Nov. 19, 1957 G. H. ROBERTSON 2,813,990

ELECTRON BEAM DISCHARGE DEVICE

Filed Dec. 30, 1953

FIG. 1

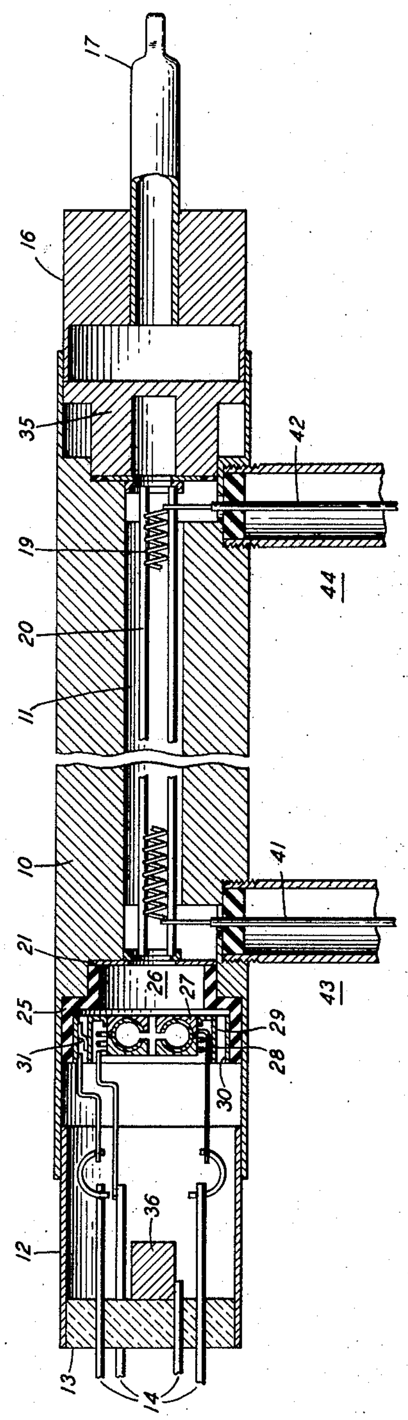
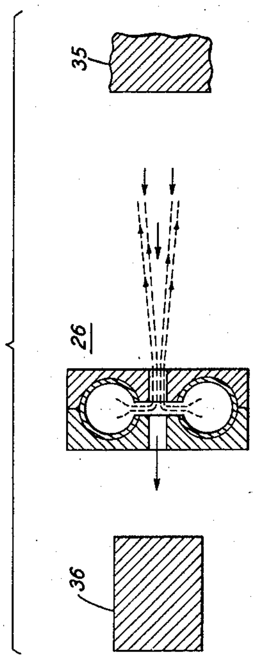


FIG. 3



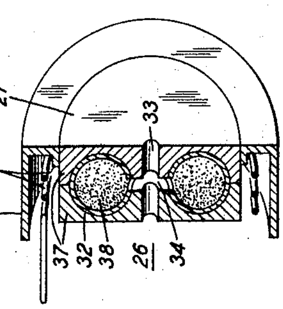


FIG. 2

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ELECTRON BEAM DISCHARGE DEVICE

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8 Claims. (Cl. 313—85)

This invention relates to high intensity electron beam discharge devices and more particularly to hollow electron sources therefor of the type disclosed in the applications Serial Nos. 361,527, 361,623 and 361,663, filed June 15, 1953, of D. MacNair.

In electron tubes which depend for operation upon a small concentrated beam or pencil of electrons, the provision of an electron source which is capable of supplying copious emission over a long period of time is of prime importance. Commonly used sources of electrons are equipotential cathodes which include a planar surface coated with a mixture of the oxides of barium, calcium and strontium. Of course, the larger the emissively coated area is in size, the greater is the number of electrons available. In vacuum tubes such as cathode ray or traveling wave tubes where it is highly desirable that the electron source form a concentrated beam, either comparatively small emissive surfaces have been employed despite the limitation on quantity of electrons available, or elaborate focusing systems were used without complete success. The need for providing an improved electron source is indicated by an estimate that 80 percent of the failures of cathode ray tubes are due to poor emission. One cause of poor emission of the cathode is the gradual evaporation of the electron producing material, for example, free barium from the limited area of emissive coating. Another cause of failure of the electron source, which has been noted particularly in traveling wave tubes, is bombardment of the emissive surface by charged particles, particularly positive ions. Instances have been noted where the back bombardment was so great that the cathode was actually punctured and the heater wire burned through, ending the life of the device.

With these difficulties in mind, it is a general object of this invention to improve electron sources for electron beam vacuum tubes.

More specific objects of this invention are to enhance the quantity of electron emission of cathodes while insuring long life of the electron source; to minimize the evaporation of electron emissive material from cathodes; and to eliminate detrimental bombardment of the electron source.

These objects are attained in accordance with this invention, one specific illustrative embodiment of which comprises a traveling wave tube including a highly evacuated envelope containing an electron source, a helical electrode and a collector electrode. Electromagnetic wave input and output transmission lines are coupled to the terminations of the helical electrode. The electron source comprises a metallic body including a cavity which is coated with electron emissive material. The cavity is in the form of a torus joining an annular passage which communicates between the cavity and an electron exit aperture.

An additional electrode is positioned opposite the aperture in the metallic body so as to capture positive ions or particles in the region of the emitted beam of electrons.

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A feature of this invention involves the configuration of the electron source whereby a large reservoir of electron producing material enclosed within the metallic body provides a concentrated beam of electrons from a restricted opening in the body.

In accordance with another feature of this invention no portion of the electron emitting surface is exposed to bombardment by positive ions.

Another feature of this invention relates to the inclusion of an aperture in the cathode in the path of positive ion bombardment.

Still another feature of this invention relates to the presence of a positive ion collecting electrode opposite the aperture in the electron source.

A more complete understanding of this invention may be had from the following detailed description and by reference to the accompanying drawings in which:

Fig. 1 is an axial sectional view of a traveling wave tube embodying this invention;

Fig. 2 is a magnified view of the electron source of the traveling wave tube of Fig. 1; and

Fig. 3 is a schematic representation of the electron and positive ion paths within the device of Fig. 1.

Referring now to Fig. 1, one specific illustrative embodiment, a traveling wave tube, may be seen. It comprises a highly evacuated metallic housing **10** including a central bore **11** therein, a cathode base member **12** mounting a vitreous disc **13** including terminal pins **14** extending sealed therethrough, and a collector base member **16** including an exhaust tubulation **17**. Within the bore **11** is a helix **19** mounted from a series of insulating rods **20**, for example, three, which are disposed in a circular arrangement and extend between an accelerating grid **21** and an electron collector **35**. The ends of the helix **19** are electrically connected to the center conductors **41** and **42** of coaxial input and output transmission lines **43** and **44**. Mounted from a stepped vitreous ring **25** adjacent grid **21** is an electron source or cathode generally designated **26**. It comprises a metallic body **27**, for example, of nickel, encompassed by a heater wire **28**, a heater shell **29** and a heat shield **30**. The heat shield **30** fits snugly within the stepped ring **25**, and the heater shell **29** and metallic body **27** are suspended from the shield **30** by a series of fingers **31**, one of which is shown. The cathode **26** is electrically connected to one of the terminal pins **14** by a nickel lead as are the ends of the heater wire **28**. Aligned with cathode **26** at the opposite end of helix **19** is the electron collector **35** in position to receive electrons emitted from cathode **26** after they have pased through the helix **19**. On the opposite side of the cathode **26** from the helix **19** and the electron collector **35** is a positive ion collector **36** in the form of a solid block of nickel.

The details of cathode **26** may be seen more clearly in Fig. 2. The metallic body **27** comprises a pair of recessed cylinders **37** secured together as by welding. The recesses form a toroidal cavity **32** within the body **27**. A sprayed or compressed coating **38** of electron emissive material, a mixture of the oxides of barium, calcium and strontium, covers the recessed surfaces of the cylinders **37** forming the cavity **32**. As an exit for electrons emitted from the enclosed cavity **32**, the body **27** includes a central aperture **33**, which is coaxial with the toroidal cavity **32**, and an annular passage **34** communicating between the cavity **32** and the aperture **33**. The coating **38** constitutes an electron reservoir of substantial area compared with the ultimate emitting orifice, aperture **33** or to the annular passage **34** both of which tend to concentrate the electron flow.

Electron emission is achieved when the coating is heated by the heater wire **28** and electrons pass through the passage 34 and are drawn from aperture 33 by an accelerating field, in this embodiment supplied by accelerating grid 21.

In Fig. 3 the relative position of the electrodes of the device of Fig. 1 are shown along with a representation of the paths of electrons from the cathode 26 and of positive ions originating in the electron stream. The electron stream is indicated by dotted lines emerging from the toroidal cavity 32, passage 34 and aperture 33 to be drawn to the electron collector 35. The electron stream is shown as diverging but this characteristic may be modified by auxiliary electrodes if desired or by the cathode itself where the diameter and the length of aperture 33 are correlated, as taught in the application Serial No. 361,527 mentioned heretofore. Positive ions shown in Fig. 3 as solid lines travel toward the cathode 26 being concentrated largely within the bounds of the electron beam. Owing to the configuration of cathode 26, substantially all of the positive ions within the electron beam pass completely through the aperture 33 and may advantageously be collected by the ion collector 36. Any positive ions drawn to the cathode outside of the confines of the electron beam will strike its uncoated exterior surface and can do no damage to the emissive coating. Electrons easily traverse the path from the cavity 32 through the passage 34 and out of aperture 33. Positive ions on the other hand having a mass many times greater than that of the electrons deviate slightly, if at all, from a straight-line path from their point of origin in the electron stream to the cathode, their motion terminating at either the ion collector or the cathode surface. In operation the ion collector 36 and cathode 26 may be electrically connected together to operate at the same potential or, advantageously, the ion collector may be biased negative with respect to the cathode.

The electron source in accordance with this invention is disclosed as a part of a traveling wave tube to indicate the relative positions of the cathode and ion collector. Its application, of course, is not limited to traveling wave tubes or devices employing an ion collector, but it may be readily applied to cathode ray tubes or electron beam type tubes generally.

As was explained in the related applications identified above, the hollow cathodes as disclosed therein produce high intensity electron beams at low accelerating electrode potential. In accordance with this invention not only is a high current density obtained, but longer life of the electron source results. The mechanisms by which copious electron emission for a long period of time is obtained from the electron source of this invention are not fully understood but by way of explanation it is suggested that, first, an extremely large emissive area is present within the body 26 supplying electrons through a comparatively small opening readily heated to emissive temperature by the heater wire 28 and the toroidal disposition of the emissive surface minimizes the retarding effect of electron space charge upon cathode emission.

According to conventional emission theory the confined arrangement of the electron emitting material in cathodes of this invention would give rise to a high space charge within the cavity 32 severely limiting the electron current available. Such is not the case. It is believed that in the circular cross-sectional cavity the point of highest space charge would be the geometrical center but owing to the discontinuity in the cavity wall due to the presence of passage 34, the normal space charge distribution is disturbed resulting in a space charge minimum in the region of the passage 34. Electrons emerging from the coating 38 with sufficient thermal energy can reach the space charge minimum adjacent passage 34 and travel therethrough to come under the effect of the accelerating field.

Secondly, loss of portions of the emissive coating, particularly free barium, due to evaporation or migration is greatly restricted owing to the confined nature of the emissive surface. Furthermore, emissive coating migrating to the passage 34 and to aperture 33 would still be available for supplying electrons, and the rate of deposition on other electrodes is greatly reduced.

Thirdly, damage to the cathode and emissive coating due to positive ion bombardment is virtually eliminated.

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. A high intensity electron beam source for an electron discharge device comprising a metallic body including an electron exit aperture extending therethrough, said body having a toroidal electron reservoir therein bounded by a substantially unipotential surface and disposed about said electron exit aperture and communicating therewith, and heater means for raising said reservoir to electron emission temperature.

2. A high intensity electron beam source for an electron discharge device comprising a metallic body including a central aperture extending therethrough, said body including an interior surface defining a toroidal cavity encircling said central aperture and communicating therewith through a restricted passage, an electron reservoir coating on said surface, and heater means for raising said coating to electron emissive temperature.

3. A high intensity electron beam source for an electron discharge device comprising a metallic body including an interior surface defining a toroidal cavity, a coating of electron emissive material upon substantially all of said surface, said body including a central aperture extending therethrough along the axis of the toroidal cavity and a passage communicating between the emissively coated interior surface and the central aperture, and a heater for said body.

4. A high intensity electron beam source for an electron discharge device comprising a metallic body including an aperture therethrough and an interior surface defining a toroidal cavity encompassing said aperture and communicating therewith by means of an annular passages, a coating of electron emissive material upon portions of said interior surface, and a heater for said body.

5. A high intensity electron beam source for an electron discharge device comprising a metallic body including a planar face and an electron exit aperture extending through said body in the direction substantially perpendicular to said planar face, an electron reservoir toroidally disposed about the electron exit aperture and communicating with said aperture through a restricted annular passageway in said body, and a heater for said body.

6. A high intensity electron beam source in accordance with claim 5 wherein said electron reservoir comprises a coating of electron emissive material upon a toroidal internal surface of the metallic body coaxial with the electron exit aperture therein.

7. An electron discharge device comprising a highly evacuated envelope, an electron source comprising a metallic body including an electron exit aperture extending therethrough, an electron reservoir within said body and disposed about said electron exit aperture and communicating therewith, heater means for raising said reservoir to electron emission temperature, an electron accelerating electrode spaced from said electron source and in alignment with the electron exit aperture therein, and a positive ion collector electrode spaced from said electron source on the opposite side from said electron accelerating electrode and in alignment with the electron exit aperture in said electron source, said electron reservoir being enclosed within said metallic body and shielded thereby from said electron accelerating electrode and said positive ion collector electrode.

8. An electron discharge device electrode assembly comprising a metallic body including an electron exit aperture extending therethrough, an electron reservoir

within said body and disposed about said electron exit aperture and communicating therewith, heater means for raising said reservoir to electron emission temperature, a positive ion collector electrode, and means mounting said metallic body, and means mounting said positive ion collector electrode in alignment with the aperture in said metallic body.

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