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CATHODE FOR ELECTRON TUBES

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Fig. 1.

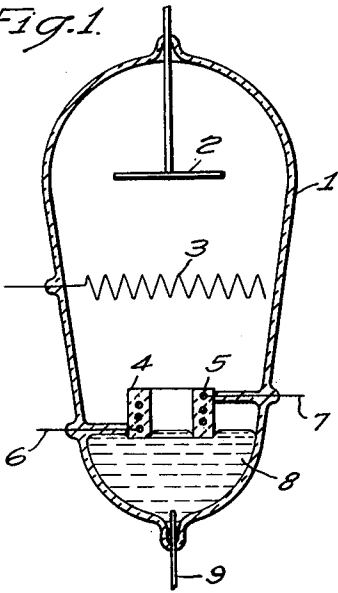


Fig. 2.

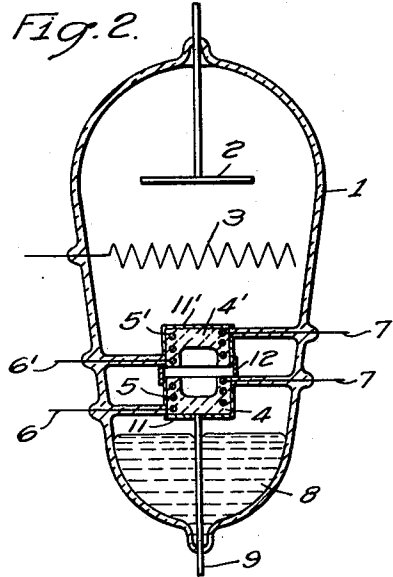


Fig. 3.

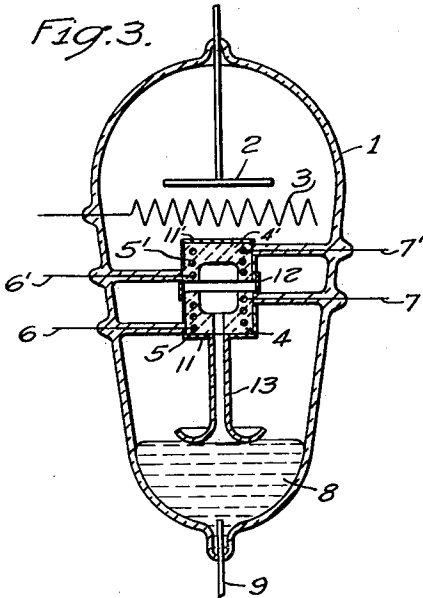
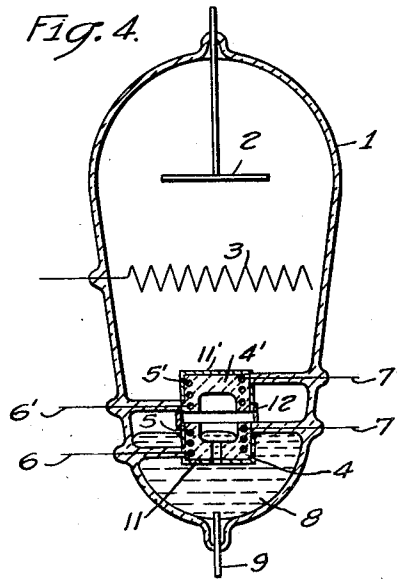


Fig. 4.



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CATHODE FOR ELECTRON TUBES

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4 Claims. (Cl. 250—27.5)

My invention relates to gaseous electric discharge devices and, in particular, to such discharge devices embodying cathode structures adapted to provide copious supplies of ionized gas in the region adjacent the cathode surface.

One object of my invention is to provide a cathode structure in which a partially enclosed region is provided about a thermionically-emissive cathode surface, this region being especially adapted to maintain a high degree of ionization in a gas or vapor within its confines.

Another object of my invention is to provide a cathode structure with means for constantly maintaining a higher pressure of a gas or vapor in the region of the cathode surface than in the vicinity of an anode and/or a control electrode within a gaseous discharge tube.

Still another object of my invention is to provide a cathode structure adapted to continually supply a stream of gas or vapor drawn from a reservoir of liquid material within an electrical discharge tube to the region about a thermionically-emissive cathode surface.

Still another object of my invention is to provide an electrical discharge tube structure adapted to establish paths of circulation in which a liquid is vaporized, the vapor conducted to a restricted region about a thermionically-emissive cathode surface, is then conducted away from this region, recondensed and returned to the aforesaid liquid.

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

Figure 1 illustrates a simple form of tube structure embodying some of the principles of my invention;

Fig. 2 represents a similar discharge tube having a modified form of cathode adapted to provide a nearly enclosed chamber for ionized gas in the region of the thermionically-emissive cathode surface;

Fig. 3 discloses still another modification of the aforesaid tube in which ducts are provided for conducting vapor emanating from a liquid to the region surrounding the thermionically-emissive cathode surface, and other passages are provided for conducting the vapor away from the aforesaid region to places where it recondenses and flows back to the liquid body; and

Fig. 4 shows a modified cathode structure which performs the same functions as have been pointed out in connection with Fig. 3.

The total current which may be drawn from electrical discharge tubes of the type embodying thermionically-emissive cathodes is roughly proportionate to the total area of the cathode surface and, in the case of high-vacuum tubes, is limited to a relatively moderate current per square inch of thermionically-emissive surface.

High-vacuum discharge tubes for producing large current outputs are accordingly prohibitively expensive. By introducing certain gases or vapors in place of the high-vacuum, the current density per square inch of the cathode surface may be greatly increased, and high current tubes with cathodes of practical size are accordingly possible. Such high current flow is facilitated, and the voltage-drop between the electrodes increased if the cathodes are made in the form of nearly closed chambers, since ionization of the gas about the cathode surface is promoted. Over a wide range of pressures, the current which may be used for each square inch of the thermionically-emissive cathode surface is greater as the gaseous pressure is made greater and it is accordingly desirable where very high current tubes are contemplated to maintain a high gaseous pressure in the region of the thermionically-emissive surface. However, it is found that, if gases at such high pressures are present in the region surrounding the anodes or control-electrodes in such tubes, difficulties are liable to be encountered from lack of control-sensitivity or from back-firing to the anodes. My invention accordingly contemplates, as one of its features, arrangements in which the gaseous pressure in the region adjacent the anode or control-electrode in an electrical discharge tube shall be maintained at a relatively low value, while at the same time a considerable gaseous pressure is produced in the region adjacent the surface of a thermionically-emissive cathode.

One of the most practical arrangements for effecting this result is to employ as the gaseous atmosphere within the tube the vapor of a liquid, such as mercury, the liquid being maintained in a reservoir adjacent a heated thermionically-emissive surface and caused to continually vaporize, but to recondense before it diffuses to the portions of the tube adjacent the anode or control electrodes. In order to facilitate the ionization of the gaseous atmosphere and the maintenance of a high vapor pressure adjacent the thermionically-emissive surface, the latter is made to form a nearly enclosed chamber, having a vent through which the electric discharge current can flow to the anode. However, I have found that, if this vent is made too restricted in area, the voltage drop between the electrodes of the tube becomes undesirably high and also it is very difficult to find materials for the cathode structure capable of withstanding the high temperatures in the vicinity of the vent. On the other hand, if the vent is made of too large area, it is extremely difficult to maintain a sufficient difference of pressure between the region adjacent the thermionic surface and the remainder of the discharge tube. The cathode structures which are shown in the appended drawing are

accordingly designed to provide vents of sufficient area to permit large current flow between the electrodes of the tube, while at the same time maintaining a high density of ionization adjacent the thermionically-emissive surface.

Referring in detail to Fig. 1, an electrical discharge tube 1, which may be of glass or other suitable material well known in the art, is provided with an anode 2, and a control-electrode 3 which may be of a conventional type and accordingly need not be described in detail. The cathode comprises a cylindrical wall 4 which may be molded from some refractory insulating material such as barium oxide or strontium oxide, or a mixture of these two materials by methods which are well known in the electrical tube art. Alternately the wall 4 may be a cylinder of alumina or the like having its inside surface coated with nickel. Within the interior of the cylinder 4 is embodied a heater 5 which may be of nickel or other material well known in the art and which is provided with leads 6 and 7 through which it may be supplied with heating current. Whatever may be the refractory material used in making the cylinder 4, its interior surface should be coated with some thermionically-emissive substance well known in the art, such as a mixture of barium oxide and strontium oxide.

The above-described tube may be evacuated to a high degree by processes now well standardized in the electrical tube art and may have introduced into it a body of some liquid, such as mercury or gallium, to which current may be conducted by a lead-in wire 9. The quantity of the liquid 8 is preferably so proportioned that it rises a short distance above the lower edge of the cylinder 4, although it is within the purview of my invention that the liquid level may stand below the edge of the cylinder 4.

When the above-described tube is connected in circuits well known in the electrical art which heat the surface of the cylinder 4 to a temperature at which it freely emits electrons, current may be drawn through a circuit including the anode 2 and the lead-in wire 9, and current flow therein may be controlled as is well known in the art, by varying the electrical potential of the control electrode 3, or by resistance in the anode circuit. It will be found that the heat incident upon the liquid 8 will cause vaporization of the latter and that such vaporization will be more rapid in the interior of the cylinder 4 than on the surface of the liquid outside the cylinder. There will accordingly be a continual stream of the vaporized liquid rising through the interior of cylinder 4, and this vapor will strike the walls of the tube 1 and be condensed thereon, inasmuch as they will remain cooler than the liquid surface within the cylinder 4. In consequence of the foregoing action, there will be a higher pressure of the liquid vapor in the interior of the cylinder 4 than will exist in the region of the anode 2 or control electrode 3. In accordance with my invention, the internal diameter of the cylinder 4 and the heater current flowing through the winding 5 are so proportioned as to maintain a highly ionized gas of substantial pressure within the cylinder 4, while the gaseous pressure in the vicinity of anode 2 and control-electrode 3 is materially lower. In general the pressure difference between the inside of cylinder 4 and the remainder of the tube will be increased by raising the current through heater 5 or by decreasing the diameter of the upper end of cylinder 4, and by cooling the walls of tube 1.

The arrangement illustrated in Fig. 1 may be very greatly improved by forming the thermionically-emissive cathode as illustrated in Fig. 2, in which the same reference numerals indicate similar structural elements to those in Fig. 1. The cathode in Fig. 2 consists of two refractory cups 4 and 4' which may be of the same material as the cylinder 4 in Fig. 1, and which embody electrical heaters 5 and 5' of the same type described in connection with Fig. 1 which are supplied with heating current from leads 6, 6' and 7, 7'. As a preferable, but not absolutely necessary, feature of construction, the refractory cups 4, 4' may be molded to form linings of metal cups 11, 11' which may be of nickel or other suitable material. The cylinders 4, 4' may be connected by metal bars 12, so that they form an integral unit, and the spacing between the bars 12 is made such as to provide paths for electric current to the anode which are sufficiently wide to avoid undesirable voltage drop and overheating of the bars 12 by current flow between them. The structure 4, 4' may be supported on an inleading wire 9 which may make contact to the metallic cup 11 if the latter is used; if not, the wire 9 should be in electrical contact with the thermionically-emissive surface of refractory cups 4 and 4'. The tube is evacuated in the manner pointed out in connection with Fig. 1 and is provided with a filling 8 of mercury or other suitable liquid which preferably, although not necessarily, stands with the level of its surface somewhat below the lower face of the cylinder 4.

The mode of operation of the structure just described will be clear without separate description, as it is substantially similar to that of Fig. 1. Vapor from the liquid 8 will enter the interior of the cups 4, 4' and, when the latter are heated by current flow to the windings 5, 5', will be in a highly ionized condition in the interior of the cathode chamber thus formed.

Fig. 3 shows an arrangement which is similar to Fig. 2 in many respects, but adds an arrangement comprising the duct 13 which may suitably be of nickel or other metal and is adapted to continually supply a stream of vapor from the liquid 8, which may be of mercury, to the interior of the cups 4, 4' which form the cathode chamber as in Fig. 2. The tendency of the above-described arrangement is to heat the liquid 8 at the lower opening of the duct 13, thereby vaporizing it and causing the stream of the vapor to continually flow up the duct 13 and into the cathode chamber having the thermionically-emissive walls. The diameter and length of the duct 13 may be shortened to such an extent as to increase to substantially any desired degree the rapidity of vaporization of the liquid 8 at the lower orifice of the duct and thereby to produce any desired drop in pressure between the interior of the chamber 4, 4' and the space external thereto in the neighborhood of the electrodes 2, 3. It may be found desirable to heat insulate the exterior of the duct 13 and even to provide an electric heating means to facilitate the vaporization of the liquid 8. In any of the tubes described herein, I may find it desirable to provide artificial cooling for the electrodes 2 and 3 or for the walls of the container 1 in order to insure a more rapid condensation of the vapor issuing from the apertures between the bars 12, thereby insuring a low vapor pressure in those portions of the tube which lie outside the confines of the cups 4, 4'. The external circuit connections and method of making the tube 1 are so similar to those already described in con-

nection with Figs. 1 and 2 as to require no separate description. Increase of the heater current and decrease of the free space between the bars 12 tend to increase the vapor-pressure within the cups 4, 4'.

In Fig. 4, a modified arrangement somewhat similar to that of Fig. 3 is illustrated. The cups 4, 4' are provided with heaters 5, 5' and electrical circuits therefor similar to those already described in connection with Figs. 2 and 3. However, the lower cup 4 has one or more openings through its walls and the liquid, for example, mercury, which is to be vaporized in the tube, is introduced to such a level that it makes good thermal contact with the heated cup 4 and even flows to a level above the bottom thereof inside the cathode chamber. The heat radiated and conducted to the liquid within the cup 4 will accordingly cause a rapid evolution of vapor within the cathode chamber, and there will be a considerable fall of pressure incident to the outflow of this vapor between the openings of the bars 12. The magnitude of this pressure difference may be increased to substantially any desired value by increasing the amount of heat in heaters 5, 5' and by raising the level of the liquid in the cup 4, and if necessary, by increasing the cooling facilities for the exterior of the tube 1. Except for the foregoing, the tube of Fig. 4 is so similar in structure and method of preparation to the tubes in Figs. 1, 2 and 3 as to need no detailed description.

I have described the cups 4, 4' in the foregoing as lined on the interior surface with a mixture of barium oxide and strontium oxide, but in order to insure that the activities of the ionized vapors within the cathode chamber shall not erode or otherwise damage the interior walls thereof, it may be desirable to line these walls with a sintered mixture of thermionically-emissive oxides, such as barium and strontium oxides, with metallic particles, such for example, as nickel powder or filings. For a description of how to make such a sintered mixture, see Percy Patent No. 1,981,245. Alternatively, the wires of the heaters 5, 5' may be coated with some refractory insulator, and the entire cups and cylinders 4, 4' be molded out of the above-mentioned sintered mixture.

As typical examples of operative embodiments of my invention, the tube 1 may be of glass about four inches in diameter and six inches long. The anode 2 may be of graphite in the form of a cylinder about $1\frac{1}{4}$ inches in diameter and $\frac{1}{4}$ inch long, and the control electrode 3 may be of nickel wires about $\frac{1}{16}$ inch in diameter spaced $\frac{1}{8}$ inch apart. The anode may be spaced about $2\frac{1}{2}$ inches above the upper face of the cathode and the control-electrode 3 be spaced about $\frac{1}{2}$ inch from the anode. The cylinder 4 may be about $\frac{1}{2}$ inch high, of $\frac{1}{4}$ inch in internal diameter and $\frac{5}{8}$ inch outside diameter. The heater wire 5 may be of tungsten approximately .020 inch in diameter and 6 inches long. It may be supplied with sufficient current to raise the interior surface of cylinder 4 to about 900° C.

In the arrangements of Figs. 2 to 4, the cups 4, 4' have an external diameter of about $\frac{3}{8}$ inch and an internal diameter of about $\frac{1}{2}$ inch and their bottoms are about $\frac{1}{8}$ inch thick. The space between their adjacent ends may be about $\frac{1}{8}$ inch and the total free area between the bars 12 may be approximately 35 square inch. In Fig. 3, the

duct 13 may be of nickel about $\frac{1}{4}$ inch in internal diameter and about 1 inch long from its juncture to the cup 11 to the surface of the liquid 8. In Figs. 3 and 4, the pressure inside the cathode chamber may be adjusted by regulating the level of the liquid 8, the pressure naturally becoming greater with increased closeness of thermal contact between the liquid 8 and the walls of the cup 4. As an example, the pressure within the cathode chamber may be 90 microns, while the pressure in tube 1 in the vicinity of anode 2 may be adjusted by varying the cooling of the walls of the tube to a value of about 6 microns.

The tubes having the dimensions just described would be adapted to carry an average current between the principal electrodes of about 4 amperes and to operate on a circuit of about 110 terminal volts.

While I have described one typical set of embodiments of my invention, the principles thereof are of broader application, which will be apparent to those skilled in the art. I accordingly desire that the following claims shall receive the broadest construction of which they are capable in view of their express terms and the limitations imposed by the prior art.

I claim as my invention:

1. An electrical discharge device comprising a vacuum-tight container enclosing an anode and a cathode, said cathode having the form of a chamber electron-emissive on its internal surface only and pierced by apertures which face in directions different from the direct line connecting said anode and said cathode, and a reservoir of mercury within said evacuated container and a duct connecting said mercury with the interior of said cathode chamber.
2. An electrical discharge device comprising a vacuum-tight container enclosing an anode and a cathode, said cathode having the form of a chamber electron-emissive on its internal surface only and pierced by apertures which face in directions different from the direct line connecting said anode and said cathode, a reservoir of liquid within said container and a duct connecting said liquid with the interior of said cathode chamber.
3. An electrical discharge device comprising a vacuum-tight container enclosing an anode and a cathode, said cathode having the form of a chamber with thermionically-emissive walls pierced by apertures which face in directions different from the direct line connecting said anode and said cathode, and a reservoir of liquid within said evacuated container, said liquid being in close contact with a portion of the wall of said cathode chamber and an aperture in said portion whereby said liquid may flow into said chamber.
4. An electrical discharge device comprising a vacuum-tight container enclosing an anode and a cathode, said cathode having the form of a chamber with thermionically-emissive walls pierced by apertures which face in directions different from the direct line connecting said anode and said cathode, and a reservoir of mercury within said evacuated container, said mercury being in close contact with a portion of the wall of said cathode chamber and an aperture in said portion whereby said mercury may flow into said chamber.

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