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[54] LENS-GRID SYSTEM FOR ELECTRON TUBES

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[51] Int. Cl.^{2} H05G 1/30
[58] Field of Search 250/403, 404, 405, 399, 250/401, 396; 313/452, 454, 453

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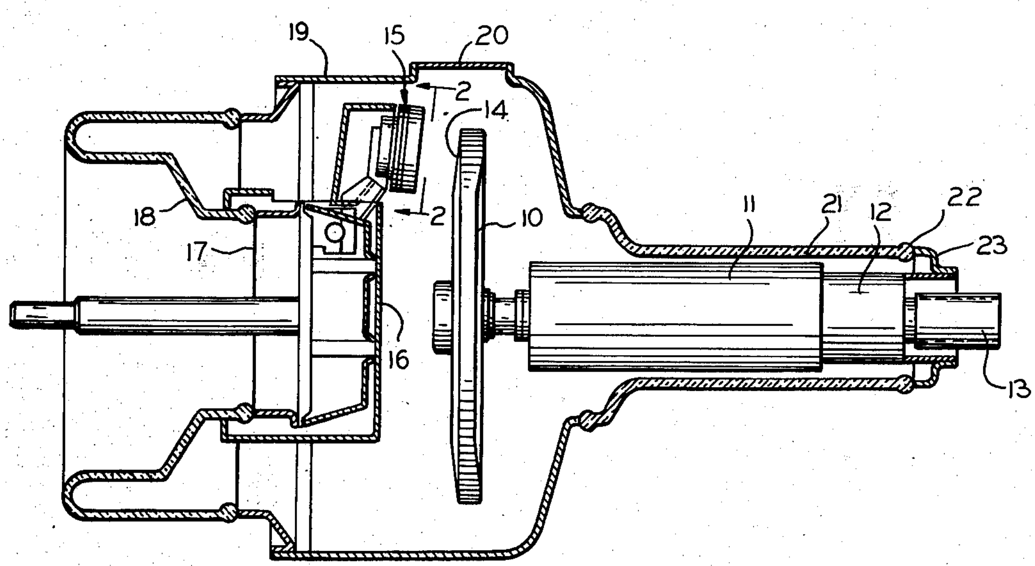
[57] ABSTRACT

An electron tube such as an x-ray tube has an anode target spaced from an electron beam emitting structure which include a cathode, focusing electrode and a control electrode. The control electrode surface nearest the anode is contoured to conform with selected equipotential values in the electrostatic field between the cathode and anode which equipotential is a predetermined percentage of the total cathode to anode voltage. When the control electrode is operated at a corresponding positive potential, the electrons follow certain trajectories and focus on the anode. Means are provided for varying the control voltage through a range from beam cut-off voltage to various positive voltages that permit control of the focal spot size regardless of the selected beam current and selected anode voltage.

8 Claims, 8 Drawing Figures



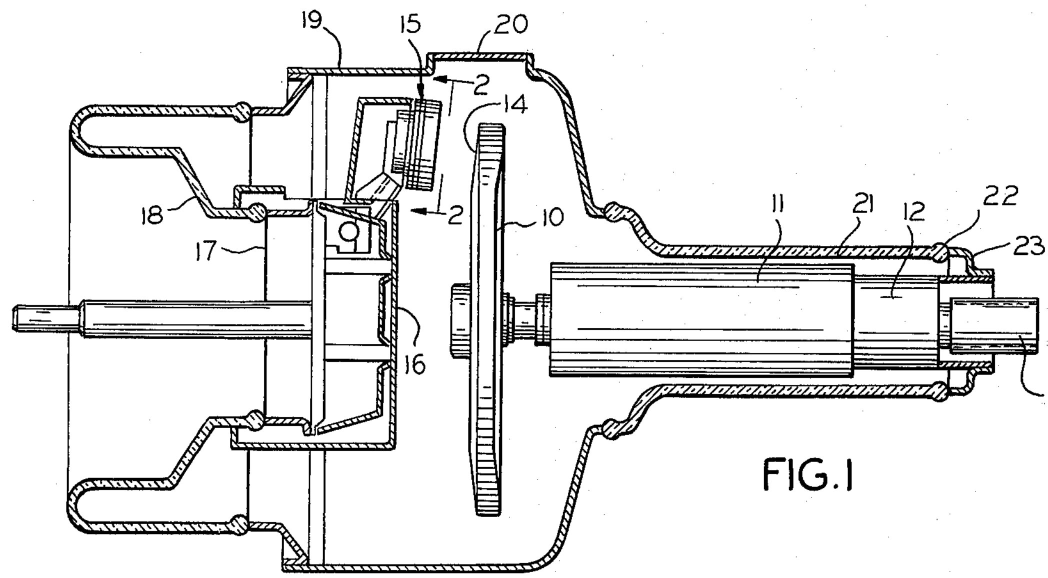


FIG.1

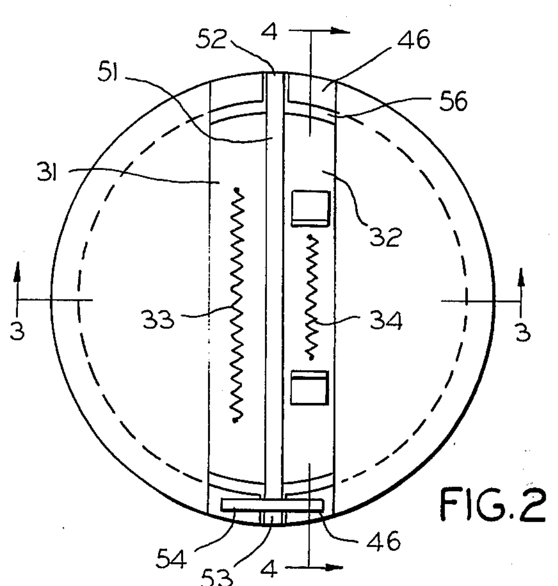


FIG.2

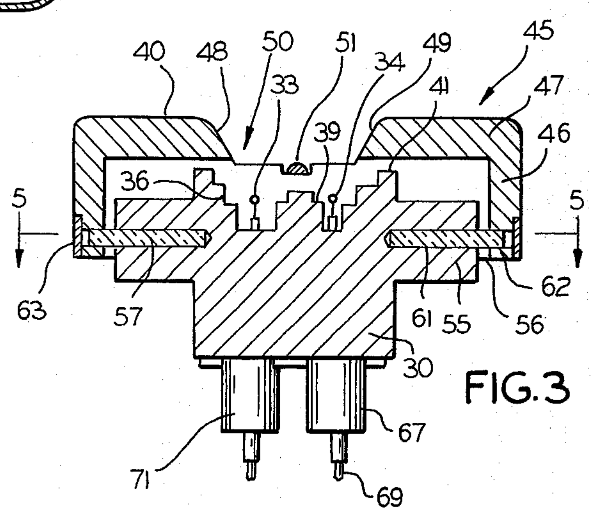


FIG.3

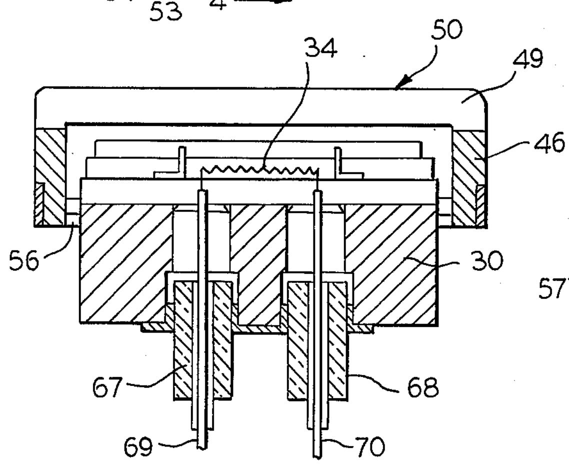


FIG.4

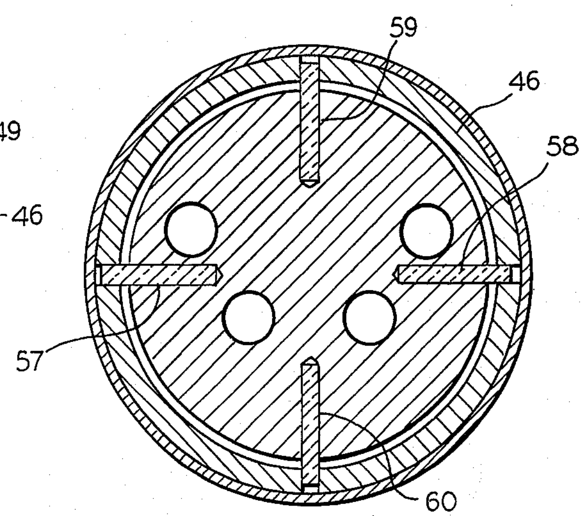


FIG.5

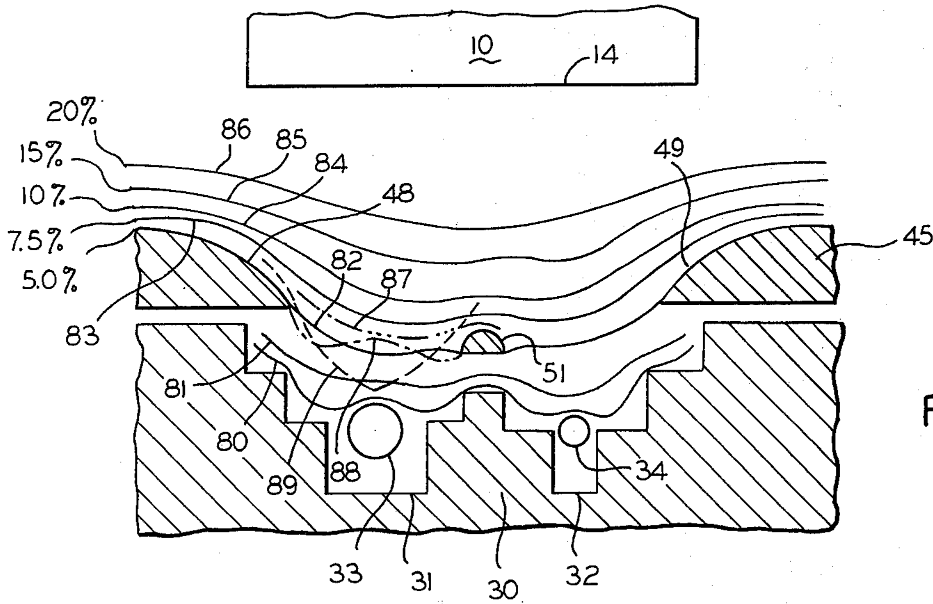


FIG. 6

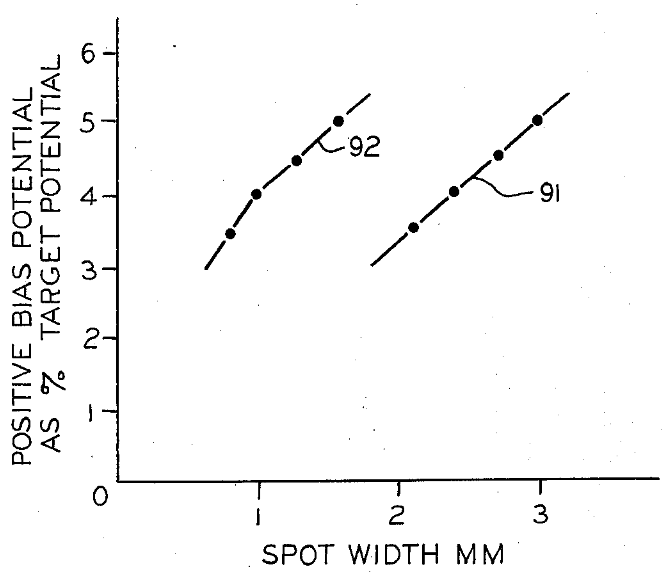


FIG. 7

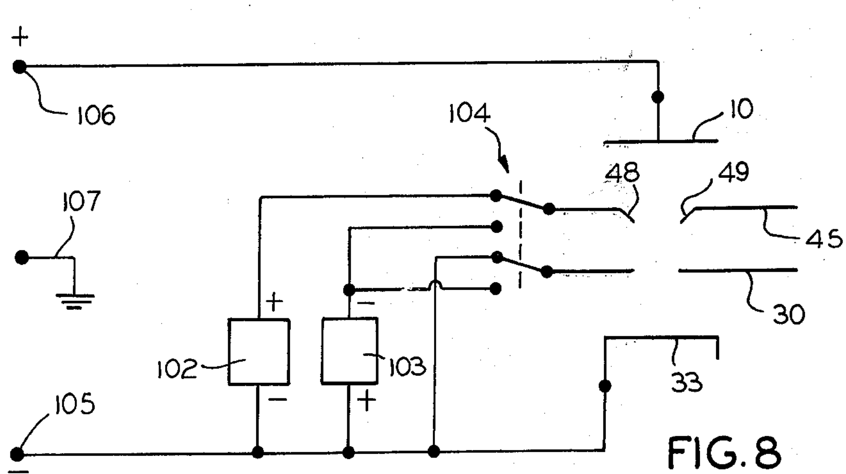


FIG. 8

LENS-GRID SYSTEM FOR ELECTRON TUBES

BACKGROUND OF THE INVENTION

This invention pertains to electron tubes and will be exemplified in an x-ray generator tube.

In connection with x-ray generators used for medical diagnosis it is customary to provide for selecting the operating characteristics such as the anode to cathode voltage, the electron beam current, the focal spot size and the conduction or exposure time interval. For high speed, short duration exposure technics such as cineradiography, the x-ray tube is usually provided with a focusing electrode to shape the electric field around the electron emitting filament for controlling the beam cross section so that a suitable focal spot is formed on the anode target. The control electrode is usually operated at cathode potential for full electron beam current and is sometimes biased negatively when electron beam cutoff is desired. The control electrode undesirably reduces the electric field strength in the vicinity of the cathode filament and an electron space charge which limits maximum available beam current results. Heretofore it has been the practice to compromise maximum obtainable beam current, minimum bias cutoff potential and focal spot size. This results in part from bias cutoff potential, as a practical matter, being a function of focal spot size. Insofar as is known, the largest focal spot size with cutoff bias capability is typically 1.2mm (millimeter) since switching bias voltages of greater than 5 kilovolts in the millisecond exposure or conduction intervals required is not practical for larger sizes. High beam currents have not generally been biased to cutoff.

Most rotating anode diagnostic x-ray tubes have one large and one small filament which are switched on selectively to produce a single focal spot size for each filament. Biasing power supplies for focusing electrodes are available which permit reduction of the width dimension of the focal spots but these have the disadvantage of reducing the available tube current by biasing the thermionic cathode toward beam current cutoff when a negative voltage is applied to the electrode for reducing focal spot size. Up to the present, continuously variable focal spot widths have not been practical nor available because of the wide variations in available beam current that would result.

In reference to prior art x-ray tubes, the difficulty of controlling focal spot size and beam cutoff with reasonably low bias voltages has placed a limitation on permissible beam current. Generally x-ray tubes are operated in a temperature or emission limited mode which is to say that beam current is controlled by adjusting filament current and, hence, filament temperature. However, the geometry of the focusing electrodes, the electrostatic field configuration and the high required biasing potentials prevailing in prior x-ray tubes militated against obtaining beam current intensities commensurate with the emissivity limits of the filament.

SUMMARY OF THE INVENTION

A general object of the present invention is to overcome the above noted disadvantages and to provide a more efficient and more readily controllable electron emission device such as an x-ray tube.

Further objects of this invention are as follows:

To permit varying the focal spot size in an x-ray tube for any practical value of target anode voltage without markedly affecting tube current;

To enable maintaining the focal spot size constant when tube current is held constant for any practical value of anode voltage;

To permit switching a high voltage x-ray tube on and off at a high rate with a low control or bias voltage;

To significantly increase beam current over that which is obtainable at corresponding cathode temperatures in prior art tubes;

To enable use of positive voltages on the control electrode or grid of an x-ray tube without substantial electron current flow in the control electrode circuit;

To provide a grid which is not imaged in the focal spot on the x-ray tube anode;

To substantially vitiate the effect of space charge in the vicinity of the emitting cathode in an x-ray tube; and

To provide a new cathode support structure which overcomes the heretofore experienced misalignment and distortion that results from cyclical heating and cooling of cathode structures.

The invention may be characterized briefly as a new lens-grid system for an electron tube such as an x-ray tube. The new lens-grid system or cathode structure comprises a metal focusing electrode in which a cup-shaped recess is formed. The recess has a pair of spaced apart bottom slots in which there are individual filaments, one for obtaining a high range of beam currents and the other for obtaining a relatively lower range of beam currents. The filaments may be energized alternately. There is the usual anode or target on which the electron beam impinges in a focal spot from which x-rays emanate. This much of the construction of the tube is known.

In a tube of the character just described, a high gradient electric field is produced between the cathode and the target anode when the latter is energized at high voltages. In diagnostic systems the anode voltage may range from 70 peak kilovolts (pkv) to 150pkv though sometimes the range extends to even lower and higher voltages. As is known, equipotential lines or surfaces of the electric field can be measured and determined or plotted between the cathode and the anode. The configuration of the various equipotentials and the potential gradient governs the focusing effect of the field. To obtain full electron beam current, the focusing cup electrode is established at the same potential as the cathode filament in which case the beam will focus on the target in a spot having predetermined width. When it is desired to cutoff the beam, the potential of the focusing electrode is made very negative with respect to the filament.

In prior art tubes, an additional control electrode or grid is sometimes interposed between the focusing electrode and the target anode to obtain further control over electron beam current. A major disadvantage of this is that if grid biasing potential goes positive with respect to the cathode excessive grid current flows which results in overheating the grid. Hence, prior control electrodes were usually operated at some negative voltage with respect to the filament to avoid grid current in which case beam current could not be drawn up to the temperature governed limits of emissivity of the cathode or filament because of space charge limitations. Prior art control grids also adversely affected focal spot quality because the grid was imaged in the focal spot.

In the new lens-grid system described herein, a control electrode is located near the focusing electrode. The control electrode surface most remote from the filament in the anode direction is made coincident with and in substantial contour conformation with a particular equipotential. In its preferred form, an equipotential representing a predetermined potential, such as a relatively low percentage of the cathode to anode voltage, is chosen. When this low percentage of the cathode to anode voltage is applied to the new control element in reference to the cathode, the electron beam from the chosen filament focuses on the anode with a predetermined focal spot size since the trajectories of the electrons are not changed. Variations of the potential on the control electrode, however, permit enlarging or decreasing the width dimension of the beam and focal spot without requiring any anode potential change and without significantly affecting the total electron beam current. When the control electrode is made about half as negative as was heretofore required, the beam current is completely cut off. The control electrode has no grid wires which could be imaged in the focal spot.

How the foregoing and other more specific objects of the invention are achieved will be evident in the ensuing description of an illustrative embodiment of the invention taken in conjunction with the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal section view of a rotating anode x-ray tube with some parts omitted and which incorporates the new lens-grid system;

FIG. 2 is a plan view of the cathode structure or lens-grid system taken along the line 2—2 in FIG. 1;

FIG. 3 is a section taken along the line 3—3 in FIG. 2;

FIG. 4 is a section taken along the line 4—4 in FIG. 2;

FIG. 5 is a section taken along the line 5—5 in FIG. 3;

FIG. 6 is a schematic representation of the new lens-grid structure and showing the configuration and position of some of the equipotential lines;

FIG. 7 is a graph showing the relationship between the positive bias potential on the control electrode versus the focal spot width for two different focal spot sizes in a tube which uses the principles of the invention; and

FIG. 8 is an electric circuit diagram for an x-ray tube in which the invention is incorporated.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. 1 shows an x-ray generator or tube in which the new lens-grid structure is used. The tube comprises a target or anode **10** which is mounted on a rotor **11** that is internally journaled for rotation on a stem **12**. An extension **13** affords a place for connecting an anode voltage supply line. Anode **10** has a beveled electron impact surface **14** on which an electron beam is focused in a spot from which x-rays emanate. Spaced from target **10** is the new cathode structure or lens-grid which is generally designated by the number **15**. The cathode structure **15** is supported on a mounting device **16** that has a base annulus **17** whose edges are sealed into the ends of an annular reentrant glass section **18** that forms part of the evacuated x-ray tube envelope. The midregion of the envelope comprises a thin metal shell **19** that is provided with a thin window **20**, which may be metal or glass, through which the useful x-ray beam emanates from the focal spot on target surface **14**. Metal section **19** is sealed at one end into a glass tubular element **21** which joins sealingly at **22** with a mounting ferrule **23** for the rotating anode structure. The conventional field coils for inducing rotor **11** to rotate are omitted from FIG. **1**.

Refer now to FIGS. 2–5 for a more detailed description of the cathode structure or lens-grid system **15**.

In FIG. 3 it is apparent that the structure comprises a metal body **30** of substantially circular configuration. Body **30** is herein called a first focusing electrode. Focusing electrode **30** may experience as high as about 800° C during tube operation so it is desirable to make the body of a suitable temperature resistant metal such as nickel or molybdenum although other suitable refractory metals may be used. The upper portion of electrode **30** is provided with a pair of slots **31** and **32**. Slot **31** accommodates a large or heavy current filament **33** and slot **32** accommodates a smaller lower current filament **34**. The filaments are electrically isolated from the focusing electrode. The slots may be spaced symmetrically from a diametral line that runs across the top of electrode **30** in a direction normal to the drawing where the numeral **35** is affixed in FIG. **3**. Slot **31** has diverging stepped walls **36** and **37** whose configuration has an effect on electrostatic field and equipotential line distribution in the vicinity of filament **33**. Similarly, slot **32** has divergent stepped side walls **38** and **39** which serve the same purpose. The open space between the topmost projections **40** and **41** in electrode **30** is characterized as a focusing cup or focusing electrode. In a single filament tube the diverging walls of the focusing cup recess would be symmetrical to the filament.

The structure is also provided with a second electron permeable lens-grid electrode that is generally designated by the number **45** and is supported from electrode **30**. Electrode **45** is preferably cylindrical and has an annular side wall **46** and substantially planar portion **47**. Portion **47** has a diametral or transverse slot in it and the sides or edges **48** and **49** of this slot diverge outwardly from each other with a particular contour or configuration that will be discussed in more detail later. The slot is generally designated by the number **50**. A small rodlike element **51**, which in this case is semicircular in cross section, extends lengthwise of the slot **50** and along its midline. The rod **51** should be as flat and thin as possible but it is made semicircular to obtain requisite strength. As can be seen in FIG. **2**, rod **51** has one end **52** spotwelded to annulus **46** and has its other end **53** overlaid by a metal strip **54** whose opposite ends are also spotwelded to wall **46**. Thus, rod **51** is restrained from being removed but it can expand lengthwise under strip **54** when it is subjected to intense heat without developing internal stresses that would otherwise deform it. Rod **51** participates in establishing the electrostatic field configuration involved in focusing and controlling each of the separately selected electron beams.

It is evident in FIGS. 3 and 4 that the annular wall or rim **46** of control electron **45** is in concentric spaced relationship with the radially extending portion **55** of electrode body **30**. Thus, an annular gap **56** is formed between portion **55** and wall **46** to isolate the control element 45 electrically from electrode 30. There are four equiangularly spaced ceramic pins 57–60 extending from holes 61 in electrode 30. These pins enter holes 62 in the control electrode annular wall 46 and the pins are constrained to remain in the holes by a surrounding circular metal band 63 which is inset into the outer periphery of wall 46 and fastened thereto such as by welding. The pin support construction affords control electrode 45 and electrode 30 an opportunity to expand and contract thermally without generating undue internal stresses in either of these parts. An advantage of the construction is that it obviates the need for matching the thermal expansion coefficients of the control element and focusing cup body in which case a wider choice of metals for making these components is allowed.

As can be seen in FIG. 4, electrical connections to filament 34 are made through ceramic bushings 67 and 68 through which lead wires 69 and 70, respectively, extend to join the ends of filament 34. The leads for large filament 33 are also extended through a pair of ceramic bushings one of which, 71, is visible in FIG. 3.

Refer now to FIG. 6 for a discussion of the functional features of the lens-grid system. This FIGURE shows schematically the geometrical relationship of the focusing electrode 30, the control electrode top surface 45, the electrode recess dividing rod 51 and the anode 10 with its electron impact target surface 14. Filaments 33 and 34 are shown in their slots 31 and 32, respectively. Some of the electrostatic equipotential lines between the cathode structure and the anode are also illustrated. Note that the longitudinal axes of the filament wire coils 33 and 34 are in parallelism with electron impact surface 14 of anode 10 in FIG. 6. It is to obtain this parallelism that the cathode structure 15 in FIG. 1 has its face nearest target surface 14 at an angle with respect to the longitudinal axis of the tube. In FIG. 1 the longitudinal axes of filaments 33 and 34, not visible in this FIGURE, extend generally radially from the center of the x-ray tube or in the radial direction of the target. If the filament axes and target surface 14 are grossly nonparallel electrostatic field and equipotential symmetry would be lost when control voltage is varied. Dividing rod 51 is also present in FIG. 6. As suggested earlier, rod 51 should preferably be flat and as thin as possible so as to lie in a plane coincident with the plane of the equipotential surface which represents a potential equal to a predetermined percent of the cathode to anode potential.

In FIG. 6 the solid equipotential lines 80–86 are those that exist when the lens-grid 45 is biased to a potential equal to the equipotential value of the line that coincides with the contour of its surfaces 48 and 49. As explained earlier, when this condition exists, the electron beam emitted from either of the cathode filaments 33 or 34 will focus on anode surface 14 with a predetermined spot size and the trajectory of the electrons will not be affected by the selected equipotential. The particular equipotential plot shown in FIG. 6 represents the case where 5% of the cathode to anode voltage is applied between lens-grid 45 and the filaments 33 and 34. The values of the equipotential lines in terms of percent of cathode to anode voltage are also applied to solid lines 80–86. Equipotential lines between 20% of cathode to anode voltage and 100% are omitted from the plot in FIG. 6. The omitted lines gradually become more straight than the 20% line 86 and eventually become substantially parallel to the anode surface 14 and to each other. The equipotential plot has been obtained by methods that are familiar to those skilled in the electron tube arts and need not be described in detail.

In FIG. 6, the lens-grid 45 could also be formed to have its contoured surfaces 48 and 49 and the straighter surfaces confluent therewith to coincide with some other equipotential line such as the 7.5% line or something under 5% such as the 4% or 3% lines which are not shown. In any case, within limits, it is necessary to apply to control electrode 45 a bias potential equal in value to the equipotential to obtain the result that the trajectories of the electrons traversing the field will not be altered by the equipotential surface coincident with the surface of the lens-grid. Practically, it is desirable to locate control electrode 45 on an equipotential corresponding in value with a bias potential in the range of 1 to 15% of the applied cathode to anode voltage. Choosing a higher than 15% equipotential would require operating at unduly high bias voltage.

In FIG. 6 the normal 6% equipotential existing when 5% bias voltage is applied to lens-grid 45 is shown partially as a dash-dot-dot line 87. The purpose is to illustrate what happens when the bias voltage on the lens-grid is changed to 6% of the cathode to anode voltage in a case where the contour of the lens-grid coincides with the 5% equipotential. Thus, when a 6% bias voltage is applied to the lens-grid, the 6% equipotential shifts to partially follow the contours of surfaces 48 and 49 which are equipotential and to further assume the shape of the dash-dot line 88. The actual result is that cathode filament 33 comes under a more positive influence. In other words, the field strength presented to the emitting filament 33 or 34 is increased and an increase in the maximum available beam current results provided the filament is not being operated in an emission or temperature limited mode. However, x-ray tubes are usually operated in a filament temperature limited emission condition and there is usually substantial space charge but the operative effect of increasing the positive potential on lens-grid 45 according to the invention permits changing focal spot width without significantly altering target current or target voltage which is a desired objective of the invention.

An important aspect of having the contour of the lens-grid electrode 45 coincide with a selected equipotential is that positive control voltages may be applied to the lens-grid 45 without substantial electron current flowing to it. Thus, in accordance with the invention, beam current is not diminished as a result of grid control nor is consequential grid heating experienced as was the case in prior art grid controlled tubes. By way of example, in an x-ray tube constructed in accordance with the invention, a grid current of only 600 microamperes was measured when the tube was conducting 1,800 milliamperes of electron current between the cathode and anode even though the lens-grid was positive with respect to the active filament.

Besides permitting beam width control by varying the positive bias potential on lens-grid 45, the new lens-grid system permits complete current cutoff from the x-ray tube when it is operating at high cathode to anode potentials. As was implied earlier, it is believed that heretofore the largest focal spot size with cutoff bias capability was typically 1.2mm size since switching bias voltages of greater than 5 kilovolts in the millisecond exposure times was considered impractical. Typically in the prior art, at cathode to anode voltages of 75 kvp, a negative bias voltage of 5 kilovolts was required to cutoff a focal spot size of 1.2mm. With the present invention, complete beam current cutoff is obtained with 3.5 kilovolts negative bias on the lens-grid **45** with respect to the filament at a cathode to anode voltage of 150 kvp for any focal spot size. Moreover, to typify the effect of positive grid control in accordance with the invention, a variable spot width capability of less than 0.6 to greater than 2.0mm in a single tube was obtainable. Spot width could be varied with unsubstantial change in beam current over most of the useful operating range.

FIG. **7** is a graph of positive bias potential applied to the lens-grid in terms of percent of voltage between the cathode and anode of the tube versus spot width in millimeters in which tube the new lens-grid system was used. Note that the large spot width produced by the beam from filament **33** was varied from under 2mm to over 3mm at constant cathode to anode voltage and constant beam current. The small focal spot which is represented by line **92** was varied from about 0.5 to over 2mm where the bias potential was changed from about 3 to 5.5% of cathode to anode voltage.

The means for selecting one or the other of the filaments are not shown but it will be understood by those skilled in the art that when a high current beam is desired such as for various radiographic technics, large filament **33** will be energized. When low beam current is desired such as for fluoroscopy, filament **34** will be selectively energized to the exclusion of the other filament. It will also be understood that the equipotential plot shown in FIG. **6** and discussed primarily in respect to use of filament **33** is symmetrical so that what has been said applies equally as well to use of filament **34.**

It is also of interest that with a tube made in accordance with the present invention, 3,000 milliamperes of beam current were obtainable at 65 kvp anode voltage at filament temperatures equal to those at which about half of the same beam current was obtained in prior art tubes. The reason for this is that the positively biased lens-grid in accordance with the invention enables greater field influence in the vicinity of the filaments in which case the space charge effect is more nearly vitiated and this limitation in prior art tubes is removed.

FIG. **8** is a schematic diagram for illustrating how an x-ray generator using the new lens-grid is operated. Only one cathode or electron emitter **33** is shown for the sake of simplicity since the electrical connections are the same for the other selectable emitter **34.** The target anode is marked **10,** the focusing cup electrode is marked **30** and the lens-grid electrode is marked **45** as they are in the previously discussed figures. Two bias voltage sources **102** and **103** are shown in block form. These sources are connected to the electrodes through a double pole, double throw switch **104** which is symbolized as a mechanical switch although various types of switches may be used. Potential for accelerating electrons from cathode **33** to target anode **10** may be applied across terminal **105** and **106** with the potential on terminal **105** being negative and below ground potential by as much as the absolute value of the potential on terminal **106** is positive or above ground potential. A ground or midpoint potential terminal is shown. Midpoint is obtained from the center tap of the high voltage transformer which is not shown since it is of a known type. The metal shell **19** of the x-ray tube shown in FIG. **1** may be established at ground potential.

In FIG. **8,** when switch **104** is in the state in which it is depicted, bias source **102** makes lens-grid **45** positive with respect to cathode **33** and focusing electrode **30** and full electron beam current flows to anode **10.** Adjustment of bias source **102** permits attainment of different selected focal spot sizes in accordance with the level of positive potential on lens-grid electrode **45** as described in detail hereinbefore.

Switching switch **104** to its alternate state applies voltage from bias source **103** to lens-grid **45** and focusing electrode **30** at the same time so that these electrodes are both negative with respect to emitter **33** and electron flow to anode **10** is cut off. Typically, a negative potential of about 3500 volts will effectuate cutoff even when the anode **10** to cathode **33** potential is 150 kvp.

Although an illustrative embodiment of the new lens-grid system and its operating characteristics have been described and a new mode of mounting a lens-grid has been described in considerable detail, such description is intended to be illustrative rather than limiting for the invention may be variously embodied and is to be limited only by interpretation of the claims which follow.

We claim:

1. An x-ray generator comprising:

a. cathode means including electron emitter means whose electron emission is limited and controlled primarily by the selected temperature of said emitter means and whose electron emission available for forming an electron beam is subject to further limitation by space charge in the vicinity of said emitter means,

b. said cathode means including first field forming electrode means adjacent said emitter means for focusing emitted electrons into a beam in response to a potential on said first electrode means,

c. target anode means spaced from said emitter means and having a surface arranged to be impacted by said beam to produce x-radiation, said surface being at the 100% equipotential and said emitter means being at the 0% equipotential among equipotentials caused by applying a positive potential to said target anode relative to said emitter means,

d. second control elecrode means adjacent said first electrode means and substantially closer thereto than to said 100% equipotential for altering the electric field in the vicinity of said space charge such that additional electrons therefrom are made available for forming said beam and only a reduced amount of space charge remains when a predetermined potential is applied to said second electrode means that is positive relative to said cathode means, said predetermined potential also establishing the width of said beam,

e. said second electrode means being the sole electrode between said field forming electrode means and said target anode means and comprising an element having a surface disposed generally transversely to said beam and having an opening for passage of said beam,

f. said last named surface and portions of the margins of said opening being other than planar and coinciding and conforming substantially with a selected equipotential which is other than planar and has a value in the range of 1 to 15% of the potential difference between said target anode and said cathode means,

g. application of said predetermined positive potential to said second electrode means having a value equal substantially to the value of said selected equipotential effectuating said reduced space charge and maintaining the trajectories of said electrons in said beam to follow substantially the path they would follow in the absence of said second electrode means and varying said predetermined potential unsubstantially causing a change in the width of said beam with minor alteration of said space charge such that the intensity of said beam is still limited and controlled primarily by the temperature of said emitter means and is substantially independent of the potential on said target anode.

2. The device set forth in claim **1** wherein:

a. said first electrode means has a plurality of holes therein,

b. said second electrode has a portion surrounding said first electrode means in spaced relation therewith, said second electrode means having holes presented toward the holes in said first electrode means, and

c. insulating pin means extending from within said holes in said first electrode means to within holes in said second electrode means for supporting said second electrode means from said first electrode means.

3. The invention set forth in claim **1** wherein:

a. said first field forming electrode means has at least two transverse recesses and oppositely diverging side walls defining the same for shaping said electric field,

b. said emission means comprising an elongated filament in each of said recesses.

4. The invention set forth in claim **1** wherein:

a. said second control electrode means has at least two transverse recesses and oppositely diverging side walls defining the same for shaping said electric field,

b. said emission means comprising an elongated filament in each of said recesses, and

c. rod means coextensive with said opening and intermediate the sides thereof and between said emission means and disposed substantially on said selected equipotential.

5. The invention set forth in claim **1** wherein:

a. said second control electrode is located substantially coincident with an equipotential whose value is in the range of 1% to 15% of the potential between said cathode and anode means.

6. An electron discharge device comprising:

a. an anode and cooperating cathode means,

b. said cathode means including a first field forming electrode means and means for emitting electrons,

c. a second electrode means electrically isolated from and spaced from said first electrode in the direction of said anode and disposed generally transversely to the path for an electron beam from said means for emitting electrons to said anode,

d. said second electrode means comprising a surface having an opening therein which surface substantially conforms to a selected equipotential through which electrons from said emitting means may pass with the trajectories of said electrons being substantially unaltered whereby when said second electrode means is energized with a positive potential substantially equal to said equipotential it will permit substantially unintercepted passage of electrons through said opening,

e. said first electrode means having a cylindrical portion and said second electrode means having a portion circumjacent to said first electrode means and in spaced relationship therewith, and

f. a plurality of insulating members substantially equiangularly spaced around said first electrode means and having corresponding ends engaged with said first electrode means and opposed corresponding ends engaged with said cylindrical portion of said second electrode means.

7. An x-ray generator comprising:

a. target anode means and a first electric field forming electrode means spaced therefrom,

b. electron emission means proximate to said first electrode means for providing a beam of electrons to impinge on said target anode means for producing x-radiation,

c. second control electrode means interposed between said first electrode means and said target anode means and including a conductive member disposed generally transversely to the path of said electron beam and having an opening therein, said member having a surface presented toward said target anode means,

d. said opening being defined by a margin surface which together with said surface of said member substantially conform with a selected equipotential existing when there is a positive potential on said anode means relative to said first electrode means, said selected equipotential being one across which electrons may pass with their trajectories being substantially unaltered, whereby said second electrode means is adapted to be energized with a positive potential relative to said second electrode means which positive potential is substantially equal in magnitude to said selected equipotential such that it will permit substantially unintercepted passage of electrons through said opening,

e. said first field forming electrode means having at least two recesses each of which has generally diverging sides,

f. said electron emission means being disposed in said recesses, respectively, and

g. a conductive rod means extending across the opening in said second electrode means and aligned intermediately of said recesses, said rod means being electrically connected with said second electrode means.

8. An x-ray generator comprising:

a. target anode means and a first electric field forming electrode means spaced therefrom,

b. electron emission means proximate to said first electrode means for providing a beam of electrons to impinge on said target anode means for producing x-radiation,

c. second control electrode means interposed between said first electrode means and said target anode means and including a conductive member disposed generally transversely to the path of said electron beam and having an opening therein, said member having a surface presented toward said target anode means,

d. said opening being defined by a margin surface which together with said surface of said member substantially conform with a selected equipotential existing when there is a positive potential on said anode means relative to said first electrode means, said selected equipotential being one across which electrons may pass with their trajectories being substantially unaltered, whereby said second electrode means is adapted to be energized with a positive potential relative to said second electrode means which positive potential is substantially equal in magnitude to said selected equipotential such that it will permit substantially unintercepted passage of electrons through said opening,

e. said second electrode means includes an annular part which is enclosed on one end by said transversely disposed member, said annular part surrounding said first field forming electrode means and being in substantial concentric spaced relationship therewith,

f. a plurality of insulating pin means which each have corresponding ends engaged with said first electrode means and opposed corresponding ends engaged with said annular portion of said second electrode means for supporting said second electrode means from said first electrode means.

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