Oct. 15, 1957 D. MacNAIR 2,810,090

CATHODES FOR ELECTRON DISCHARGE DEVICES

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FIG. 1

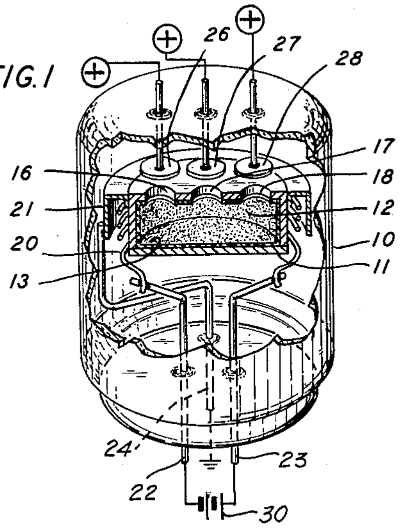

FIG. 2

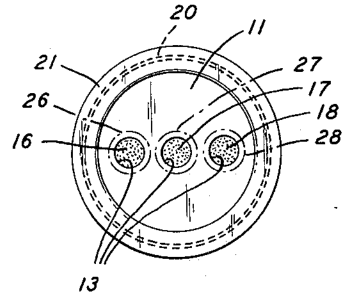

FIG. 5

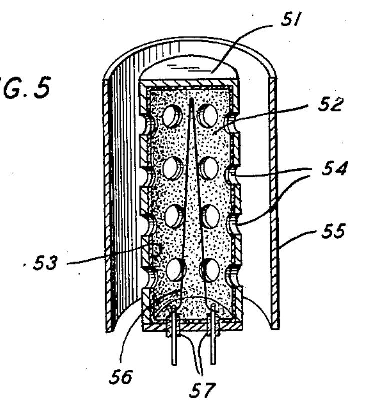

FIG. 6

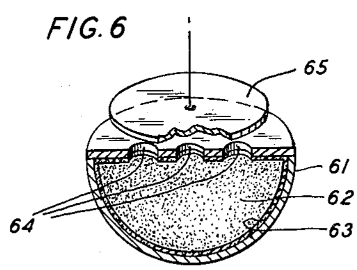

FIG. 7

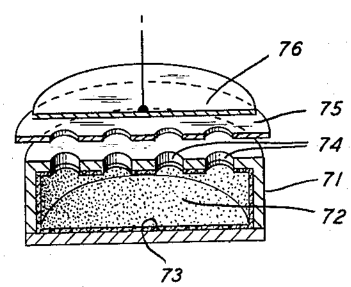

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FIG. 3

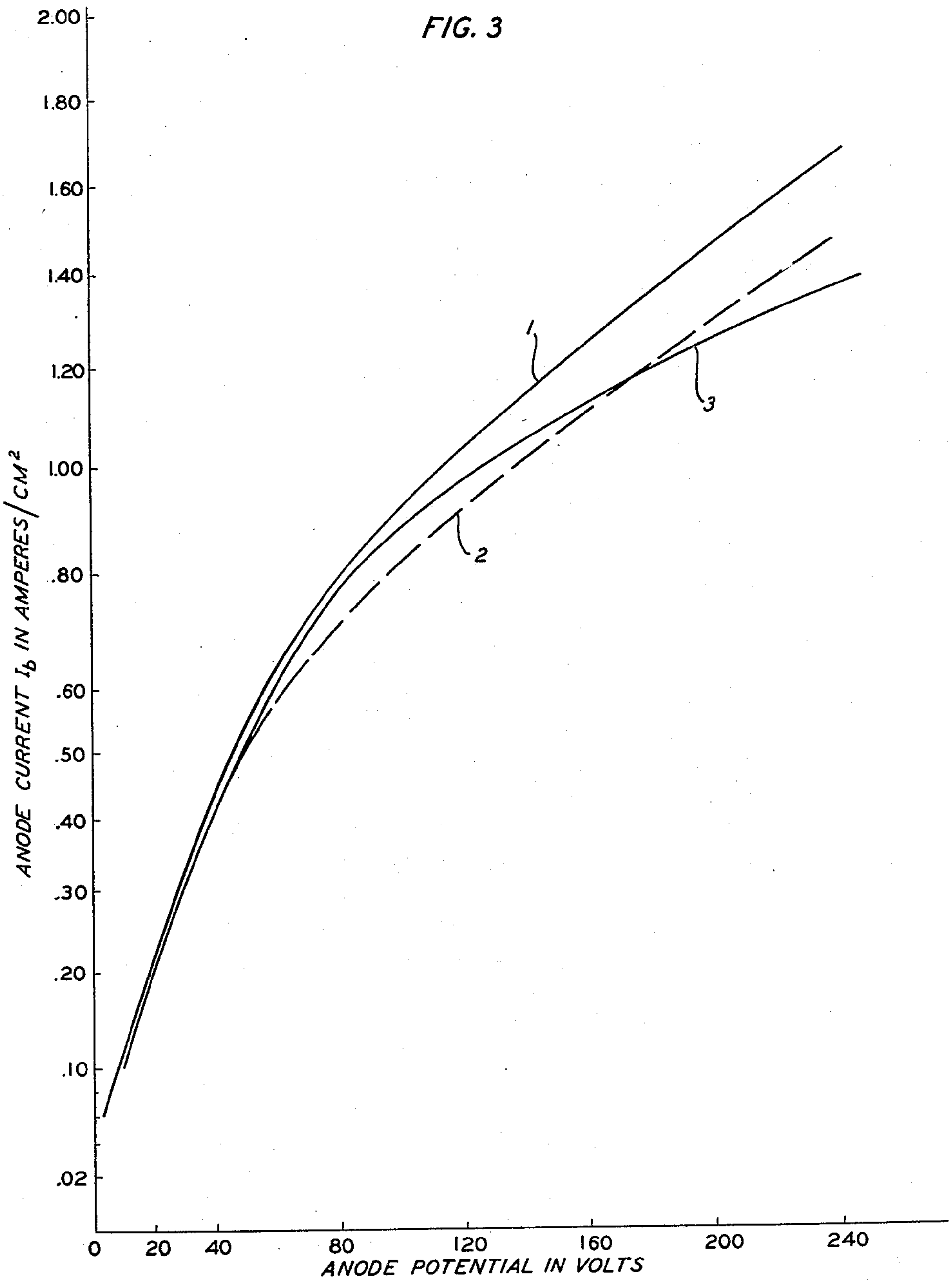

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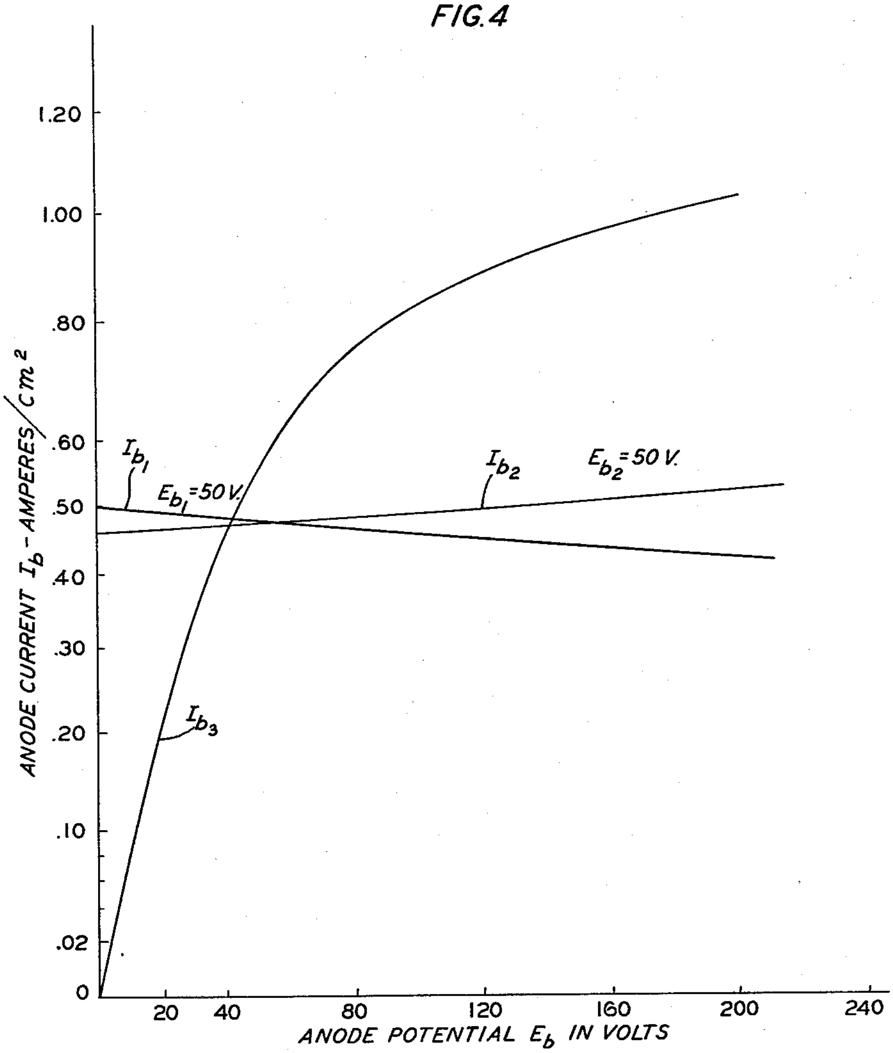
FIG. 4



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CATHODES FOR ELECTRON DISCHARGE DEVICES

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Application June 15, 1953, Serial No. 361,663

10 Claims. (Cl. 313—339)

This invention relates to electron discharge devices and more particularly to such devices including cathodes of the type disclosed in my applications Serial Nos. 361,527 and 361,263 filed June 15, 1953.

As disclosed in detail in the applications above identified, extremely high current densities and perveances are realizable with thermionic cathodes of the general construction wherein an electron emissive coating is provided upon the inner wall of a hollow body, the cavity in the body being substantially completely enclosed except for an aperture for egress of the electron emission from the coating.

One general object of this invention is to realize improved performance characteristics for hollow cathodes of the general character above noted. Another, and more specific, object of this invention is to enable attainment of unique and eminently advantageous emission and operating characteristics for such cathodes. More specifically, it is an object of this invention to obtain a plurality of individually controllable high density electron beams from a single hollow cathode.

The present invention is predicated in part upon the discovery that unique operating characteristics are attainable with devices including hollow cathodes having a plurality of apertures therein and one or more electrodes each in electron controlling or electron receiving relation with a corresponding one of the apertures.

Thus, in accordance with one broad feature of this invention, in an electron discharge device having a hollow cathode, the cathode is provided with a plurality of apertures, whereby a plurality of individual electron beams are produced, and a plurality of electrodes each in cooperative relation with a respective aperture.

In accordance with a more specific feature of this invention, a device of the general construction above described comprises a plurality of anodes each opposite or aligned with a respective aperture in the cathode and means are provided for controlling the intensity of the electron stream to any one or all of the anodes. It has been found that, despite the fact that the source of the electron streams is the same for all, the intensity of each stream can be varied over a wide range without significant alteration in any of the other streams.

In one specific embodiment, the inner surface of the cathode is defined by a hemispherical wall and a substantially plane wall extending across the base of the hemispherical wall and having a group of apertures therein.

In another specific embodiment, the cathode is in the form of a hollow cylinder, closed at its ends and the cylindrical wall is provided with a plurality of apertures, equal in number to the number of electron streams or beams desired.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is an elevational view partly in section and

partly broken away of an electron discharge device in accordance with this invention along with its plate voltage and heater current power supplies;

Fig. 2 is a plan view of the cathode and heater assembly of the device depicted in Fig. 1;

Fig. 3 is a graphical representation of the electron emission characteristics of the cathode in Fig. 2;

Fig. 4 is a graphical representation of the relationship between the emission characteristics of individual electron emitting orifices of the cathode in Fig. 2;

Fig. 5 is a longitudinal sectional view of a cylindrical hollow cathode in accordance with this invention;

Fig. 6 is a partial section view of another embodiment of this invention with portions broken away for clarity; and

Fig. 7 is a longitudinal sectional view of an electron discharge device in accordance with this invention.

Referring now to Fig. 1, an electron discharge device may be seen comprising a highly evacuated envelope **10** which contains a hollow body **11** including a cavity **12**. The internal surface of body **11** defining cavity **12** is covered with a coating **13** of electron emissive material, for example a mixture of the oxides of barium, strontium and calcium. Communicating between cavity **12** and the exterior of body **11** are a plurality of orifices or apertures **16**, **17** and **18**. A heater **20** comprises a series of turns of resistance wire about body **11** and a heater shield **21** encompasses both body **11** and heater **20**. The ends of the heater **20** are connected via lead wires **22** and **23** to a battery **30**.

A series of electrically independent anodes **26**, **27** and **28** are positioned each opposite a respective orifice **16**, **17** or **18** of body **11**. The anodes **26**, **27** and **28** are each connected to an independent plate supply voltage and the body **11** is grounded through its lead **24**. For purpose of illustration, apertures **16**, **17** and **18** are shown arranged in a single line as are anodes **26**, **27** and **28**. The arrangement of the apertures along with its respective anode may be varied without departing from the scope of this invention. Each anode **26**, **27** and **28** is in position to receive the high intensity electron stream emerging from its respective aperture and passing through the intervening space to the anode, without affecting either the other electron streams or anodes.

In Fig. 2, which is a plan view of the cathode of Fig. 1, the front face of body **11** including aligned orifices **16**, **17** and **18** is shown. Portions of coating **13** may be seen through each of the apertures and the positions of anodes **26**, **27** and **28** are shown by dotted lines encompassing the apertures. As was described in my applications cited heretofore, high intensity continuous electron beams in the order of 1 to 5 amperes per square centimeter are produced from hollow cathodes upon which the electron emissive coating is located on the surface bounding an internal cavity as opposed to a maximum continuous emission of approximately 500 milliamperes for a conventional oxide coated cathode. Cathodes of this invention obtain such high emission, for example, in a hollow cylinder as shown in Fig. 2 including three orifices 0.020 inch in diameter producing an electron beam from each orifice of one ampere per square centimeter of orifice size with each anode at a potential of approximately 120 volts. The total emission from this cathode is, therefore, three amperes per square centimeter, which is an increase of sixfold over emission of conventional oxide coated cathodes. Emission from each individual orifice is greater by a factor of two than emission of conventional oxide coated cathodes.

Fig. 3 represents graphically the electron emission of the three apertures of the device of Fig. 1 when the same variable potential is applied to the anodes **26**, **27** and **28**. The emission characteristic curves are nearly superimposed. Any differences noted are attributed to such factors as variations in orifice size, individual anode potential, and limitations upon the accuracy of measurement of anode current.

Over and above the high beam intensity obtained from this form of hollow cathode, the beam intensity from each orifice is substantially independent of potential or changes in potential of the anodes associated with each of the other orifices. This characteristic is clearly shown in Fig. 4 wherein a constant potential of 50 volts was maintained upon the anodes **26** and **27** while the potential of anode **28** was varied over the range from zero to 200 volts. Emission from orifice **18**, designated as I_{b3}, varied over this range by a factor of fifteen showing an emission characteristic illustrated above in Fig. 3. The emission of orifices **16** and **17**, I_{b1} and I_{b2}, respectively, subject to the constant potential of their respective anodes remained substantially constant at a value in the order of 0.5 ampere per square centimeter. For all intents and purposes, the emission from orifices **16** and **17** is completely independent of emission from orifice **18** and the field established by anode **28**.

Thus, in accordance with this feature of the invention, a single hollow cathode may be utilized to produce a plurality of high intensity electron beams each of which is independently controllable, and the effect upon a single beam of control of adjacent electron beams is negligible upon its emission. This structure finds application as a replacement for a plurality of individual cathodes in multiple electron beam devices resulting in a notable simplification in design and a reduction in heater power required as well as enhanced cathode emission.

Another embodiment of this invention is shown in Fig. 5 comprising a hollow cylindrical tube or body **51**, the ends of which are closed. The internal surface of body **51** defines a cavity **52** and that surface is covered with a coating **53** of electron emissive material. Along the cylindrical walls of body **51** are a series of apertures **54**. A tubular anode **55** encompasses body **51** in position to receive electrons emitted from the tube **51** through apertures **54**. A hairpin type heater **56** extends through the interior of tube **51** and is insulated therefrom by bushings **57**. The cathode of this embodiment includes a large electron emissive surface bounding a cavity within the hollow body. A plurality of apertures allows egress of electrons emitted from the coating **52**. The coating itself is substantially completely shielded from positive ion bombardment from the anode. This embodiment obtains the high intensity electron emission of the hollow cathode in a form particularly adapted for use in cylindrical or flattened tubular electrode structures and, particularly, beam power vacuum tubes.

Referring now to Fig. 6, another embodiment of this invention may be seen comprising a hemispherical body **61** defining cavity **62** bounded by an internal surface of body **61** which is covered with a coating **63** of electron emissive material. Body **61** includes a planar wall in which the plurality of apertures or orifices **64** are positioned. An anode **65** is mounted in spaced relationship from the planar wall of body **61** in position to receive electron emission through orifices **64**. In this particular embodiment the major portion of emissive coating is positioned upon a hemispherical surface bounding the cavity within body **61**. The planar anode may be positioned at a substantially uniform distance from the orifices in the hollow body **61** despite the spherical configuration of the majority of the coating **63** of electron emissive material.

In Fig. 7 a hollow cathode may be seen including a plurality of electron emitting orifices or apertures from which an anode receives electron emission and a modulating electrode interposed between the orifice and the anode. In that embodiment, body **71** defines cavity **72** bounded by an internal surface of body **71** upon which a coating **73** of electron emissive material is positioned. A series of apertures **74** extend across one face of the body **71**. Opposite the aperture **74** an anode **76** is mounted and interposed between the orifices **74** and anode **76** is a modulating electrode **75** which, for example, may comprise a mesh grid or, as shown, a plate perforated to match orifices **74**. The modulating electrode is so positioned that openings therein correspond to orifices **74** and the electron beam emitted from orifices **74** is, therefore, not dissipated to any appreciable extent by striking the modulating electrode **75**.

As is taught in my application Serial No. 361,527 mentioned heretofore, the configuration of an electron beam emitted from a hollow cathode can be controlled and, in particular, the size of the beam is substantially that of the emitting orifice. Under such conditions the openings in modulating electrode **75** may correspond in size to the size of orifices **74** to control the electron beam. Since a single anode and single modulating electrode are shown in connection with this embodiment, the anode current depends upon the total emission obtained from all of the apertures **74** and the effect of modulating electrode **75**. To obtain a plurality of independently controllable electron beams, an individual anode and modulating electrode for each orifice may be substituted for the electrodes **76** and **75** respectively.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising a highly evacuated envelope, a conducting body within said envelope having a cavity therein, a coating of electron emissive material upon the interior surface of said body bounding said cavity, said body being closed except for a plurality of distinct electron emission apertures communicating between the cavity and the exterior of said body, means for heating said body, and individual electron accelerating means within said envelope each positioned adjacent a respective aperture.

2. A multiple electron beam discharge device comprising a highly evacuated envelope, a conducting body within said envelope, said body including an internal surface defining a cavity therein and being closed except for a plurality of distinct electron emission apertures communicating between the cavity and the exterior of said body, a coating of electron emissive material upon the internal surface of said body, means for heating said body, a plurality of electron accelerating electrodes positioned adjacent said body each aligned with a respective one of said apertures, and means for electrically biasing each of said electron accelerating electrodes independent of the other of said electron accelerating electrodes.

3. An electron discharge device comprising a highly evacuated envelope, a body having a cavity therein mounted within said envelope, a coating of electron emissive material on the bounding surface of said cavity, said body being closed except for a plurality of apertures communicating between said cavity and the exterior of said body, individual means for independently controlling the electron beam intensity from each of said apertures and a heater for said body.

4. An electron discharge device comprising a highly evacuated envelope, a cathode within said envelope comprising a body including a planar wall and having a hemispherical cavity therein adjacent said planar wall, a coating of electron emissive material upon the bounding walls of said cavity, said body being closed except for a plurality of electron egress apertures in said planar wall communicating between the cavity and the exterior of said body, electron accelerating means in spaced juxtaposition with said plurality of apertures, and a heater for said cathode.

5. A high vacuum electron discharge device comprising

an envelope, a cathode within said envelope comprising a hollow tube which is closed except for a plurality of electron egress apertures, a coating of electron emissive material upon the inside of said tube, electron accelerating means in spaced juxtaposition with the plurality of apertures in said cathode, and means for heating said hollow tube.

6. An electron discharge device comprising a highly evacuated envelope, a hollow cathode cylinder, a coating of electron emissive material upon the internal surface of said cylinder, said cylinder being closed except for a plurality of apertures in the curved side wall communicating between the interior and exterior of said cylinder, an anode encompassing said cathode cylinder, and a heater for said cathode cylinder.

7. An electrode assembly for an electron discharge device comprising a conducting body including a cavity therein, a coating of electron emissive material upon the bounding wall of said cavity, said conducting body being closed except for a plurality of distinct electron egress apertures communicating between the cavity and the exterior of said body, a heater for said body, an electron accelerating means spaced from said body, and a modulating electrode positioned between said body and said electron accelerating means, said electron accelerating means and said modulating electrode being aligned with the apertures in said body.

8. An electrode assembly in accordance with claim 7 wherein said modulating electrode comprises a plate including apertures corresponding in position to the apertures in said body.

9. An electrode assembly in accordance with claim 8 wherein the apertures in said plate are substantially the same size as the apertures in said body.

10. An electron discharge device comprising a highly evacuated envelope, a conducting body including a cavity therein mounted within said envelope, a coating of electron emissive material upon the internal surface of said body bounding said cavity, said body including a wall defining a plurality of electron emission apertures communicating between the cavity and exterior of said body, said body being closed except for the electron emission apertures in said wall, a heater for said body, and electron accelerating means adjacent the wall of said body and in juxtaposition with said apertures.

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