Oct. 29, 1957 G. R. BREWER 2,811,667

ELECTRON GUN

Filed Dec. 9, 1954 2 Sheets-Sheet 1

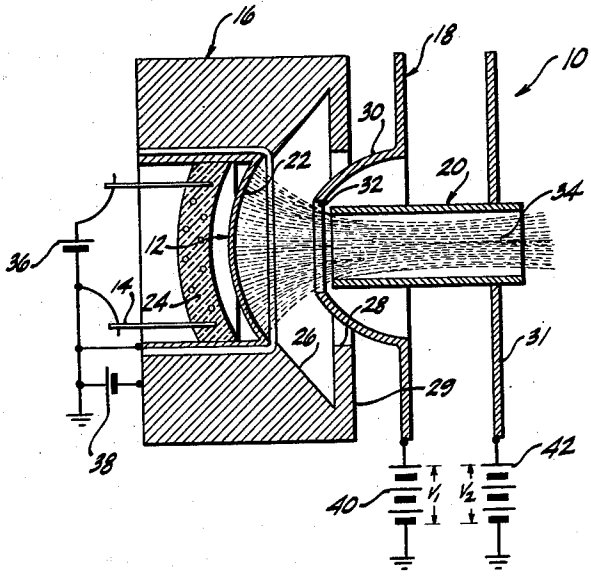


FIG. 1.

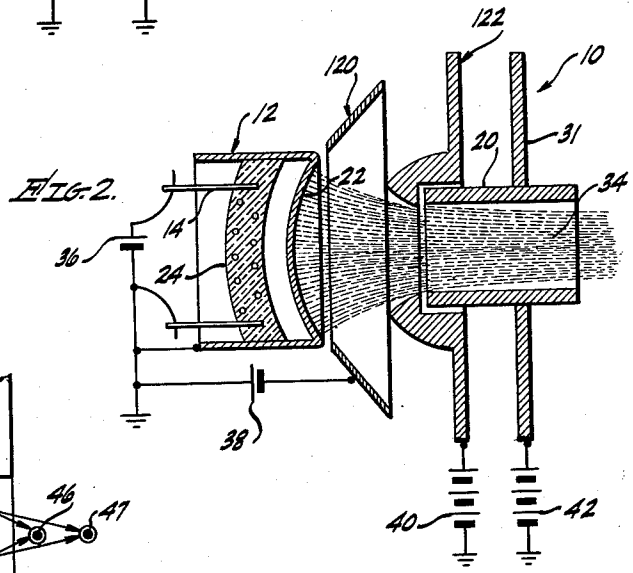


FIG. 2.

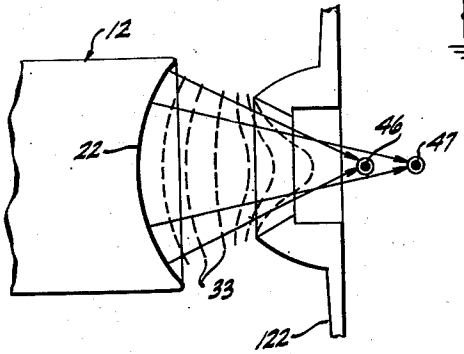


FIG. 3.

INVENTOR.
GEORGE R. BREWER,
By
Henry Heyman
ATTORNEY.

Oct. 29, 1957 G. R. BREWER 2,811,667

ELECTRON GUN

Filed Dec. 9, 1954 2 Sheets-Sheet 2

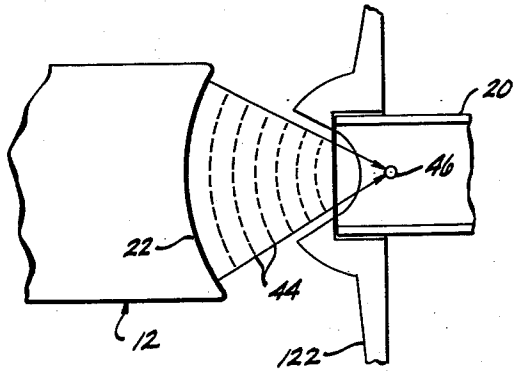


FIG. 4.

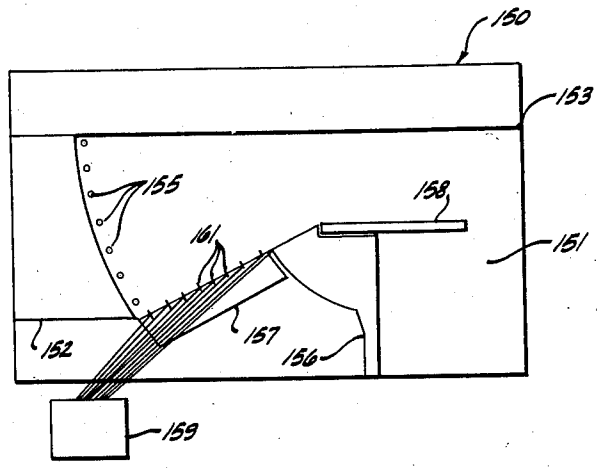


FIG. 5.

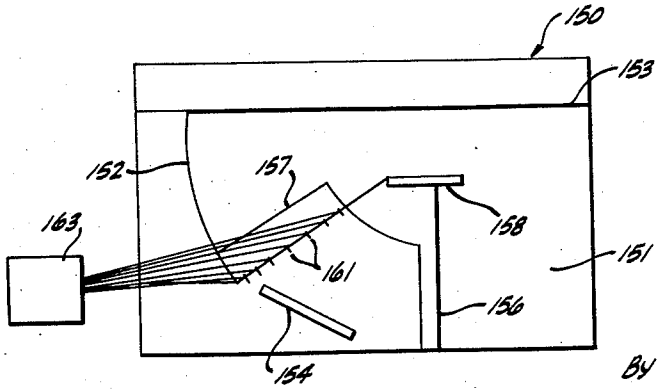


FIG. 6.

INVENTOR.
GEORGE R. BREWER,
BY
Henry Heyman
ATTORNEY.

United States Patent Office

2,811,667

Patented Oct. 29, 1957

2,811,667

ELECTRON GUN

George R. Brewer, Palos Verdes Estates, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application December 9, 1954, Serial No. 474,078

4 Claims. (Cl. 315—15)

This invention relates to electron tubes anl more particularly to an electron gun for producing an electron stream having a substantially uniform diameter over its length.

Electron guns which are employed to produce relatively high current electron streams generally comprise a cathode having an emission surface which is concave with respect to the electron stream, a frusto-conical focusing electrode disposed concentrically about the cathode, and a dish-shaped anode having an apertured central surface concave with respect to and spaced from the cathode emission surface. All of the gun electrodes are properly shaped and maintained at appropriate potentials to cause substantially all of the electrons which emanate from the cathode to be focussed toward the same point along a predetermined electron stream path. The gun electrodes are thus employed to develop a solid cylindrical electron stream having a uniform current density over its cross section. When the gun actually accomplishes this result, an electron stream thus produced is said to be well collimated.

It may be particularly desirable to produce collimation of electrons in an electron stream which is magnetically focused in a manner well known in the art as Brillouin flow. This is true because the Brillouin type of flow allows a given stream to be focussed or confined with a magnetic field of a minimum strength. However, unless certain precautions are taken in the design of the gun and magnetic field system, electron stream diameter variations invariably occur in Brillouin flow. These variations physically manifest themselves as a plurality of ripples which are disposed at periodic stationary intervals along the stream causing the stream to expand and contract. When such a stream is employed in a microwave tube, such as a traveling-wave tube, the efficiency of the tube is generally reduced by the stream diameter variations. These ripples can also cause a number of other deleterious effects on traveling-wave tube performance. In such a case it is therefore definitely desirable to minimize these variations by producing a collimated electron flow.

At present it is frequently the practice to design the several electrodes of a converging beam gun as though the anode aperture through which the beam passes were not in existence. A focusing error is thus produced which impairs a collimated electron flow. This focusing error results in a large part from the distortion of the electric field lines, imparting undesirable transverse motion to the electrons.

An object of the invention is, therefore, to provide an improved electron gun for a traveling-wave tube.

Another object of the invention is to provide an electron gun for developing a substantially collimated flow of electrons.

In accordance with the invention as second anode having a cylindrical internal surface is disposed adjacent to and partly within the dish-shaped anode of an otherwise more or less conventional converging beam gun. The

electric field contiguous to the gun cathode may thus be modified in such a way as to be more uniform and thus to improve collimation when the second anode is maintained at a potential somewhat greater than that of the dish-shaped anode.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description taken in connection with the accompanying drawings, in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Figs. 1 and 2 are sectional views of different embodiments of an electron gun constructed in accordance with the invention;

Figs. 3 and 4 are schematic views of an electric field distribution which may exist contiguous to the cathode of the gun shown in Figs. 1 and 2; and

Figs. 5 and 6 are diagrammatic views of an electrolytic tank which may be employed in the designing of the gun of the present invention.

Referring to Fig. 1, an electron gun **10**, which may, for example, have a perveance of 2×10^{-6} or higher, is shown comprising a cathode **12** which is provided with a filament **14**, a focusing electrode **16**, a dish-shaped anode **18**, and a second hollow cylindrical anode **20**.

Cathode **12** is itself a hollow cylinder having an enclosed end portion **22** concave with respect to its electron stream and which serves as an electron emissive surface. The emissive surface may be, for example, spherical. Filament **14**, which has a helical shape, is surrounded by a concave dish-shaped block of a refractory material **24**. Block **24** and filament **14** are thus situated concentrically within the cylinder of the cathode **12** adjacent the end portion **22**.

Focusing electrode **16** is disposed concentrically about the cylinder of the cathode **12** having a frusto-conical internal focusing surface **26**. Focusing electrode **16** also has an aperture **28** in a disc-shaped end portion **29** through which a concave sheet **30** forming the central portion of dish-shaped anode **18** extends. Dish-shaped anode **18** is likewise provided with an aperture **32** through which electron flow is produced.

Cylindrical anode **20** is disposed partially within the concave sheet **30** in order that an improved collimation of electrons along a predetermined path, e. g., a path **34**, may be produced. Cylindrical anode **20** is provided with an encompassing supporting disc **31** with which cylindrical anode **20** may be mounted in an electron tube.

Filament **14** is heated by a filament battery **36** which is connected thereacross. Cathode **12** and the negative terminal of battery **36** are maintained at ground potential by a suitable connection thereto.

Focusing electrode **16** may be maintained a few volts negative with respect to ground by a focusing electrode source of potential **38**. Depending upon the position and exact shape of focusing surface **26**, focusing electrode **16** may be maintained negative or at zero potential with respect to the potential of cathode **12**.

Dish-shaped anode **18** is maintained at a relatively large positive potential with respect to that of focusing electrode **16** by means of a first anode source of potential **40**. Cylindrical anode **20** is maintained at a still larger positive potential by a second anode source of potential **42**.

Through empirical studies of electric field patterns in an electrolytic tank, which method of examination is well

known in the art, it has been found that best collimated electron flow is produced in the range of

$$1.1<\frac{V_2}{V_1}<1.5 \quad (1)$$

depending on the design the electrode **20** and its disposition with respect to anode **32**, where V_2 is the voltage of cylindrical anode **20** and V_1 is the voltage of dish-shaped anode **18**. Some improvement in electron collimation can be obtained when V_2 is simply larger than V_1; however, if V_2 is more than twice as large, the improvement may be negligible, and the performance may even be impaired.

The electrodes of the gun **10**, excluding the second anode **20**, may be designed according to the procedure related in U. S. Patent No. 2,268,165, granted December 30, 1941, to C. V. Parker et al. The cathode **12**, the focusing electrode **16**, and the first anode **18** may also be maintained at appropriate relative potentials as set out in the Parker patent.

The principal reason for using the cylindrical anode **20** arises out of the fact that for a relatively high perveance gun the size of the first anode aperture diameter is of the same order of magnitude as the distance from the first anode to the cathode. This generally decreases the focusing capabilities of the dish-shaped anode **18** by causing a distortion of the electric equipotential lines from their desired spherical shape. However, this effect is essentially negligible in relatively low perveance guns.

The gun **10** is shown again in Fig. 2 with both a differently shaped focusing electrode **120** and first anode **122**. Focusing electrode **120** performs the same function as focusing electrode **16**; however, focusing electrode **120** consists simply of a frusto-conical metallic sheet. The structure of first anode **122** differs from that of dish-shaped anode **18** in that the interior of the dish-shaped outer wall of the first anode **122** is partially filled with metal in order to improve the performance of the gun **10** and shaped to accommodate a portion of cylindrical anode **20**.

The schematic diagrams of Figs. 3 and 4 illustrate in particular how the cylindrical anode **20** may be emloyed to improve the collimation of stream electrons when maintained with a potential range set out in the inequalities of the expression (1). Cathode **12**, focusing electrode **120** and first anode **122** are shown in both Figs. 3 and 4 whereas cylindrical anode **20** is only shown in Fig. 4. A plurality of dashed lines **33** in Fig. 3 and **44** in Fig. 4 represent equipotential lines which would be produced by the electrodes shown in the respective Figs. 3 and 4.

In order to produce a collimation of stream electrons, it is necessary to direct the electrons emitted at the end portion **22** of cathode **12** toward a common focusing point, viz. points **46** in Figs. 3 and 4. However, in Fig. 3 where cylindrical anode **20** is not employed, the transverse forces resulting from the distortion of the equipotential lines **33** will cause electrons at the outer edge of the stream to be directed toward the focal point **46** nearer the cathode **12** than a focal point **47** to which the electrons at the center of the stream will be directed. This is true because the equipotential surfaces represented by the dashed lines are not concentric; giving rise to transverse defocusing fields which act upon the stream electrons. The density of electron emission in Fig. 3 likewise varies with the radius of the electron stream, whereby collimation may be exceedingly poor. In extreme cases a large number of the electrons may be caused to strike the anode. However in Fig. 4 where cylindrical anode **20** is employed, all of the equipotential lines **44** are substantially parallel and good collimation is produced. The magnitude of ripples in Brillouin flow may thereby be reduced and the efficiency of microwave tubes, such as, for example, traveling-wave tubes, may be thus increased.

In order to obtain a properly shaped and spaced second anode and to obtain the optimum potential at which it should be maintained, an electrolytic tank design procedure may be most effectively employed. Such a tank **150** is illustrated in Figs. 5 and 6 and is filled with water **151** up to a water level **153**. A first conductive sheet **152** in the tank represents one-half of the cathode surface **22**. A second conductive sheet **154** illustrated only in Fig. 6 represents focusing electrode **120**. A third conductive sheet **156** represents first anode **122**, and a fourth conductive sheet **158** is employed to represent the structure of cylindrical anode **20**. Suitable potentials are applied to sheets **152**, **154**, and **156**, and the potential applied to sheet **158** is varied as the electric field pattern is detected by a probe disposed in the water **151**.

In arriving at a correct design for the various electrodes of the gun, one must vary two parameters, the position and shape of the focusing electrode so as to achieve the desired potential distribution along the beam boundary and the shape, position, and potential of the second anode **158** relative to the anode in such a way that the electric gradient adjacent to the surface of the cathode is uniform over the cathode surface. These desired shapes can be obtained as follows:

In the electrolytic tank **150** the required boundary conditions at the edge of the beam are: (*a*) the electric gradient normal to the beam boundary must be zero, and (*b*) the potential must be continuous across this boundary. These conditions are fulfilled by placing a dielectric strip **157** along the desired beam boundary with a series of thin spaced metallic strips **161** which can be held at the desired potentials by external circuitry indicated by **159**. The presence of the dielectric strip **157** insures that no current flows normal to the beam boundary in the tank, thus forming the analog of the zero normal field condition. In addition, the metallic strips **161** can be adjusted in potential to provide a potential distribution along the inner surface which is identical to that produced on the outside of the dielectric strip **157** by the focusing electrode **120**, thus satisfying the second boundary condition. The potential along the edge of the beam should follow that found by Langmiur and Blodgett, Phys. Rev. 24, page 49 (1924), which is

$$V/V_a=(-\alpha/-\alpha_a)^{4/3} \quad (2)$$

where $-\alpha$ is represented by the series of Langmiur and $-\alpha_a$ is the value of α at the anode, or any other desired and suitable distribution law. The position and shape of the conductive sheet **154** may then be determined in the manner indicated in Fig. 6 where **163** indicates a metering device for ascertaining the potential distribution along the metallic strips **161**.

The shape and potential of electrode **153** is adjusted while measuring the electric gradient normal to the cathode at several points **155** therealong until this gradient is substantially uniform. Under this condition it can reasonably be assumed that the emission density will be uniform, the equipotential lines being essentially concentric with the cathode emission surface and the focusing properties of the gun being that desired. The dependence of emission current density on the normal potential gradient contiguous to the cathode emission surface may be observed by reviewing the emission equation. For example, using planar equations

$$J_0=K\frac{V_a^{\frac{3}{2}}}{L^2}=K\left[\frac{V_a}{L}\right]^2\frac{1}{V_a^{\frac{1}{2}}} \quad (3)$$

where:

J_0 is emission current density;
K is a constant;
V_a is the first anode voltage; and
L is the first anode spacing.

If the potential gradient

$$E_0=\frac{V_a}{L}$$

is the gradient immediately adjacent the cathode in the absence of space charge then

$$J_0=K\left(\frac{E_0}{V_a}\right)^2 \quad (4)$$

Thus if E_0 is uniform over the cathode surface, then J_0 will also be uniform over the cathode surface.

It is then evident that a converging beam electron gun may be constructed which will give a collimated electron stream with a minimum disturbance of rippling in an axial magnetic field. This is made possible by the uniform emission current density provided and by the symmetrical focusing which may be obtained in practicing the present invention.

What is claimed is:

1. An electron gun for producing a substantially collimated flow of electrons, said electron gun comprising a thermionic cathode having a concave emission surface with respect to emitted electrons, a focusing electrode disposed about said cathode, an anode having a central dish-shaped surface disposed partially within said focusing electrode, said central portion of said anode being concave toward said cathode, and a second anode having one end disposed partially within said dish-shaped anode, said second anode having a cylindrical internal surface extending throughout its length to permit an electron flow therethrough, whereby equipotential surfaces with curvatures substantially concentric to the emission surface of said cathode may be produced by the application of appropriate voltages to said anodes, said cathode, electrode, and anodes being concentrically aligned with each other.

2. An electron gun for developing a substantially collimated flow of electrons along a predetermined path, said electron gun comprising a thermionic cathode having a substantially concave spherical electron emissive surface with respect to emitted electrons, a focusing electrode disposed about said cathode having a substantially frusto-conical internal focusing surface converging inwardly toward said cathode, a dish-shaped anode having an apertured central surface disposed concave toward said cathode and disposed partially within the frusto-conical surface of said focusing electrode, a hollow cylindrical anode disposed about said path having one end disposed partially within the central portion of said dish-shaped anode, means for maintaining said dish-shaped anode at a first predetermined potential with respect to said cathode, and means for maintaining said cylindrical anode at a second predetermined potential with respect to said cathode larger than said first predetermined potential said cathode, electrode, and anodes being concentrically aligned along said predetermined path.

3. An electron gun for producing a substantially collimated flow of electrons along a predetermined path, said electron gun comprising a thermionic cathode having an emission surface concave with respect to emitted electrons, a focusing electrode disposed about said cathode, a dish-shaped anode having a central dish-shaped surface disposed partially within said focusing electrode, said central portion of said dish-shaped anode being concave toward said cathode, a second anode having one end disposed partially within said dish-shaped anode, said second anode having a cylindrical internal surface extending throughout its length to permit electron flow therethrough, and means for maintaining said second anode at a potential greater than that of said dish-shaped anode with respect to said cathode and less than twice the potential of said dish-shaped anode with respect to said cathode whereby equipotential surfaces substantially parallel to the emission surface of said cathode may be produced said cathode, electrode, and anodes being concentrically aligned along said predetermined path.

4. An electron gun for developing a substantially collimated flow of electrons along a predetermined path, said electron gun comprising a thermionic cathode having a substantially spherical electron emissive surface concave with respect to emitted electrons, a focusing electrode disposed about said cathode having a substantially frusto-conical internal focusing surface converging inwardly toward said cathode, a dish-shaped anode having an apertured central surface concave toward said cathode disposed partially within the frusto-conical surface of said focusing electrode, a hollow cylindrical anode disposed about said path having one end disposed partially within the central portion of said dish-shaped anode, and means for maintaining said cylindrical anode at a predetermined potential from 1.1 to 1.5 times the potential of said dish-shaped anode with respect to said cathode.

References Cited in the file of this patent

UNITED STATES PATENTS

2,268,165	Parker et al.	Dec. 30, 1941
2,268,196	Pierce	Dec. 30, 1941
2,355,795	Glass	Aug. 15, 1944
2,573,287	Szegho	Oct. 30, 1951