

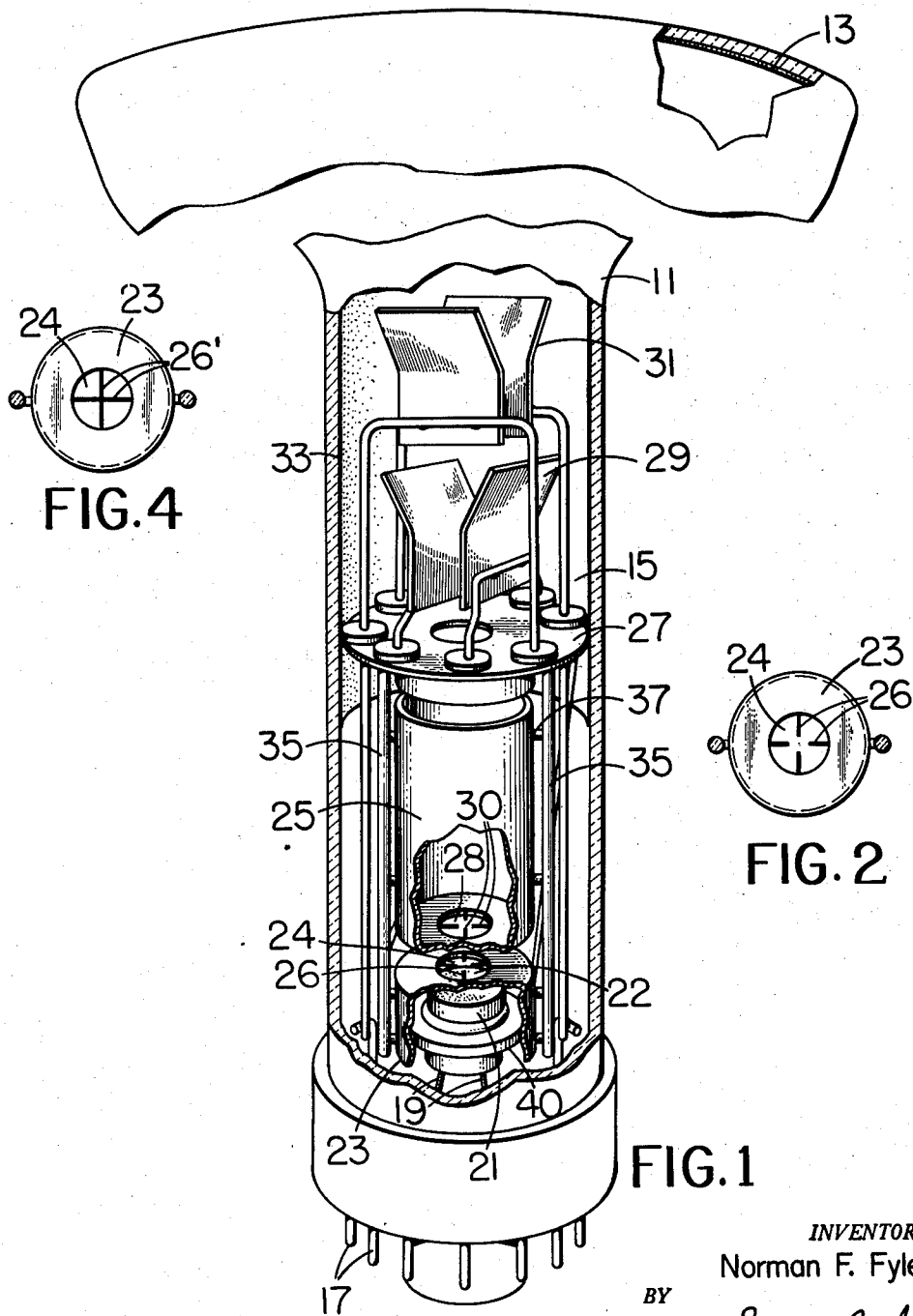
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N. F. FYLER
ELECTRON GUN STRUCTURE

2,887,600

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2 Sheets-Sheet 1



INVENTOR.

Norman F. Fyler

BY

George S. Fyler
ATTORNEY

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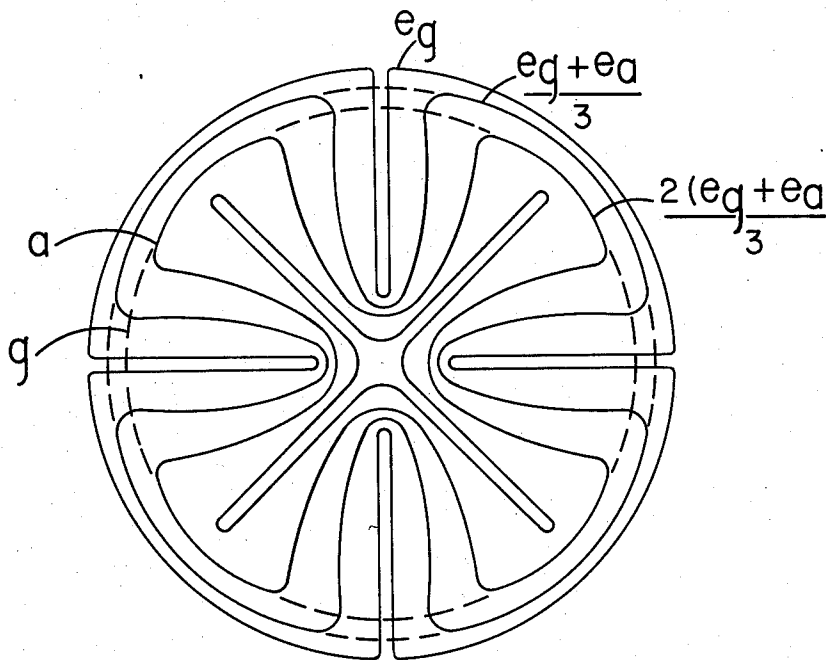


FIG. 3

INVENTOR.
Norman F. Fyler

BY

George E. Routh
ATTORNEY

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ELECTRON GUN STRUCTURE

Norman Francis Fyler, Newburyport, Mass., assignor to Columbia Broadcasting System, Inc., Danvers, Mass., a corporation of New York

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The invention relates to electron guns and particularly pertains to the construction of the control electrodes therein.

The construction of the conventional electron gun is cathode ray tubes used for displaying signals on a luminescent screen is well known. In such guns, an indirectly heated cathode, usually disc-shaped, is first energized to emit electrons of relatively low velocities. A control electrode, usually a cup-shaped element having a circular aperture formed therein, is positioned near the cathode and an accelerating electrode having a similar shape is placed near the control electrode. The resultant field from the two electrodes operates on the electrons emitted from the cathode. A control signal, commonly called the grid drive signal, is impressed on the control grid to vary the density of the electrons passing through the aperture in the control grid in proportion to the magnitude of the potential between the cathode and the control electrode. Since the electrons have a low velocity adjacent the cathode, this control is relatively easy to accomplish. The electrons which pass through the aperture in the control electrode are then directed through the accelerating electrode and other electrodes to form a high-energy electron beam to energize a luminescent screen in accordance with the grid drive signal. Means deflecting the beam in any desired manner are also provided as required, either as an integral part of the electron gun as in electrostatic deflection systems or as a separate component externally of the gun as in the magnetic deflection systems. By properly synchronizing the grid drive signal and the deflecting means, an intensity modulated image is obtained in the luminescent material to display the desired signal.

Although an electron gun such as that generally described is satisfactory for many applications, its performance in many respects is less than ideal. Many factors underlie deterioration of the gun; among the more important of such factors are several which are intrinsic to electron-emitting surfaces and electron beams. The distribution of the velocities as well as of the electrons emitted from any known emissive surface may be considered to be random in the absence of an external field. The control electrode furnishes an external field that changes distribution of the electrons and the velocities, but its effect is not constant over the emitting area. The circular aperture in the control electrode causes the electric field adjacent the emitting surface to have a gradient radially thereof. Further, the strength of this field at each point on or adjacent the emitting surface depends on the potential applied to the control electrode at any given time, so that the effective emitting area of the cathode varies. A change in effective emitting area of the cathode, in turn, gives rise to a characteristic remote cutoff effect wherein the control characteristics of the gun are degenerated as cutoff potential is approached.

To put it another way, the transconductance, which is a figure of merit of the gun, decreases as the effective area of the cathode decreases. As the transconductance

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of the gun decreases, the grid drive signal must be increased to attain the same degree of control of the density of electrons. In a typical case, for example, when the control electrode of a television picture tube is biased 10 volts below the cathode, a current of about 300 milliamperes flows to the anode of the tube and a drive signal of 5 volts causes the current to change about 50 milliamperes; when the control electrode is biased to minus 30 volts, about 100 milliamperes flows to the anode and a drive signal of 5 volts changes the anode current only about 25 milliamperes.

Modified versions of the conventional gun have been designed to minimize the variable control effect of an apertured control electrode. Among such designs, are those which incorporate an inwardly curved cathode to decrease the spread of the electrons emitted therefrom, thus decreasing the apparent area of the emitting surface and minimizing the effect of the field gradient. It is customary in this connection to provide a control electrode which has a curved end so that the end corresponds in shape to an equipotential line in the field. The main advantage of the curved cathode-curved control electrode type of gun, therefore, is that the effectiveness of the emitting surface of the cathode is increased and its dependency on the field is lessened. However, construction of the required elements is much more difficult than the corresponding elements in a conventional gun so that use of the curved cathode-curved control electrode type of gun is restricted to those applications which justify the expenses of its superior performance.

Another approach to the solution of the problem entails the use of a fine rectilinear mesh over the aperture in the control electrode as described in "Electron Optics" by O. Klemperer, Cambridge University Press, 1953. However, when such a structure is used, the spacing between the cathode and the control electrode must be very much less than the radius of the aperture in the control electrode. This means, in a practical case, that the spacing between the two elements be in the order of .001". Such a close spacing obviously requires that tolerances in the dimensions of the parts be held to very close limits to prevent short-circuiting. Even when methods such as photoengraving and the like are used to form the grid structure across the aperture in the control electrode, great difficulty is experienced in producing satisfactory parts. Moreover, the grid structure causes the electrons to be split into a number of beams. When more than one beam is formed within the gun, the problem of focusing becomes acute. In fact, under certain conditions, it becomes impossible to obtain proper focus on the luminescent screen of the tube. As a result, adequate resolution is not obtained, unless the parts are made and fitted precisely. In fact, the care required does not permit manufacturing such guns except at such great cost as to make them prohibitively expensive for almost all common applications.

Therefore, an object of the invention is to provide an emissive and control structure for an electron gun having a substantially constant transconductance over the operating range.

Another object of the invention is to provide an emissive and control structure for an electron gun that does not require critically close spacing between the elements therein.

Still another object of the invention is to provide an emissive and control structure for an electron gun providing a sharp cutoff characteristic.

According to the invention, the electrode structures are arranged in such manner that the electric field adjacent the cathode is more efficient as far as controlling the intensity of electrons emitted by the cathode is concerned. The improvement is attained in one embodiment

ment by placing thin tangs radially of the aperture in the control electrode at equal intervals. In this form, it is preferred that the tangs not be extended inwardly so far as to intersect or overlap. As a result of such a structure, the field from the control electrode extends over a greater area of the emitter and exerts more control over the density of the electrons emanating therefrom. At the same time, no centrifugal forces are exerted on any of the electrons so focusing is easier. In another form of the invention, the inwardly projecting tangs on the control electrode aperture are crossed, thus increasing the control effect of the control electrode. A similar set of tangs is affixed to the accelerating electrode aperture in registry with the tangs on the control electrode aperture. The second set of tangs (or wires) acts to compensate for the centrifugal forces which must of necessity operate on some of the emitted electrons thus making focusing easier. For a ready application of the invention to the problem at hand, an express embodiment, given by way of example only, is described with reference to the accompanying drawing in which:

Fig. 1 is an isometric view, partially cut away and expanded, better to show the critical portion of the invention, of a tube incorporating an embodiment of the invention;

Fig. 2 is a plan view of the control electrode showing the critical apertures in the tube shown in Fig. 1;

Fig. 3 is a graphical representation of the electric field existing adjacent the cathode of a tube made according to Fig. 1, greatly exaggerated to show the principles of the invention; and

Fig. 4 is a plan view of an alternative embodiment of a control electrode of an electron gun that may be used advantageously in place of the one shown in Fig. 1.

Referring now to Fig. 1, an operative cathode ray tube embodying the principles of the invention is shown in some detail. The tube consists of an evacuated envelope 11 having a luminescent screen 13 laid down on one end and an electron gun 15 positioned on the other end. A plurality of lead-in wires connected to pins 17 are sealed through the wall of the envelope 11 adjacent the electron gun 15 to energize each of the active elements therein as required. The particular electron gun shown consists of a heater element 19 disposed within a cathode 21, a control electrode 23, an accelerating electrode 25, a focusing electrode 27, and two pairs of deflection plates 29, 31. Coacting with the gun 15 is a final anode 33, which may take the form of a conductive coating on the inside of the envelope 11 as shown. The various named parts of the gun 11 may be held in a fixed spatial relationship one to another by rods 35 formed of an insulating material and having short straps as shown at 37 affixed at approximate points between the heater 19 and cathode 21. The cathode 21 is held in position within the control electrode 23 by means of a spacer 40 while the heater 19 is frictionally retained within the cathode.

The cathode 21, which may be formed of nickel, has a disc-shaped coating 22 of electron emissive material of any known type deposited on it. Oppositely of the coating 22, a circular aperture 24 is formed through the control electrode 23 coaxially with the disc-shaped coating 22. A plurality of inwardly projecting conductors or tangs 26 are affixed to the periphery of the aperture 24 with equal spacing between tangs. A circular aperture 28 is formed in the base of the accelerating electrode 25 oppositely of the aperture 24 in control electrode 23. A similar plurality of tangs 30 to tangs 26 is affixed to the periphery of the accelerating electrode aperture 28. The tangs 30 are so oriented that each one of them is shadowed by one of the tangs 26. The tangs 30 are not essential to the operation of the invention but do improve results considerably.

The focusing electrode 27 is conventional, as are the

deflection plates 29, 31 and the final anode 33. It should be noted that the method of deflection illustrated is not the only one which may be used without departing from the spirit of the invention. Electromagnetic deflection means, for example, could just as well be employed in place of the electrostatic method using the deflection plates shown.

Referring now to Fig. 2, the arrangement of the tangs 26 in the aperture 24 may be more clearly seen. Each tang extends radially inwardly of the periphery of the aperture a predetermined distance leaving the central part of the aperture open. While the figure shows the tangs 26 made of wire welded, or otherwise attached, to the control electrode 23, the tangs may be formed integrally with electrode 23 by electroforming. Whatever the form the tangs take or however they are made, it is desirable that they be as thin as possible in order to ensure a high degree of transparency of the aperture. A high degree of transparency of the control electrode aperture, of course, permits easier penetration of the accelerating field through to the cathode, thereby reducing the magnitude of the potential required properly to accelerate the electrons. Moreover, the number of electrons intercepted by the control electrode is reduced so that less power need be dissipated by the cathode to obtain a cathode beam of any given intensity.

The spacing between the emitting surface and the cathode is no more critical than that encountered in conventional electron guns. That is, the spacing need not be any closer than about .006" + .002". This requirement contrasts markedly with the spacing requirement when a rectilinear cross-grid structure is employed wherein it is common to employ spacings in the order of .001" as previously mentioned. It is evident that the problems of insulation and positioning is much more critical when the spacing is only one mil. The construction of the aperture in accelerating electrode 25 is exactly the same as that described above for reasons which will become apparent hereinafter.

The operation of the invention may best be understood by comparison as shown in Fig. 3 of the field obtained with a gun according to the invention to that encountered in a conventional gun. In the ordinary case, the equipotential lines due to the interacting potentials on the control electrode and accelerating electrode are essentially circular, as shown by the combination of solid and broken lines, portions *a* and *b*, in Fig. 3, and the gradient is positive radially inwardly from the periphery of the emitter. As the potential on the control electrode is changed, the position of the equipotential lines adjacent the emitter change correspondingly. Cutoff is obtained by causing the potential adjacent the emitter to become less than the contact potential of the emitter. However, as the cutoff point is approached, it has been found that the change in useful current per unit change in control electrode potential decreases; in other words, there is a remote cutoff.

When a control electrode such as that shown in Fig. 2 is used, the field distribution shown in solid lines in Fig. 3 may be taken as a qualitative representation of the conditions existing when operating potentials are applied to the various electrodes. The equipotential lines are non-circular, being deformed inwardly between the tangs on the control electrode. For clarity of explanation, the various equipotential lines are marked with hypothetical values. It should be understood, however, that voltages designated by means of standard notation need not be present at all times; e.g., the exact value of the control grid voltage, e_g , may or may not be found adjacent the emitting surface as shown. However, the field is generally shaped as shown, there being a depression or trough in the field under each separate tang, due to the effect of the low voltage thereon, that extends inwardly toward the center of the emitting surface. At the same time, elevations between the troughs exist that are disposed midway between the troughs because of the symmetry of the tangs.

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It is evident that the area subtended on the emitting surface between any two given equipotential lines is greater when the field is so deformed than in the case when the field is circular in cross-section. Such an increase in area between equipotentials increases the effectiveness of changes in the control electrode potential, especially as cutoff potential is approached. As a result, a sharper cut-off is attained.

It will be noted, however, that the gradient in the electric field shown in Fig. 3 is always directed so as never to impart any acceleration to any electrons in a direction outwardly of the emitting area. In fact, any acceleration imparted to the electrons tends to bend the paths thereof inwardly. This fact makes the structure illustrated effective in assisting to focus the electrons into a small area whereby more satisfactory operation is obtained. The small cross-sectional area of the structure required to accomplish the foregoing results also contributes to the advantages of the invention. For example, in a practical embodiment, it has been found that the cross-sectional area of the tangs 26, 30 need not exceed 8% of the area of the apertures 24, 28 in which they are placed. This means that the transparency of the apertures in such a case is 92%. In other words, the tangs intercept only about 2% of the electrons which would, in the absence of the tangs, pass through the aperture. In practice, such a high degree of transparency is highly desirable and cannot be approached by any type of rectilinear mesh structure intended to perform the same functions as the invention.

Referring now to Fig. 4, an alternative arrangement of the tangs in the apertures may be seen. The construction shown in Fig. 4 is quite similar to that shown before except that the tangs 26 meet at the center of the aperture 24 thus appearing more like wires than tangs. However, it will be noted that each of the tangs is disposed radially of the aperture as before. Further, the aperture in the accelerating electrode is treated in the same manner in order to minimize distortion whereas such treatment was previously only optional. While the structure shown in Fig. 4 has the advantage that greater control of the electron density may be attained by its use, it exhibits, under certain conditions, one of the main disadvantages of the rectilinear mesh type control structure; i.e., the beam is broken up into four distinct parts. Division of the beam in such a manner may result in the appearance on the screen of four separate images. Unless the images can be forced to superposition, the quality of the visual display is lower than the acceptable minimum. Elimination of multiple images may be accomplished, however, by carefully assembling the parts so that the tangs on the two electrode apertures are aligned with one another and by properly proportioning the potentials. In any event, the theory of operation of the embodiment shown is quite similar to that described before with the exception that the aperture in the accelerating electrode must be treated as described in order to prevent the splitting of the beams.

The invention claimed is:

1. In an electron gun, an electron emitting and control structure comprising a cathode and a control electrode, means energizing said cathode and control electrode, said control electrode consisting of a cup-shaped electrically conductive member having a circular aperture formed centrally through the base thereof and a plurality of tangs affixed to and equally spaced around the periphery of said

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aperture and extending radially inwardly thereof a predetermined distance.

2. In an electron gun having at least a source of electrons and a first and a second cup-shaped control electrode sequentially disposed therefrom in operative relationship, an electron beam control structure comprising a circular aperture formed centrally of the base of each said control electrode, a plurality of tangs equally spaced around the periphery of each said aperture, each tang being disposed in the plane of its respective said base and affixed thereto and radially of its respective said aperture, the length of each tang being a predetermined amount less than the radius of its respective said aperture, a corresponding separate one of said tangs coacting with the aperture in said second control electrode being aligned with a separate one of said tangs coacting with the aperture in said first control electrode, and means applying a predetermined electric potential to said source of electrons and said first and said second control electrode.

3. An electrode for an electron gun comprising a hollow cylindrical member, a flat annular base and a plurality of tangs, the outer edge of said base being attached integrally to one end of said cylindrical member, each of said plurality of tangs being affixed to the edge of the opening in said base at equally spaced points and projecting radially inwardly thereof a predetermined distance, said cylindrical member, said base and said plurality of tangs being fabricated of an electrically conductive material.

4. In an electrode for an electron gun having an aperture formed therein, a plurality of tangs affixed to the periphery of said aperture at equally spaced points and projecting radially inwardly of said aperture a predetermined distance, the total cross-sectional area of said tangs being equal to an area of 5 to 15% the area of said aperture, said electrode and said plurality of tangs being fabricated of an electrically conductive material.

5. A cathode ray tube comprising an evacuated envelope having an electron gun and a luminescent screen disposed in opposite ends thereof, said electron gun including a source of electrons, means controlling the density of the electrons emanating from said source of electrons and accelerating said electrons toward said luminescent screen, said means including a substantially electron impermeable hollow control electrode having an aperture formed therein adjacent said source of electrons and a plurality of equally spaced electrically conductive elements, each element being affixed to the periphery of said aperture and extending radially inwardly a predetermined distance less than the radius of said aperture and toward the center thereof, and a substantially electron impermeable hollow accelerating electrode having an aperture formed therein oppositely of said aperture in said control electrode and a plurality of equally spaced electrically conductive elements corresponding to and aligned with said conductive elements affixed to said control electrode.

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