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ELECTRODE HEAT EXCHANGER FOR ELECTRON DISCHARGE TUBES

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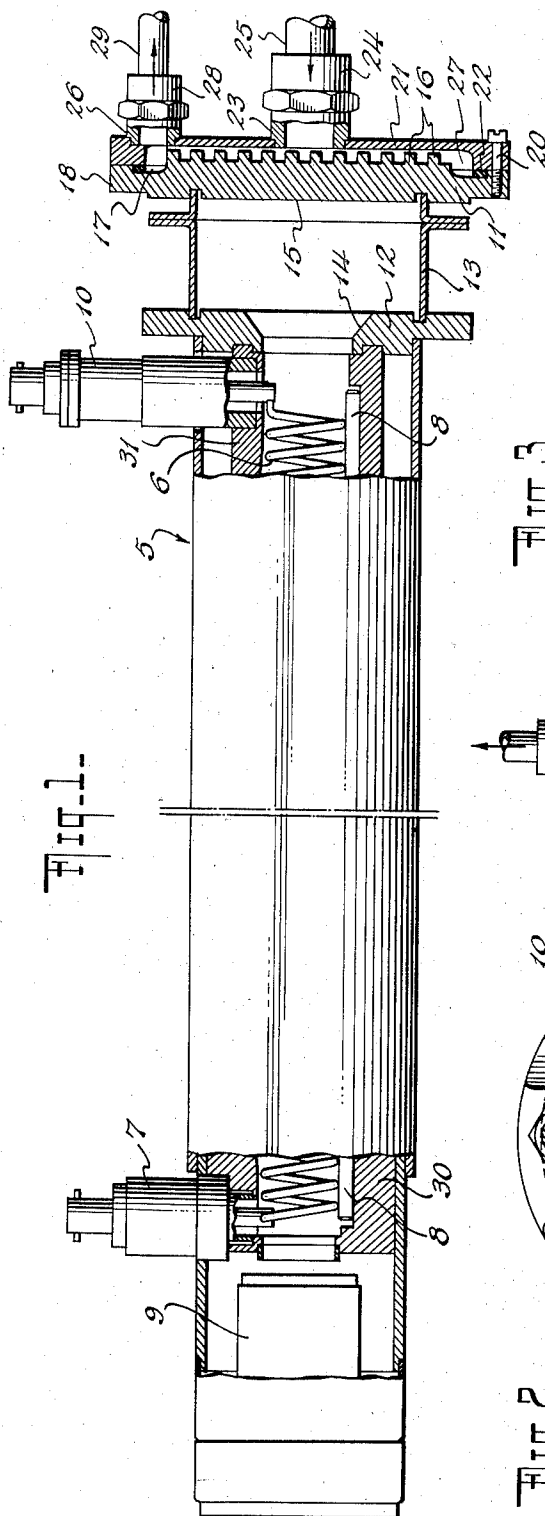


Fig. 3-

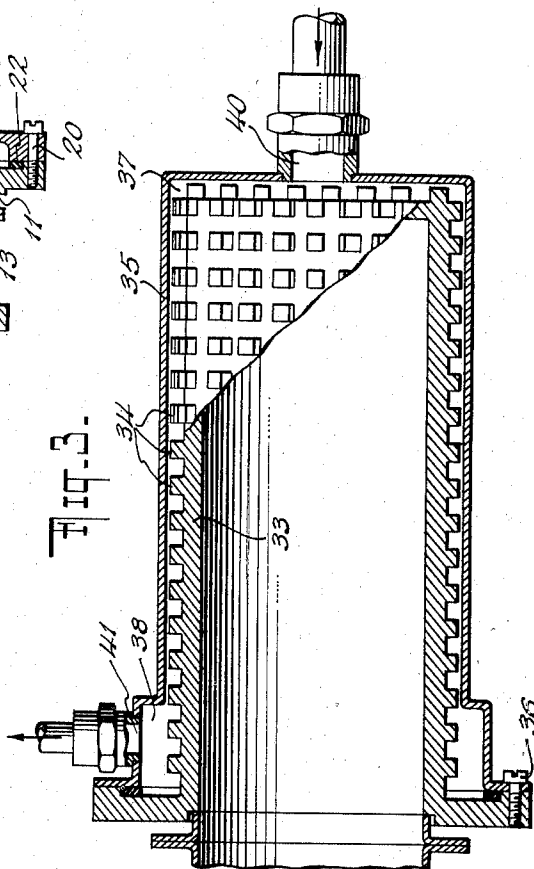
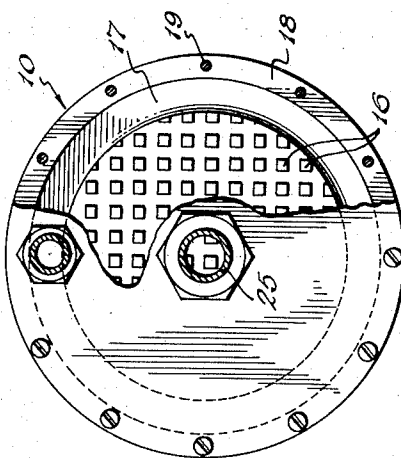


Fig. 2-



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ELECTRODE HEAT EXCHANGER FOR ELECTRON DISCHARGE TUBES

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This invention relates to improvements in the structure of electron discharge tubes. More particularly, it concerns a novel heat-exchanging or cooling arrangement for electrodes which collect electrons discharged in such tubes at power levels that tend to raise the tube temperature an excessive amount.

A high power traveling wave tube, for example, is an electron discharge tube wherein a large proportion of the power input is converted into heat in the tube body. Klystrons and certain high power diodes, triodes and tetrodes fall in the same category. In traveling wave tubes and in certain types of klystrons, the bulk of the electron beam is normally dissipated in the collector electrode, while in the other tubes, the bulk of electrons are received by an external anode or plate element. Accordingly, it is sometimes necessary to provide an arrangement for artificially cooling such electrode elements, in order to prevent serious tube injury.

The present invention is related to and is an improvement over prior art arrangements that achieve cooling by providing a flow of a fluid substance, liquid or gas, over normally hot portions of the tube. To this end, the present arrangement employs a collector electrode or anode (depending on the tube to which the invention is applied) which is integrally provided on its outwardly-facing surface with a large number of outwardly-projecting, symmetrically-spaced spines or protuberances. A housing is fitted over the spined surface for containing a fluid coolant which is supplied through conduit means by natural or forced convection. The housing and supply conduit are positioned in such a manner with respect to the spined surface and a manifold-like discharge chamber formed in the assembly of housing and electrode that the fluid coolant is caused to be turbulently distributed in all directions in a uniform general flow pattern from the supply conduit to among the numerous spines, finally to enter the discharge chamber and to exit by way of an outlet conduit connected to the chamber.

The spines thus included in the electrode on the surface thereof opposite to that which receives the electrons serve to increase the available wetted area, hence they proportionately increase the rate of heat transfer. A further increase in the rate of heat transfer arises from the turbulence of flow induced by the spines. Such turbulence is promoted at low rates of flow where the coolant motion, in the absence of spines, would be laminar. That is to say, with spines absent, turbulence could be achieved by increasing the rate of flow of coolant above a given critical velocity. However, high flow rate is unobtainable with natural convection and is disadvantageous from the viewpoint of efficiency with forced convection, since the pressure drop, and therefore the pumping power requirement where a circulating pump is employed, increases in proportion to a considerably greater exponential power of the discharge than does the coefficient of heat transfer.

The principal object of the present invention, therefore, is to provide an improved heat exchanging or cooling arrangement for electrodes which collect electrons in electron discharge tubes at power levels that tend to raise the temperature of such tubes an excessive amount.

Another object is the provision of an outwardly-spined surface on the external electrode of an electron discharge tube including an arrangement for uniformly dis-

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persing fluid coolant from a given area centrally located of the spined surface to the outer extremities of the surface by way of the interstices formed by the spines.

With the foregoing and other objects in view, the present invention includes the novel elements and the combinations and arrangements thereof described below and illustrated in the accompanying drawings, in which—

Fig. 1 is a side view, partly in section, of a traveling wave tube to which the present invention is applied;

Fig. 2 is an end view, partly in section, of the output end of the tube depicted in Fig. 1; and

Fig. 3 is a side view, partly in section, of a canister-like electrode element embodying the present invention.

In Fig. 1, the invention is embodied for illustrative purposes in a traveling wave vacuum tube 5. Radio frequency energy may be coupled into the left-hand or input end of a helical conductor 6 by way of a transmission line input connection, which may be a coaxial line connector 7, so as to interact in a well-known manner with an electron beam provided by an electron gun element 9 to the left of the input coupling connection. Helix 6 runs longitudinally of and within tube 5, being supported by a plurality of ceramic rods 8, the mounting arrangement for which includes the transition elements 30, 31. Amplified radio frequency energy may be coupled from the right-hand output end of helix 6 by way of a second transmission line connection which may be a coaxial line connector 10 like connector 7.

The output end of tube 5 includes a collector electrode 11 of novel configuration to be more fully described and a magnetic focusing pole piece 12, the collector electrode 11 being joined to the pole piece 12 by means of a conductive cylindrical shell 13 forming part of the evacuated envelope of the tube. The pole piece 12 has an opening 14 therethrough for passage of the beam of electrons axially of the tube towards the collector electrode 11 from electron gun 9 at the input end of the tube.

Collector electrode 11 is preferably of highly conductive material and includes a circular plane surface 15 normal to the tube axis, which surface faces the input end of the tube and directly communicates with the evacuated interior of the tube. The other or external surface of the collector electrode 11 includes a multitude of equally-dimensioned, outwardly-projecting and symmetrically-spaced spines 16, the aggregation of which is circularly bounded near the outer circumference of electrode 11 by a shallow annular channel-like depression 17 (see Fig. 2) in the outer surface of the electrode. The portion of electrode 11 between the depression 17 and the electrode's circumference forms an annular flange 18 provided with a plurality of tapped holes 19 to receive screws 20 for mounting a flanged housing or container 21 in position over the outer surface of the electrode. A gasket 22 provides a fluid-tight connection between container 21 and the electrode surface.

It is to be understood that wherever the term "spine" is employed in the description of the present invention, it is meant to include protuberances that are prismatic, cylindrical, or conical in shape. In fact, the spines may be those protuberances that would be produced by deeply knurling the electrode's outer surface. Accordingly, while in the embodiments illustrated, the spines are prismatic and form a waffle-iron type of structure, this particular type of spinal-configuration is by way of illustration and is not to be taken in a limiting sense.

The container 21 is provided with an outwardly-projecting inlet conduit 23 through which a fluid coolant is supplied to the container. Conduit 23 is coaxial both with tube 5 and the spined surface portion of electrode 10 (see Fig. 2). A compression fitting 24 serves to couple conduit 23 to a pipe 25 connected to the coolant source.

Container 21 is also provided with an outwardly pro-

jecting outlet conduit 26 through which fluid coolant is exhausted from the container. Conduit 26 communicates with the annular depression 17 in the outer surface of electrode 11, which depression together with a portion of container 21 overlapping the spinal extremities of the outer surface forms an annular manifold-like discharge chamber 27 for the fluid coolant supplied from conduit 23. A compression fitting 28 serves to couple conduit 26 to a pipe 29 which may be integral with pipe 25 if natural convection is to be relied upon for fluid circulation, or which may be connected to the sump of a circulating pump supplying pipe 25 if forced convection is to be employed.

Three major factors in the design of the present apparatus apart from the spines themselves determine the success of the apparatus in providing a turbulent distribution of fluid coolant in all directions in a uniform general flow pattern from the supply conduit to among the numerous spines, finally to enter the discharge chamber and to exit by way of an outlet conduit connected to the chamber. Two of the design factors are met respectively by the central or coaxial location of the inlet conduit 23 equidistant from the spined extremities of the electrode's outer surface, and by the provision of an annular discharge chamber 27 surrounding such extremities. That is to say, the coaxial location of the inlet conduit 23 permits distribution of fluid coolant in all directions, while the annular configuration of chamber 27 insures a uniform resistance to the flow of the coolant toward discharge so that no particular direction of general flow from conduit 23 is favored.

The third major design factor is met by providing a close spacing between the outer ends of spines 16 and the adjacent wall of container 21 so that a greater resistance is offered to coolant flow toward discharge through such spacing than through the paths or interstices formed by spines 15. Hence, since fluid tends to flow in a path of least resistance, the primary flow of the fluid takes place among the spines, thereby to produce a maximum cooling effect. If desired, the spacing between the outer ends of spines 16 and the adjacent wall of container 21 may be eliminated altogether, in which event part of the heat in the spines would be directly conducted to container 21 from whence it would be radiated.

Referring now to Fig. 3, the invention is depicted as it may be applied to a collector electrode, the collecting surface of which is canister-shaped, or to the cylindrical anode of certain high power tubes where such anode is external and forms the major portion of the evacuated envelope of the tube. Thus, in Fig. 3, a canister-shaped electrode 33 is integrally provided on its outer surfaces (both plane and cylindrical) with a multitude of equally-dimensioned, outwardly-projecting and symmetrically-spaced spines 34. A flanged canister-like container 35 is secured by a plurality of screws 36 to a flanged portion of the base of electrode 33, and the container is such as to fit closely over the outer ends of spines 34. An annular chamber 37 coaxial with electrode 33 is formed at the spinal extremities of the electrode's planar surface, i. e., where the cylindrically-disposed spines meet the plane-disposed spines. Another annular chamber 38 coaxial with electrode 33 is formed between container 35 and electrode 33 at the spinal extremities of the cylindrical surface adjacent the flanged portions where the container and electrode are connected.

Fluid coolant is supplied to container 35 through an outwardly projecting inlet conduit 40, which like conduit 23 (Fig. 1) is coaxial with the spined-planar surface of the electrode. Coolant is removed, however, through an outlet conduit 41 in direct communication with chamber 38 instead of chamber 37. By this arrangement, the coolant that enters inlet conduit 40 turbulently disperses in all directions in the interstitial conduits among the plane-disposed spines in a generally radial flow pattern to enter chamber 37, thence to further disperse in all directions in the interstitial conduits among the cylindrically-disposed

spines in a generally longitudinal flow pattern to discharge into chamber 38 and finally exit through outlet conduit 41. Thus, the advantages obtained from close container spacing, annular discharge chambers, and an inlet conduit location equidistant from the spinal extremities of electrode surface are once again attained in Fig. 3 as in Fig. 1.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electron discharge tube having an electrode element forming a body portion of said tube and adapted to receive the bulk of electrons discharged in said tube on a planar surface of said electrode element exposed to the interior of said tube, said electrode element having an outer surface provided with a multitude of outwardly-projecting spines, a fluid-tight container equidistant from and closely fitted over the outer ends of substantially all of said spines and secured to said tube, first conduit means for introducing fluid into said container to disperse in the interstices among said spines, said first conduit means being disposed adjacent a portion of said outer surface that is equidistant from the spined extremities of said outer surface, said container including a manifold-like chamber surrounding said extremities for receiving fluid that has passed among said spines, and second conduit means for removing fluid from said chamber whereby fluid flow paths of equal resistance and high turbulence are provided.

2. The electron discharge tube of claim 1 wherein the outwardly-projecting spines are equally-dimensioned and symmetrically spaced.

3. An axially-extending electron discharge tube having an electrode element forming an end portion of said tube and adapted to receive the bulk of electrons discharged in said tube on a surface of said electrode element internal of said tube, said internal surface being planar in configuration and normal to the tube axis, said electrode element having a surface external of said tube integrally provided with a multitude of outwardly projecting spines, a fluid-tight container secured to said electrode and closely fitted over said external surface so that fluid introduced to said container may freely disperse in the interstices among said spines, first conduit means for introducing fluid into said container, said container including a manifold-like fluid discharge chamber surrounding the spined extremities of said external surface, said first conduit means being dispersed centrally of said spined extremities and discharge chamber so that dispersion of the fluid introduced to said container is in a generally radial flow pattern toward said discharge chamber, and second conduit means communicating with said discharge chamber for providing an outlet for fluid discharged into said chamber thereby providing fluid flow paths of equal resistance and high turbulence.

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