Dec. 20, 1949 R. O. McINTOSH ET AL 2,491,995

ELECTRON BEAM TUBE

Filed June 26, 1948

Fig. 1.

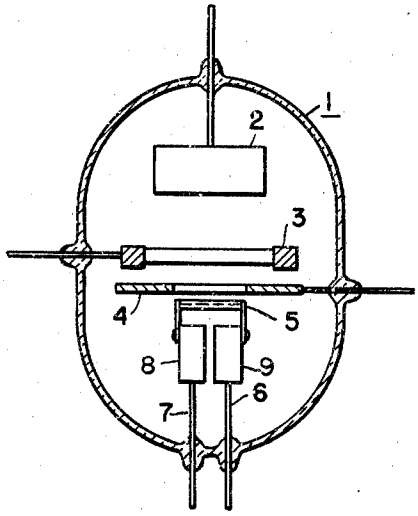


Fig. 4.

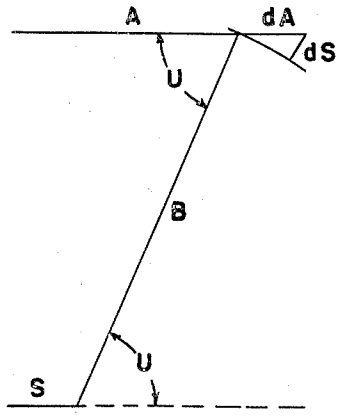


Fig. 2.

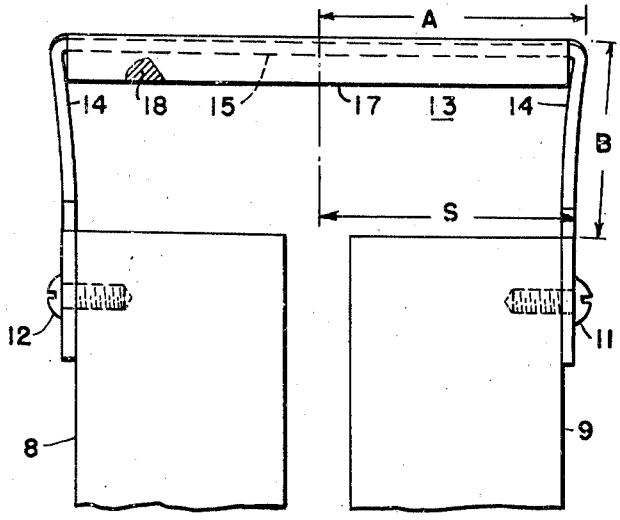
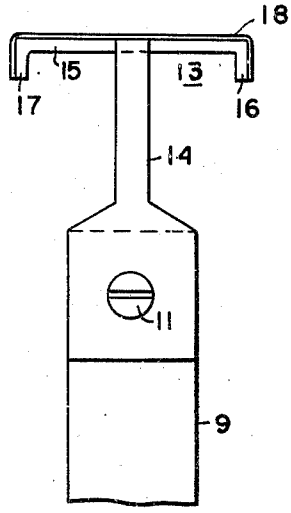


Fig. 3.



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ELECTRON BEAM TUBE

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5 Claims. (Cl. 250—27.5)

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Our invention relates to an electrical discharge tube and, in particular, relates to such a tube embodying a novel type of cathode structure adapted to maintain constant spacing between the cathode and other electrodes of the tube despite some variations of temperature of the structure.

Certain types of electron discharge tubes embodying an anode, at least one control electrode and a cathode are designed with very small spacing intervening between the cathode and one of the control electrodes. The cathodes of such tubes are designed to operate at high temperatures, and due to the substantial coefficients of thermal expansion of the materials employed in the cathode structure, the dimensions of the cathode naturally change as the temperature changes in the course of operation. Where the spacing between the control electrode and the cathode is extremely small, as is the case with certain types of electron tube, these changes of dimensions in the cathode structure tend to alter such spacing by amounts which produce substantial changes in the electrical characteristics of the discharge tube. In some tubes, the temperature of the cathode is a controlling factor in the power output of the tube. Thus it is important that the cathode position remain fixed as the temperature is varied to control the power output of the tube. It is also important that the cathode be uniformly at the same temperature over its area.

One object of our invention is, accordingly, to provide a novel type of cathode structure in which temperature variations of the cathode do not result in alteration of the spacing between the electron-emissive surface of the cathode and the associated electrodes in the tube, and in which the active cathode area is uniformly heated and rigid in form.

Another object of our invention is to provide a novel type of cathode structure in which the changes in dimension of various portions of the structure cancel each other as far as their effect on altering the spacing between the electron-emissive surface of the cathode and the control electrode is concerned.

Still another object of our invention is to provide an improved structure for mounting the electrodes of an electrical discharge tube of the hot cathode type.

Other objects of our invention will become apparent upon reading the following description, taken in connection with the drawing, in which:

Figure 1 is a diagrammatic showing of an electrical discharge tube having electrodes embodying the principles of our invention;

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Fig. 2 is a side elevation of a cathode embodying the principles of our invention;

Fig. 3 is an end elevation of the cathode structure shown in Fig. 2; and

Fig. 4 is a diagram useful in explaining the principles of our invention.

Referring in detail to the drawing, a vacuum-tight container 1 encloses an anode 2, an accelerator electrode 3, a control electrode 4 and a cathode 5, the latter being of a novel form according to the principles of our invention. The cathode 5 is supported on a pair of inleads 6, 7 sealed through the walls of the container 1 and terminating in a pair of relatively massive end portions 8, 9. Inleads 6, 7 are relatively massive and well-conducting thermally or the massive end portions 8, 9 can be fluid cooled through inleads 6, 7. Supported on the end portions 8 and 9 by some suitable means, such as screws 11, 12, is a thin metal-sheet bridging member 13 having risers 14 of relatively restricted cross-section, and having a horizontal portion 15 of larger cross-sectional area bridging the space between the risers 14. The horizontal portion 15 may be bent to form two aprons 16, 17, which constitute a rigid portion. The upper surface of the portion 15, 16, 17 may be coated, in a way too well known in the electron cathode art to require detailed description, with a coating of barium oxide and strontium oxide or other suitable electron-emissive material which, with the base metal, form a composite layer 18.

When operating, heating current is conducted through the leads 6, 7 and end portions 8, 9 to the risers 14 and thence through the bridging member 13, thereby raising the temperature of the latter sufficiently high to produce a satisfactory electron emission from the layer 18. External circuits well known in the electrical discharge tube art may thereafter be connected between the leads 6, 7 and the anode 2, accelerator electrode 3 and control electrode 4. To take only one illustration of the circuits in which a tube of the type here disclosed is useful, reference may be made to an application of David H. Sloan, Serial No. 583,257, filed March 17, 1945, for a Tube, assigned to the assignee of the present application. The bridging member 13, 14, 15 of the cathode may, of course, be made of any suitable metal or alloy capable of withstanding the desired operating temperature and having the specific resistivity to generate the heat desired for maintaining the temperature of the

layer 18. For example, we have found tantalum to be a suitable material for this bridging member, although nickel or tungsten may be desired for certain specific types of cathode.

A moment's consideration will show that the heat generated by the flow of the heating current in the bridging member 13 will cause an expansion in the dimensions of the bridging member 13 and will also result in heat flow through the risers 14 to the terminal portions 8 and 9. The latter are designed with sufficient mass, surface area and conductive cooling to dissipate the heat flowing into them before it seriously affects the seals at the inleads 6 and 7. As a result, the portion of the bridging member 13 which supports the emissive layer 18 will stand at an elevated temperature, while the lower ends of the risers 14 will be at the much lower temperature approximating that of the terminal portions 8 and 9. The cross-section of the risers 14 is made small in order to minimize the heat flow to the members 8, 9; and may be so proportioned that the heat generated in it so compensates for that flowing to the end portions 8 and 9 as to avoid substantial temperature gradient between the midpoint and the ends of horizontal portion 15 of the cathode.

As a result of the high temperature to which the horizontal portion 15 of the bridging member 13 is heated, the length of portion 15 will increase when the tube is put in operation, but at the same time the lesser temperature rise of the risers 14 will expand their length to a substantially smaller degree. The increase in length of the portion 15 will displace the upper ends of the risers 14 in a horizontal direction so that the angle between them will increase; and except for the above-mentioned concomitant expansion in length of the risers 14 mentioned in the preceding sentence, this displacement would result in displacing the bridging portion 15 downward toward the terminal portions 8 and 9. However, this downward displacement tends to be compensated by the expansion in length of the risers 14 and by properly proportioning the length of the latter to the length of the horizontal portion 15, it is possible to make these opposite tendencies toward vertical displacement of the horizontal portion 15 exactly compensate and cancel each other.

The relation between the above-mentioned lengths which will result in such compensation may be determined in the following way.

In Fig. 4, we diagram the hot, flat surface 15 of half-length A supported by risers 14 from fixed end portions 8 and 9 which have the half spacing S. The distance B can be measured from the line of support to the end of surface 15. It is possible to measure the minimum angle U between the line of B and the surface 15, which, as Fig. 2 shows, is also the angle between the line of B and the surface through the support line and parallel to surface 15.

The condition that the surface 15 remains fixed in distance from end portion 9 is met if

$$(1) \qquad \frac{dB}{dA}=\cos U$$

where dA is the reversible incremental increase in A (here due to increase in the temperature of surface 15) and dB is the corresponding simultaneous increase in B.

The validity of this condition may be shown as follows:

$B \sin U$ is to remain constant

Taking the differential,

$$(2) \qquad d(B \sin U)=0=dB \sin U+B \cos U dU$$

$$(3) \qquad dU=-\frac{dB \sin U}{B \cos U}$$

From the geometry of the structure,

$$(4) \qquad A=B \cos U+S$$

taking the differential,

$$(5) \qquad dA=dB \cos U-B \sin U \, dU$$

substituting from (3) in this equation for dU

(6)

$$dA=dB \cos U+B\frac{dB \sin^2 U}{B \cos U}=dB \frac{\cos^2 U+\sin^2 U}{\cos U}$$

$$(7) \text{ Therefore} \qquad \frac{dB}{dA}=\cos U$$

We also have another expression for U by the geometry:

$$(8) \qquad \cos U=\frac{A-S}{B}$$

(9) Thus, from (7) and (8)

$$\text{Cos } U\frac{A-S}{B}=\frac{dB}{dA}$$

It is thus obvious that given any

$$\left|\frac{dB}{dA}\right|<1$$

and any A, we can always find values of B and S to satisfy (9).

In practice, the dimension A is fixed by the electrical requirements of the tube. The dimension B is chosen to fall between convenient limits determined by the space available. At the operating temperature, a small variation in temperature causes a small ΔA and ΔB which can be measured. The ratio

$$\frac{\Delta B}{\Delta A}$$

is approximately equal to

$$\frac{dB}{dA}$$

and thus determines cos U, which in turn determines S.

It is expressly our intent to use structures which have angle U greater than 0 degrees and less than 90 degrees.

While we have equated the displacement $d(B \sin U)$ to zero in Equation 2 to represent a zero change in the separation of the cathode from the other electrodes, it will be evident that in certain cases it may be desirable that this separation vary at a predetermined rate with cathode temperature changes and in such cases the said predetermined rate should be substituted for zero in the second member of Equation 2.

Since the net displacement of the cathode in the vertical direction remains zero, its change in distance from the other electrodes 2, 3 and 4 will likewise remain zero, and the desired result of preventing variations in temperature of the cathode 5 from changing its spacing away from the electrode 4 will have been attained.

While we have described our invention as used to maintain a desired separation of the heated cathode of an electrical discharge tube from other electrodes therein, it may be applied in ways evident to those skilled in the art to maintain a desired separation between other heated surfaces

and structural elements operatively supported adjacent to them; as, for example, in furnaces, ovens, toasters, dryers and the like.

We claim as our invention:

1. A cathode structure for an electrical discharge tube comprising a member of sheet metal having a central portion of length 2A supported by end portions making angles U therewith from two terminal blocks maintained at a relatively low temperature, the distance between the adjacent ends of said terminal blocks and the ends of said central member being equal to B, the values of A, B and U being related approximately in accordance with the following formula:

$$\frac{dB}{dA}=\cos U$$

where dA and dB are respectively the increases in A and B resulting from a small increase in temperature of said central portion.

2. A cathode structure for an electrical discharge tube comprising a member of sheet metal having a central portion of length 2A supported by end portions making angles U therewith from two terminal blocks provided with means for efficiently dissipating heat, the distance between the adjacent ends of said terminal blocks and the ends of said central member being equal to B, the values A, B and U being related approximately in accordance with the following formula:

$$\frac{dB}{dA}=\cos U$$

where dA and dB are respectively the increases in A and B resulting from a small increase in temperature of said central portion.

3. An electrical discharge tube comprising a vacuum-tight container having an anode, at least one control electrode and two cathode-support members supported from said container the distance between said cathode-support members and said control electrode being substantially fixed, a cathode of sheet metal supported on said cathode-support members and comprising a first portion and two second portions making an angle U therewith, means attaching said second portions to said cathode-support members so that the distance between the ends of said first portion and the end of said cathode-support members is B, the length of said first portion being 2A, and the dimensions A, B and U being related by the following formula:

$$\frac{dB}{dA}=\cos U$$

where dA and dB are respectively the increases in A and B resulting from a small increase in temperature of said central portion.

4. An electrical discharge tube comprising a vacuum-tight container having an anode, at least one control electrode and two cathode-support members supported from said container the distance between said cathode-support members and said control electrode being substantially fixed, a tantalum cathode supported on said cathode-support members and comprising a first portion and two second portions making an angle U therewith, means attaching said second portions to said cathode-support members so that the distance between the ends of said first portion and the end of said cathode-support members is B, the length of said first portion being 2A, and the dimensions A, B and U being related by the following formula:

$$\frac{dB}{dA}=\cos U$$

where dA and dB are respectively the increases in A and B resulting from a small increase in temperature of said central portion.

5. An electrical discharge tube comprising a vacuum-tight container having an anode, at least one control electrode and two cathode-support members supported from said container the distance between said cathode-support members and said control electrode being substantially fixed, a cathode of sheet metal supported on said cathode-support members and comprising a first portion and two second portions making an angle therewith, the dimensions of said cathode being so proportioned to said angle that the changes in said distance which result from a temperature variation of said first portion compensate the changes in said distance which result from the concomitant temperature variation in said second portions.

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The following references are of record in the file of this patent:

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