Sept. 15, 1959 C. F. AULT **2,904,721**

ELECTRON BEAM CONTROL SYSTEM

Filed Dec. 31, 1956 2 Sheets-Sheet 1

FIG. 1

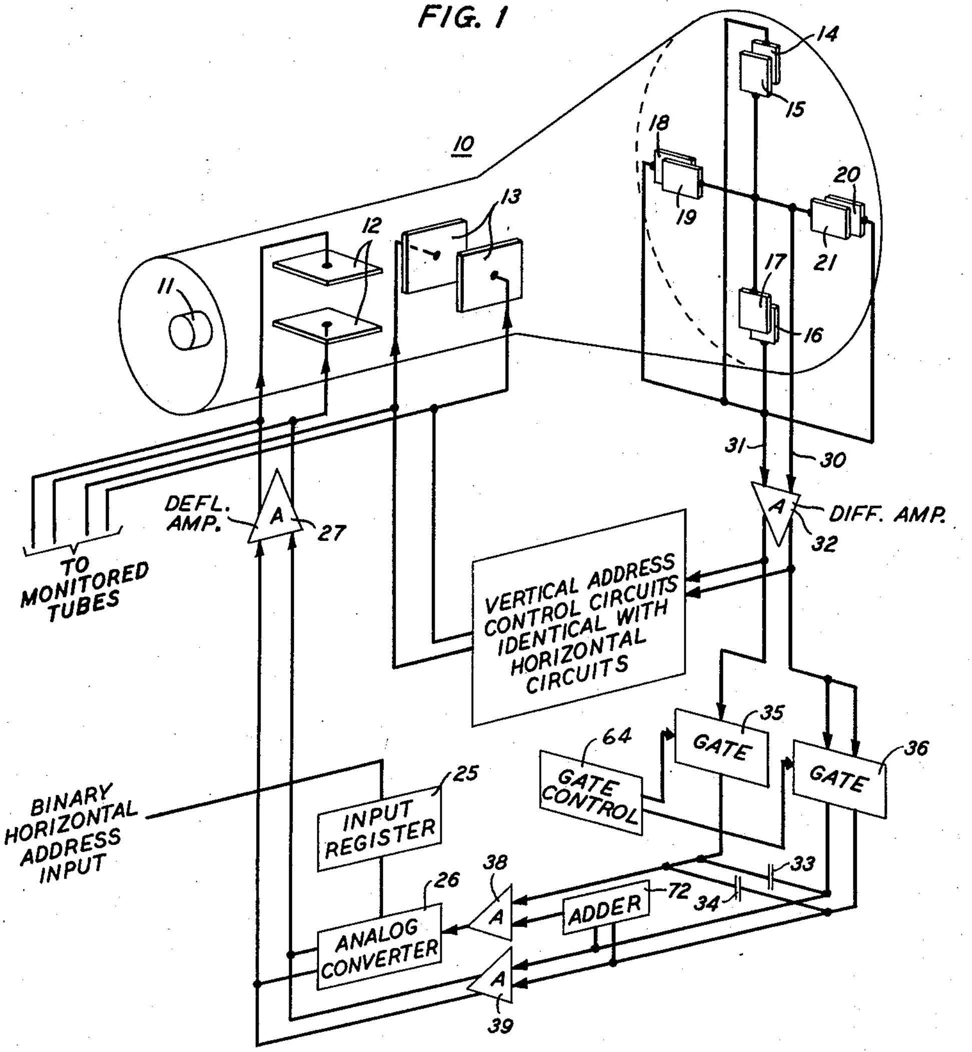

FIG. 3

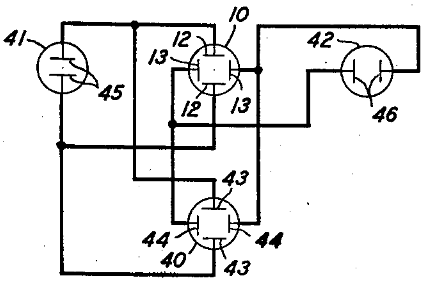

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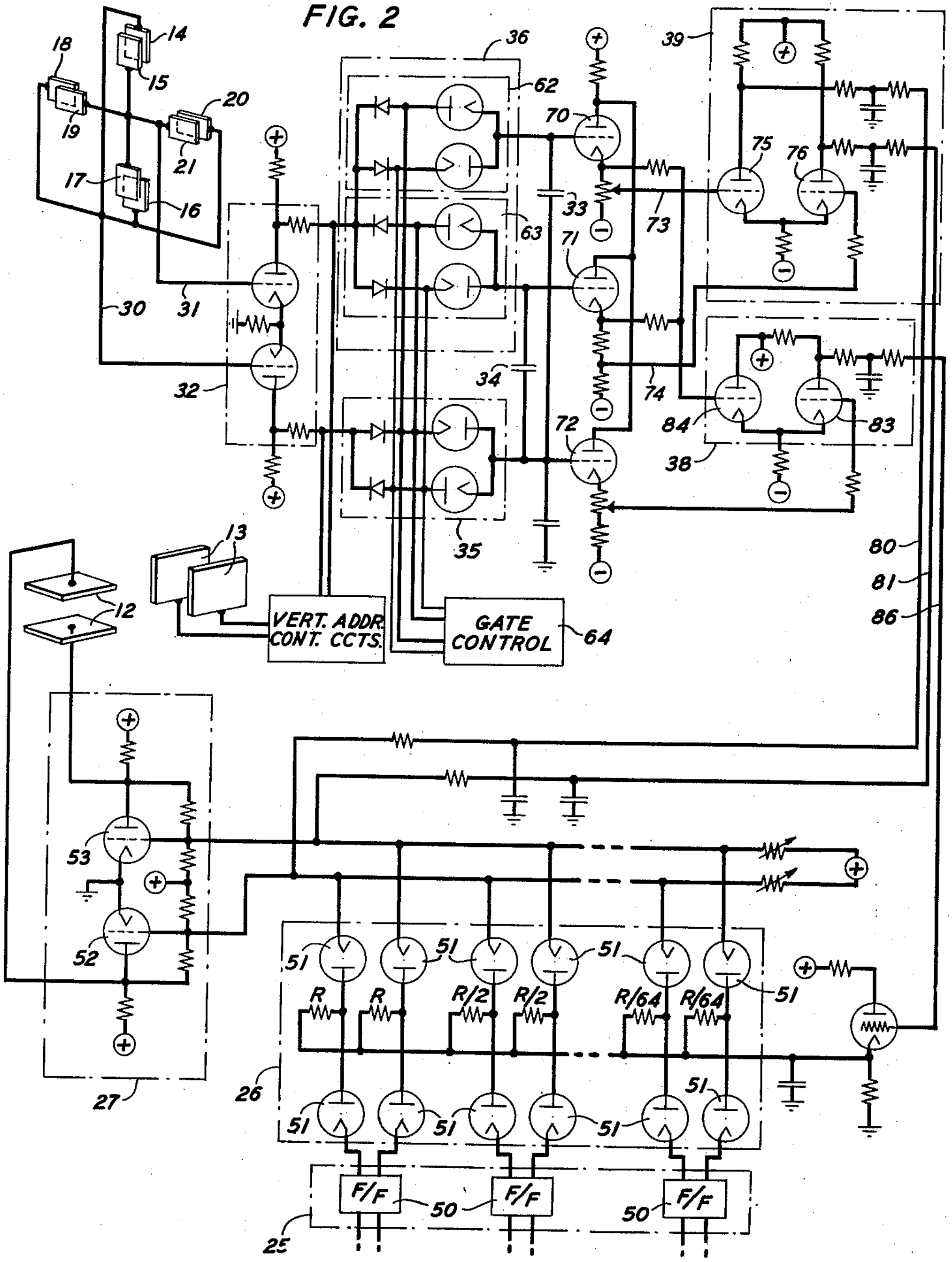
FIG. 2



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ELECTRON BEAM CONTROL SYSTEM

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Application December 31, 1956, Serial No. 631,554
21 Claims. (Cl. 315—8.5)

This invention relates to electron discharge apparatus and more particularly to cathode ray devices comprising a plurality of target elements.

For various beam positioning applications, notably in information storage systems, it is essential to obtain rapid and accurate positioning of the cathode ray tube beam on the precise area of the storage surface from which information is to be derived or at which information is to be stored.

The positioning system which will comply with these exacting requirements and maintain a high performance standard over long periods must necessarily comprise a minimum of active elements subject to wear and consequent variation.

In order to appreciate more fully the requirements of such a positioning system, a storage system utilizing a barrier grid storage tube as described in R. W. Sears Patent 2,675,499, issued April 13, 1954, provides for upwards of 15,000 discrete information bearing areas on a relatively small storage surface, any one of which areas is to be selected by coordinate deflection of an electron beam in a matter of microseconds and the information located thereat read out.

Initial positioning of the beam to achieve the precise coordinate deflections required in such a system places a severe strain on positioning equipment involving the conventional digital to analog conversion and direct current amplification of input signals to the deflection plates, as known in the art.

Other approaches to the accurate positioning problem involve the use of a positioning control device to monitor the storage tube beam deflection. The control device may be a cathode ray tube with a binary coding mask as described in an application Serial No. 581,073, filed April 27, 1956, of C. W. Hoover and R. W. Ketchledge, now Patent 2,855,540, issued October 7, 1958. In this instance the control tube beam is deflected to a position corresponding to the desired position in the storage tube. Output signals obtained from passage of the control tube beam through the coding mask are compared with the input deflection signals and the resultant signals are applied to the deflection plates to reposition the beam to the precise desired position. The storage tube has its deflection plates connected in parallel with those of the control tube, so that the storage tube beam deflection matches that of the control tube.

In this example, as in other monitoring systems operating on a servo positioning principle, the feedback loop operation controls the beam positioning speed, and the speed obtained thereby may not be sufficient to satisfy requirements in high speed storage applications.

Accordingly, it is an object of this invention to provide an improved beam positioning system, and more specifically a beam positionng system which is independent of voltage variations due to instability and aging of active components.

It is another object of this invention to achieve accurately reproducible electron beam deflections in one or more cathode ray devices.

It is a further object of this invention to facilitate the realization of such accurately reproducible beam deflections.

It is a still further object of this invention to improve the beam positioning speed while maintaining requisite accuracy.

In one illustrative embodiment of this invention, a cathode ray device comprises an electron gun, means focusing the stream of electrons from the gun on a target area, pairs of overlapping collector plates positioned in cartesian coordinates of the target area, a deflection system to deflect the beam to the collector plates and means for adjusting input signals to the deflection system in accordance with output signals from coordinate pairs of said collector plates. The deflection system of this device is connected in parallel to one or more storage tube deflection systems to provide comparable beam deflections therein.

In one construction the edges exposed to the electron beam formed by each pair of overlapping collector electrodes establish geometric positions in space equidistant in their respective coordinates from the coordinate intersection and on opposite sides thereof. Periodically input voltage of one polarity is applied to the deflection plates to drive the electron beam to one edge, and then an equal but opposite polarity voltage is applied to the deflection plates to drive the beam to the other edge, intersecting the same coordinate axis. The beam impinging uniformly about each edge in one coordinate indicates accurate beam positioning in that coordinate.

Should a majority of the vertically deflected beam impinge the collector plate above each edge, intersecting the vertical coordinate, for example, an upward drift error in the electron beam deflection circuitry is indicated, and a current flows from the upper collector plate in each pair of vertical collector plates, serving to charge associated capacitors equally but in opposing polarity. The difference in voltage between the capacitors is detected and serves to alter the beam deflection so as to correct for the drift error. Similarly, drift in the opposite direction results in a difference voltage signal from the capacitors of opposite polarity tending to compensate for drift in the opposite direction.

Should the vertically deflected beam strike above the overlapping edge of the upper pair of collector plates and below the overlapping edge of the lower pair of collector plates, or vice versa, an error in gain is indicated. The capacitors will be charged equally and with the same polarity in this instance. Since no voltage difference exists between the capacitors, no drift correction results. The voltage on each capacitor serves instead to vary the gain of the associated deflection circuitry to restore the proper beam deflection.

Thus, successive positioning of the monitor tube beam on two remote geometric positions in one coordinate will permit repositioning of the beam to compensate for errors in drift and gain derived from the deflection system input circuitry for that coordinate.

In accordance with one feature of this invention, an electron discharge device comprises a plurality of pairs of overlapping collector plates positioned such that edges formed thereby intersect cartesian coordinates in spaced apart positions.

Another feature of this invention relates to coordinate deflection of an electron beam to impinge first and second pairs of collector plates in succession.

It is another feature of this invention that capacitors are charged in accordance with the position of beam impingement on the collector plates and serve to formulate signals to adjust for errors in the beam deflection.

A complete understanding of this invention and of the above-noted and other features thereof may be gained from consideration of the following detailed description and the accompanying drawing in which:

Fig. 1 is a diagrammatic representation of a cathode ray device and associated circuitry illustrative of one embodiment of this invention;

Fig. 2 is a schematic representation of one specific embodiment of this invention in accordance with Fig. 1; and

Fig. 3 is a diagram illustrating one manner in which devices as shown in Fig. 1 may be utilized to produce coordinate deflecting potentials for a plurality of cathode ray devices.

Referring now to the drawing, Fig. 1 depicts a cathode ray tube and related circuitry in accordance with one specific illustrative embodiment of this invention. The cathode ray tube, shown generally at **10**, comprises an evacuated envelope, such as of glass, an electron gun **11**, deflection plates **12** and **13**, and overlapping pairs of collector electrodes **14** and **15**, **16** and **17**, **18** and **19**, and **20** and **21**, mounted in space quadrature. Thus collector pairs **14**, **15** and **16**, **17** are positioned on the vertical axis equidistant from the intersection with the horizontal axis and on opposite sides thereof. Similarly, collector pairs **18**, **19** and **20**, **21** are positioned on the horizontal axis equidistant from the intersection with the vertical axis and on opposite sides thereof. Each of the vertical and horizontal axes is defined by a beam scanned across the tube face under control of one coordinate deflection system and with zero signal on the deflection system for the other coordinate. Each pair of collectors overlaps to form a distinct edge exposed to the electron beam and advantageously intersecting the respective axes at right angles.

Coordinate deflection of the electron beam is performed in a manner well known in the art, in which input information is applied in parallel binary form to input registers for each deflection coordinate. The horizontal deflection circuitry is identical to the circuitry for vertical deflection so that a description of the horizontal circuitry will suffice to describe the structure and operation of this specific embodiment of this invention.

Defects in deflection circuitry result in errors in beam positioning classified generally as drift errors and gain errors. A drift error is due to a variation in potential in the same direction on both deflection plates for one coordinate. Thus, a positive variation in potential on the horizontal deflection plates will cause the beam to be deflected consistently above the desired deflection positions. A gain error is due to a variation in potential in opposite directions on the deflection plates for one coordinate. Thus, an increase in potential applied to the horizontal deflection plates, tending to increase the potential difference therebetween, will cause upward beam deflections above the desired deflection positions and downward beam deflections below the desired deflection positions.

Positioning control devices known in the art, such as that described in the patent of Hoover and Ketchledge cited hereinbefore, monitor all possible beam positions, thereby providing an extremely accurate control system. The monitored devices, however, are delayed in performing their peculiar functions after each application of input information while the beam position is checked by the monitor device. Such delay cannot be tolerated in many high speed memory operations.

Beam positioning errors occur gradually so that information contained in a specific storage tube may be scanned several times before errors occur of sufficient magnitude to produce spurious output information. Thus, in accordance with this invention, beam repositioning is reduced to periodic coordinate drift and gain correction. The circuitry and operations involved in horizontal and vertical deflection correction are identical, so that a description of vertical deflection correction will suffice.

Binary information for vertical deflection is fed into input register **25**, converted to analog form in analog converter **26**, amplified in deflection amplifier **27**, and applied as opposite potentials to deflection plates **12**. The input register **25** and its associated analog converter **26** may be of any of a number of circuits capable of generating analog representations on simultaneous application thereto of a plurality of horizontal address input pulses; for example, as best shown in Fig. 2, input register **25** may comprise a series of bistable flip-flop units **50** arranged to feed simultaneously through diodes **51** of analog converter **26**, which is capable of passing analog stepped amounts of current to deflection amplifier **27**. Amplifier **27** advantageously comprises triodes **52** and **53** which supply output voltages to the deflection plates **12** of opposite polarities representing a summation of analog values.

The vertical coordinate repositioning operation involves applying horizontal address input information to the deflection plates **12** with the plates **13** at zero potential. If the horizontal address input information is correct, the beam will be deflected in succession to the edges formed by the collector pairs **14**, **15** and **16**, **17**.

In accordance with this embodiment of this invention, deflection of the electron beam so as to straddle any of the edges formed by the overlapping collector electrodes will produce equal currents in leads **30** and **31** to differential amplifier **32**. Advantageously, the odd numbered inner collectors **15**, **17**, **19**, and **21** are commonly connected to lead **30** and even numbered outer collectors **14**, **16**, **18**, and **20** are commonly connected to lead **31**. Thus the beam impinging any of the collector plates will produce current flow in at least one of the leads **30** and **31** to differential amplifier **32**.

The output of differential amplifier **32** is received in capacitors **33** and **34** after being directed through gates **35** and **36** in accordance with signals from gate control **64**. If the beam is positioned so as to impinge a pair of overlapping collector electrodes uniformly about the edge, there is no output from differential amplifier **32** and the capacitors **33** and **34** are not affected.

If a positioning error is present which causes an upward or downward drift, the predominant portion of the beam will impinge upon the collector electrode above or below each edge intersecting the vertical deflection path, respectively, thereby generating more current flow in one of the leads **30** and **31**. Differential amplifier **32** in turn will produce output signals of opposite polarity which are directed through gates **35** and **36** so as to increase the charge in opposite directions on capacitors **33** and **34**.

If a positioning error is present due to a variation in gain in the vertical deflection circuitry, the predominant portion of the beam will impinge upon the collector electrode below one edge and the collector electrode above the other edge intersecting the vertical deflection path. At the former position the unbalanced current flow in leads **30** and **31** will cause amplifier **32** to produce an output signal of one polarity, serving to charge one of the capacitors **33** and **34** in one direction. At the latter position the same unbalanced current flow in leads **30** and **31** will cause amplifier **32** to produce an output signal which is gated so as to charge the other capacitor in the same direction.

Increases in charge on capacitors **33** and **34** in the same direction will generate a signal through adder **72**, differential amplifier **38** and analog converter **26** to the deflection plates **12**, indicating an error in gain. Increases in charge in opposite directions on capacitors **33** and **34** will produce an output signal from differential amplifier **39** to the deflection plates **12**, indicating a drift error. The various circuits in this feedback path will be described in detail hereinafter.

Gates 35 and 36, as best shown in Fig. 2, advantageously comprise solid state and vacuum tube diodes combined in parallel push-pull arrangements normally biased so as to be nonconducting. Gate 36 contains two branch gates 62 and 63. Gate control 64 applies signals effective to enable gate 35 and branch gate 62 in unison when the beam is positioned on collector plates 14, 15. Similarly, with the beam positioned on collector plates 16, 17, gate control 64 applies signals to enable gate 35 and branch gate 63 in unison. In this fashion only the collector current signals produced after the deflected electron beam has come to rest on a pair of collector electrodes will be passed by gates 35 and 36.

Signals passed concurrently by gate 35 and branch gate 62 charge capacitor 33 while signals passed by gate 35 and branch gate 63 charge capacitor 34. The charge stored on capacitors 33 and 34 determines the amount of error due to drift and gain. Timing the enablement of gates 35 and 36 assures that the charges on capacitors 33 and 34 will remain constant while the beam is being deflected between collector electrodes 14, 15 and collector electrodes 16, 17.

Differential amplifier 38 is responsive to the charge on capacitors 33 and 34 to provide output signals compensating for errors due to gain. The charge on capacitor 33 determines the grid potential of tube 70. Likewise, the charge on capacitor 34 determines the grid potential of tube 71, and the combined charges on capacitors 33 and 34 determine the grid potential of adder tube 72. Voltage variations in the cathode circuits of tubes 70 and 71 control the grid potential of tube 84 in differential amplifier 38 while a voltage variation in the cathode circuit of adder tube 72 varies the grid potential of tube 83 therein. Output signals from differential amplifier 38 are fed over lead 86 to the analog converter 26.

If a gain error is present, capacitors 33 and 34 will be charged in the same direction as described hereinbefore. Sufficient delay is built into the circuit to assure that both capacitors are charged according to positioning of the beam on each pair of overlapping collector electrodes prior to providing an output from the error compensating circuitry. Thus the cathode voltages of tubes 70 and 71 are varied in the same direction and add so as to vary the grid potential of tube 84. Also, the cumulative charges on capacitors 33 and 34 alter the bias on adder tube 72 which in turn varies the grid potential of tube 83 opposite to that of tube 84. The output on lead 86 represents the difference in potentials applied to the grids of tubes 83 and 84 and is applied to the analog converter 26 to vary the gain of the deflection circuitry.

If a drift error is present, capacitors 33 and 34 will be charged in opposite directions. Thus the grid potential of adder tube 72 and consequently tube 83 remains unchanged. Also resultant opposite voltage variations in the cathode circuits of tubes 70 and 71 effectively cancel each other at the grid of tube 84 leaving its potential unchanged and no output from gain control differential amplifier 38 is provided. The oppositely directed voltage variations in the cathode circuits of tubes 70 and 71 also are applied to the grids of tubes 75 and 76 in drift control differential amplifier 39 over leads 73 and 74, respectively, and are effective to produce an output therefrom as oppositely directed voltage variations in leads 80 and 81 to deflection amplifier 27. Such output signals correct for the variation in beam deflection due to drift which was responsible for the storage of oppositely directed charges on capacitors 33 and 34. Capacitors 33 and 34, when charged in the same direction due to a gain error, will serve to raise the grid potential of tubes 75 and 76 in like amounts, so that no output from drift control differential amplifier will be provided at this time.

Drift and gain errors in the horizontal coordinate also are corrected in the manner outlined above. Proper timing of the gate control 64 assures charging of capacitor 33 with the beam positioned on one pair of collector electrodes in one coordinate and charging of capacitor 34 with the beam positioned on the opposite pair of collector electrodes in the same coordinate. The magnitude of charge on each capacitor 33 and 34 will determine the magnitude of gain or drift correction applied to the respective deflection plates.

The primary function of this arrangement, in accordance with this embodiment of this invention, is to monitor the positioning of electron beams in one or more storage or related tubes having their deflection plates connected in parallel with the deflection plates of tube 10. As shown in Fig. 3, for example, the deflection plates of monitor tube 10 may be connected to devices deflected in two coordinates such as tube 40 or single coordinate deflection tubes such as 41 and 42. The monitored devices 40, 41, and 42 may be any cathode ray devices, but the positioning arrangement of this invention is particularly useful in accurate and rapid positioning of tubes of the storage type such as the Barrier Grid tube. The deflection plates 12 are connected in parallel with the deflection plates 43 of device 40 and deflection plates 45 of device 41; the plates 13 similarly are connected to plates 44 of device 40 and plates 46 of device 42. Hence the deflecting potential across any pair of deflection plates 43 and 45 will be the same as that across the plates 12, and that across plates 44 and 46 the same as that across plates 13. With the voltages across the respective deflection plates 12 and 13 accurately representative of signal voltages impressed on monitor tube 10 when the beam is deflected to the collector electrode edges in one coordinate, accurately reproducible deflections of the beams in devices such as 40, 41, and 42 may be obtained.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A beam positioning system comprising an electron discharge device including target means and means for projecting a beam toward said target means, storage means, means for gating a signal to said storage means responsive to said beam impinging said target means, means deflecting said beam to impinge said target means successively in at least two discrete deflected positions to produce at least two discrete signals, and means connected between said storage means and said deflection means transmitting deflection correcting indications to said deflection means after receipt in said storage means of both of said signals.

2. A beam positioning system comprising an electron discharge device including a plurality of target elements, means for projecting a beam initiated by a source in an electron discharge device toward said target elements and deflection means, means for applying input signals to said deflection means to position said beam on said target elements, gating means, storage means receiving a first signal through said gating means upon positioning of said beam on certain of said target elements, said storage means receiving a second signal through said gating means upon positioning of said beam on other of said target elements, means comparing said first and second signals, and means applying signals resulting from said comparison to said deflection means.

3. A beam positioning system comprising an electron discharge device including target means and means for projecting a beam toward said target means, means for deflecting said beam to impinge said target means successively in at least two discrete positions, storage means, gating means connected between said storage means and said target means applying a first signal to said storage means responsive to said beam impinging said target means in a first discrete position and applying a second

signal to said storage means responsive to said beam impinging said target means in a second discrete position, means for comparing said first and second signals, and means applying the resultant of said comparison to said deflection means.

4. A beam positioning system in accordance with claim 3 wherein said target means comprises a plurality of pairs of overlapping collector electrodes, a first pair of said overlapping collector electrodes presenting a first exposed edge to said beam intersecting a beam deflection path and a second pair of said overlapping collector electrodes presenting a second exposed edge to said beam spaced apart from said first edge.

5. A beam positioning system in accordance with claim 4 wherein said first and second edges are mutually parallel and intersect said beam deflection path equidistant from the undeflected beam position in said beam deflection path.

6. A beam positioning system in accordance with claim 5 wherein said storage means comprises first and second capacitors.

7. A beam positioning system in accordance with claim 6 wherein said signal applying means comprises first and second gating means, said first gating means applying said first signal to said first capacitor and said second gating means applying said second signal to said second capacitor.

8. A beam positioning system in accordance with claim 7 and further comprising gate control means connected to said first and second gating means, said gate control means enabling said first gating means with said beam positioned on said first pair of collector electrodes and enabling said second gating means with said beam positioned on said second pair of collector electrodes.

9. A beam positioning system in accordance with claim 8 wherein said comparison means comprises first and second comparison circuits, said first comparison circuit providing an output responsive to said first and second capacitors charged in the same direction, and said second comparison circuit providing an output responsive to said first and second capacitors charged in opposite directions.

10. A beam positioning system comprising an electron discharge device including means for projecting an electron stream substantially along the axis of said device, a pair of first and second collector electrodes positioned on each side of a plane through said axis, said first electrode in each pair being positioned closer to said axis than said second electrode in each pair, means for causing said electron stream to scan successively one pair of said electrodes and then the other pair of said collector electrodes, and means for applying correction signals to said scanning means when the predominant portion of said electron stream impinges on said first electrode of one pair and said second electrode of the other pair.

11. A beam positioning system comprising an electron discharge device including means for projecting an electron stream substantially along the axis of said device, a first set of collector electrodes on opposite sides of a plane through said axis, a second set of collector electrodes on opposite sides of said plane and positioned closer to said axis than said first set, means for causing said electron stream to scan successively said electrodes on one side of said plane and then said electrodes on the opposite side of said plane, and means for applying correction signals to said scanning means when the predominant portion of said electron stream impinges on the same set of said collector electrodes.

12. A beam positioning system comprising an electron discharge device including means for projecting an electron stream substantially along the axis of said device, a set of first collector electrodes spaced apart from each other on opposite sides of a plane through said axis and substantially in a plane normal to said plane through said axis, a set of second collector electrodes differently spaced from said axis than said first collector electrodes, means for causing said electron stream to scan successively a pair of said electrodes on one side of said plane and then a pair of said electrodes on the opposite side of said plane, means for applying correction signals to said scanning means when the predominant portion of said electron stream impinges on said first electrode of one pair and said second electrode of the other pair, and means for applying different correction signals to said scanning means when the predominant portion of said electron stream impinges on the same set of said collector electrodes.

13. A beam positioning system comprising an electron discharge device including first and second target means, means opposite said target means for projecting a beam toward said target means, and means deflecting said beam to impinge said first target means and said second target means successively, storage means, gating means passing signals to charge said storage means in response to said beam impinging said first and second target means, and means providing an output to said deflection means indicative of the level of charge in said storage means.

14. A beam positioning system comprising an electron discharge device including at least two pairs of overlapping collector electrodes, means opposite said electrodes for forming and projecting an electron beam toward said electrodes, and means for deflecting said beam to strike successively first and second pairs of said collector electrodes, first and second storage means, means connected between said storage means and said electrodes applying a signal to said first storage means upon impingement of said beam on said first pair of collector electrodes and applying a signal to said second storage means upon impingement of said beam on said second pair of collector electrodes, means for comparing said signals stored in said first and second storage means, and means for applying the resultant of said comparison to said deflection means.

15. A beam positioning system in accordance with claim 14 wherein said collector electrodes are positioned in planes normal to the path of said beam when undeflected, said first and second pairs of overlapping collector electrodes each presenting an exposed edge to said beam, said edges being spaced apart and intersecting a deflection coordinate of said beam.

16. A beam positioning system in accordance with claim 15 and further comprising third and fourth pairs of overlapping collector electrodes each of said pairs presenting an exposed edge to said beam, said edges being spaced apart and intersecting another deflection coordinate of said beam.

17. A beam positioning system in accordance with claim 16 wherein said signal applying means comprises first, second and third gating means, said first storage means connected between said first and second gating means and said second storage means connected between said first and third gating means.

18. A beam positioning system in accordance with claim 17 wherein said signal applying means comprises differentiating means connected between said gating means and said collector electrodes, said differentiating means responsive to current flow from a pair of said overlapping collector electrodes with said electron beam impinging thereat other than uniformly about the edge formed thereby to transmit a signal to said gating means.

19. A beam positioning system in accordance with claim 18 wherein said signal applying means comprises gate control means connected to said first, second and third gating means, said gate control means transmitting enabling pulses to said gating means in accordance with the positioning of said electron beam whereby said first and second gating means are enabled with said beam positioned on said first pair of collector electrodes and said

first and third gating means are enabled with said beam positioned on said second pair of collector electrodes.

20. A beam positioning system in accordance with claim 19 wherein said signal comparing means comprises gain indication means and drift indication means, said gain indication means being connected to said storage means so as to provide an output responsive to signals stored in one direction in said storage means, and said drift indication means being connected to said storage means so as to provide an output responsive to signals stored in opposite directions in said storage means.

21. A beam positioning system in accordance with claim 20 and further comprising means for applying deflection signals to said deflection means, said gain indication means being connected to said deflection signal applying means and said drift indication means being connected to said deflection means.

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