the helical walls for the introduction and removal of a coolant.

5. A system for cooling a cylindrical surface of a conductive electron tube member, said system comprising cylindrical baffle means uniformly spaced at all points from the cylindrical surface, a plurality of helical walls consisting of wire members of uniform diameter affixed to the baffle means and contacting the cylindrical surface along the full length of said surface and means of access to and egress from the channels between the helical walls for the introduction and removal of a coolant.

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