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Rate, Jr. et al.

[11] **3,882,339**

[45] **May 6, 1975**

[54] **GRIDDED X-RAY TUBE GUN**

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[73] Assignee: **General Electric Company,** Schenectady, N.Y.

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[21] Appl. No.: **479,746**

[52] **U.S. Cl.** **313/60;** 313/55; 313/410; 313/449

[51] **Int. Cl.** **H01j 35/06**

[58] **Field of Search** 313/55, 56, 60, 410, 449

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Primary Examiner—R. V. Rolinec
Assistant Examiner—Darwin R. Hostetter
Attorney, Agent, or Firm—Ralph G. Hohenfeldt; Fred Wiviott

[57] **ABSTRACT**

An X-ray generator has a Pierce type electron gun comprising an electron emissive cathode, field shaping electrodes connected thereto, a first accelerating anode spaced from the cathode and an X-ray target anode spaced from the accelerating anode for being impinged upon by a focused electron beam. Control grid means are disposed between the cathode and the first anode. The grid means are constructed such that with use of proper grid potentials, the electron beam may be selectively biased to cutoff or electrons can be withdrawn from selected areas of the cathode or from the entire cathode to produce focal spots of different sizes and various electron current magnitudes on the target anode.

8 Claims, 12 Drawing Figures

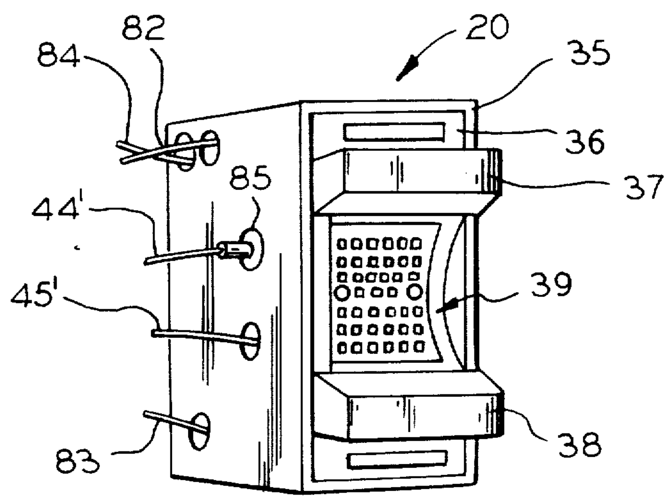

FIG.1

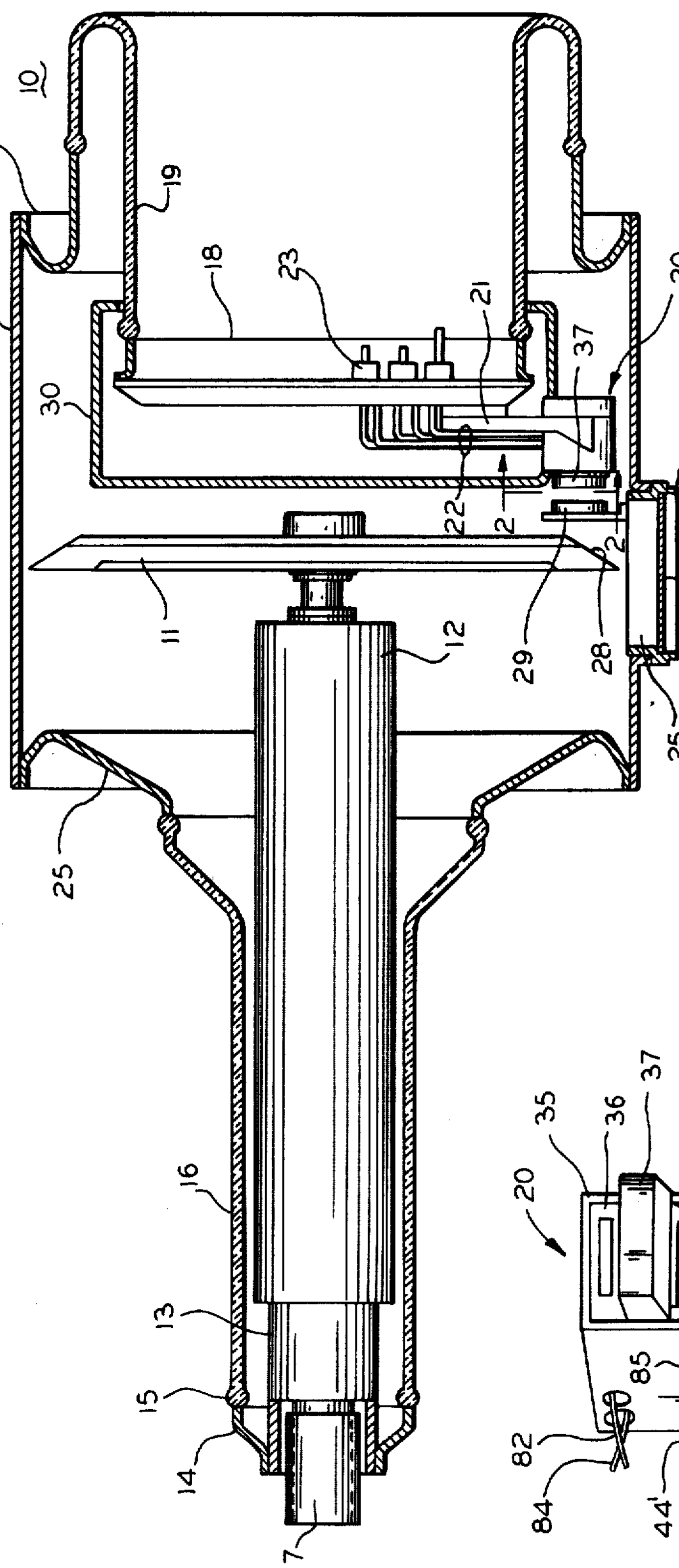
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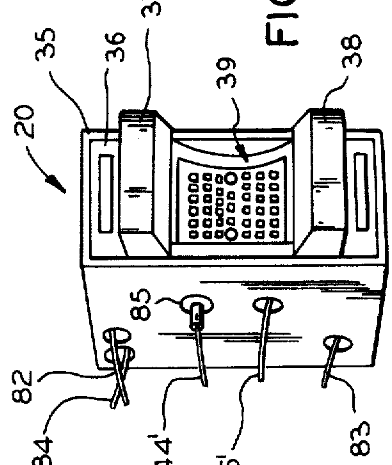
FIG.2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44'
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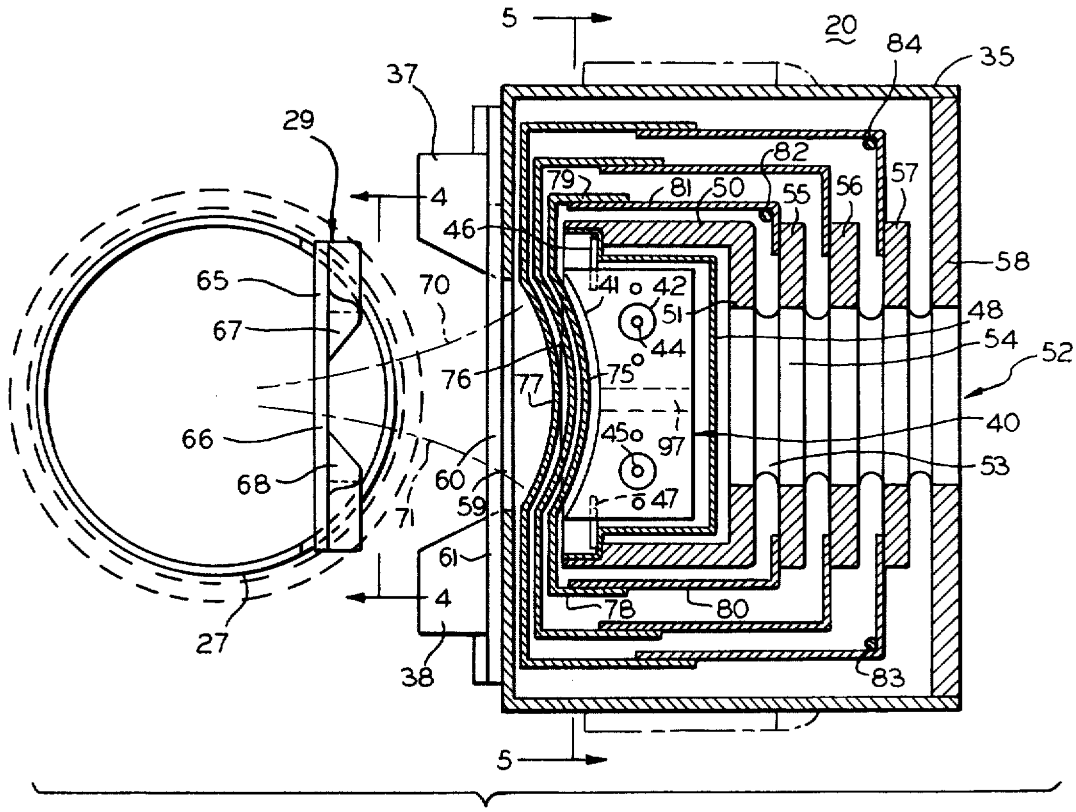
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5

FIG.3

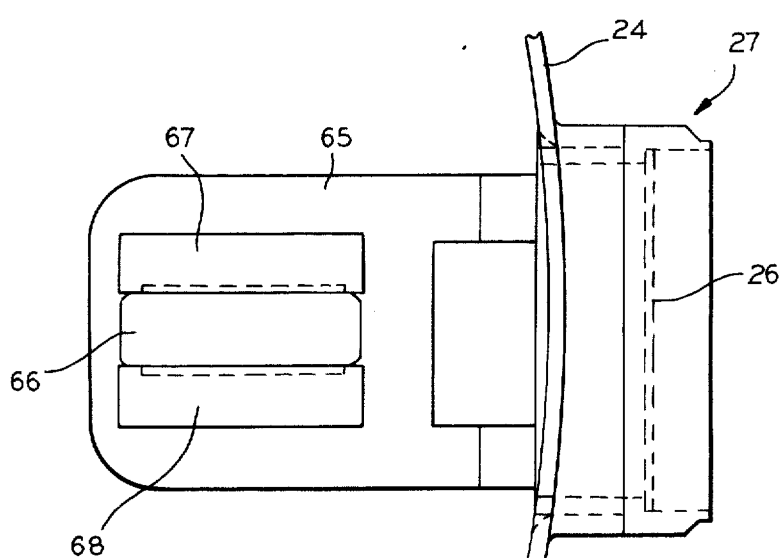
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FIG.4

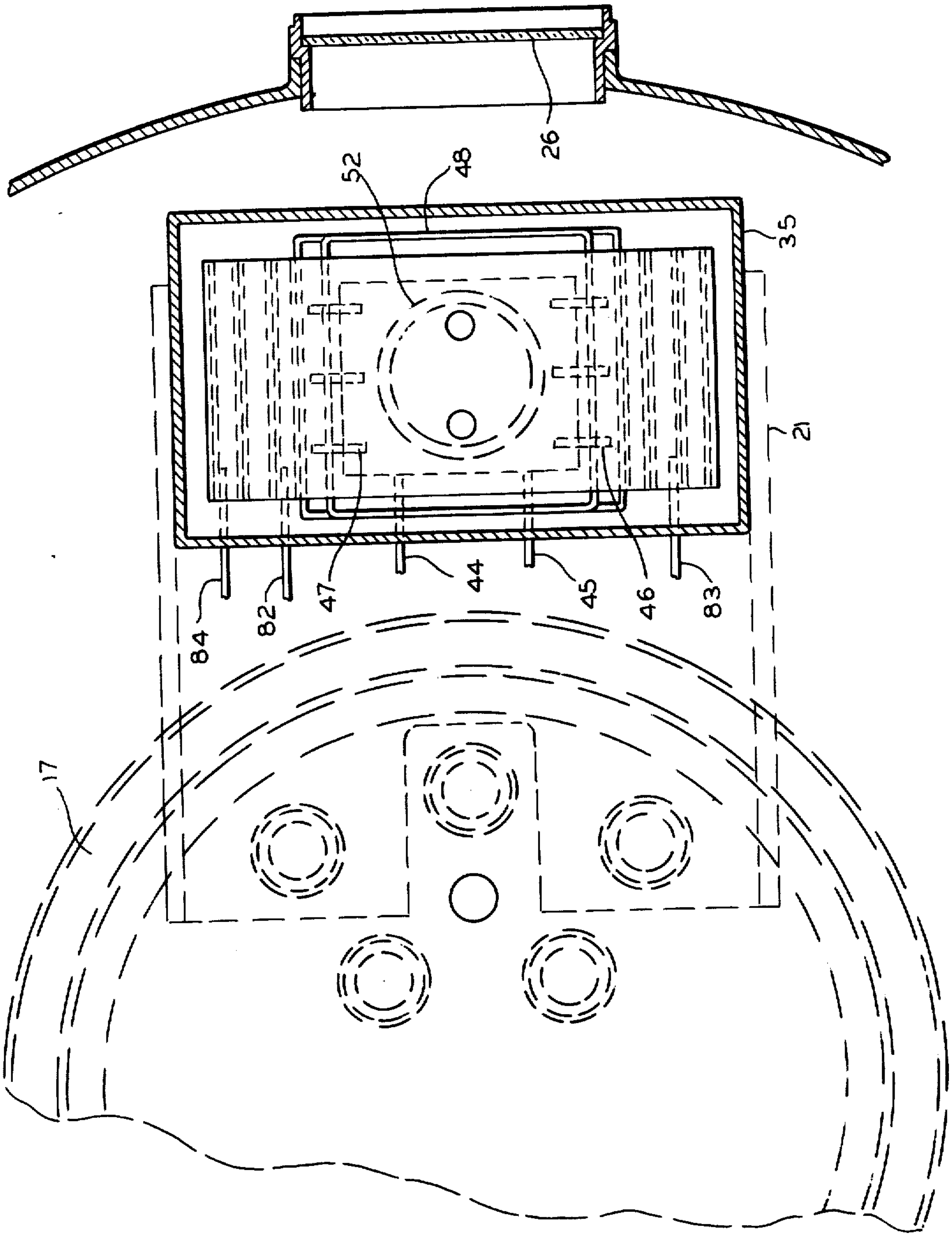


FIG.5

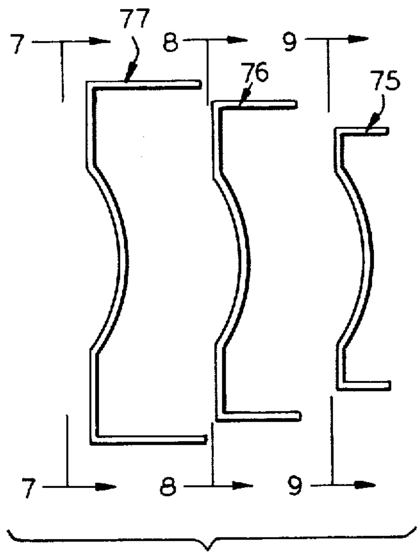


FIG.6

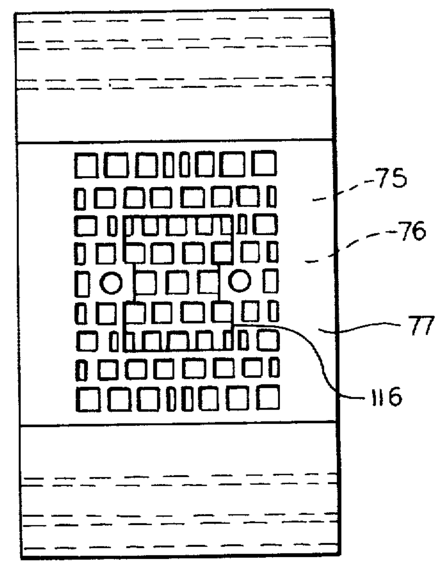


FIG.10

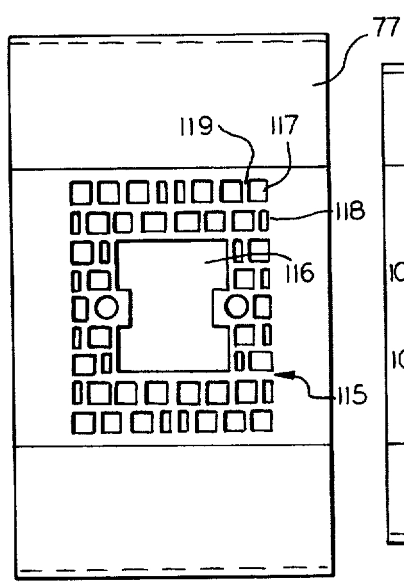


FIG.7

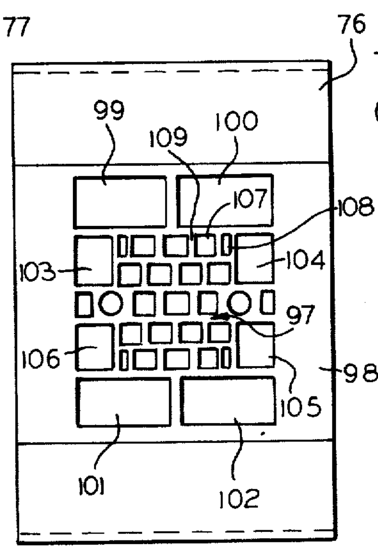


FIG.8

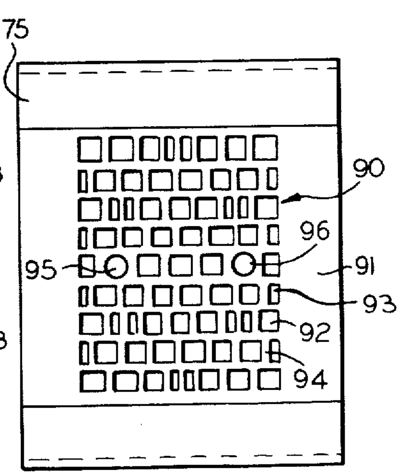


FIG.9

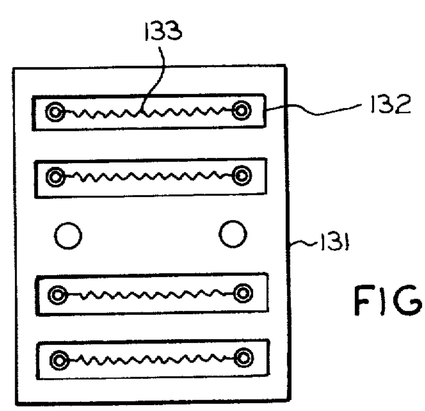
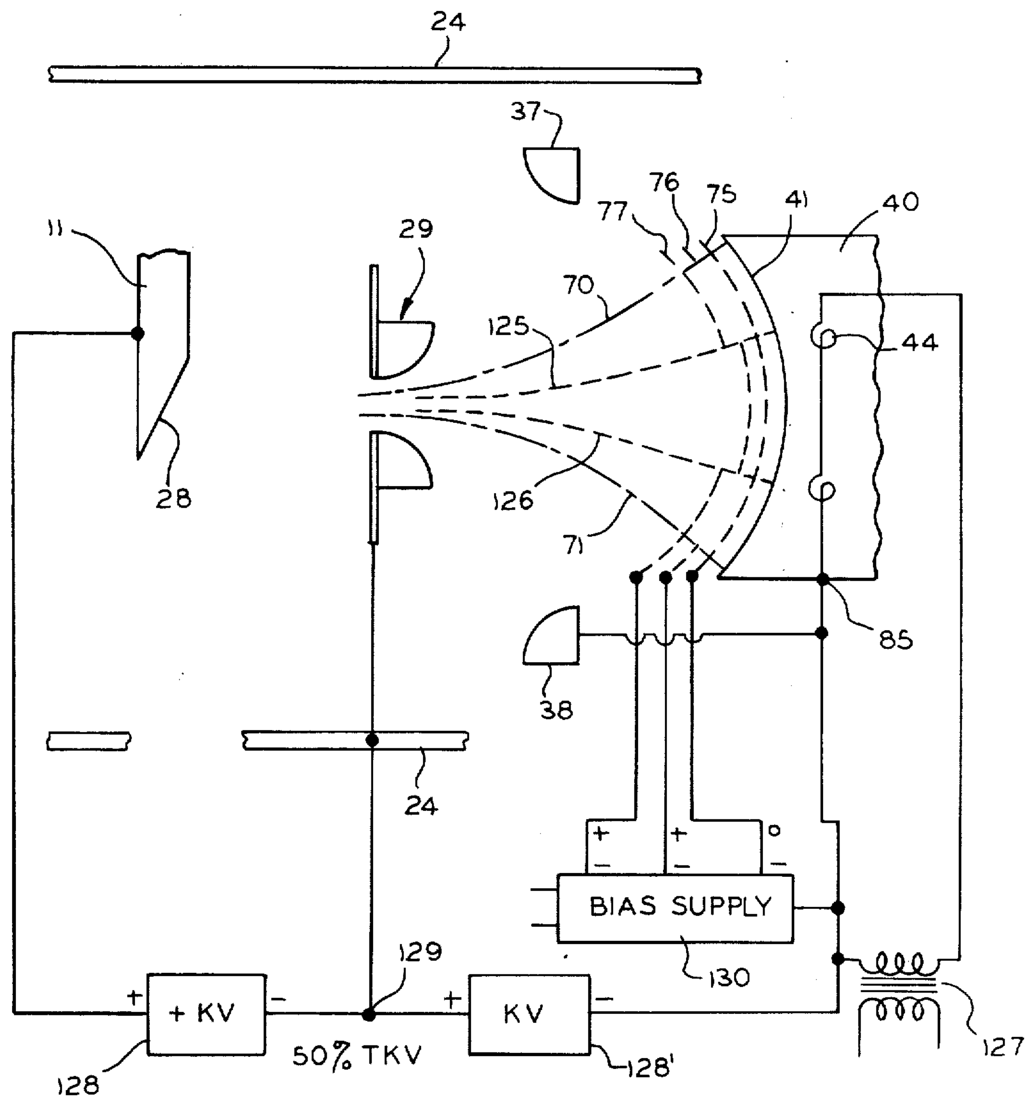


FIG.11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37
76
75
41
40
77
11
29
70
125
44
28
126
71
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o
BIAS SUPPLY
129
130
+
+ KV
−
+
KV
−
50% TKV
128
128'
127

FIG.12

GRIDDED X-RAY TUBE GUN

BACKGROUND OF THE INVENTION

The invention pertains to X-ray generators or X-ray tubes as they are commonly designated. The invention is particularly concerned with controlling the electron beam current magnitude and with selecting beam focal spot size in an X-ray tube.

The well-known Pierce type of electron gun has been used in various electron tubes including X-ray tubes for producing a focused electron beam that impinges on a traget anode. This type of gun comprises an electron emissive cathode having a curved emitting surface and electric field shaping or focusing electrodes connected to the cathode and located near it. The field causes the emitted electrons to converge. Further along the electron beam path there is an apertured accelerating anode which increases the energy of the electrons such that most of the electrons in the convergent beam pass through the aperture and impinge on the X-ray target anode.

Pierce guns can be designed for producing high electron beam currents and are desirable for use in X-ray tubes for that reason. However, the beam current magnitude of such guns is not ordinarily controllable with a grid because the grid would have to be at a positive potential to avoid distortion of the electric field produced between the accelerating anode and the cathode. However, if the grid is at a positive potential with respect to the electron emitter, the grid will collect electron beam current. The resulting disadvantages are heating of the control grid and reducing beam current, thereby reducing radiation output of the X-ray tube.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a Pierce type electron gun in an X-ray generator with grid control capability without experiencing the above mentioned disadvantages.

Other objects of the invention are to provide in an X-ray tube, a control grid system which permits electron beam cutoff with low bias voltage, which enables use of positive grid voltages without significant grid current flowing, and most importantly, which enables selection of emission areas on the cathode so that various focal spot sizes may be selectively produced on the X-ray target without adversely affecting the electric field produced by the Pierce anode.

A further object is to obtain beam current magnitude control independently of focal spot size control for various focal spot sizes.

Another more specific object of the invention is to enable operating an X-ray tube using a Pierce gun such that the apertured accelerating anode of the Pierce gun may be at very high potential with respect to the emissive cathode and yet be at zero or ground potential in reference to metallic parts comprising the envelope of the X-ray tube.

In general terms, the new X-ray tube design is characterized by an electron gun having a curved thermionic cathode surface or filaments arranged in an arc from which electrons are emitted. Focusing electrodes are on opposite sides of the beam path close to the cathode and at the same potential as the cathode. The apertured accelerating anode of the gun is positioned between the cathode and X-ray target anode as in the conventional Pierce gun arrangement discussed earlier. In accordance with the invention, however, there are control grid means located adjacent the electron emissive cathode. The first grid nearest the cathode covers its entire area. At least one following grid element has electrically isolated reticulated or gridded areas. The applied potentials on the different grid areas are chosen such that electrons can be extracted from the entire cathode area or from selected areas in various combinations for producing different beam current magnitudes and focal spot sizes or the grid elements may be driven negatively for cutoff of the electron beam. In addition, any of the grid areas other htan the one nearest the cathode may be driven positively without significant flow of grid current and without adversely affecting the shape of the electric field produced by the accelerating anode.

How the above mentioned objects and other more specific objects of the invention are achieved will appear in the following more detailed description of an illustrative embodiment of the invention which will be set forth in reference to the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a lonitudinal section view taken through a typical X-ray generator in which the new electron gun device is incorporated;

FIG. **2** is a perspective view of a cathode structure isolated from FIG. **1** as viewed in the direction of the arrows **2—2** in FIG. **1**;

FIG. **3** is a sectional view of the cathode structure associated with the accelerating anode;

FIG. **4** is an elevation view of the accelerating anode and X-ray generator window structure;

FIG. **5** is a section of the cathode structure taken on a line corresponding approximately with **5—5** in FIG. **3** which structure is shown mounted in a fragmentarily illustrated X-ray generator;

FIG. **6** is a side view of the control grids which normally nest within each other in accordance with an embodiment of the invention;

FIG. **7, 8** and **9** are frontal views of the control grids taken in directions corresponding with the lines **7—7**, **8—8** and **9—9**, respectively, in FIG. **6**;

FIG. **10** is a front elevation view of the control grid assembly;

FIG. **11** is an alternative embodiment of a thermionic electron emitter which may be employed in the invention, and

FIG. **12** is a schematic diagram of essential components of an X-ray generator incorporating the invention and the electric circuitry associated therewith.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** shows a rotating anode X-ray generator **10** which is typical of electron discharge devices in which the invention may be incorporated. Generator **10** comprises an X-ray target or anode **11** which is fixed on a rotor **12**. The rotor is journaled internally on a stationary member **13** which is mounted on a ferrule **14**. The ferrule is sealed at **15** into the end of an annular glass member **16** which is part of the envelope of the X-ray generator. A terminal connector **17** is provided for enabling energization of anode **11** with a high potential.

In spaced relationship with anode **11** is disk-like cathode support member **18** which is in the nature of a vacuum tight diaphragm. Member **18** has a ferrule whose rear edge is sealed into the end of a reentrant glass member **19** which is part of the generator envelope. A cathode structure, generally designated by the number **20**, comprising a part of the new X-ray tube electron gun is mounted on a pair of arms **21** which are fastened to support member **18**. Several electrical leads which are collectively designated by the number **22** extend from the cathode structure and pass through sealed insulating bushings **23**. A conventional shield **30** is supported from member **18** for well-known purposes.

The two end members **16** and **19** comprising the envelope and made of glass or other suitable vacuum impervious insulating material are sealed to an intermediate annular metal shell **24** by means of a pair of metal rings **25** and **26**, respectively. For reasons that will be discussed more fully later, cylindrical metal shell **24**, in accordance with the invention, is established at a potential or reference point midway between the potential that is applied to anode **11** with respect to cathode **20**.

Shell **24** is equipped with an X-radiation exit window assembly **27** constituting a generally cylindrical member that is sealed into shell **24** and has an opening **25** covered by an X-ray permeable window **26** which may be glass or metal that has a low X-ray absorption coefficient.

When the generator is operating, a beam of electrons is directed from cathode **20** to the beveled periphery **28** of target anode **11**. The electron beam is focused in a spot from which a beam of X-rays emanates as anode **11** rotates. Thus, a cone of radiation is projected through window **26**.

Note also in FIG. **1** that there is an apertured accelerating anode assembly **29** interposed between cathode stucture **20** and anode target surface **28**. As will be discussed more fully later, the electron beam from cathode structure **20** passes through the aperture of accelerating electrode **29** and finally impinges on target surface **28**. Generally speaking, a cathode structure such as **20** and an accelerating anode **29** are the principal elements of conventional Pierce electron guns. However, in accordance with the invention, the cathode structure is modified by incorporating control grid means to which potentials may be variously applied to select different focal spot sizes and beam current magnitudes and to cut off beam current completely. It will be evident that since the accelerating electrode **29** is mounted directly on metal window ring **27** which is in turn electrically connected to shell **24**, the accelerating electrode, window, ring and shell will always be at the same potential.

The general appearance of cathode structure **20** when viewed in the direction of the line **2—2** in FIG. **1** is shown in FIG. **2** where the structure is rotated 90°. Generally, the cathode structure comprises an outer metal box **35** having a front plate **36** on which there are a pair of electric field shaping or focusing electrodes **37** and **38**. In the space between electrodes **37** and **38** there are a set of control grids, in this embodiment, collectively designated by the number **39**. There are one or more such grids of different configurations behind the front grid which is apparent in FIG. **2**.

FIG. **3** shows the cathode structure **20** in section adjacent accelerating anode **29** which is mounted over window ring **27**. The cathode structure comprises an electron emitter **40** which is essentially a metallic block having a concave front face or emitting surface **41**. Emitter **40** is variously called a matrix emitter or a dispenser cathode. It is composed, for example, mainly of a refractory metal such as tungsten impregnated with barium carbonate to enhance its thermionic emissivity. Emitter **40** has a pair of lateral holes **42** and **43** which are occupied by filaments or heating elements **44** and **45**, respectively which, when energized, raise the temperature of the emitting surface **41** to emission temperature. Other types of emitters may also be used as will be discussed later.

The matrix type emitter **40** has embedded in it upper and lower rows of metal rods **46** and **47**, respectively, which are more evident in FIG. **5**. These rods facilitate supporting matrix emitter **40** from a shield cup **48** to which the rows of rods **46** and **47** are fastened by spot-welding, for example. Thus, emitter **40** and cup **48** are at the same potential at all times.

Cup **48** fits into and is electrically connected to a channel **50** which has a hole **51** in its back. The hole receives an end of an insulating post **52** which has several annular grooves such as **53** that are spaced apart from each other by full diameter portions such as **54**. The latter portions **54** are metallized on their outer peripheries to facilitate bonding with an element such as channel **50** at the interface of hole **51** and post **52**. The grooves **53** are clear of metallization and serve as long insulating paths between adjacent conductive elements. There are a plurality of additional perforated plate members **55**, **56** and **57** bonded onto post **52** and in insulating spaced relationship from each other. Post **52** is bonded in and supported from the back **58** of the cathode structure box **35**.

The front of cathode structure box **35** has an opening **59** which is substantially congruent with an opening **60** in a plate **61** on which focusing electrodes **37** and **38** are mounted. Thus, electrons emitted from any region of the concave emitting surface **41** of emitter **40** are able to pass through aligned holes **59** and **60** in their path for impingement on the target surface **28** of rotating anode **11**.

The accelerating anode **29** in FIG. **3** may be variously constructed but in this case it comprises a plate **65** having a slotted opening **66** on opposite sides of which there are elongated electric field shaping electrodes **67** and **68**. When the cathode is operated to produce a beam of electrons for impingement on beveled target surface **28** of rotating anode **11**, the beam passes through slot opening **66** with very few electrons being defocused or attracted to electrodes **67** and **68** under prevailing operating conditions.

The main elements described thus far, that is, an electron emitter **40**, a pair of downstream focusing electrodes **37**, **38** and an apertured accelerating anode **29** are the principal elements of a conventional Pierce electron gun. With this type of gun the electrons are focused into a beam by focusing electrodes **37** and **38**. Typically the outside margins of the beam will have a configuration such as is defined between the dash-dot lines **70** and **71** in FIG. **3** where it will be seen that the beam converges sufficiently by the time it passes through aperture or slot **66** of accelerating anode **29** that relatively few electrons are attracted to this first anode **29** in the beam path although anode **29** is normally held at a positive potential relative to electron emitter **40** when the X-ray generator is conducting. A desirable characteristic of this basic Pierce gun is that the electrons emitted from emissive surface **41** remain well collimated and do not have a tendency to crossover the paths of each other. A disadvantage experienced heretofore is that this type of gun was not amenable to grid control for modulating electron flow or electron beam current.

In accordance with the invention, electron beam current magnitude, the areas of emission from emissive surface **41** and, accordingly, focal spot size on the anode target are made selectable by disposing first, second and third control grids **75, 76** and **77**, respectively, in front of emissive surface **41** and between this surface and a transverse plane through focusing electrodes **37** and **38.** In this embodiment, the active regions of the grids **75–77** are concave in the same direction as emitting surface **41** and the grids are concentric with each other and spaced from and electrically isolated from each other. The curves of each of the grids **75–77** are generated from a common point that is longitudinally displaced from them along the axis of electron flow. In FIG. **3,** one may see that the first grid **75** nearest emissive surface **41** has rearwardly extending wings **78** and **79** which are spotwelded to L-shaped members **80** and **81,** respectively. Members **80** and **81** are in turn spotwelded to plate **55** which is supported from insulating post **52.** The second grid **76** is similarly mounted on elements that are spotwelded to plate **56** and the third grid **77** is mounted from plate **57.** Because these grids are electrically isolated from each other in cathode structure **20,** it is posible to apply different potentials to them on a selective basis. For this purpose grid **75** has a wire **82** welded to it and grids **76** and **77** have wires **83** and **84** welded to them. As can be seen in FIG. **2,** these wires extend through the side of the box **35** of cathode structure **20** and are part of the group of wires **22** in FIG. **1** which exit from the X-ray generator through bushings **23.** Incidentally, it will be observed in FIG. **2** that wires **44'** and **45'** extending from cathode heaters **44** and **45** also extend through cathode housing **35** and form part of the group of wires **22** in FIG. **1.** Note also that heater filament wire **44'** is connected to the cathode structure housing **35** by brazing or similar process as indicated in FIG. **2** in the region of reference number **85.**

The control grids, which are collectively designated by the number **39** in FIG. **2** and are individually marked **75–77** in the other FIGURES, are shown in profile in FIG. **6** and frontally in FIGS. **7–9.** The grids are preferably made of a refractory metal such as molybdenum.

In FIG. **9** it is evident that the first grid **75,** that is, the one that is nearest to emissive surface **41** of emitter **40** has a perforated or gridded area **90** surrounded by an imperforate area **91.** Gridded area **90** could be made in the form of a large number of parallel wires extending across a single aperture in the vertical direction as viewed in FIG. **9** or parallel strips of thin metal could be used insofar as the electric properties of the grid is concerned. It has been found, however, that thin wires or strips are inclined to sag and deform when subjected to the intense heat of the adjacent thermionic emitter. Hence, in this case the gridded area is reticulated and is comprised of a plurality of square holes such as **92** and **93** in FIG. **9** separated by webs such as **94.** This provides a sufficiently open grid structure and enhances resistance to warping under thermal stress. Note that the holes **92** and **93** in every other row are aligned with each other to form columns and that the holes in intervening rows are offset laterally and form columns. This tends to merge the shadows in the focal spot which the grid would otherwise cast if they were made with their holes totally in aligned columns and rows or if they comprised parallel wires or strips.

Grid **75** in FIG. **9** is seen to have a pair of index holes **95** and **96** and the other grids shown in FIGS. **7** and **8** have similar holes equally spaced. These holes are to enable stacking the grids on dowel pins, not shown, to obtain alignment of the other grid holes when the grids are being assembled to the emission matrix **40.** As can be seen in FIG. **3,** the dowel pins, not shown, may be inserted in a pair of holes **97** and it will be understood that these pins are removed after the parts of the cathode structure are welded together.

The first grid **75** nearest to electron emission surface **41** in FIG. **3** has a gridded area **90** substantially coextensive with the area of the emissive surface. Hence, as will be discussed more fully later, when grid **75** is biased negatively with respect to emission matrix **40,** flow of electrons from any part of emissive surface **41** is inhibited.

The second grid element **76** is shown in FIG. **8.** It has a central gridded area **97** and imperforate areas **98** on each side. There are also pairs of large apertures **99, 100** and **101, 102** on opposite sides of gridded area **97** and some relatively smaller apertures **103–106** adjacent the gridded area. The small holes such as **107** and **108** and the webs such as **109** are congruent with corresponding webs and holes in first grid element **75** when the elements are in place as in FIG. **3.** In other words, if one views the grids frontally from the point at which their curvatures are generated, there is a clear line of sight down any of the small holes to the emissive surface such that there are small holes behind small holes and webs directly behind webs.

In FIG. **7** it is evident that the third grid element **77** has a gridded area **115** surrounding a large central aperture **116.** Again, the gridded area **115** is comprised of several small holes such as **117** and **118** separated by webs **119.** When grid element **77** is in place as in FIG. **3,** its small holes will align on a line of sight with the small holes in the preceding first and second grid elements but the large central aperture **116** of element **77** will be superposed over the gridded area **97** of element **76** which is shown in FIG. **8.** Moreover, the small hole area of element **77** will lie substantially over or in alignment with the apertured areas **99–105** in the FIG. **8** element **76.**

The congruency of the small holes is evident in FIG. **10** where the foremost or third grid element **77** is superposed over the preceding grid elements **76** and **75.**

A variety of gridded and apertured areas may be provided on the different control grids and more than the three grids discussed in this embodiment may be utilized. However, as described, the control grid arrangement permits selection of the area on emission surface **41** from which electrons are to be withdrawn such that emission may be obtained from selected areas or the entire area of the emitter. Briefly, if the grids are controlled such that the first grid element **75** is at the potential of the emitter, the second grid element is more positive and the third grid element is negative or at emitter potential, electrons will be withdrawn in a beam substantially equal in cross-sectional area to the gridded area of the second grid element **76,** these electrons passing through the small holes in gridded area **97** of element **76** and through the large central aperture

116 of third grid element 77 to produce a focal spot of predetermined size and current magnitude on target anode surface 28.

As another example, if the first grid 75 is at emitter potential while the second grid 76 is negative and the third grid 77 positive, the positive gridded area of the third grid will draw electrons through apertures 99–105 of the preceding grid to produce another focal spot size on the X-ray target anode in which case electrons will be withdrawn from the emissive surface over an area substantially equal to the total area of either the apertures 99–105 of element 76 or the gridded area 115 of element 77.

If grids 77 and 76 are made positive at the same time while grid element 75 is relatively negative, emission will be obtained from the entire emissive surface 41 which results in a large focal spot of maximum current magnitude.

FIG. 12 is a schematic diagram of the principal components of the X-ray generator and its associated power supplies in connection with which the operating mode of the new grid system will be discussed. Components which have been described heretofore are given the same reference numerals as in previous FIGURES.

In FIG. 12, the heaters 44 for the matrix emitter 40 are connected across the low voltage secondary winding of a transformer 127. One end of the heater coils is connected to emitter 40 at 85 and so are the parts 37 and 38 of the focusing electrodes. Thus, the focusing electrode, the electron emitter and the heater are always at the same potential. The potential for accelerating the electron beam from emitter 40 to the target anode 11 of the X-ray generator is derived from a dual high voltage rectified but not necessarily filtered power supply 128, 128'. The midpoint 129 of the high voltage power supply is connected to the cylindrical metal part 24 of the X-ray generator envelope. The accelerating anode 29 of the Pierce electrode is also connected to envelope 24 so that the accelerating electrode 29, the metal part of the envelope 24 and the midpoint 129 are always at the same potential and this is always 50 percent of the kilovoltage peak (KVP) produced between emitter 40 and anode 11 by dual voltage power supply 128, 128'. Thus, target anode 11 is always at a positive potential with respect to accelerating electrode 29 and emitter 40 is always negative with respect to the accelerating electrode by a potential of equal amplitude. By way of example, the maximum total kilovolts applied between emitter 40 and target anode 11 is usually up to about 150 kvp in which case anode 11 will be 75 kvp positive with respect to envelope 24 and accelerating anode 29 and the emitter 40 will be at 75 kvp negative with respect to the last named components.

A bias voltage supply 130 is also provided for applying potentials of proper polarity on selected control grids 75–77 in accordance with whether a large focal spot, a small focal spot or cutoff of the electron flow through the generator is desired. The magnitudes of the grid potentials also affect beam current magnitude as implied above and as will be further discussed below. As indicated adjacent the conductors leading from bias supply 130 to grids 75–77, the bias supply may be variously operated to provide positive, negative and zero voltages on the grid elements selectively with respect to emitter 40.

To illustrate the operating mode, assume that high voltage power supply 128 is turned on in preparation for an X-ray exposure whereupon target anode 11 will be at a preselected high positive potential relative to emitter 40. If during the exposure interval, the largest electron beam current focal spot is desired, the bias supply will be operated such that the first grid 75 will be biased at zero potential by connecting it to emitter 40 and the second and third grids 76 and 77 will be simultaneously biased positively to a potential in the range of 200 to 500 volts. In such case electrons will be withdrawn from the entire emitter surface 41 so that a collimated beam of electrons lying between the dash-dot lines 70 and 71 will be produced. The reason that electrons are not captured by grid elements 76 and 77 when they are relatively positive is that the electrons emitted from surface 41 flow toward the grid webs of the first grid element 75 whereupon they encounter a field which diverts them through the small holes in grid 75. The electrons are then aligned with the small holes in the centrally gridded second element 76 and with the small holes in the third grid element 77 which has only its outside margins gridded and its central area apertured.

It is also possible to obtain an intermediate size focal spot by applying a positive bias potential to the third grid 77 while the second grid 76 is maintained negative and the first grid is at zero potential. This attracts electrons from emission surface 41 in two columns one of which is defined by dash-dot line 70 and dashed line 125 and the other of which is defined by dash-dot line 71 and dashed line 126.

To obtain the smallest focal spot, by deriving emitted electrons from the center area of emissive surface 41 only, the second grid 76 is made positive such as up to 1500 volts while the third grid 77 is maintained negative in the range of 200 to 500 volts and the first grid 75 is held at zero potential. This attracts electrons from emissive surface 41 in a beam defined between dashed lines 125 and 126 in FIG. 12. The electons emitted from the central region of emissive surface 41 will again be diverted by the grid wires of first grid 75 such that they will flow through the small holes of the positively biased centrally gridded area of the second grid 76. The negative gridded outer margins of the third grid 77 will preclude emission from the area which these gridded areas cover.

Electron flow can quickly be cut off even while a high positive potential is applied between emitter 40 and target anode 11 by operating the bias supply 130 such that it applies a negative voltage on all three grids 75–77 simultaneously. Negative voltages on the grids on the order of 250 to 500 volts will sharply cut off electron flow at the highest rated cathode to anode voltages.

In X-ray generators used for diagnostic purposes, it is not only desirable to be able to control the focal spot by selecting the areas of the emitter from which electrons are withdrawn, in accordance with the above described invention, but it is also desirable to control the electron beam current magnitude and, hence, the X-radiation intensity independently of the spot size. This is accomplished by controlling the magnitude of the biasing potentials applied to the grids 75–77 as well as their polarities.

Thus, by applying a relatively high negative potential to the first grid 75 with respect to emitter 40 so as to suppress emission from its entire area, beam current can be reduced even though the second grid is positive to draw electrons from the central area or if the third grid is positive to draw electrons from the margin areas or if both grids **76** and **77** are positive to draw electrons from the whole emissive area. As the potential of first grid **75** is adjusted less negatively, beam current will increase.

Alternatively, beam current magnitude may be controlled by varying the magnitude of the positive biasing potential on whichever or both of the second **76** or third **77** grids are made positive to select emission areas. A combination of adjusting negative potential magnitude on the first grid **75** and the positive biasing potential magnitude on either or both the second grid **76** or third grid **77**, in accordance with the emission areas desired may also be used to set beam current magnitude.

The new grid control system may be used in electron emission tubes or X-ray generators which employ an electron emitter other than the matrix type **40** exemplified herein. An emitter comprised of several distributed filaments such as in FIG. **11** is an example of an alternative form. In this FIGURE there is a block **131** having a plurality of recesses such as **132** in each of which there is a filament such as **133**. This is a plan view of the alternative electron emitter comparable to looking frontally at emissive surface **41**. The front face of block **131** is similarly concave such that the filaments **133** lie on the arc of a circle. Grids such as **75–77** may be used with this emitter arrangement but it may also be desirable to modify the gridded and apertured areas of the grid elements to account for the fact that emission is from individual filaments in discrete areas as opposed to total area emission with a matrix emitter.

In summary, a new controllable X-ray generator has been described. It is distinguished by disposing a first grid in line with substantially the entire electron emissive area of an electron emitter to obtain control over the entire area when desired and disposing at least another grid means in line with this area such that various portions of said another grid means may be made selectively positive for withdrawing electrons from the entire emitter area or from corresponding selected areas of the emitter. The number of different beam cross-sectional sizes is determined by the number of electrically isolated gridded areas of the said other grid means. Beam current magnitude is controlled by the magnitude of the biasing potentials on the first grid and the subsequent isolated grid areas.

In practice, where a tungsten-barium carbonate matrix or dispenser cathode was used for emission, it was found that beam currents as high as ten amperes were obtainable and that currents of about three amperes, which is much higher than commonly found in X-ray generators, could be completely cut off with relatively small negative bias voltages being applied to the control grids. Moreover, despite certain of the control grids being driven positively under some circumstances, no consequential grid currents could be measured.

Although an embodiment of the invention has been described in considerble 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. electron emission means having a substantial electron emission area,

b. first anode means spaced from said emission means for producing X-radiation when impinged upon by electrons from said emission means,

c. second anode means having an opening and being interposed between said emission means and said first anode means, said second anode means when at a positive potential relative to said emission means producing an electric field effective to converge electrons emitted in a path from said emission means into a beam for passing through said opening to impinge on said first anode means,

d. means for selecting the portion of said emission means from which electrons are withdrawn including first grid means nearest said emission means having a gridded area substantially coextensive with the entire electron emission area, and

e. other grid means more remote from said emission means than said first grid means, said other grid means having electrically isolated gridded areas adjacent each other and generally transverse to said beam path to enable biasing said isolated areas individually or jointly at a positive potential relative to said emission means and said first grid means to thereby withdraw electrons from portions of said emissive means corresponding substantially with said isolated gridded areas.

2. An X-ray generator comprising:

a. electron emission means having a concave electron emitting region,

first anode means spaced in a longitudinal direction from the concavity of said emission means for producing X-radiation when impinged upon by electrons from said emission means,

c. second anode means having an opening and being interposed between said emission means and said first anode means, said second anode means when at a positive potential relative to said emission means producing an electric field for focusing electrons from said emission means into a beam for passing through said opening to said first anode means,

d. field shaping electrode means near said emission means and electrically connected thereto and defining an opening for electron flow therethrough,

e. means for selectively controlling the portion of said emission means from which electrons are withdrawn comprising a succession of longitudinally spaced apart grid means interposed in the electron flow path from said emission means,

f. the first of said grid means nearest said emission means having a gridded area substantially transversely coextensive with the electron flow path,

g. the second of said grid means having at least one gridded area and at least one apertured area adjacent said gridded area,

h. the third of said grid means having at least one gridded area and at least one apertured area, the apertured area of said third grid means being substantially aligned with the gridded area of said first grid means and the gridded area of said third means being substantially aligned with the apertured area of said second grid means.

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

a. said control grids are concave and substantially concentric with each other and with said electron emission region.

4. The device defined in claim **2** wherein:

a. said gridded area of said second grid means extends over the central area thereof, said one aperture being contiguous with one side of said central area and including another aperture contiguous with the other side of said central area, and

b. said aperture of said third grid means extends over its central area, said gridded area of said third grid means being subdivided into two area parts which are contiguous with opposite sides, respectively, of said central area.

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

a. said electron emission means is a dispenser cathode means.

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

a. said electron emission means comprises a plurality of thermionic filaments arranged to define said concave region.

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

a. gridded area of said second grid means lies in the central area thereof, and there is another aperture in said grid means, said one and another apertures being on opposite sides of said gridded area, and

b. said aperture in said third grid means lies in the central area thereof and said grid area is subdivided into two gridded areas lying on opposite sides of said central aperture.

8. The device defined in claim **7** including:

a. means for biasing said grid means at selected potentials relative to each other for withdrawing electrons from the central area of said emission means to obtain a relatively small focal spot of electrons on said anode means when said second grid means has a negative potential relative to said emission means, and for obtaining a relatively large focal spot on said anode when said second grid means has a negative potential and said third grid means has a positive potential with respect to said emission means, and for cutting off electron flow to said anode means when all of said grid means have a negative potential with respect to said emission means.

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