March 16, 1954 P. W. CHARTON 2,672,573

BEAM SHIFT ELECTRON TUBE

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FIG. 1.

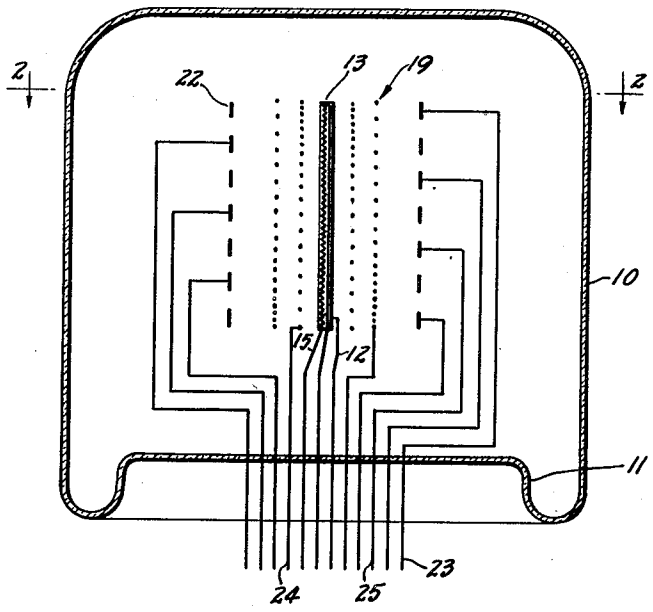
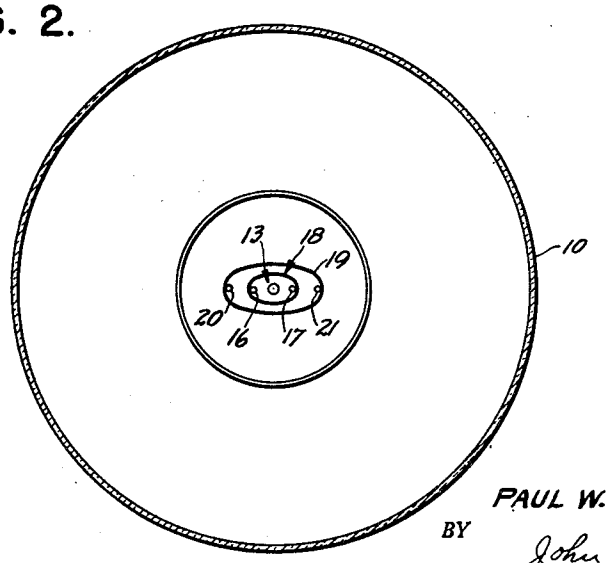



FIG. 2.




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FIG. 3.

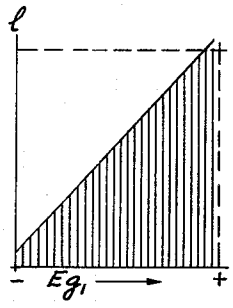



FIG. 4.

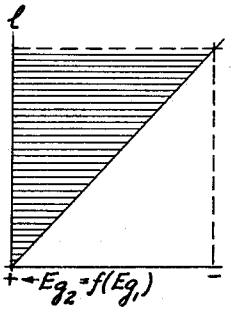



FIG. 5.

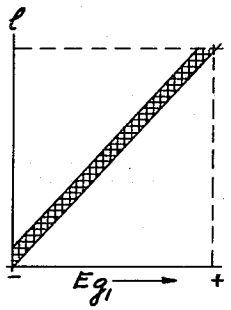



FIG. 6.

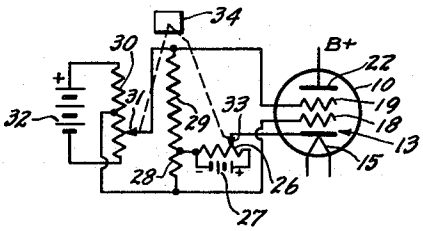



FIG. 7.

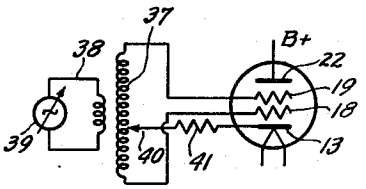
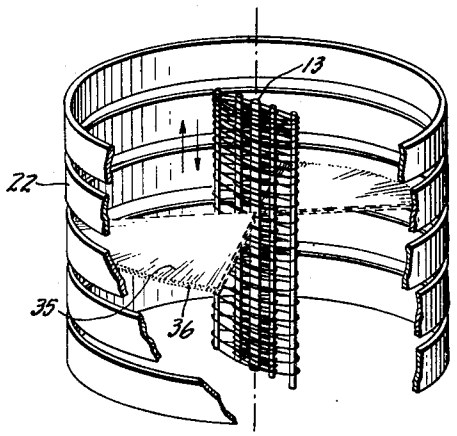



FIG. 8.




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FIG. 9.

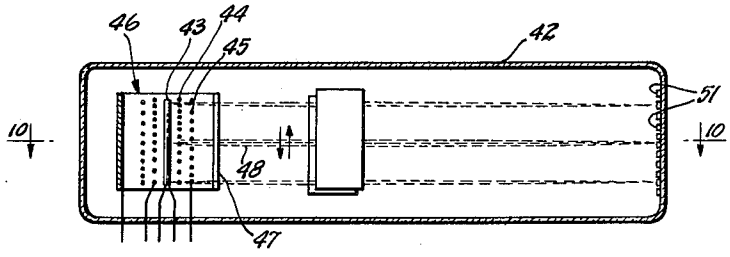



FIG. 10.

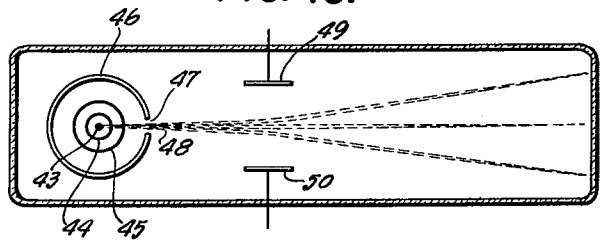
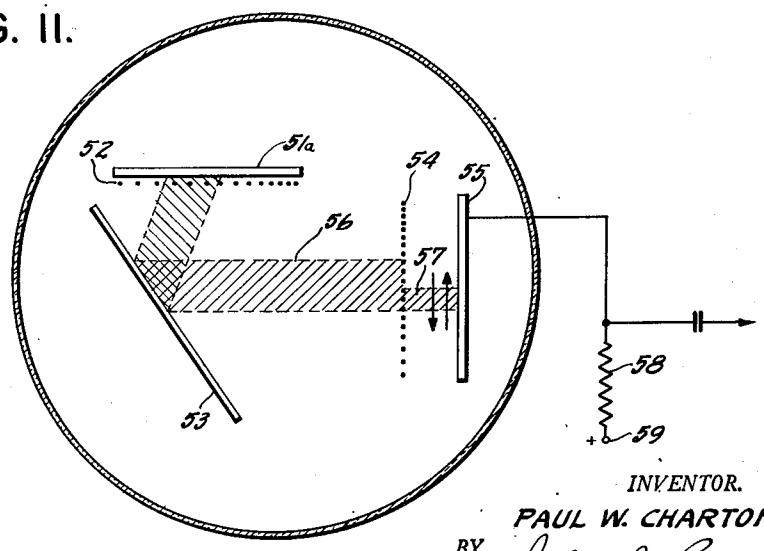



FIG. 11.




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FIG. 12.

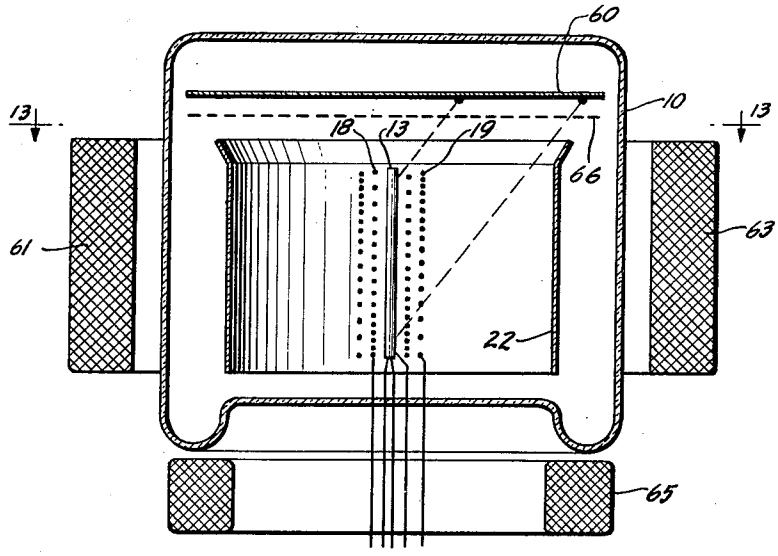
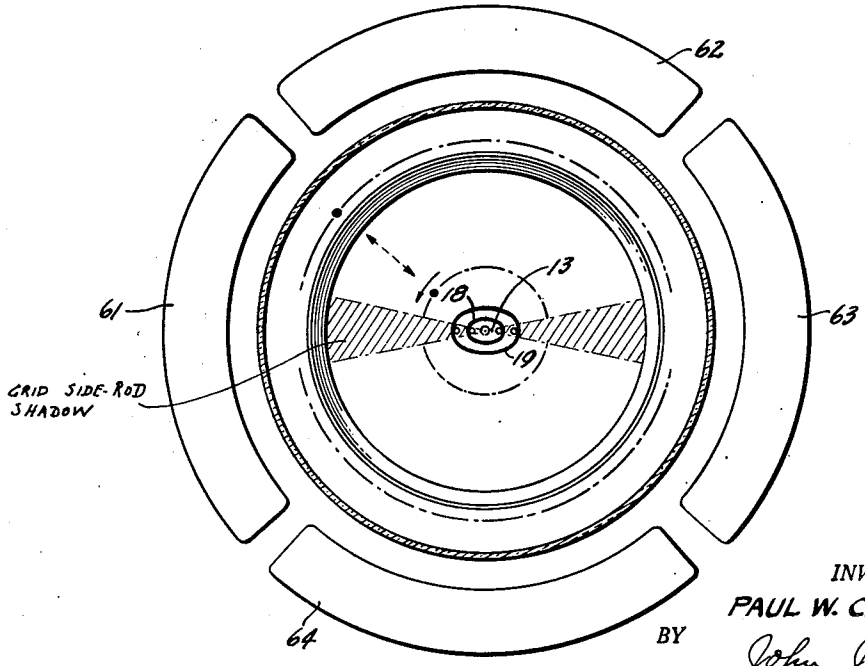



FIG. 13.




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FIG. 14.

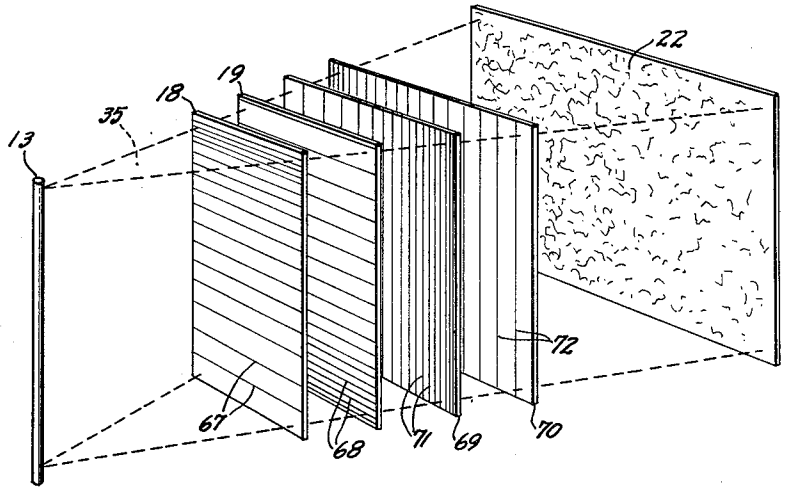



FIG. 15.

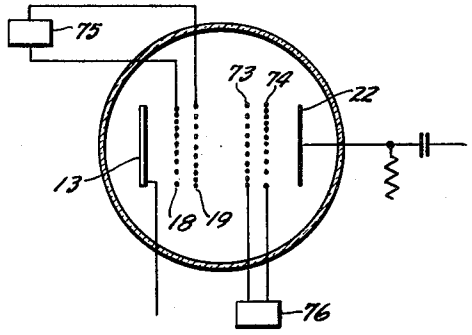



FIG. 16.

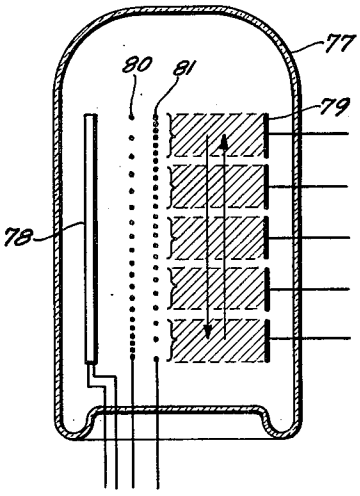
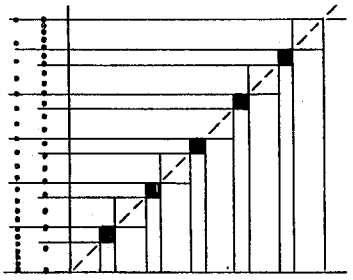



FIG. 17.



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FIG. 18.

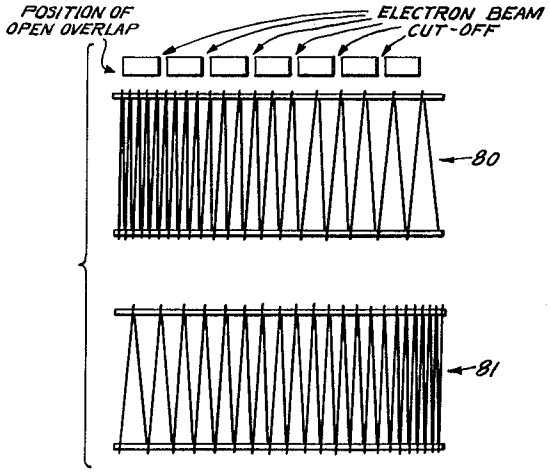



FIG. 19.

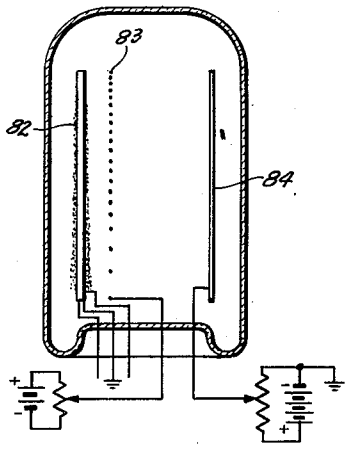



FIG. 20.

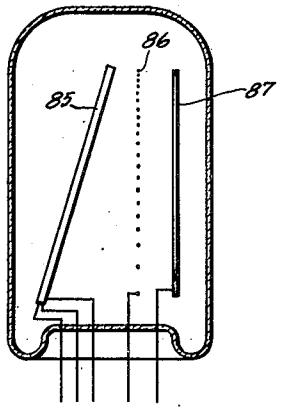



FIG. 22.

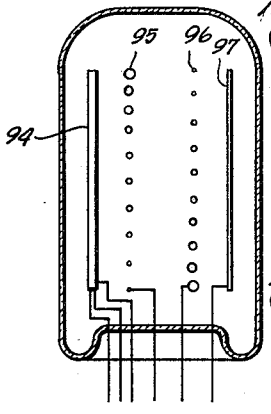



FIG. 24.

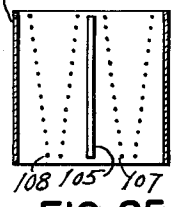



FIG. 25.

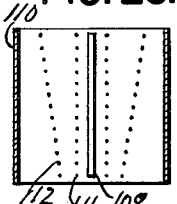



FIG. 21.

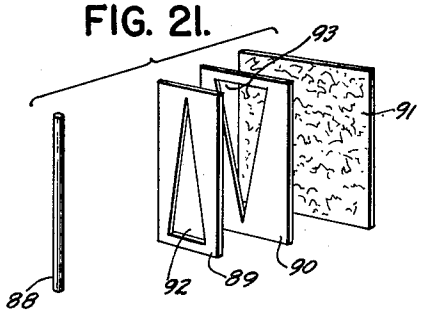
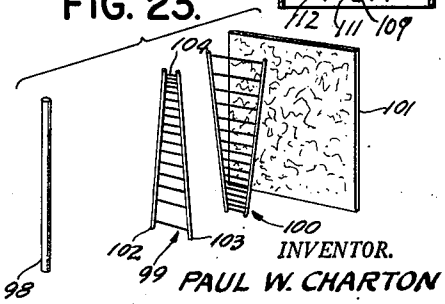



FIG. 23.




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Patented Mar. 16, 1954

2,672,573

# UNITED STATES PATENT OFFICE

2,672,573

## BEAM SHIFT ELECTRON TUBE

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Application March 15, 1951, Serial No. 215,699

17 Claims. (Cl. 315—12)

1

This invention relates to electron tubes, and more especially to tubes of the kind wherein the electron beam is controllably shifted over a predetermined area.

A principal object of the invention relates to an electron tube having a novel controllable electron beam cut-off arrangement for producing a resultant beam whose trajectory termination can be controllably shifted in any desired pattern.

Another object is to provide an electron tube having an electrode array for controllably shifting an electron beam along a path which extends parallel to the length of an electron-emitting cathode, while restricting the effective area of the cathode to a localized region of the cathode.

Another object is to provide a novel organization of electrodes for confining the effective emitting area of a cathode to a signal-controlled shiftable localized portion of the cathode surface.

Another object is to provide a novel method and organization of electrodes in an electron tube, for scanning a target or series of targets with a localized electron beam.

Another object is to provide a novel form of cathode-ray tube for subjecting an electron beam to two-dimensional movement over an area to be scanned.

A further object relates to an electron tube having a novel combination of elements for causing an electron beam to be controllably shifted in three mutually perpendicular relations.

Another object is to provide a novel form of electron tube of the beam-stepping kind.

A feature of the invention relates to an electron tube having a pair of electron beam controlling sections of mutually opposite variable-mu characteristics to select a particular portion of the electron beam from a cathode of extended area, and for variably shifting the trajectory termination of said selected portion.

Another feature relates to an electron tube having an electron emitting cathode, in conjunction with a pair of electron control sections of opposite variable-mu characteristics.

Another feature relates to a cathode-ray tube having a fluorescent target which is mounted at substantially right angles to an elongated cathode, and a plurality of variable-mu electrode arrays and magnetic field-producing means to cause the said target to be scanned in a circular or annular area by electrons emitted from controllably localized areas along the length of the cathode.

Another feature relates to an electron tube having a primary emitter, a secondary emitter

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and a collector or target, in conjunction with a series of variable-mu electrodes or grids for causing the target to be scanned by the electrons emitted from any desired area of the cathode.

Another feature relates to an electron tube having a series of variable-mu grids located between a primary-emitting cathode and a target, which grids are mounted in predetermined angular relation and energized so that the target can be scanned in any desired pattern by suitable energization of said grids.

A further feature relates to the novel organization, arrangement and relative location and interconnection of parts which cooperate to provide a novel and improved electron tube of the electron scanning beam type.

Other features and advantages not particularly enumerated, will become apparent after a consideration of the following detailed description and the appended claims.

In the drawing, which shows certain preferred embodiments,

Fig. 1 is an elevational and sectional view of an electron tube according to the invention.

Fig. 2 is a plan sectional view of Fig. 1, taken along the line 2—2 thereof.

Figs. 3, 4 and 5 are graphs used in explaining the tube of Figs. 1 and 2.

Fig. 6 shows one typical circuit arrangement for energizing the electrodes of the tube of Figs. 1 and 2.

Fig. 7 is a modification of the circuit arrangement of Fig. 6.

Fig. 8 is a perspective and partially broken-away view of the tube of Figs. 1 and 2.

Fig. 9 is an elevational view of a cathode-ray tube embodying features of the invention.

Fig. 10 is a plan view of the tube of Fig. 9.

Fig. 11 is a further modification of the invention employing a primary emitter and a secondary emitter.

Fig. 12 is an elevational view of a further modification of the invention.

Fig. 13 is a sectional view of Fig. 12, taken along the line 13—13 thereof.

Fig. 14 is a perspective view of another modification of the invention, for producing coordinate scanning.

Fig. 15 is a further modification of the invention embodied in a double coincidence detector.

Fig. 16 shows a still further embodiment of the invention embodied in a stepping tube for producing stepping motion of an electron beam.

Fig. 17 is a graph explanatory of the operation of Fig. 16.

Fig. 18 is an enlarged view of the grids of Fig. 16.

Figs. 19 through 25 represent respective additional modifications of the invention.

Referring to Figs. 1 and 2 of the drawing, the numeral 10 represents any suitable evacuated enclosing bulb or envelope having for example, at one end thereof, the usual press or header 11 through which the various lead-in and electrode support wires are sealed.

Suitably mounted on the support wire 12 is an electron-emitting cathode 13, which may be of any type well known in the electron tube art. Merely for illustration purposes, this cathode is shown in the drawing as of the indirectly heated type, comprising an elongated thin walled metal sleeve 14 having on the interior thereof an insulated heater wire 15. Surrounding the cathode 13 and supported on the usual grid side rods 16, 17, is a wire wound grid 18 such as is well known in the electron tube art. This grid is of the variable-mu type, that is, the individual turns or grid laterals are spaced apart unevenly along the length of the grid. For example, as shown in Fig. 1, the turns or laterals which surround the upper end of the cathode 13, are relatively closely spaced, and the spacing between successive laterals increase towards the lower end of the cathode. Preferably, the spacings of successive grid laterals vary in accordance with a predetermined law. For example, this spacing may increase in an exponential manner. It will be understood, however, that the invention is not limited to any particular spacing sequence. The action of such variable-mu grids in controlling the cut-off of the plate current of an electron tube in accordance with the voltage applied to the grid, is well known in the art, and for a detailed explanation thereof, reference may be had to "Radio Engineering" by F. E. Terman, published by McGraw-Hill Book Company, Inc., New York, N. Y., First Edition, page 355. Also surrounding the cathode 13 is an additional variable-mu grid 19 having the grid laterals wound around or supported on the respective grid side rods 20, 21.

In accordance with one phase of the invention, the grid 19 has its grid laterals spaced apart in a manner which is a reverse of the spacing of the grid laterals of grid 18. Thus, as shown in Fig. 1, the grid laterals of grid 19 adjacent the upper end of the cathode 13, are widely spaced and this spacing decreases towards the lower end of the cathode. Preferably, although not necessarily, the grids 19 and 18 surround each other in relatively close relation as compared with the spacing between the grids and the various succeeding electrodes, such for example as the anodes 22.

As shown in Fig. 1, the grids are surrounded by a series of short cylindrical metal plates or anodes 22, which are spaced or insulated from each other and each of which may be provided with a separate lead-in wire 23. It will be understood, of course, that if desired, a well-known suppressor grid and screen grid may be interposed between the variable-mu grid 19 and the anodes. It will also be understood that for certain applications, instead of using a series of separate anodes 22, a single continuous anode may be provided. Furthermore, while the tube shown in Figs. 1 and 2 has the electrodes in the form of tubular or cylindrical elements, this is not necessary. For example, the grids 18 and 19 may be single planar elements mounted in parallel planar array with a corresponding series of planar anodes or plates, and if desired these anodes and plates may be coated with suitable fluorescent material, which fluoresces visibly in response to electron bombardment. The variable-mu grid 18 is provided with its respective lead-in 24, and the variable-mu grid 19 is also provided with its respective lead-in 25.

Fig. 6 shows in schematic form, a typical manner of connecting the various electrodes of Figs. 1 and 2 in circuit to achieve the objects of the invention. The elements of Fig. 6 which are identical with those of Fig. 1, bear the same designation numerals. Thus as shown in Fig. 6, the electron-emitting cathode 13 is connected through a suitable adjustable bias circuit, comprising for example the potentiometer 26 and the direct current bias source 27; the negative terminal of this bias source being connected through resistor 28 to the variable-mu control grid 18. Likewise, the second variable-mu grid 19 is connected through resistance 29, and thence through the potentiometer-bias elements 26, 27, to the cathode 13. In order to adjust the relative direct current bias on the grid 19 with respect to the grid 18, the resistances 28 and 29 have bridged thereacross, another adjustable potentiometer resistor 30, whose adjustable arm 31 is connected directly to the grid 19. The center point of resistor 30 is directly connected to the grid 18. A suitable direct current source 32 is connected across resistor 30 with the polarity as indicated. By this arrangement it is possible to vary in any desired manner the direct current bias potential on grid 18 and on grid 19.

Since the grids 18 and 19 each have a variable pitch winding or variable-mu control characteristic, as the bias applied to each is made to vary, for example by adjusting the potentiometer arms 31 and 33, the cut-off point for the flow of plate current to the anodes 22 travels linearly along the length of the cathode 13. In other words, considering the cathode 13 and the first grid 18, for very high negative potentials the electrons from the cathode flow through the grid only at the more open or wider spaced regions of that grid. Therefore, by reducing this negative direct current bias from its maximum to a lower negative bias, the effective length of the cathode 13, so far as emission through the grid 18 is concerned, can be made to vary linearly with the direct current bias applied to grid 18. Likewise, with respect to grid 19, for a predetermined maximum negative bias on that grid, electrons from the cathode will pass through grid 19 only at the open or wide spacing end thereof, but as this negative bias is reduced in magnitude, successively greater areas along the length of the cathode 13 become effective in emitting electrons through the grid 19. Therefore the windings or spacings of the grid laterals of the two grids 18 and 19, can be so arranged that there is only a small "open" overlap of the two effective sections of the cathode controlled respectively by each of the two variable-mu grids. In other words, the two grids are both electronically "open" to simultaneously pass electrons to the anode or anodes only over a small portion of the cathode, the size and location of which portion varies with the relative potentials applied to the grids 18 and 19. This relation is roughly and diagrammatically illustrated in Figs. 3, 4 and 5.

In Fig. 3, the abscissae represent the successive magnitude of voltages applied to grid 18,

and the ordinates represent the corresponding effective length of the cathode 13 so far as electrons passing to the anode are concerned. The shaded area in Fig. 3 therefore represents for any given grid voltage the corresponding effective conductive area along the length of the cathode. Likewise, in Fig. 4, the abscissae represent the corresponding relation between the voltages applied to grid 19 and the corresponding effective emitting length of the cathode 13, so far as electrons passing to the anode are concerned. Fig. 5 shows the combined result of the simultaneous action of both grids 18 and 19 in controlling the flow of plate current to the anode or anodes. As will be seen from Fig. 5, the effective emitting area of the cathode, so far as electrons reaching the anode or anodes are concerned, that is the overlapping "open" sections of both grids, is relatively narrow and it moves along the length of the cathode in a relatively linear manner. If, therefore, each of the anodes 22 is provided with a fluorescent coating, the variation of the potentials on the grids 18 and 19, will result in the electrons which pass the grid 19 impinging successively upon the said anodes, which impingement will be indicated by a corresponding fluorescent effect.

Fig. 8 shows in pictorial perspective form, the position of the electron stream from the cathode for one particular relation of potentials applied to grids 18 and 19. By reason of the alignment of the grid side rods, the electron stream is shadowed by those side rods in a manner well known in the electron tube art, so that the electrons which pass through the grid 19 are substantially in the form of fan-shaped sheets or streams extending diametrically opposite from the cathode 13 to the anode. In the particular relation shown in Fig. 8, these electron sheets by reason of the particular potentials applied to the grids 18 and 19, impinge upon the second anode 22, and by varying the relative potentials on the grids 18 and 19, these sheets can be made to travel upwardly and downwardly as indicated by the arrows, thus impinging in succession upon the respective anodes 22.

It will be understood, of course, that since the grid 19 is closer to the anodes than the grid 18, it may be necessary to adjust the potentials of these grids in such a way as to produce the linear relation illustrated in Fig. 5. Thus in Fig. 6, the arms 31 and 33 can be ganged to a common control member or device 34 to preserve the required potential relations. It will be understood, of course, that it is not absolutely necessary that these relations be truly linear, since in any event the combination will result in the production of a sheet or beam 35 of the desired thickness 36 and whose position can be made to vary linearly along the cathode with respect to any desired parameter.

The invention is not limited to the conjoint adjustment of the potentials on the grids 18 and 19. These potentials may be made to vary independently of each other, and in fact the thickness 36 of the beam 35 can be made to vary while its location considered along the length of the cathode is being varied. Thus, it is possible to control the beam width so that it can overlap two or more adjacent anodes 22.

If desired, the two grids 18 and 19 can be excited by alternating current potentials. Thus as shown in Fig. 7, the grids 18 and 19 are connected across the secondary winding 37 of a suitable input transformer whose primary winding 38 is energized from a suitable source 39 of signal-controlled alternating current potentials. The cathode 13 is returned to an adjustable tap 40 on the secondary winding 37 through a resistor 41. The tap 40 can be adjusted so as to control the "open" overlapping electron-passing sections of the two grids 18 and 19, thus in effect causing the electrons to scan the anode 22 in a direction parallel to the length of the cathode 13.

Figs. 9 and 10 show the invention embodied in a two-dimensional scanning tube of the cathode-ray type. This tube may comprise a suitable enclosing envelope 42 having mounted interiorly thereof at one end, an electrode assembly comprising an elongated or linear electron-emitting cathode 43, a first variable-mu grid 44, a second variable-mu grid 45, and an anode 46 having a slot 47 in linear alignment and parallel to the cathode 43. The grids 44 and 45 have respective opposite variable-mu characteristics as described above for grids 18 and 19. Consequently, when the grids are suitably energized as above described, the "open" overlap region of the two grids 44 and 45 will travel along the length of the cathode 43 to produce in effect a relatively narrow beam 48. Thus the vertical height of the beam is controlled by the above-mentioned "open" overlap of the grids 44 and 45, and the width of that beam is controlled by the width of the slot 47. Mounted in the path of this beam 48 is any suitable beam-deflecting system, comprising for example the laterally-spaced electrostatic deflector plates 49 and 50 which can be energized in any desired manner to deflect the beam 48 in a direction transverse to its movement relative to the length of the cathode 43. Suitably mounted within the envelope 42 at the opposite end from the cathode 43 is a screen or target which may comprise a series of discrete elements 51, carrying any well-known fluoroscent material which fluoresces when impinged upon by the electron beam 48. Thus it is possible to subject the beam 48 to any desired two-dimensional scanning movement by appropriate energization of the grids 44, 45, and of the plates 49 and 50.

As pointed out above, it is not necessary that the two opposite variable-mu grids be mounted in parallel array. Thus in Fig. 11 these grids are shown mounted in perpendicular relation and cooperating with a secondary emission surface. Thus in Fig. 11 the primary electron-emitting cathode $51^a$ may be similar to the cathode 13 and may have mounted adjacent one side thereof a planar control grid 52 having the grid wires or laterals spaced apart successively greater distances considered from one end of the cathode to the other. Mounted in inclined relation to the cathode $51^a$ is a secondary emission plate or target 53 which has its surface facing the cathode 51 treated or coated so as to render it an efficient emitter of secondary electrons when bombarded by primary electrons from cathode 51. Mounted in spaced relation to the target 53, and for example at right angles to the cathode $51^a$, is another variable-mu control grid 54 having the grid laterals successively spaced unequally to provide the desired variable-mu characteristic. Mounted in spaced relation to the opposite side of grid 54 is a suitable electron collector plate 55 which collects the secondary electrons that pass through the grid 54. By mounting the grids 52 and 54 with their fine mesh portions adjacent as shown, it is clear that the grid 52 when it re-

ceives a potential of a certain magnitude, permits the primary electrons from cathode 51a to pass therethrough from a relatively restricted portion along the length of that cathode as indicated by the shaded area. Likewise, the beam 56 of secondary electrons will have a corresponding width. However, because of the variable-mu or cut-off characteristic of the grid 54, only a portion of the width of the beam 56 is able to pass through the appropriate mesh of the grid 54 to reach the collector 55. Thus by varying the relative potentials on the grids 52 and 54, the section 57 of the beam 56 can be made to move across the target 55 as indicated by the arrows. The manner of connecting the cathode 51a, the grids 52, 54, and the target 53 in circuit, may be the same as that shown in connection with Figs. 6 and 7. The collector 55 will of course be connected to a suitable load circuit 58 and to a suitable positive direct current biasing potential 59.

Referring to Figs. 12 and 13, there is shown a further modification of the invention, wherein the beam can be subjected to controlled motion in three mutually perpendicular directions. In these figures, the parts which are the same as those of Figs. 1 and 2, bear the same designation numerals. They include the central electron-emitting cathode 13, the first variable-mu control grid 18, and the second variable-mu control grid 19. The anode 22 may be in the form of a single continuous metal cylinder. Suitably mounted at the upper end of the described electrodes is a circular disc 60 which may be coated with fluorescent material. This disc may, for example, be of mica or other transparent material having the fluorescent coating thereon on the surface facing the electrode assembly. Surrounding the envelope or bulb 10 is a series of excitation coils 61, 62, 63, 64, which can be connected to a polyphase alternating current supply, so as to produce a rotating electromagnetic field whose axis of rotation is along the length of the cathode 13. Mounted adjacent the lower end of the bulb is another coil 65 for producing an electromagnetic field extending through the tube parallel to the length of the cathode 13. As a result of the combined rotary field and the longitudinal field acting on the electrons from the cathode 13, and as a result of the selective opening effect of the two variable-mu grids 18, 19 as above described, the beam which reaches the surface 66 can be given a rotary motion as indicated by the arrows in Fig. 13, and the termination of this beam at disc 60 can be varied in a radial distance outwardly from the center thereof. In other words, when the grids 18 and 19 are relatively energized so that only a restricted region at the upper end of the cathode 13 is effective, the selected beam trajectory passing through the overlapped open sections of the two variable-mu grids terminates at the disc 60 near the center thereof, and at the same time can be given a rotary motion. On the other hand when the potentials of the grids 18 and 19 are adjusted so that the effective beam is that leaving lower regions of the cathode 13, this beam strikes the surface 60 at a correspondingly further distance from the center thereof, and likewise can be given a rotary motion. This arrangement therefore provides a convenient method of producing fluorescent traces in polar coordinate fashion. For example, the radial distance of the fluorescent spot appearing on the disc 60 considered from the center thereof, can represent one coordinate such as distance, and the circumferential position of that spot considered around the center of the disc 60 can represent angular position or azimuth. It will be understood, of course, that the windings 61–64 can be energized at a fixed rate of speed, and if desired an additional grid 66 can be mounted between the above-described electrodes and the disc 60, and this grid 66 can be energized with suitable blanking pulses or the like so as to cut off the beam striking the disc 60 except when received signals are to be displayed on that disc.

Fig. 14 shows, in perspective diagrammatic form, a further modification of the invention, and wherein the elements which are the same as those of Figs. 1 and 2, bear the same designation numerals. Thus the electron emitting cathode 13 is provided with a pair of oppositely-directed variable-mu control grids 18, 19, whose grid laterals 67, 68, may extend perpendicular to the length of the cathode 13. Between the grid 19 and the fluorescent target or anode 22, there is mounted another pair of variable-mu grids 69, 70. However the grids 69 and 70 have their grid laterals 71, 72, disposed at right angles to the laterals 67, 68. Here again, however, the laterals of grid 69 are spaced unevenly from one side of the grid to the other, and likewise the laterals of grid 70 are spaced unequally from one side to the other of that grid but with the opposite relation of spacing as compared with the spacing of the laterals of grid 69. Consequently, by suitably energizing the grids 18 and 19 as above described, there is produced in effect a beam or sheet 35 which moves vertically along the length of the cathode. In a similar manner, by suitable energization of the grids 69 and 70, the sheet which passes grid 19 is further subdivided in a horizontal direction, that is, a direction perpendicular to the length of the cathode, so that in effect the target or anode 22 can be scanned by an electron spot, and this spot can be given any desired coordinate movement or pattern of trace over the surface of target 22. It will be understood, of course, that the showing of Fig. 14 is schematic and that the various electrodes are supported in any conventional manner within an evacuated envelope or bulb which is omitted from Fig. 14 for purposes of clarity.

Fig. 15 shows a still further modification, wherein the invention is embodied in a double coincidence detector or gating tube. In this embodiment, there is provided the cathode 13 and the oppositely-directed variable-mu grids 18, 19, above described. In addition, another set of variable-mu grids 73, 74, is provided, these latter grids having oppositely-directed variable-mu characteristics. For example, the grid 73 may have its laterals spaced unevenly, or to produce a variable-mu effect similar to that produced by grid 18; whereas grid 74 has its laterals spaced to produce a variable-mu effect similar to that of grid 19. Consequently, in order to have any output at the anode 20, it is necessary that the signals applied from the source 75 and the signals applied from the source 76, be coincident in time and adequate in magnitude.

As pointed out hereinabove, the invention is not limited to any special law of variation of spacing of the variable-mu grid laterals of each pair of grids, so long as the openness of their respective meshes varies in opposite considered along the length of the cathode. However it is possible with certain predetermined spacings to achieve speical results. Thus instead of the spac-

ing between the successive laterals of a grid varying progressively, these laterals of the grid may be arranged in groups and may be used to provide an improved form of stepping tube. Thus as shown in Fig. 16, the evacuated bulb 77 encloses an elongated electron-emitting cathode 78 and a series of anodes or targets 79. Interposed between the cathode and anodes is a first variable-mu grid 80 which has its grid laterals arranged in groups with the spacing between the individual laterals of any given group equal, but with the interlateral spacing in successive groups of increasing openness or mesh. Likewise the second variable-mu grid 81 has its laterals arranged in groups with the interlateral spacing for any given group equal, but with the interlateral spacing in successive groups progressively increasing. These two grids are mounted so that the progression of the mesh in one grid extends in the opposite direction to the progression of the mesh in the other grid, the relation of the two grids being more clearly illustrated in the magnified view of Fig. 18.

By applying increasing potentials to the grids 80 and 81, for example by moving the contact arms 31, 33, the electrons from successive regions of the cathode along its length will be selectively passed in succession to the corresponding anodes 79, as indicated by the arrows in Fig. 16. While Fig. 16 shows a series of beams striking the respective anodes, it will be understood that for any given energization of the grids 80 and 81, only one such beam will arrive at the corresponding anode. Fig. 17 shows in composite chart and graph form, the relation between the two grids and the blanking "on" and "off" of the beam in successive steps as it moves from one anode to another.

Since the invention is concerned broadly with the provision of a tube having at least two successive variable-mu sections, it will be understood that the two overlapping variable-mu effects can be achieved by other well-known means. For example, instead of using two successive variable-mu wire-wound grids, one such grid may be used, and the cathode itself may be coated along its length in a variable manner. Thus as shown in Fig. 19, the cathode 82 is coated so that the thickness or diameter of the coating decreases from the upper end to the lower end. The grid 83 will then be a variable-mu grid with its closer mesh adjacent the upper end of the cathode, and this mesh increasing in openness towards the lower end of the cathode. With the arrangement of Fig. 19, the electron beam will move downwardly from the top to the bottom of plate 84 as the direct current plate potential is increased from a lower positive value to a higher positive value, while the grid potential is simultaneously varied from a less negative to a more negative value.

Fig. 20 shows another embodiment wherein the cathode 85 is uniformly coated along its length, but is inclined with respect to the variable-mu grid 86, this grid having its closer spaced mesh adjacent the nearer part of the cathode 85 so that the spacing between the cathode 85 and the grid 86 is in relation to the openness of the grid mesh. Thus by impressing suitable potentials on the grid 86, electrons from corresponding localized areas of the cathode 85 will impinge upon the anode 87.

It will be understood, of course, that the invention is not limited to the use of wire-wound grids. For example as shown in Fig. 21, the



cathode 88 has associated therewith two control grids 89, 90 and an anode 91. The control grid 89 has a tapered slot 92, and likewise the grid 90 has a reversely positioned tapered slot 93, thus providing the required successive variable-mu effects so that when the grids 89 and 90 are energized as explained in connection with Fig. 6 or Fig. 7, the electrons from corresponding localized regions along the length of cathode 88 strike the anode 91.

If desired, the variable-mu effect may be achieved both by a variation of the openness of the grid wire mesh, and also by a variation in the thickness of the said wire mesh. Thus as shown in Fig. 22, the cathode 94 has associated therewith variable-mu grids 95, 96, and anode 97. The grid laterals of grid 95 are progressively spaced apart, and these laterals are also of gradually varying thickness. The grid 96 may be similarly constructed, but mounted in the reverse sense with respect to grid 95.

Instead of using variable-mu grids with parallel grid side rods and with the grid laterals of equal length extending between the side rods, the grids may be made with inclined side rods. Thus as shown in Fig. 23, the cathode 98 has associated therewith variable-mu grids 95, 96, and anode 101. The side rods 102, 103, of grid 99 are inclined towards each other, and the grid laterals 104 may either be equally spaced or of progressive spacing. The grid 100 may be similarly constructed, but mounted in a reverse manner to achieve the localization of the electron beam from various regions along the length of the cathode 98.

Fig. 24 shows a still further modification wherein the cathode 105 and the plate or anode 106 are concentric and substantially cylindrical, whereas the first grid 107 is of the variable winding pitch type and is also of conical shape with the narrow end of the cone adjacent the top of the cathode 105 and the wider end of the cone adjacent the lower end of the cathode. On the other hand, the second grid 108 is also of the variable winding pitch type and is also of conical shape but with the narrow end of the cone adjacent the lower end of the cathode and the wider end of the cone adjacent the upper end of the cathode. Thus, by varying the potentials on the grids 107, 108, as illustrated in Fig. 6 or Fig. 7, the desired stepping action of the electron beam along the length of the plate 106 can be effected. It is not necessary that the individual turns of the grids 107 and 108 be of variable winding pitch, that is with different spacings between successive turns. If desired, each of these grids 107, 108, may be of uniform winding pitch since the "mu" of the first grid 107 at successive levels, varies with the distance between the two grids 107, 108, and the "mu" of the second grid 108 likewise varies with its distance to the anode 106 at successive levels.

Fig. 25 shows a still further modification wherein the cathode 109 and the anode or plate 110 are coaxial and of simple cylindrical form. In this embodiment the inner grid 111 can be of uniform pitch and of cylindrical form, that is of uniform diameter along the length of the cathode. On the other hand, the second grid 112 can be of conical form and with its wider end adjacent the upper end of the cathode and its lower end adjacent the lower end of the cathode. Here again, the variable-mu effect of the grid 111 at any given level is determined by the variable spacing between grids 111 and 112, and the vari-

able-mu effect of the grid 112 at any given level is a function of the spacing between that grid and the anode 110 at any given level. If desired of course, either or both of the grids 111 and 112 can be of variable-mu or progressively variable winding pitch.

What is claimed is:

1. An electron tube, comprising an evacuated envelope enclosing an elongated electron-emitting cathode, a first variable-mu electrode having a series of openings of progressively different size with the openings disposed along the length of the cathode, a second variable-mu electrode also having a series of openings of progressively different size and extending along the length of the cathode, the said first electrode being mounted with its openings decreasing progressively in size considered from one end of the cathode to the other, and the said second electrode being mounted with its openings increasing progressively in size considered along the opposite direction of the length of said cathode.

2. Electron tube apparatus, comprising an evacuated envelope enclosing an elongated electron-emitting cathode, anode means for said cathode, and means to scan said anode means with an electron beam emanating from any desired section along the length of the cathode, the last-mentioned means including a source of variable voltage, and a pair of variable-mu control electrodes each connected to said source, said electrodes having respectively oppositely-directed variable-mu characteristics considered along the length of the cathode, with the said characteristics progressively varying along the electrode length.

3. An electron tube, comprising an evacuated envelope enclosing an elongated electron emitting cathode, anode means for said cathode, at least one variable-mu grid located between the cathode and the anode, said grid having a progressively coarser mesh along its length, said cathode being inclined toward said grid with the closer end of the cathode adjacent that portion of the grid having the finer mesh.

4. Electron tube apparatus, comprising an evacuated envelope enclosing an elongated electron-emitting cathode, first and second variable-mu control grids surrounding said cathode said grids having their grid laterals arranged to form the electrons into a disc-like beam, one of said grids having its laterals of progressively increasing spacing from one end to the other end of the cathode, the other of said grids having its laterals of progressively decreasing spacing from said one end of the cathode to said other end of the cathode, and means to apply respective control potentials to said grids to cause said beam selectively to shift to any desired region along the length of said cathode.

5. Electron tube apparatus according to claim 4, in which a plurality of target elements are mounted in spaced array along the length of said cathode and successively scanned by said beam in response to said control potentials.

6. Electron tube apparatus, comprising an evacuated envelope having an electron-emitting cathode, anode means for said cathode, first grid means for cutting off electron flow from said cathode to said anode means, second grid means for cutting off electron flow from said cathode to said anode means, said first grid means having a progressively increasing cut-off effect considered in one direction along the cathode, the other grid means having a progressively decreasing cut-off effect considered in said one direction along the cathode, and means to apply control potentials simultaneously to said grids to cause the electrons from the cathode to impinge upon said anode means in any desired localized region thereof.

7. Electron tube apparatus according to claim 6, in which said anode means comprises a series of target elements mounted in spaced array along the length of the cathode, each of said grids being wire wound to form the electrons which pass the second grid into a sheet-like beam.

8. Electron tube apparatus, comprising an evacuated enclosing envelope, an electron emitting cathode, anode means for said cathode, said anode means comprising a plurality of targets to be scanned by an electron beam, said cathode constituting one of the electrodes of an electron gun for developing said beam, a pair of variable-mu electrodes having respective opposite variable-mu characteristics considered along one dimension of the cathode and each variable-mu electrode having a progressively varying variable-mu characteristic along its length, means including a source of variable voltages connected to said variable-mu electrodes to cause said beam to scan said targets in one direction, and separate beam deflector means to cause said beam to scan said targets in a different direction.

9. Electron tube apparatus according to claim 8 in which said cathode is of elongated shape and said variable-mu electrodes and said variable voltage source cut-off said beam from reaching said targets except in a region corresponding to a desired localized portion along the length of the cathode, said separate beam deflecting means deflecting the non-cutoff portion of the beam in a direction transverse to the length of the cathode.

10. Electron tube apparatus according to claim 8 in which each of said variable-mu electrodes is a variable-mu control grid, the said grids being respectively of progressively varying mesh along their lengths and with the coarse mesh of one grid in registry with the fine mesh of the other grid.

11. An electron tube, comprising a primary electron emitter, a secondary electron emitter, target means, a first variable-mu electrode located between said emitters, and a second variable-mu electrode located between said secondary emitter and said target for subjecting said target to scanning by electrons derived from any selected portion along the length of said emitter.

12. Electron tube apparatus, comprising an elongated electron-emitting cathode, anode means for said cathode, means including first and second variable-mu grids and a source of variable voltages connected to said grids to exert a variable-mu control on the electrons from the cathode to produce a beam which emanates substantially radially from any desired section along the length of the cathode in accordance with said variable potentials, signal controlled electric field means to deflect said beam in a direction parallel to the legnth of the cathode, and other electric field means to cause said deflected beam to rotate around a longitudinal axis of said cathode.

13. Electron tube apparatus according to claim 12, in which a luminescent target is mounted in concentric relation to said cathode at one end thereof, and is scanned in successive circular paths of increasing radius under control of said variable-mu means and both said field means.

14. Electron tube apparatus, comprising a central linear cathode, anode means surrounding

said cathode, a first variable-mu grid surrounding the cathode, a second variable-mu grid surrounding the cathode, target means concentrically mounted adjacent one end of the cathode, means to simultaneously energize said control grids by respective potentials to select a particular region of the cathode to be effective in producing an electron beam terminating at said target means, and field producing means to deflect said beam radially outward from the center of the target and for rotating the beam concentrically around the target.

15. An electron tube, comprising an elongated cathode, target means to be scanned by electrons from the cathode, a first variable-mu beam control electrode having a progressively increasing mu along its length, a second variable-mu beam control electrode having a progressively decreasing mu along its length, said grids being mounted with one grid having an increasing mu from the top to the bottom of the cathode, the other grid being mounted to have a decreasing mu from the top to the bottom of the cathode both of said electrodes being located between the cathode and target and energized to subject the electrons from the cathode to a series of successive variable-mu cut-off effects and thereby to cause said target to be scanned at any desired localized area thereof.

16. An electron tube according to claim 15, in which the first variable-mu means comprises a pair of variable-mu grids of the unevenly-spaced grid lateral type, said pair of grids being mounted with the coarse-spaced laterals of one grid in registry with the fine-spaced grid laterals of the other grid and with the grid laterals of both grids extending transverse to the length of the cathode; said second variable-mu means comprising another pair of variable-mu grids of the unevenly-spaced grid lateral type with the coarsely-spaced grid laterals of one grid in registry with the finely-spaced grid laterals of the other grid, the grid laterals of both of said second pair of grids being mounted substantially parallel to the length of the cathode.

17. Electron tube apparatus, comprising an evacuated envelope enclosing an electron-emitting cathode, a series of target electrodes mounted in spaced array along the length of the cathode, a first variable-mu grid having its mu progressively increasing along its length, a second variable-mu grid having its mu progressively decreasing along its length, both of said grids being located between the cathode and targets, said grids being mounted with the coarse mesh of one grid in registry with the fine mesh of the other grid, the meshes of both grids being correlated so that for successive increments of control potentials applied to both grids the electrons from the cathode are formed into a beam which successively scans said targets.

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**References Cited** in the file of this patent

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 1,452,386 | Hartley | July 16, 1925 |
| 2,031,137 | Steimel | Feb. 18, 1936 |
| 2,041,904 | Cone | May 26, 1936 |
| 2,048,224 | Snow | July 21, 1936 |
| 2,048,228 | Snow | July 21, 1936 |
| 2,048,229 | Snow | July 21, 1936 |
| 2,048,230 | Snow | July 21, 1936 |
| 2,048,232 | Snow | July 21, 1936 |
| 2,075,202 | Jonker | Mar. 30, 1937 |
| 2,090,318 | Miller | Aug. 17, 1937 |
| 2,092,893 | Snow | Sept. 14, 1937 |
| 2,113,395 | Braden | Apr. 5, 1938 |
| 2,235,498 | Herold | Mar. 18, 1941 |
| 2,340,594 | Jonker | Feb. 1, 1944 |
| 2,460,062 | Charton | Jan. 25, 1949 |
| 2,492,643 | Ishler | Dec. 27, 1949 |