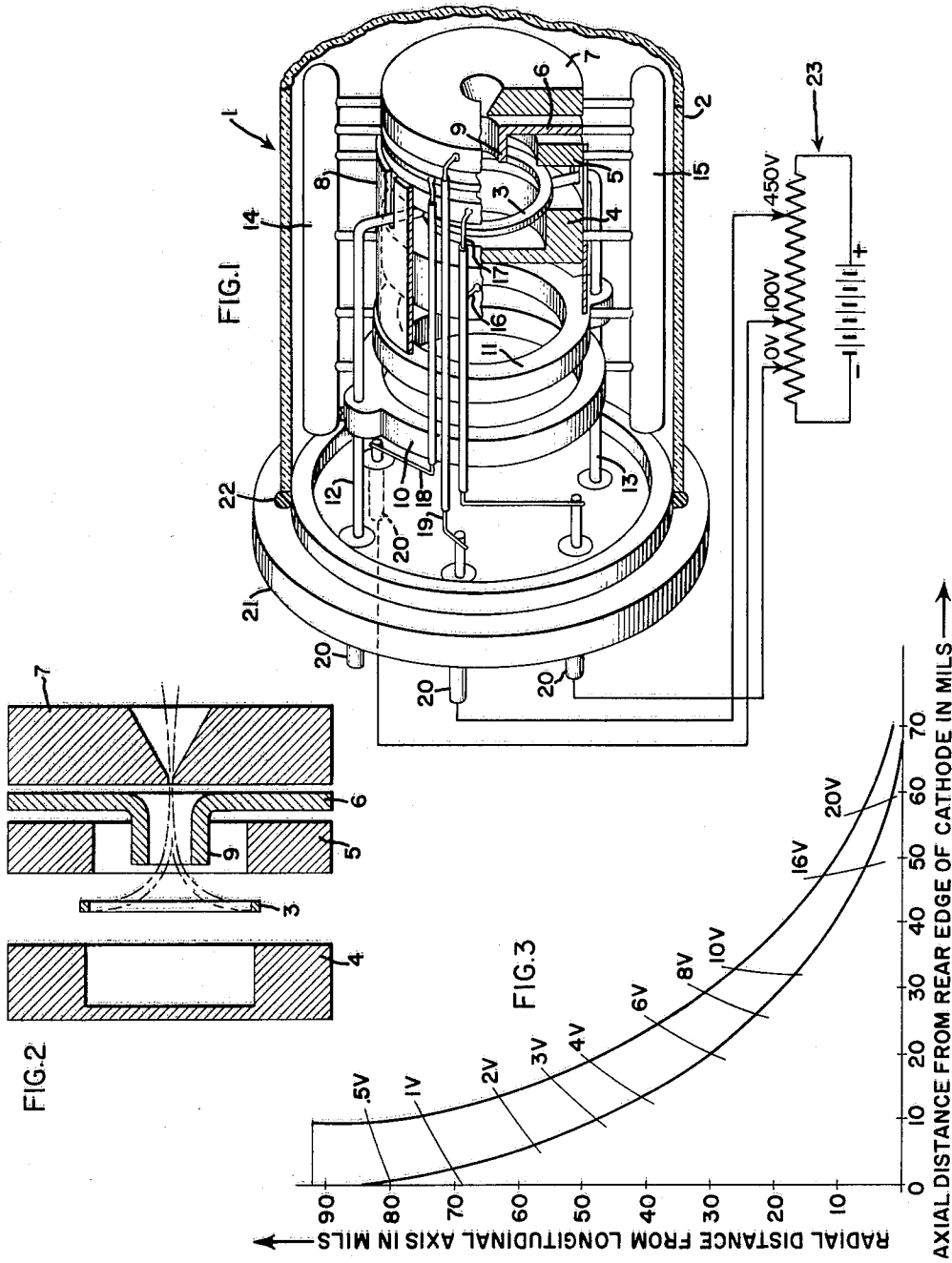


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ELECTRON GUN ASSEMBLY WITH LONG LIFE ANNULAR CATHODE
CURVILINEAR ELECTRON FLOW
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**ELECTRON GUN ASSEMBLY WITH LONG LIFE
ANNULAR CATHODE CURVILINEAR ELEC-
TRON FLOW**

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The present invention relates to a novel electron gun assembly having a cathode of appreciably extended useful life.

The present gun assembly has application to many types of electron discharge devices wherein the cathode life may be limited for such causes as high evaporation rates due to high filament heating temperatures, and also because of cathode bombardment which may produce numerous undesirable effects, e.g., poisoning, oxidation and sputtering of the cathode emissive surface.

For example, in conventional display and storage tubes, the generation of a relatively high density, small spot size beam normally requires a cathode having a restricted emissive area. To provide the required high emissivity for such operation, it is necessary to employ high filament heating temperatures which cause rapid evaporation of the cathode emissive surface. This can be a limiting factor with respect to the operating life of the cathode. In addition, since the emissive surface of these cathodes must be in axial alignment with the generated electron beam, they are subjected to the previously noted undesirable effects of cathode bombardment caused by backwardly directed positive ions and charged particles. With respect to the employment of oxide coated cathodes, cathode poisoning results in the surface becoming non-emissive. This is due to a change in its chemical composition caused by the combining of impinging ions with the metal oxide coating. Oxidation of the cathode occurs when the emissive surface is oxidized by the bombarding elements, thereby increasing the surface evaporation. This may be of significance in limiting the life of both oxide coated and pure metal cathodes. A sputtering or chipping of the cathode surface may also be a significant effect in destroying the emissive surface of these cathodes.

The problem of cathode bombardment becomes particularly severe in tubes where excessive impurities are present, such as in demountable vacuum systems wherein relatively poor vacuums are obtained. In particular, in certain types of demountable tube structures, such as are employed in recently developed thermoplastic tape recording systems, the effects of cathode bombardment are great. For example, in such systems the outgassing from the recording medium contained within the vacuum system produces heavy organic charged particles and water vapor which contribute greatly to the impurities present.

In addition, in high power tubes such as many travelling wave tubes, wherein axial alignment of the cathode emissive surface is normally required, the operating life of the cathode, in many instances, is seriously effected by cathode bombardment.

The gun assembly of the present invention is constructed so as to be free of the above noted adverse effects of cathode bombardment, has reduced filament heating temperature requirements, and further is capable of providing a concentrated high density electron beam where required.

Accordingly, it is an object of the present invention to provide an improved and readily constructed electron gun assembly which employs a cathode of extended useful life.

It is another object of the present invention to provide an improved electron gun assembly of relatively simple

construction for generating a concentrated electron beam from a cathode exhibiting an extended useful life.

It is another object of the present invention to provide an improved electron gun assembly of relatively simple construction for generating an electron beam of very high density.

It is still another object of the present invention to provide an improved electron gun assembly of relatively simple construction having a cathode of reduced current density loading and one relatively free of deleterious effects of cathode bombardment.

It is a further object of the present invention to provide an improved electron gun assembly which generates an electron beam for use in an electron discharge device having impurities present, said gun assembly being of relatively simple construction and employing a cathode unaffected by said impurities and having an appreciably extended useful life.

It is still a further object of the present invention to provide an improved electron gun assembly which generates a concentrated electron beam for use in a demountable vacuum system, said gun assembly being of relatively simple construction and employing a cathode of reduced current density loading and one that is relatively free from the deleterious effects of cathode bombardment.

In accordance with one aspect of the invention, there is provided an electron gun assembly for use in an electron discharge device having a ring type cathode in combination with first and second electrodes, each having central apertures, in axial alignment with the cathode and consecutively disposed in the order recited immediately forward of said cathode, and a third electrode in axial alignment with the cathode and disposed immediately rearward thereof. Said second electrode has an axially protruding central portion of cylindrical configuration extending within the aperture of said first electrode. The cathode, first, second and third electrodes are energized so as to provide in the vicinity of said cathode and said first and second electrodes an electric field configuration which accelerates the emitted electrons along a curvilinear path through the apertures of said first and second electrodes into a restricted crossover region which forms the apex of a concentrated electron beam. Accordingly, a composite electric field is established in the initial region of electron travel having an axial component in the forward direction provided essentially between the second and third electrodes and a radial component extending towards the axis of alignment provided essentially between the first electrode and the protruding portion of said second electrode. The described electrode configuration and electric field produces a concentrated electron beam having as its source a relatively large emissive area of annular configuration. In addition, the backwardly directed positive ions will be accelerated in the axial direction so as to strike said third electrode and not the cathode.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention will be better understood from the following description taken in connection with the accompanying drawings in which:

FIGURE 1 illustrates a cutaway isometric view of applicant's electron gun assembly;

FIGURE 2 is an enlarged cross-sectional view of a portion of the gun structure shown in FIGURE 1; and

FIGURE 3 is a graph illustrating the electric field configuration in the initial region of electron travel in the electron gun assembly of FIGURE 1.

Referring now to FIGURE 1 there is illustrated an exemplary embodiment of applicant's electron gun as-

sembly mounted within a demountable discharge device, which is enclosed by a glass envelope 2, of the type in which a concentrated beam is generated, only the gun portion of the device being shown. The gun assembly 1 employs a ring type cathode 3 having an electron emissive inner surface, a cup shaped back electrode 4 positioned to the rear of the cathode 3, and positioned immediately forward of the cathode in consecutive manner, a cylindrically shaped focusing electrode 5 having plane end surfaces, a first disk shaped anode electrode 6 and a second anode electrode 7, each electrode, except back electrode 4 having a central aperture. The cathode 3 and electrodes 4 to 7 are aligned along a longitudinal axis of the discharge device. A shield 8 is fitted around cathode 3 and electrodes 4 and 5 to exclude extraneous field effects in this region. The first anode 6 has an axially protruding portion 9 of generally cylindrical configuration which extends within the aperture of focusing electrode 5. The construction and relative dimensions of the cathode 3 and electrodes 4, 5 and 6 are shown more clearly in FIGURE 2.

Mounting rings 10 and 11, conductive rods 12 and 13, and insulator members 14 and 15 are employed for supporting the cathode 3 and electrode structures 4 to 7 in a conventional manner. Rods 12 and 13 also provide a current path for heating of the cathode 3. Conductors 16, 17, 18 and 19 apply operating potentials to electrodes 4, 5, 6 and 7, respectively. Base terminal pins 20 form a part of the supporting structure and also introduce the operating potentials into the discharge device through a vitreous base member 21. A vacuum seal, such as a neoprene O-ring 22, is inserted between base 21 and glass envelope 2.

The cathode ring 3 may be constructed from a number of suitable materials. For example, it may be constructed of a pure molybdenum or tungsten metal, or it may be an oxide coated metal with the coating placed on the inner surface of the ring. In one operating embodiment molybdenum was employed. In the width of the emissive surface of the cathode was approximately 16 mils and the diameter of its aperture about 150 mils, providing an emissive area about 10^4 times that of a hairpin type cathode of comparable total emissivity. The cathode was heated to about 2150°K ., a considerably lower temperature than required for restricted emissive area cathodes. Hence, the rate of evaporation of the emissive surface is appreciably reduced. There was obtained a prefocused beam current density in the crossover region of approximately .83 amperes per square inch from a cathode current density of approximately .0037 amperes per square inch. The lower heating temperature requirements, in addition to the avoidance of bombardment of the cathode which will be explained in more detail subsequently, results in extending the useful operating period of the cathode by more than an order of magnitude over conventional structures providing comparable beam intensity. It may be noted that the annular emissive surface configuration as a characteristic of its large area emissive surface provides a further advantage in that axial alignment of the cathode need not be as critical as it is required to be for restricted emissive area cathodes. In addition it may be appreciated that the large cathode emissive area provided will permit the generation of a very high density beam current when the cathode is heated close to the maximum allowable heating temperature.

The diameter of the cavity of back electrode 4 and the diameter of the aperture of focusing electrode 5 are approximately equal to the diameter of the cathode aperture. The diameter of the aperture of the accelerating electrode 6 is approximately $\frac{1}{3}$ of the first recited diameters. In the operating embodiment being considered, the thickness of the focusing electrode 5 was about 60 mils, which dimension provides an opposing surface with

respect to the protruding portion 9 of the anode 6 and will be seen to be significant with respect to generation of the radial component of the electric field in the region of initial electron travel. The second accelerating anode 7 has a limiting aperture the diameter of which was on the order of 4 mils. It should be understood, however, that, for purposes of the invention, the second anode is primarily for the purpose of providing a strong axially directed electric field for causing further convergence of the beam. It thus need not include a limiting aperture and may be of conventional construction other than that illustrated, and it may actually be a part of the lens of the subsequent focusing system, which itself is of conventional construction and is not shown.

The cathode 3, back electrode 4 and focusing electrode 5 are biased at approximately the same potential, normally at ground potential. Accordingly, these structures can be considered as a single electrode means the inner surface of which forms a cylinder closed at one end. An input signal is normally applied between the focusing electrode 5 and the cathode 3 for modulating the electron beam. In the embodiment of the invention considered, a potential of approximately 100 volts was applied to the first accelerating anode electrode 6 and a potential of approximately 450 volts was applied to the second accelerating anode electrode 7. The various bias potentials may be supplied from a tapped potentiometer 23.

An electric field is established in the vicinity of cathode 3 which draws electrons away from the inner surface thereof in a curvilinear path which extends through the apertures of electrodes 5, 6 and 7, as illustrated in FIGURE 2. It may be noted that when considering pure metal cathodes, it is essentially the inner surface only that is emissive because a negligible accelerating field exists at the other surfaces. Thus, the emitted electrons converge in a constricted crossover region in the vicinity of the limiting aperture of electrode 7 so as to form a high density beam which may be focused onto a phosphor screen or recording surface by the focusing system, not illustrated. The equipotential lines of the electric field in the region of the initial electron travel are shown in FIGURE 3. This electric field configuration is essentially provided by an axial field component existing between the first anode electrode 6 and the back electrode 4, along the longitudinal axis of the discharge device towards said first anode 6, and a radial field component existing between the protruding central portion 9 of anode 6 and the focusing electrode 5, in the direction towards the longitudinal axis. The axially extending side portions of the cup-shaped back electrode 4 serve to confine the electric field existing to the rear of the cathode and contribute to providing an optimized electric field configuration in the vicinity of the cathode. Further, the back electrode 4 serves to establish an axial field component which will provide a smooth curvilinear path of electron flow converging in a region forward of the anode electrode 6. Accordingly, the disclosed electrode configuration and applied potentials provide an electric field in the region between the cathode emissive surface and the aperture of anode electrode 6 having a radial and axial component, said radial component being a maximum in the vicinity of the emissive surface, gradually decreasing and becoming minimum in the vicinity of the anode aperture and said axial component being a minimum at the emissive surface, gradually increasing and becoming maximum in the vicinity of the anode aperture. The described electric field accelerates emitted electrons away from the cathode in a gradually curved path bending in the forward axial direction of the discharge device, as seen in FIGURE 3. In addition, the equipotential lines of the electric field are of a configuration such that any positive ions or charged particles which are backwardly accelerated through the apertures of the gun electrodes will not strike the emissive surface of the cathode but will proceed in a direction es-

entially along the longitudinal axis and be collected by the back electrode 4.

It may be appreciated that although the present electron gun assembly has been described as useful with electron discharge devices which generate high density solid beams, it may be of appreciable value for the generation of hollow beams. In addition the invention has application for employment in travelling wave type tubes, which tubes normally utilize a spherical cathode positioned on the longitudinal axis of the device. Such cathodes are often subjected to intense bombardment by backwardly directed positive ions which distort the emitted beam configuration and ultimately cause cathode failure. Applicant's invention would prevent such phenomenon and accordingly lengthen the life of the cathode in tubes of this type.

Accordingly, the appended claims are intended to be construed as embodying all modifications and variations that fall within the true scope and spirit of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron gun assembly for generating an electron beam in an electron discharge device comprising:

- (a) a cathode having an electron emissive surface of annular configuration,
- (b) first and second annular electrodes each having an aperture therein, said electrodes being arranged in consecutive manner forward of said cathode and in coaxial relationship therewith, said second electrode having an axially protruding central portion extending within the aperture of said first electrode, and
- (c) a third electrode having a cavity therein disposed immediately rearward of said cathode, said first, second and third electrodes being energized so as to create an electric field having a predominantly radial component in the vicinity of said cathode and a predominantly axial component in the vicinity of the aperture of said second electrode which accelerates electrons from said emissive surface in a converging curvilinear path passing through the aperture of said second electrode.

2. An electron gun assembly for generating an electron beam in an electron discharge device comprising:

- (a) a ring shaped cathode having an electron emissive inner surface,
- (b) a cylindrical focusing electrode positioned forward of said cathode and having an aperture therein the diameter of which is approximately equal to the diameter of said cathode,
- (c) an anode electrode positioned forward of said focusing electrode and having an axially protruding central apertured portion extending within the aperture of said focusing electrode,

(d) a cup-shaped back electrode positioned immediately rearward of said cathode, and

(e) means for applying substantially equal bias potentials to said cathode, focusing and back electrodes and a relatively positive potential to said anode electrode for providing an electric field having a predominantly radial component in the vicinity of said cathode and a predominantly axial component in the vicinity of said anode aperture which accelerates electrons from said emissive surface in a converging curvilinear path passing through said anode aperture.

3. An electron gun assembly for generating an electron beam in an electron discharge device comprising:

- (a) a cathode having an electron emissive surface of annular configuration,
- (b) electrode means including a first apertured, cylindrically shaped electrode having plane end surfaces positioned immediately forward of said cathode, and a second apertured, disk shaped electrode positioned coaxially with and immediately forward of said first electrode and having an axially protruding central portion extending within the aperture of said first electrode, and
- (c) a third electrode disposed immediately rearward of said cathode in approximate axial alignment with the apertures of said first and second electrodes, said first, second and third electrodes being energized so as to create an electric field having an axial and radial component the magnitudes of which are inversely related and gradually varying, said radial component being maximum in the vicinity of said emissive surface and said axial component being maximum in the vicinity of the aperture of said second electrode, said electric field thereby accelerating electrons from said emissive surface in a converging curvilinear path passing through the aperture of said second electrode.

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