Dec. 13, 1955 H. J. DAILEY ET AL 2,727,177

ELECTROSTATIC LENS SYSTEM

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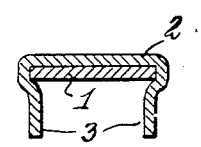


Fig. 1.

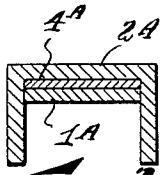


Fig. 3.

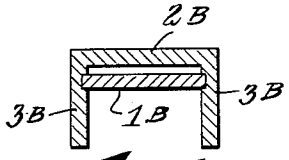


Fig. 4.

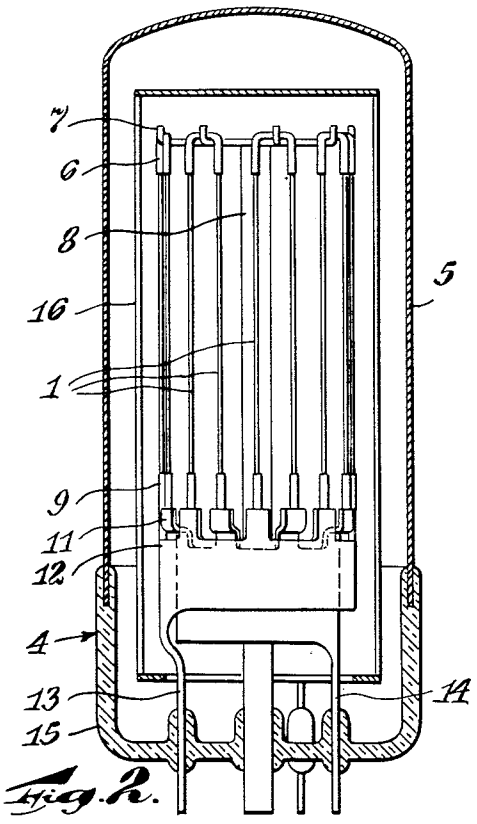


Fig. 2.

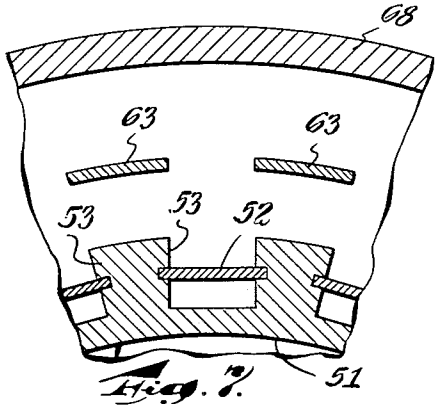


Fig. 7.

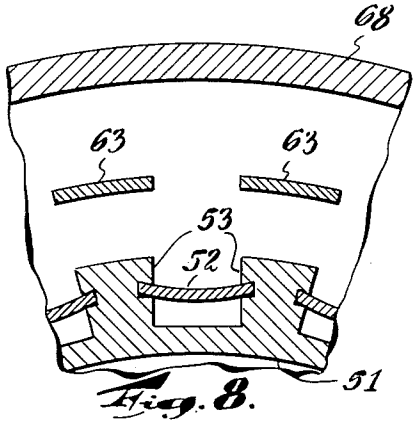


Fig. 8.

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ELECTROSTATIC LENS SYSTEM

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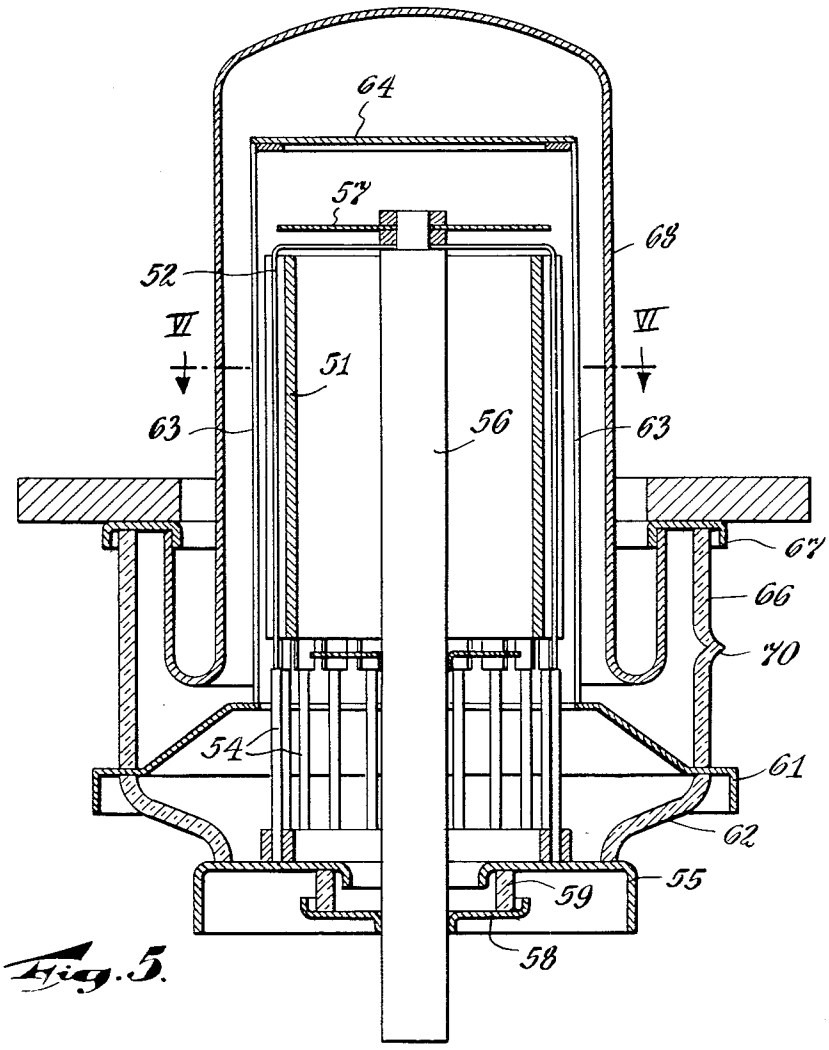


Fig. 5.

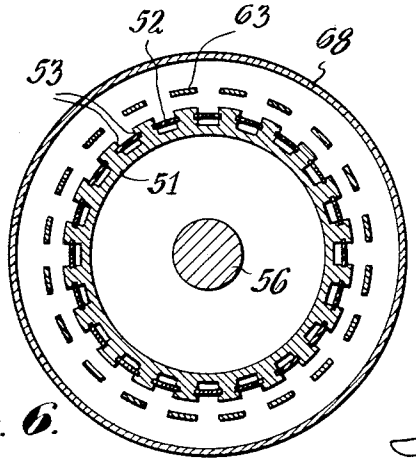


Fig. 6.

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ELECTROSTATIC LENS SYSTEM

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Application February 11, 1952, Serial No. 271,034

11 Claims. (Cl. 313—341)

Our invention relates to electrical discharge tubes and, in particular, relates to a new and improved cathode structure particularly useful in high-voltage electron tubes for high-power oscillator and amplifier service.

Electron tubes of the types just mentioned ordinarily have anodes comprising a cylindrical metallic portion of the tube wall, a control electrode comprising wires parallel to the axis of the anode and uniformly spaced away from the internal wall of the anode, and a cathode comprising a number of heated tungsten or thoriated tungsten wires paralleling the axis of the cylinder and uniformly spaced radially inward from the grid. There is a continued commercial demand for larger and larger power tubes, and this poses problems of continually greater difficulty in supporting the cathode filaments so as to maintain the uniform small spacing from the other electrodes at all times notwithstanding the expansion and contraction of the filaments in heating up to their high operating temperature.

Moreover, the control grids are required at times in the operating cycle to reach positive potentials nearly as high as that of the anode; and unless precautions were taken against it, this would result in the flow of large electron currents to the control grid. Such currents are highly undesirable for a number of well-known reasons, and among the expedients which have been adopted for minimizing them has been the provision for each cathode filament of a trough-shaped member enclosing the cathode filaments except on the side facing the anode, thereby forming an electron lens which focuses the electrons leaving the cathode into constricted streams able to pass between the control grid wires with only a small fraction of the electrons striking them. For practical reasons, the focusing members have to be spaced very closely to the cathode filaments, and the maintenance of these close spacings is an additional difficult design problem.

One object of our invention is, accordingly, the provision of a cathode structure which causes electrons to flow toward the anode in focused streams without the use of a focusing electrode differing in electrical potential from the cathode.

Another object is the avoidance of the above-mentioned difficulties of maintaining uniformity of spacing between the cathode and associated electrodes.

Still another object is to provide a carburized thoriated cathode which is provided with means to prevent depletion of the carbon by migration or otherwise from the surface layers of the thoriated tungsten in the course of use.

A still further object is to provide a cathode structure of a novel type in which the electron-emitting surface may be curved to focus the electron stream to the desired degree of concentration.

Yet another object is to provide a novel type of cathode in which a thoriated tungsten or other electron-emitting surface is supported throughout its length by a heated ancillary member of material of lower electron emissivity but greater mechanical strength.

Other objects of our invention will become apparent to those skilled in the art upon reading the following description taken in connection with the drawings in which:

Figure 1 is a cross section through a cathode filament in accordance with a first modification of our invention;

Figure 2 is a view partly in elevation and partly in section of an electron tube embodying a cathode of the type detailed in Figs. 1, 3, or 4;

Figure 3 is a cross section through a cathode filament in accordance with a second modification of our invention;

Figure 4 is a cross section through a cathode filament in accordance with a third modification of our invention;

Figure 5 is a view partly in elevation and partly in section of an electron tube embodying a cathode in accordance with a fourth modification of our invention;

Figure 6 is a detailed sectional view of a portion of the electrode system of Figure 5 on line VI—VI thereof;

Figure 7 is a sectional view to enlarged scale of a portion of Figure 6; and

Figure 8 is a detailed sectional view of a portion of a modified electrode system suitable for use in the tube of Figure 5.

Referring in detail of Figure 1 of the drawings a cathode leg or filament in accordance with the first modification of our invention comprises a thoriated tungsten wire or ribbon **1** enclosed on three sides by a trough **2** of molybdenum, tantalum or tungsten or other refractory metal. For many uses it will be found desirable that the thoriated tungsten be of the carburized type now known in the art. The filament **1** is heated to the usual operating temperature by heating-current, and since the filament **1** and trough **2** are in electrical contact, part of the heating-current will flow through and heat the trough **2**. Furthermore, the close contact between the filament and trough will result in their attaining substantially the same temperature. Even so, however, the electron emissivity of the filament material is so much higher than that of the trough material at the same temperature that substantially all the electron emission is from the filament **1** at the bottom of the trough, and the back of the trough and its projecting side walls **3** are practically non-emissive. These side walls **3** cause the electrons to issue as a narrow stream between them; and by positioning the bars of the control electrode outside the boundaries of this stream it is insured that nearly all the electrons impinge on the anode and that relatively few strike the control electrode bars to produce grid-current.

When in the prior art mentioned above cathode filaments have been provided with troughs spaced away to produce electron lens system, there was an IR drop due to heating current along the filament but the trough was a one-potential surface; hence, the electric field between filament and trough, which actually constituted the electron lens, was different at one end of each filament leg than at the other end, and the electron stream could not be uniformly and perfectly focused at all points along the filament. In contrast to this, the contact between our filament and trough **2** insures the same potential drop along each, and the focusing effect on the electron stream is uniformly the same throughout the length of the cathode.

Referring in detail to Figure 2, the composite cathode filaments of Figure 1 are supported parallel to the axis of a cylindrical tube **4**, having a cylindrical metal anode **5** forming part of its enclosing walls. The cathode filaments thus form elements of a cylindrical surface coaxial with, and of smaller diameter than, the anode

5. The upper ends of two filament legs having the cross section shown in Figure 1 are clamped in the ends of U-shaped metal holders **6** which are supported on arms **7** radiating from the center rod **8**. The lower ends of the filaments are similarly affixed to metal lead-rods **9** which are supported alternately by the crowns **11** and **12** at the upper ends of in-lead posts **13** and **14** which are sealed through the glass tube wall **15**. The center rod **8** and a control electrode consisting of vertical bars **16** are also supported on in-lead posts sealed through the glass wall **15**.

When the filament **1** is of carburized thoriated tungsten, difficulty may arise from migration of the carbon in time to the surface of the trough **2** or elsewhere, resulting in a gradual depletion of carbon on the surface layers of filament **1** and a consequent reduction in its electron emissivity. This difficulty may be overcome by using cathodes of the structures shown in cross section in Figures 3 and 4. In the Figure 3 modification, the carburized thoriated tungsten filament **1A** is enclosed on three sides by a trough **2A** of refractory metal such as tungsten, tantalum or molybdenum, but between the filament **1A** and the bottom of trough **2A** is interposed a layer **4A** of carbon. There will be a continued migration of carbon atoms from layer **4A** into the filament **1A** which will maintain an equilibrium density of carbon on the thoriated tungsten surface.

Similar results to the above can be attained by the third modification of our invention which is shown in cross section in Figure 4. Here the carburized thoriated tungsten ribbon **1B** is fixed at its edges in a trough **2B** of carbon having projecting edges **3B** which guide the emitted electrons in a confined stream toward the anode and at most with only a very small percentage of them striking the bars of the control electrode. By arranging the ribbon **1B** to engage the trough **2B** only at its edges, the heat abstracted by the trough **2B** from the ribbon **1B** may be minimized. Part of the heating current will, of course, flow through the carbon trough **2B** and heat it to some degree. The magnitude of this degree may be controlled in a substantial degree by changing the thickness of the walls of the trough as will be evident to those skilled in the art. In Figure 4 the carbon trough **2B** may thus be designed to operate at a substantially lower temperature than the ribbon **1B**.

In both the Figure 1, Figure 3, and Figure 4 modifications, the thoriated tungsten has been shown as having a flat surface, but this surface may be made concave toward the anode to direct the electrons into a narrower stream, or convex toward the anode to produce a less constricted stream. The side walls of the trough will usually be normal to the emissive surface at their junctions with it.

Figure 5 is an elevational section and Figure 6 a horizontal section of a fourth species of our invention in which carbon troughs such as appear in Figure 4 may be considered to be consolidated into a hollow cylindrical wall **51**. The electron-emissive ribbons or filaments **52** are, as appears more clearly in Figure 7, supported in troughs by having their edges engage slots **53** cut in the radial walls of the troughs. Where it is desired that the faces of the ribbons **52** which face radially outward shall be flat, as in Figure 7, the slots in the radial slot walls are cut normal thereto; but when as in Fig. 8 it is desired that the ribbon face shall be curved to more greatly concentrate the outflowing electron stream, the slots may be cut at a suitable angle to the radial trough walls.

The carbon cylinder **51** is seated on the tops of a circular row of metal standards **54** which have their lower ends set in a metal collar **55** forming part of the wall of the enclosing tube. One standard is provided for each trough in the cylinder **51**, and the respective ribbons **52** have their lower ends welded, or otherwise attached, to the associated standards **54**. The upper ends of the ribbons **52** are bent over the upper edge of the carbon cylinder **51** and projecting radially inward are attached to a center post **56** which is positioned in the central axis of the cylinder **51**. A disc **57** may be provided to shield the upper end of the tube from the heat of the cathode.

The center rod **56** is welded to a disc **58** near its base, and the latter is attached to the collar **55** by a glass ring **59** which is sealed vacuum-tight to both collar **55** and disc **58**. Heating current for the cathode thus can flow from the lower end of center rod **56**, up the latter into the respective filaments **52**, then down the latter to the standards **54** and out through the collar **55**. Part of the heating current will, of course, flow through the carbon cylinder **51** between its upper and lower ends, but since the specific resistivity of carbon is many times that of thoriated tungsten, the carbon cylinder **51** can be so designed that the higher heating effects occur in the thoriated tungsten ribbons **52**. There will, of course, be some heat flow to the carbon cylinder **51** where the edges of the ribbons **52** engage the slots in the radial walls **53**, and some heat will be radiated to cylinder **51** from the radially inward faces of the ribbons **52**, but, nevertheless, the electron emissivity of the carburized thoriated tungsten is so much higher than that of carbon that subtantially all the entire electron stream is emitted from the radially outward faces of the ribbons **52**, and the side walls **53** of the troughs in carbon cylinder **51** merely act to form the electron stream into a concentrated beam. The carbon of cylinder **51** acts, of course, to prevent depletion of the carburization of the thoriated tungsten ribbons **52**.

A metal ring **61**, sealed vacuum-tight to the ring **55** by a glass ring **62**, supports a circular row of grid rods **63** parallel with the troughs in the carbon cylinder **51**. The grid rods **63** are so positioned as to be displaced laterally from the electron stream issuing from the troughs in carbon cylinder **51**. The grid rods **63** are interconnected at their upper ends by a disc **64** or the like and constitute the control electrode of the tube.

The ring **61** is sealed vacuum-tight by a glass cylinder **66** to a flange **67** on the cylindrical metal anode **68** which completes the wall portion or the tube in conventional fashion. The flange **67** may be used to support this tube on a rack if desired, and the tube may be evacuated in accordance with conventional practice by a tubulation **70** in the glass cylinder **66**.

We claim:

1. An electron-emissive filament comprising a trough-shaped shield, and a thoriated tungsten ribbon positioned within and retained at its longitudinal edges by said trough-shaped shield, said shield having a surface which has a thermionic emissivity small compared with thoriated tungsten.

2. An electron-emissive cathode comprising a trough-shaped shield, and a thoriated tungsten ribbon having longitudinal supporting engagement within said shield and constituting a full bottom for the trough thereof, the sides of said trough of said shield having a thermionic emissivity which is a small fraction of that of thoriated tungsten.

3. An electron emissive filament comprising a trough-shaped shield providing an open side and side walls, and said shield having an element drawn from the group which consists of tungsten, tantulum, and molybdenum, and a thoriated tungsten ribbon within and extending longitudinally of the trough of said shield and transverse to said side walls and having a width greater than the width of said open side of said shield.

4. An electron-emmissive cathode comprising a thoriated tungsten core and a shield, said shield being trough-shaped and thereby providing an open side and said core being within and parallel to said shield and said shield having an inner trough surface of carbon.

5. A cathode structure comprising a cylinder having a plurality of troughs in its surface opening outwardly radially of the cylinder, said troughs having carbon on their

inner faces, and filaments of thoriated tungsten lying within said troughs and exposed longitudinally at the open side of said troughs.

6. A cathode structure comprising a cylinder having a plurality of troughs in its surface which have carbon on their inner faces, and ribbons of thoriated tungsten having their edges fixed to the side walls of said troughs.

7. A cathode structure comprising a cylinder having a plurality of troughs in its surface which have carbon on their inner faces, and ribbons of thoriated tungsten having their edges fixed to the side walls of said troughs not far above the bottoms thereof.

8. A cathode structure comprising a hollow cylinder of carbon having a plurality of troughs on its surface, and filaments of thoriated tungsten lying within said troughs.

9. A cathode structure comprising a hollow cylinder of carbon having a plurality of troughs on its surface and ribbons of thoriated tungsten having their edges in contact with the side walls of said troughs.

10. A cathode structure comprising a hollow cylinder of carbon having a plurality of troughs on its surface, and

ribbons of thoriated tungsten having their edges in contact with the side walls of said troughs not far from the bottoms thereof.

11. A cathode structure comprising a thoriated tungsten member and a member of carbon positioned in close proximity to each other and with a portion of each member in contact with a portion of the other.

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