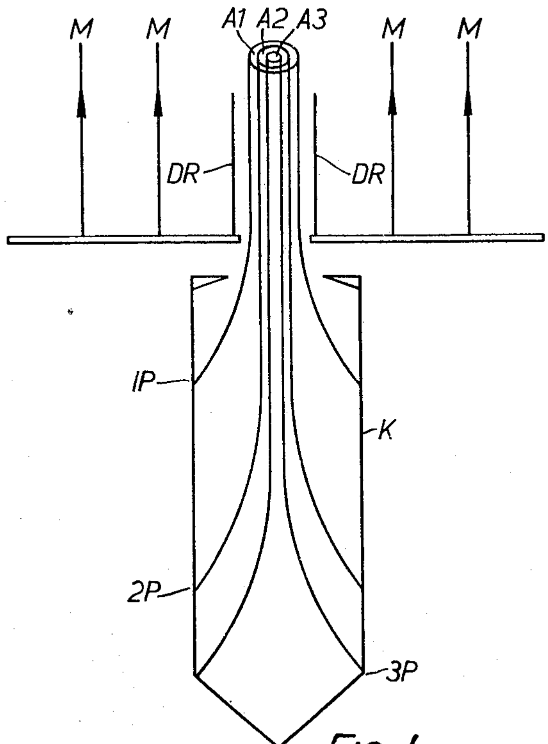

FIG. 1

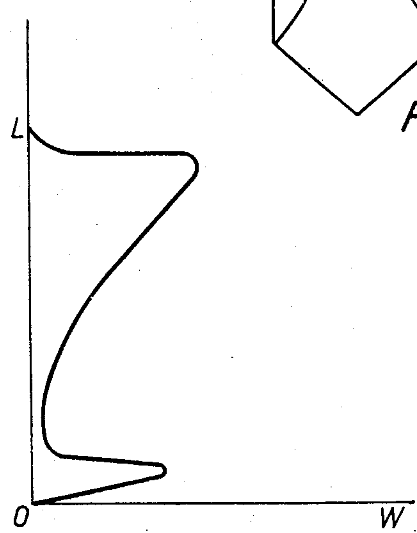

FIG. 2

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FIG. 3b

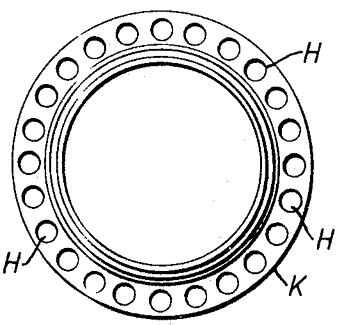
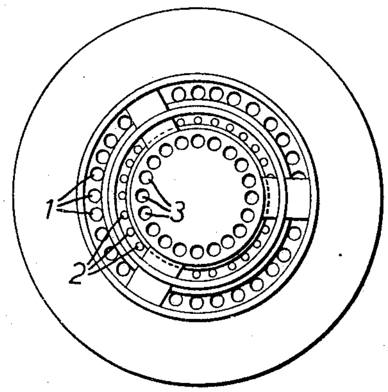


FIG. 4b



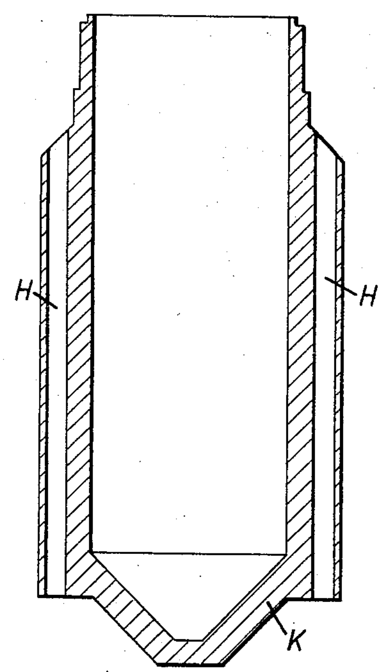


FIG. 3a

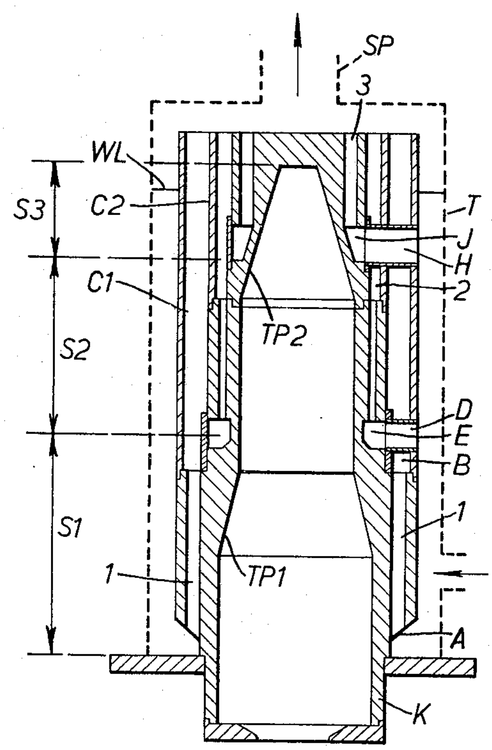


FIG. 4a

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3,500,096

ELECTRON BEAM TUBES

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Int. Cl. H01j 7/24, 61/52
U.S. Cl. 313—32 4 Claims

ABSTRACT OF THE DISCLOSURE

An electron beam tube having a vapour cooled collector is formed with a number of cooling pipes, all extending parallel to the tube axis, arranged in sets with each set in a ring of different diameter. Each set extends over a different part of the length of the collector and has a water inlet at the same corresponding end. The pipes of each set open into a water and steam outlet chamber extending in line with the pipes.

This invention relates to electron beam tubes such, for example, as klystrons and travelling wave tubes, and more specifically to electron beam tubes having vapour phase cooled (steam cooled) collector electrodes.

The invention is illustrated in and explained in connection with the accompanying drawings in which FIGURE 1 is an explanatory diagrammatic figure typifying the way in which the electron beam of an electron beam tube is collected by the collector electrode thereof; FIGURE 2 is a graph exemplifying the distribution of dissipation along the length of a collector electrode; FIGURES 3*a* and 3*b* show respectively in sectional elevation and plan a typical known collector electrode; and FIGURES 4*a* and 4*b* show respectively in sectional elevation and simplified plan one form of collector electrode in accordance with this invention.

The vapour phase (steam) cooling of the collector electrode of a high power, electron beam tube, such as a klystron, presents difficult problems mainly because of the fact that heat is not generated with uniform distribution along the length of the collector. The action which takes place is indicated, in generalised manner, in FIGURE 1. In this figure DR represents the drift tube of a klystron and K the collector electrode thereof. The focussing magnetic field is represented by the arrow headed lines M. The electron beam EB spreads out before and after entering the collector electrode. The first point of impact, near the mouth of the collector is indicated at IP. The energy contained in the outer annulus A_1 of the electron beam is dissipated over the collector surface from 1P to 2P. Similarly the energy in the annulus A_2 of the electron beam is dissipated over the surface 2P to 3P, while the remaining energy i.e., that in the central part A_3 of the beam is dissipated over the bottom of the collector. A typical curve of resultant power dissipation is shown in FIGURE 2 in which the ordinates L are distances along the collector from the mouth and the abscissae W are values of dissipation in watts per unit area. The increase in dissipation per unit area near the collector end remote from the mouth represents the total power remaining in the beam after the rest has been absorbed along the collector side walls and, therefore, the dissipation density at that end depends on the length of the collector. As will be readily appreciated, the illustration of FIGURES 1 and 2 is much generalised and based only on elementary beam spread theory. In practice, of course, this elementary theory is more or less violated by the effect of the varying magnetic beam

focussing field since this field largely determines the position of the first point of impact, and also by the effect of beam modulation, for the elementary theory assumes that all the electrons have the same velocity whereas, in practice, the electron velocities can range from zero to twice the beam voltage, the higher velocity electrons i.e., those with most energy, tending to travel to the closed tapered end of the collector.

The collector design must be such as to cater for a wide range of dissipation conditions which are only exemplified in generalised manner by FIGURE 2. To meet these requirements, collectors have to be made of large internal diameter in order to deal satisfactorily with high dissipation near the mouth and, in order to prevent over-dissipation at the end remote from the mouth, should be tapered over a considerable length.

FIGURE 3*a* and FIGURE 3*b* show a typical known steam-cooled collector electrode. The wall of the collector K is drilled with a number of long holes to form pipes H which are arranged in a ring and run parallel to the axis over the greater part of the length of the collector. In these pipes water is converted into steam, cooling being, in the main, due to the latent heat of vapourisation. The dissipation per unit length of collector depends on the number of pipes provided and, in any particular case, there is an optimum length and an optimum diameter for the pipes, the former being determined largely by the mechanism of cooling and the latter mainly by the heat transfer properties.

As regards the mechanism of cooling, this relies on water being evaporated on contact with the inner wall of a pipe, and the resultant steam being removed to allow more water to come into contact with the metal wall and be evaporated. A steam and water emulsion or mixture, which ultimately emerges from the upper ends of the pipes, is thus formed in the pipes. If the length of a pipe is too great the emulsion may become predominantly steam long before it reaches the end from which it emerges and, over the portion of the length towards that end, there will be insufficient water present to produce effective cooling of that portion. Moreover, if a pipe is too long, the pressure drop along it may rise to a point at which steam is caused to emerge from the lower end, (as well as at the top) and if this happens it will temporarily block the entry of water at the lower end with the result that there will be erratic rushes of water into the lower ends of the pipes thus producing mechanical "bumping." Either or both of these effects can occur if the pipes are too long. In any event the pipe length is determined by the overall length of the collector. Moreover a known steam-cooled collector as illustrated in FIGURES 2, 3*a* and 3*b* is expensive to construct because of the very long holes constituting the pipes H.

The present invention seeks to provide improved, relatively simple vapour phase cooled collector electrodes which shall give improved cooling, better suited to the actual heat distribution, than is obtainable with known collectors and which shall make use of cooling pipes whose lengths can be chosen to be of optimum values rather than as determined by the length of the collector itself. Moreover, as will be seen later, the invention enables the provision of inconveniently long borings to be avoided.

According to this invention the collector of an electron beam tube having a vapour cooled collector is formed with a plurality of sets of cooling pipes each set having its own water inlet and extending over a different part of the length of the collector.

The number of sets of cooling pipes depends on circumstances but three sets is a satisfactory number in many cases.

Preferably each set of cooling pipes consists of a ring of pipes extending parallel to the tube axis, the rings being of different diameters.

In a preferred construction there is a plurality of pipes, all extending parallel to the tube axis, arranged in sets with each set in a ring of different diameter, each set extending over a different part of the length of the collector and having a water inlet at the same corresponding end, the pipes of each set opening into a water and steam outlet chamber extending in line with the pipes thereof. Preferably the outlet ends of the water and steam outlet chambers are in the same transverse plane.

FIGURE 4*a* and FIGURE 4*b* show a prefered embodiment of the invention. Referring to FIGURES 4*a* and 4*b* the collector K, assumed to be part of a microwave klystron not otherwise shown, is inserted in a water jacket T (shown in broken lines) which in use is filled with water up to the level WL and which has an outlet steam pipe SP. The collector is internally tapered in two steps, the two tapers being referenced **TP1** and **TP2**, the former being nearer the mouth of the collector than the latter. In effect there are three cooling sections indicated by the references S**1**, S**2** and S**3**. Each set consists of a ring of bores constituting pipes **1**, **2** and **3**, each set extending over a different part of the collector length. So as not to complicate the drawing only a few of the pipes in each set are shown in the plan view shown in FIGURE 4*b*. The largest diameter set—pipes **1**—is at the bottom nearest the mouth of the collector and the next two sets **2** and **3** are of progressively decreased ring diameters. The diameters of the pipes themselves are chosen at optimum values as also are their lengths. In the illustrated embodiment pipes **1** are of largest diameter and pipes **2** of smallest. Each set of pipes (except the uppermost) has its own water inlet at its lower end and at its upper continues into a water steam outlet chamber C**1** or C**2**, having their outlets in a common transverse plane. As will be seen chamber C**1** extends over the combined length of pipes **2** with chamber C**2**, and chamber C**2** extends over pipes **3**.

Water from the water jacket enters the pipes **1** at A and is evaporated therein, the resulting emulsion of steam and boiling water travelling along from A to B effecting vapour phase cooling in cooling section S**1**. The vapour formed then travels along the annular chamber C**1** eventually going off to the steam outlet pipe SP. For cooling section S**2** the water enters pipes **2** via the pipes D and annular groove E. Evaporation takes place in pipes **2** the emulsion travelling along the said pipes and into the annular chamber C**2** and thence to the steam outlet. In the third cooling section S**3** the water enters pipes **3** via pipes H and annular groove J, being evaporated along said pipes **3** to form steam which proceeds to the outlet pipe SP.

It will be seen that the illustrated embodiment has the following advantageous features:

(a) The lengths and diameters of the pipes **1**, **2** and **3** can be chosen at optimum values;

(b) The maximum number of pipes **1**, **2** or **3** can be arranged to extend along the lengths where maximum dissipation is expected;

(c) The internal diameter of the collector can be tapered to best advantage. The illustrated embodiment has two tapers;

(d) Really effective cooling is obtained over the length of the collector at the far end i.e. nearest the closed end thereof;

(e) The collector is easy to manufacture, since there are no very long holes; and

(f) The collector is considerably lighter than a known collector, as shown in FIGURES 3*a* and 3*b*, of comparable total dissipation.

We claim:

1. An electron beam tube having a vapour cooled collector formed with a plurality of sets of hollow cooling pipes each set having its own water inlet and extending over a different part of the length of the collector.

2. A tube as claimed in claim **1** wherein each set of cooling pipes consists of a ring of pipes extending parallel to the tube axis, the rings being of different diameters.

3. A tube as claimed in claim **2** wherein there is a plurality of pipes, all extending parallel to the tube axis, arranged in sets with each set in a ring of different diameter, each set extending over a different part of the length of the collector and having a water inlet at the same corresponding end, the pipes of each set opening into a water and steam outlet chamber extending in line with the pipes thereof.

4. A tube as claimed in claim **3** wherein the outlet ends of the water and steam outlet chambers are in the same transverse plane.

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U.S. Cl. X.R.

313—35, 44; 315—5.38