Jan. 19, 1943. A. E. ANDERSON 2,308,800

ELECTRON DISCHARGE DEVICE

Filed Feb. 15, 1941

FIG. 1

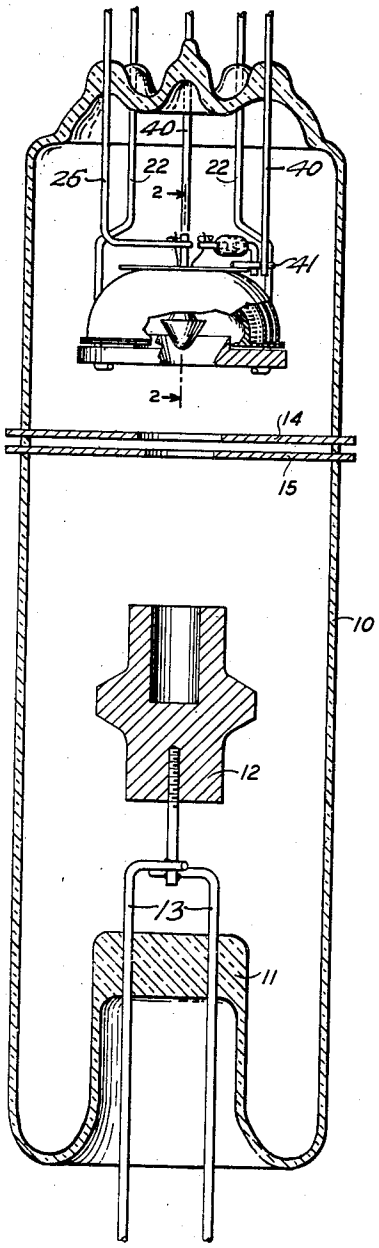


FIG. 2

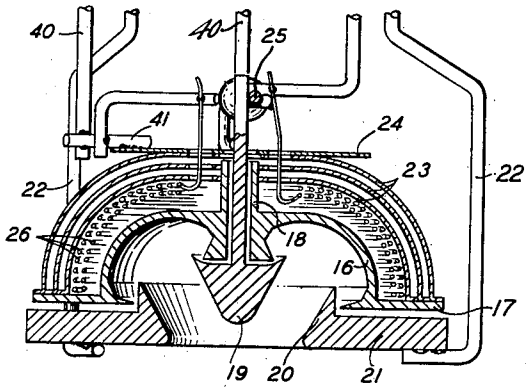
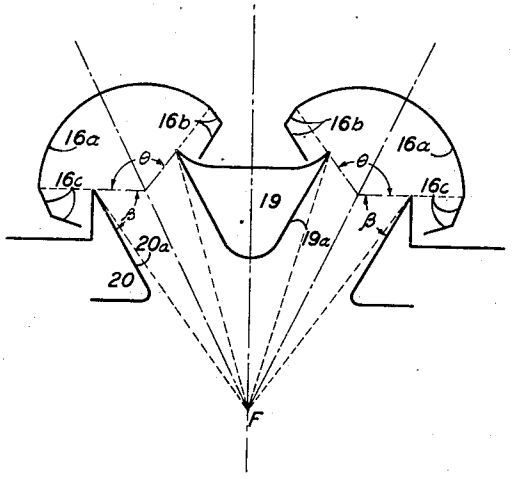


FIG. 3



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ELECTRON DISCHARGE DEVICE

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9 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices and more particularly to electrode systems, commonly designated as electron guns, for producing a beam of electrons in such devices.

In general, electron beam discharge devices comprise an electron gun for producing an electron beam, an electron receiving electrode, such as a target or anode, upon which the beam is directed, and one or more auxiliary electrodes between the electron gun and the electron receiving electrode for affecting or controlling the direction, intensity or velocity of the beam or withdrawing energy therefrom. The electron gun usually comprises a cathode and two or more electrodes in cooperative relation therewith for concentrating the electrons emanating therefrom into a beam, one of the electrodes being maintained at a positive potential with respect to the cathode and commonly referred to as the accelerating anode.

Two of the factors of considerable import in determining the operating characteristics of such devices and affecting the merit thereof are the magnitude of the current which can be obtained in the beam from a cathode of a particular rating and the degree to and uniformity with which the electrons in the beam can be affected or controlled at any particular region in the path traversed by the beam. In known devices, usually the attainment of a beam current fairly large in comparison to the total emission obtainable from the cathode necessitates the use of relatively high potentials upon the accelerating anode. Consequently, such devices have a relatively low perveance, the perveance being expressed by the relation

$$\left(\frac{I}{V^{3/2}}\right)$$

I being the total beam current and V the voltage of the accelerating anode.

It has been found also that in electron beam devices wherein the electrodes are constructed and arranged to constitute an axially symmetrical system, the fields extant in the major portion of the path traversed by the beam are of considerably less intensity along and in the vicinity of the axis of the system than at points removed from the axis. Hence, those electrons in the beam which traverse paths on and in the immediate vicinity of the axis are affected less by potentials on the auxiliary electrodes, or conversely have less effect upon the auxiliary electrodes, than those which traverse paths somewhat removed from the axis, whereby both the efficiency and the frequency range of operation of the device are limited and non-uniform interchange of energy between the beam and these electrodes results.

One general object of this invention is to improve the operating characteristics of electron beam discharge devices.

More specifically objects of this invention are to:

Attain a high perveance in electron beam discharge devices;

Extend the frequency range of operation of electron beam discharge devices;

Facilitate the focussing of concentrated electron beams;

Obtain substantially uniform fields in all paths traversed by the electrons in an electron beam;

Enable substantially uniform control of and energy transfer with all electrons in an electron beam;

Increase the efficiency of electron beam discharge devices; and

Improve the construction of electron guns.

In one illustrative embodiment of this invention, an electron gun comprises a cathode having a relatively large area emissive surface and a plurality of electrode members in cooperative relation with the cathode emissive surface for concentrating the electrons emanating therefrom into a beam of annular cross-section throughout the major portion of its length.

In a specific construction, the emissive surface conforms to an annular section of a toroid and the concentrating system includes inner and outer electrode members extending from the boundaries of the emissive surface and a pair of coaxial electrodes having juxtaposed portions defining an annular passageway converging away from the emissive surface and coaxial therewith.

The invention and the various 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 of an electron discharge device including an electron gun illustrative of one embodiment of this invention, a portion of the electron gun being broken away to show details thereof;

Fig. 2 is an enlarged view in section, along plane 2—2 of Fig. 1 of the electron gun; and

Fig. 3 is an enlarged outline view showing the configuration and relation of surfaces of the electrodes in the electron gun illustrated in Fig. 2.

Referring now to the drawing the electron dis-

charge device shown in Fig. 1 comprises an elongated evacuated enclosing vessel 10, for example of vitreous material, having at one end thereof an inwardly extending stem 11 from which an anode 12, of metal or carbon, is supported by rigid leading-in conductors 13. The anode 12 is generally cup-shaped as shown to minimize secondary electron emissive effects. An electron gun, described in detail hereinafter, is mounted adjacent the other end of the enclosing vessel 10, in coaxial relation with the anode 12 and supported by leading-in conductors sealed in the end wall of the enclosing vessel 10.

Mounted between the electron gun and the anode 12 are a pair of centrally apertured electrodes 14 and 15, coaxial with the electron gun. These electrodes, although shown as discs, may be of various forms and utilized for various purposes. Several forms which they may take and various functions thereof are disclosed in Patent 2,281,717, granted May 5, 1942 to Arthur L. Samuel. Although but a single pair of electrodes has been shown in Fig. 1, it will be understood that several pairs or an odd number of electrodes may be provided depending upon the intended operation and function of the device.

The electron gun, as shown clearly in Fig. 2, is of axially symmetrical construction and comprises a dished metallic member 16, a portion of the inner surface of which is electron emissive, having an annular peripheral flange 17 and a central hub portion 18, an inner accelerating electrode 19 and an outer accelerating anode 20 having an annular portion 21 overlying and parallel to the flange 17, the electrodes 19 and 20 being insulated from the member 16 by the gaps therebetween. The electrode 19 is supported by a leading-in conductor 25 secured to an elongated stem on the electrode 19 extending through the hub 18. The accelerating anode 20 is supported by rigid conductors 22 affixed to the annular portion 21 and sealed in the end wall of the vessel 10 as shown in Fig. 1.

A plurality of substantially hemispherical metallic members 23 are mounted in spaced relation on the flange 17, the outermost member 23 being secured, as by welding, to a metallic disc 24 which is supported from leading-in conductors 40 by rigid tie wires or connectors 41. The innermost member 23 defines a chamber with the dished metallic member 16 in which an insulated heater filament 26 is positioned, the ends of the heater filament 26 being connected to leading-in conductors sealed in the end wall of the enclosing vessel 10 as shown. The metallic members 23 and disc 24, it will be apparent, serve as shields to reduce the radiation of heat from the heater filament, so that efficient heating of the emissive surface of the member 16 is realized.

In a particular construction especially advantageous for use in devices wherein a magnetic field is employed to focus or otherwise affect the electron beam, the accelerating anode 20 and the heat shields 23 are made of magnetic material whereby the member 16 is effectively shielded from the magnetic field.

The configurations and relation of the electrodes of the electron gun are of particular character so that a conical converging electron beam annular in section and focussed at a point on the axis of alignment of the several electrodes of the device is produced. In general, the configurations and relations are determined in accordance with the principles and method described in Patent 2,268,197, granted December 30, 1941 to John R. Pierce, so that substantially all of the electrons emanating from the emissive portion of the member 16 traverse rectilinear paths in flowing to the focal point of the beam. The specific configurations and relation will be seen most clearly from Fig. 3. As shown in this figure, the dished surface of the member 16, which is generally toroidal and symmetrical about the axis of alignment of the electron gun and the anode 12, includes an arcuate portion 16*a*, which is coated with a material having good thermionic emission characteristics, and inner and outer non-emissive flanged portions 16*b* and 16*c* respectively, generally L-shaped in section. The angle θ of the arcuate portion is substantially 126.5 degrees. The electrodes 19 and 20 have juxtaposed frusto-conical surfaces 19*a* and 20*a* respectively of equal angles defining an annular passageway converging away from the emissive surface 16*a*. The angle β of the surfaces 19*a* and 20*a* is substantially 60 degrees. The surfaces 19*a* and 20*a*, it will be noted project into the gap between the juxtaposed ends of the beam forming elements 16*b* and 16*c*.

During operation of the device, the electrodes 19 and 20 are maintained at positive potentials with respect to the member 16. They may be biased at the same potential or the potential of the electrode 19 may be greater or less, for example of the order of 20 per cent, than that of the electrode 20 to control to some extent the focal point of the beam.

The portions 16*b* and 16*c*, which are at the same potential as the emissive surface 16*a*, function as beam forming electrodes and in cooperation with the accelerating anodes 19 and 20 concentrate substantially all of the electrons emanating from the emissive surface 16*a* into a hollow conical beam having a focal point F on the axis of the system and in which all of the electrons traverse substantially rectilinear paths. The boundaries of the beam are indicated by the dotted lines in Fig. 3.

There is thus obtained an efficient electron gun inasmuch as the total beam current is commensurate with the total emission from the surface 16*a*, and also a concentrated sharply focussed beam. Furthermore, it will be appreciated that substantially uniform fields are realized within the beam boundaries, whereby uniform control of all the electrons in the beam and uniform transfer of energy therebetween and electrodes, such as the electrodes 14 and 15, is enabled. In addition, efficient operation at frequencies of the order of 3,000 to 30,000 megacycles is possible. Moreover, it has been established that a high beam current can be obtained with relatively low potentials, for example 200 volts, on the accelerating anode 20 so that a perveance of as high as 30×10^{-6} is realized.

Although in the specific embodiment shown and described the beam forming electrode members 16*b* and 16*c* are structurally integral with the emissive portion 16*a* they may be physically separate therefrom, for example spaced from the edges of the emissive portion 16*a* of the order of 10 mils, and electrically connected to the emissive portion. Such construction is especially advantageous if creepage of the emissive coating to the beam-forming portions is found to be sufficient to render the portions 16*b* and 16*c* emissive and thereby reduce the sharpness of the focussing of the electron beam. Also, although in the specific construction shown and described, the beam-forming portions 16*b* and 16*c* have gen-

eratrices composed of straight lines, they may have curved generatrices conforming substantially to those shown. Furthermore, it will be understood that various other modifications may be made in the specific construction shown and described without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron gun comprising a cathode having an annular electron emissive surface, and means for concentrating electrons emanating from said surface into a hollow conical beam, said means comprising a pair of electrode members extending inwardly from the inner and outer boundaries of said emissive surface and forming an annular gap symmetrical with respect to and inclined toward the longitudinal axis of said cathode and a pair of spaced electrodes opposite said surface and defining an annular passageway coaxial therewith.

2. An electron gun comprising a cathode having a circular electron emissive surface arcuate in section, a pair of electrode members extending from the inner and outer boundaries of said emissive surface inclined toward one another and defining an annular gap, and a pair of electrodes opposite said surface and having juxtaposed surfaces defining an annular passageway coaxial with said gap and converging away therefrom.

3. An electron gun comprising a cathode having a dished annular electron emissive surface, a pair of electrode members extending inwardly from the boundaries of said emissive surface and defining an annular gap, and a pair of electrodes coaxial with said emissive surface, said electrodes having juxtaposed conical surfaces extending into said gap and defining an annular passageway coaxial with said emissive surface and converging away therefrom.

4. An electron gun comprising an electrode having a dished annular surface the inner and outer edge portions of which are non-emissive and the intermediate portion of which is coated with an electron emissive material, and means including said edge portions for concentrating electrons emanating from said emissive surface into a hollow electron beam, said means including also a pair of spaced electrodes opposite said annular surface and forming an annular passageway coaxial therewith.

5. An electron gun comprising a cathode having a dished annular surface the intermediate portion of which is arcuate in section and electron emissive and the inner and outer portions of which are non-emissive and inclined toward each other, an annular electrode opposite said outer portion and having a frusto-conical inner surface, and a second electrode opposite said inner portion and having an outer frusto-conical surface opposite said first frusto-conical surface and defining therewith an annular passageway converging away from said annular surface.

6. An electron gun comprising a cathode having a dished annular electron emissive surface inclined toward and symmetrical with respect to the longitudinal axis of said cathode, and a pair of electrodes opposite said surface and coaxial therewith, one of said electrodes being annular and having a frusto-conical inner wall, and the other of said electrodes having a frusto-conical portion opposite said frusto-conical wall and defining therewith an annular passageway converging away from said emissive surface.

7. An electron gun comprising a cathode having an annular surface conforming to an oblique section of a toroidal surface, a portion of said annular surface being electron emissive, an electrode opposite said annular surface, coaxial therewith and adjacent the inner edge thereof, and a second electrode having an outer portion adjacent the outer edge of said annular surface and having also an annular inner portion encompassing said first electrode and defining therewith an annular passageway coaxial with said annular surface.

8. An electron gun comprising a cathode having an annular substantially toroidal surface, an electron emissive coating on the central portion of said surface, an electrode within the boundary of said surface, adjacent the inner edge thereof and having an outer surface tapering away therefrom, and a second electrode having an outer portion adjacent the outer edge of said first surface and an inner frusto-conical wall opposite and of substantially the same form as said tapering outer surface and defining therewith an annular passageway coaxial with said first surface and converging away therefrom.

9. An electron gun comprising a cathode having a dished annular surface the edge portions of which extend toward one another, an electron emissive coating on the central portion of said surface, and a pair of electrodes in juxtaposition to said surface to concentrate the electrons emanating therefrom into a hollow conical beam converging away from said surface, one of said electrodes including an outer portion overlying the outer edge of said surface and an inner frusto-conical wall extending within the boundaries of said surface and coaxial therewith, the larger end of said wall being toward said surface, and the other of said electrodes overlying the inner edge of said surface and having a frusto-conical wall extending into the space bounded by said first wall and tapering in the same direction as said first wall.

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