Oct. 30, 1951 R. G. E. HUTTER **2,572,861**

DEFLECTION SYSTEM FOR CATHODE-RAY TUBES

Filed June 3, 1947 2 SHEETS—SHEET 1

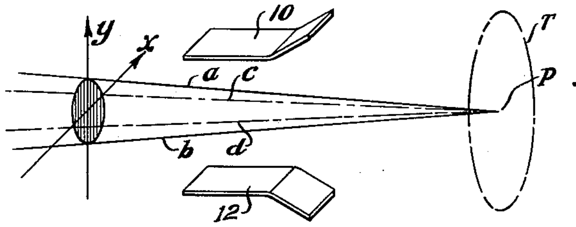

FIG. 1

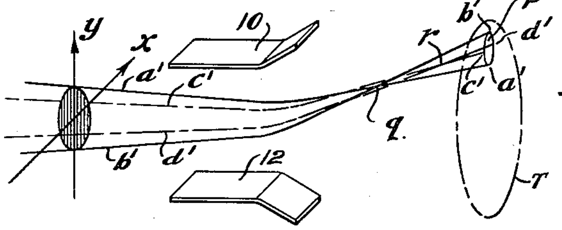

FIG. 2

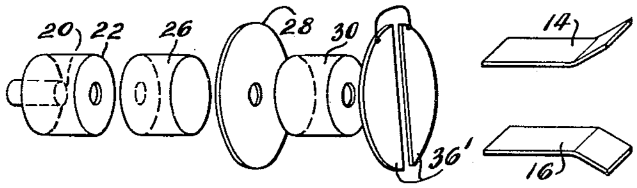

FIG. 4

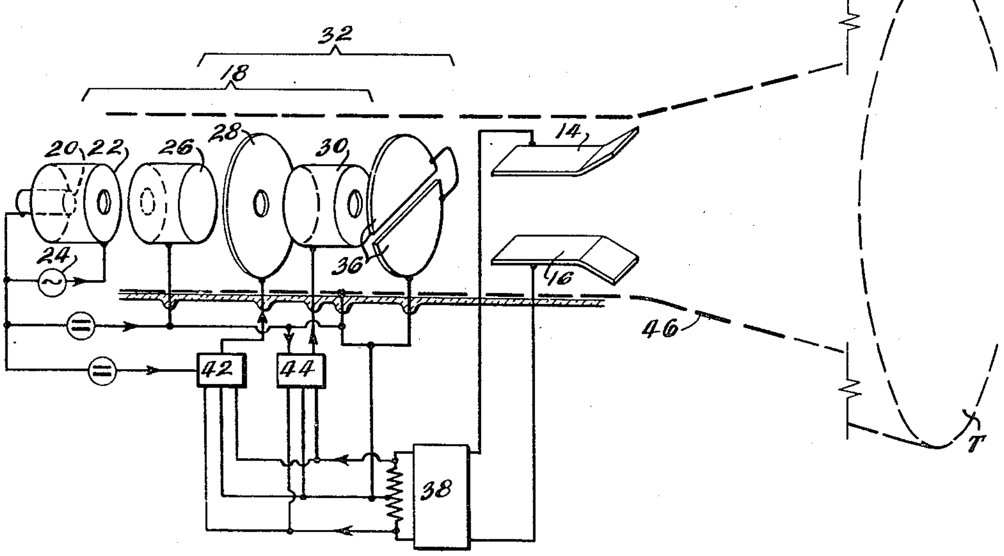

FIG. 3

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DEFLECTION SYSTEM FOR CATHODE-RAY TUBES

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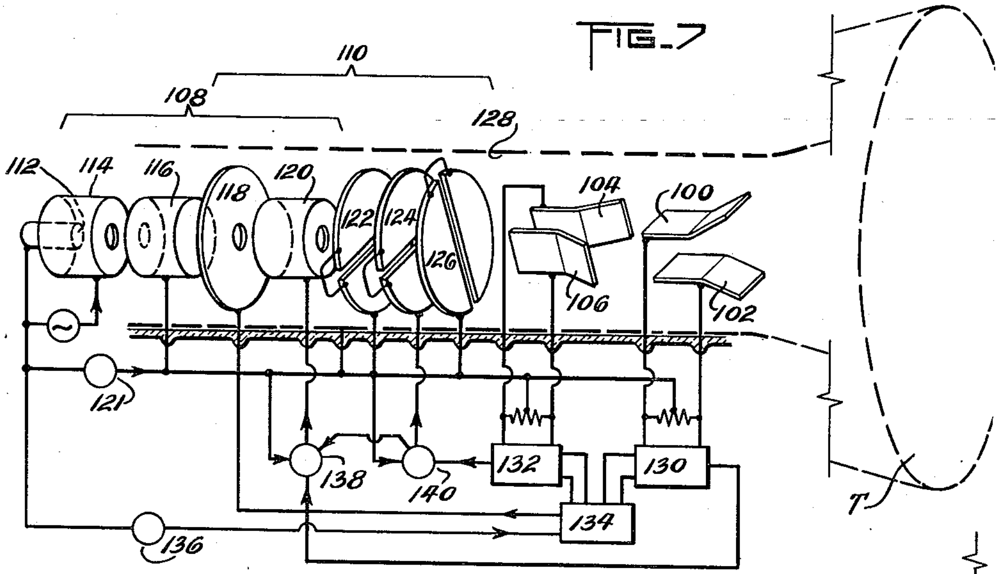

FIG. 7

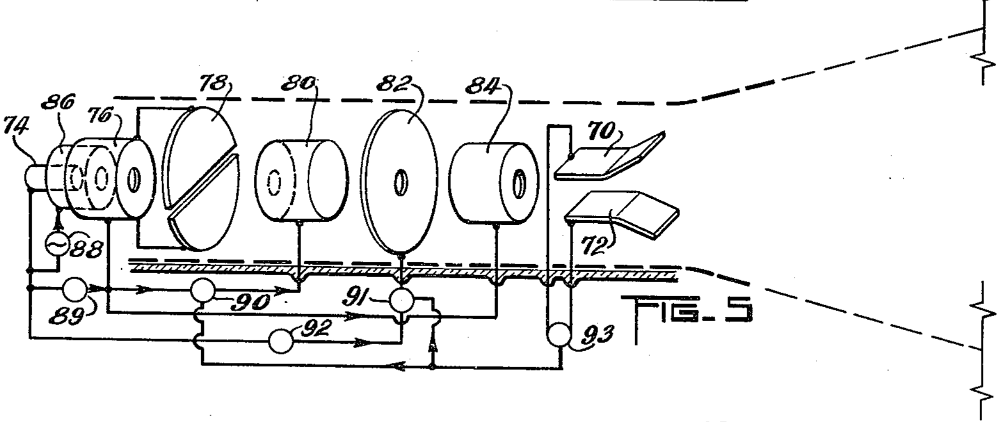

FIG. 5

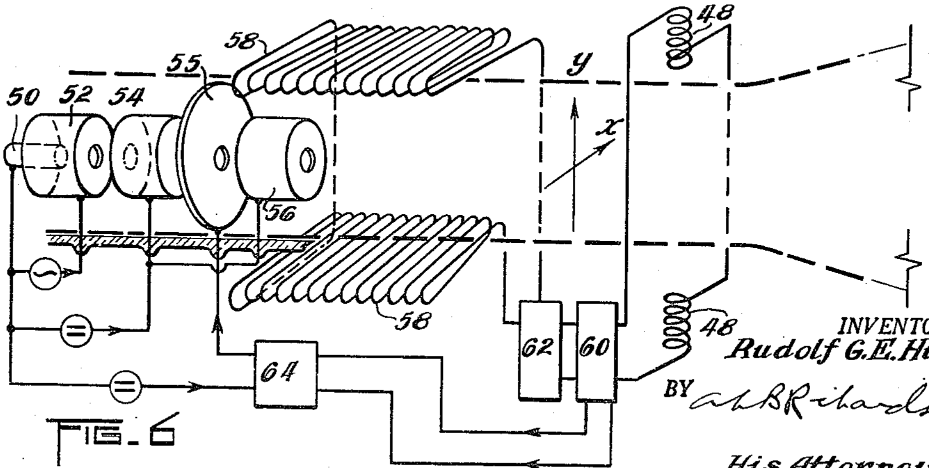

FIG. 6

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UNITED STATES PATENT OFFICE

2,572,861

DEFLECTION SYSTEM FOR CATHODE-RAY TUBES

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Application June 3, 1947, Serial No. 752,157

25 Claims. (Cl. 315—15)

The present invention relates to cathode-ray tubes and their circuits that provide a variably deflected, point-focused electron beam, and to methods of improving beam focus.

In the typical cathode-ray tube, an electron gun is provided which produces a beam or pencil of electron rays, and these are focused at a point ordinarily in the center of a photoelectric, fluorescent or comparable screen or other target such as one having discrete conductive areas. When the electron beam is deflected from the center of the target for scanning or to produce a trace, the focus of the beam at the target is distorted. This effect is usually more pronounced and objectionable with electrostatic deflection than with magnetic deflection systems, but it is serious in both types where the angle of deflection is wide. Whereas the beam produces a circular spot of small diameter at the center of the screen, there is a serious out-of-round enlargement when the beam is deflected. In television, this not only reduces the sharpness of the image (picked up or displayed) but also decreases its contrast. In applications other than television the loss of sharp focus may similarly impair the result. Accordingly, among the objects of the present invention are: to provide an improvement in the electron optical systems of cathode-ray devices, to provide novel electrical circuits for utilizing the improved cathode-ray devices, and in another aspect to improve the methods of beam focusing and deflection.

In the development of cathode-ray tubes there have been separate improvements in the electron gun, and in the deflection system. The present invention provides an improvement interrelating these two portions in such manner as to yield improved beam formation at all parts of the target, such as is now obtained in the absence of deflection signals.

The distortion of the electron beam caused by a single field or crossed fields has previously been recognized and various attempts have been made to reduce this distortion. According to one line of thought the mean potential of a pair of deflection plates can be varied according to a non-linear function of the deflection voltage and relative to the last anode of the electron gun in the cathode-ray tube. Such arrangement alters the deflection sensitivity and tends to introduce serious barrel distortion of the image. Some small part of this distortion may be desirable in order to reduce the pin-cushion distortion that is normally characteristic of electrostatic deflection fields. The desired balance between the barrel

distortion and the pin-cushion distortion is further affected by the optional inclusion of a post accelerator electrode used to increase the brilliance of the image without requiring excessive sweep voltages. Accordingly a further object of this invention is to provide a new and useful method and arrangement for correction of spot distortion adapted to control as a variable essentially independent of the image-formation and image-correction systems.

In the drawings there are shown several embodiments of the invention having an electron lens system including cylindrical lens means to introduce a certain beam distortion in advance of the deflection system which is very nearly equal and opposite to the cylindrical beam distortion caused by a transverse deflection field. For further improvement, spherical focus adjustment is also introduced. For crossed deflection fields the correction electron lens system and its energization are somewhat more complex but utilizes similar lens elements. The invention will be better understood, together with further features of novelty and objects from the following specific but illustrative disclosure including the drawings in which:

Fig. 1 is a diagrammatic view of an undeflected electron beam focused at the target;

Fig. 2 is a similar view of an electron beam vertically deflected electrostatically;

Fig. 3 is an exploded perspective view of a cathode-ray tube including a single transverse electrostatic deflection field and one form of focus-correction electrode, and a circuit arrangement for beam-distortion correction;

Fig. 4 is a similar view of cathode-ray tube elements incorporating a modified electron lens system;

Fig. 5 is a similar view of a cathode-ray tube and an operating circuit showing another arrangement of focusing and correction electrodes;

Fig. 6 is a similar diagrammatic view of a cathode-ray tube utilizing magnetic deflection in the horizontal direction together with another form of beam-correction system and a circuit for the correction system; and

Fig. 7 is a similar view of a cathode-ray tube and circuit for crossed electrostatic deflection fields with an electrostatic arrangement for correcting beam distortion.

In Fig. 1 an electron beam is shown which converges to a point *p* at target T. The pencil of electron rays is circular in cross-section before reaching the deflection plates **10** and **12** as is indicated by the shaded area. Rays *a* and *b* represent electron paths at the upper and lower extremes in the y direction, and lines c and d represent electron paths for the extremes in the x direction. It is assumed that this converging electron beam passes between electrostatic deflection plates **10** and **12** which are both at the same potential and in an equipotential space, and which therefore exert no deflection or focusing force on the electron beam. In Fig. 2 the same electron beam, including extreme paths a' and b' in the y direction and extremes c' and d' in the x direction are all deflected because of a potential difference applied between plates **10** and **12**, but at target T they do not focus at a point. Electrostatic plates characteristically exert a focusing effect in addition to their primary deflection function. As a consequence the components of the electron beam tend to cross over at various points before reaching target T, in the manner of a light beam passing through a prism having convex faces. The spot p' on target T is observed to be greatly elongated in the direction of the deflection (y) and is also somewhat spread in the x direction. Thus paths a' and b' intersect at q, some distance away from target T, whereas paths c' and d' intersect at r, considerably closer to target T.

In order to maintain a spot of minimum area, I adjust the focus of the electron rays (their angle of convergence or their lateral separation or both) before the beam enters a deflection field.

No correction is required for zero deflection in the usual type of cathode-ray system, and a substantial correction is required for extreme deflection. The means for disturbing the circular symmetry of the beam includes a cylindrical electron lens which is energized as some function of the deflection field-strength. I also use a variable spherical electron lens, energized as a function of the deflection field-strength, for further improvement in the focus correction and for improved operation of the cylindrical lens.

The term "cylindrical electron lens" is here used to mean any electron-focusing field which in effect resembles a cylindrical optical lens, in producing equal increased or decreased convergence of the electron paths in spaced parallel planes. This type of electron lens is alternatively referred to as a two-dimensional lens, and in an electrostatic system at least one of the electrodes which establish this lens variously takes the shape of a slit between two transverse equipotential plates or an axially extended space between conductive walls which are directly wired to each other but are different in potential from part of the adjacent electron-optical system. The term "spherical electron lens" is here used to mean any focusing field for an electron beam which in effect resembles a spherical optical lens, in producing equal converging or diverging effects in all planes having a common intersection coinciding with the axis of the electron-optical system. Spherical electron lenses may variously take the form of conductive plates or tubes with circular passages for the electrons, centered about the beam path, differing in potential from similar adjacent elements. Where the term "combined spherical and cylindrical electron lens" is used, the metallic construction in an electrostatic system will usually include circularly symmetrical and parallel-edged components to be energized by appropriate circuits. Optionally either lens component can precede the other in the region before the deflection field.

While electrostatic electron lenses are described herein for illustrative purposes and appear now to be more important, appropriate corrective magnetic electron lenses and combinations of magnetic and electrostatic lenses can be substituted. Thus, with either electrostatically or magnetically focused electron guns, a magnetic cylindrical electron lens appears to be superior to a like electrostatic lens when the deflection system is magnetic. Purely electrostatic correction appears to be preferable for correction of beam distortion in an electrostatic deflection arrangement.

In Fig. 3 there is shown an electrostatically focused electron gun, plates for providing a balanced transverse electrostatic deflection field and an arrangement for introducing the desired corrective distortion for the beam before it enters the deflection region. The arrangement is of use as shown, where the crossed transverse deflection field is magnetic; and it illustrates the fundamental features that are utilized in correcting beam distortion in crossed electrostatic fields.

Plates **14** and **16** constitute a vertical deflection field system, and are shown with elements **18** of a known form of cathode-ray gun that is suitable for providing an adjustably focused electron beam. Included in gun **18** are cathode **20**, grid **22** and focusing electrodes **26**, **28** and **30** severally in the form of circular-apertured plates and conductive cylinders. Source **24** provides beam intensity control voltage, as from the video amplifier in a television receiver or an adjustable D.-C. supply.

Positioned in advance of deflection plates **14** and **16** is a composite cylindrical and spherical corrective lens **32**. The corrective lens in this instance utilizes part of the focusing electrodes of gun **18** as a spherical corrective component and in addition a pair of parallel-edged plates **36** as part of a predominantly cylindrical electron lens. Plates **36** provide a slit perpendicular to the deflection plane. This slit contrasts with a circular aperture, and is seen to be an aperture that is elongated transverse to the path of the electron beam, and symmetrical about the y vertical and x horizontal axes that intersect at the center of the slit and perpendicular to the z axis along the electron beam path. Electrode **26** is preferably maintained at constant D.-C. potential with respect to the cathode, in order not to disturb the characteristic of beam-intensity triode **20**, **22**, **26**. To avoid changing the deflection sensitivity of plates **14** and **16**, the potential on the electrode closest to the deflection system should also be held constant. By maintaining the voltage on slit electrode **36** constant at the mean potential of the system, this condition is satisfied. With no deflection the potential on last circular anode **30** is made the same as that of slit electrode **36** and the potentials of focusing electrodes **26**, **28** and **30** are made such as to provide a point focus at the screen. The potential on last anode **30** can then be lowered relative to slit electrode **36** to decrease the beam convergence primarily in the vertical plane. This is accompanied by a spherical change in focus because of changed voltage gradients at both sides of anode **30**. At the same time the spherical beam focus is appropriately adjusted by properly changing the potential on electrode **28** in relation to electrodes **26** and **30**. The composite result is a slightly enlarged horizontal beam spread and an appreciably enlarged vertical spread which after traversing the deflection field is restored to point focus.

Deflection-voltage source **38** applies a balanced voltage difference to plates **14** and **16**, and at the same time source **38** energizes separate rectifying, wave-shaping, and amplifying voltage supplies **42** and **44**. The modified deflection voltage developed in supply **42** is combined with the D.-C. potential normally applied between cathode **20** and spherical focus electrode **28**. The last circular aperture electrode **30** is normally maintained at a constant potential with respect to cathode **20**, conveniently the same potential as that of first anode **26**, and this voltage is combined with the modified deflection voltage developed in supply **44**. Plates **36** are connected to each other and, if no effect on the image raster is desired, to the mean potential point of deflection-voltage source **38** as well as to the usual internal conductive coating **46** surrounding the deflection system. The potential of slit electrode **36** can thus be made the same as the mean potential of the balanced deflection system **14**, **16**.

In operation of this circuit there is no voltage at the output terminals of unit **38** when there is to be no deflection, and nothing is combined with the D.-C. voltages in units **42** or **44**. The potentials on all of the focusing electrodes at this time should be so adjusted as to provide essentially a point focus at target T. Slit electrode **36** will then be at the potential of last electrode **30**. Under normal (no deflection) conditions the potential of center aperture **28** is much lower than both first anode **26** and last aperture **30**. For correction of the beam in the presence of a deflection voltage, the circuit in the block diagram appropriately adjusts the voltages on electrodes **28** and **30**.

I have found the spot distortion to be a nonlinear function of the deflection, being the same for equal deflections on opposite sides of the axis for aligned electrodes. Consequently units **42** and **44** will include a rectifier when used in a system producing this type of distortion, and in addition, a wave-shaper.

In Fig. 4 there is shown an alternative arrangement for achieving substantially the same results as in Fig. 3, a vertical slit being substituted for the horizontal slit of Fig. 3. The electrodes are all unchanged in Fig. 4 as compared with Fig. 3, except that plates **36′** are arranged to provide a slit perpendicular to the deflection plates **14** and **16** or otherwise regarded, the slit provided by plates **36′** is parallel to the deflection. Using the same circuit as in Fig. 3 but by making the voltage on electrode **30** variably positive relative to the slit electrode it is possible to increase the convergence toward the vertical plane between electrode **30** and slit **36′**. Some change in the magnitude and wave-shape of supplies **42** and **44** is also desirable.

This arrangement provides the desired beam the vertical spread of which is sufficiently increased to correct for the inherent non-circular focusing or beam-distorting effect of deflection plates **14** and **16**. The focus in the horizontal plane of the beam can at the same time be adjusted to complement the spherical and cylindrical effects of electrodes **30** and **36′** in correcting for the tendency of the deflection plates to cause cross-over of the electron paths represented by *c′* and *d′* in Fig. 2.

Figs. 3 and 4 involve alternative methods of changing the focus of the beam emerging from first electrode **26** of the characteristically electrostatic system. The purpose to be achieved is the correction of the spot distortion caused by a transverse deflection field, without materially affecting the deflection sensitivity, and this is achieved overall by weakening the focus of the beam in a non-circular manner before the beam reaches the deflection field. This shaping of the beam is achieved without affecting its deflection by providing electrodes enabling operation with constant potential on the last electrode adjacent the deflection system. In order not to affect the beam intensity it is furthermore desirable to include a constant-potential anode between the cathode and the beam focusing and shaping region.

It is not necessary for the slit electrode (or comparable two-dimensional electron-lens component) to follow the spherical electron lens system although the arrangements described above now appear to be preferable. The arrangement in Fig. 5 is an illustration of an alternative in which the correction component precedes the circular focusing elements, retaining the independent control of beam intensity and deflection as in Figs. 3 and 4. Vertical deflection plates **70** and **72** are provided with a properly corrected beam by cathode **74**, first anode **76**, slit anode **78** and three circularly symmetrical electrodes **80**, **82** and **84**. The intensity of the beam is controlled by "grid" **86** between cathode **74** and first anode **76** by means of a video or adjustable D.-C. supply **88**. D.-C. supply **89** maintains electrodes **76** and **84** at constant potential to stabilize the characteristic of triode **74**, **86** and **76** and the deflection sensitivity. The halves of electrode **78** are wired to each other and to electrode **76**. A variable supply **90** establishes a potential difference between slit and circular electrodes **78** and **80** primarily for spreading the beam in a vertical plane while variable supply **91** and D.-C. supply **92**, connected to electrode **82**, separately adjust the spherical focus of the beam. The voltages from supplies **90** and **91** are related in appropriate manner as described in connection with Fig. 3 to the deflection voltage source **93** so that the beam distortion caused by the deflection system will be neatly compensated. Because the non-circular correction will evidently be reduced by the spherical electron lenses following, the arrangements of Figs. 3 and 4 are now regarded preferable.

In Fig. 6 an arrangement is shown for correcting the spot when magnetic deflection is used. The two-section coil **48** is provided for deflecting the beam, ordinarily circular in cross-section, produced by the electron gun comprising cathode **50**, intensity-control grid **52**, and focusing electrodes **54**, **55** and **56**. For zero deflection the focus is adjusted for incidence at the target in a spot of minimum size. When coils **48** are energized by deflection supply **60** to produce a deflection field, and the beam is closer to one of the deflection coil sections than the other, the different transverse portions of the beam will be variously affected by the magnetic deflecting field and its incidence at the target will be enlarged in the direction of the deflection.

The spot distortion is less with magnetic deflection than with electrostatic deflection, because of greater uniformity of the deflecting field and because there is no change in beam velocity; but image definition can be improved and the length of the tube decreased in a wide-angle deflection system by correcting the beam before it enters the deflection field. Thus, a flat-field coil **58**, optionally in two parts as shown, can be arranged to provide an axial field in advance of the deflection field of practically uniform field strength in the x direction, having appreciable variation in the y direction (as well as along the axis). Optionally the flat magnetic field can be arranged to coincide with the spherical focusing region to yield a shortened construction.

Current through coil **58** from wave-shaping supply **62**, and voltage provided by shaping, amplifying and rectifying supply **64** combined with the normal D.-C. voltage on anode **55** adjust the cylindrical and spherical focus. By weakening the electrostatic focus of the beam in the electron gun and compressing it in the y direction upon energization of coil **58**, the horizontal elongation of the spot or focus foreshortening that would normally be caused by coil **48** can be compensated.

It should be understood that the electrostatic focusing elements shown in Fig. 6 can be replaced by an axial magnetic coil, and its current or the current through a supplementary axial coil can be appropriately varied by a current source like supply **64**. Also crossed magnetic deflection fields can be corrected for spot distortion by mutually perpendicular axial flat-field coils like coil **58** and one or more spherical correction coils encircling the tube neck and energized in part by the deflection supplies appropriately revised to deliver wave-shaped current.

If one deflection field of a cathode-ray tube is electrostatic and a crossed deflection field is magnetic it may be found entirely satisfactory to correct for the spot distortion of the electrostatic field only, as in Figs. 3 or 4, leaving the lesser magnetically caused beam-distortion uncorrected. In the alternative the electrostatic deflection and correction arrangement of Figs. 3, 4 or 5 may be used together with a crossed magnetic deflection and correction arrangement as in Fig. 6. However, it is desirable where both of the crossed fields are electrostatic that there be a corresponding correction for both horizontal and vertical distortions of the beam focus.

In Fig. 7, a cathode-ray tube is shown including an illustrative form of correction and focusing electrode assembly for crossed electrostatic fields. Vertical deflection plates **100**, **102** and horizontal deflection plates **104**, **106** constitute the deflection system, while electron gun **108** supplies a focused beam of electrons and correction system **110** modifies the normally circular electron beam to correct the vertical or horizontal or both beam-distortion components. The corrected beam, after passing through the deflection field, will be excellently focused at target T despite the inherent circularly asymmetrical focusing action of the deflecting plates.

Electron gun **108** includes cathode **112**, intensity-control "grid" **114**, first anode **116**, center aperture **118**, and last anode **120**. A suitable bias and intensity control signal is applied to grid **114**, as from the video amplifier in a television receiver. First anode **116** is held at a high constant positive potential by D.-C. supply **121** with respect to the cathode in order that all variations in beam intensity shall be caused under control of grid **114** alone. Center aperture **118** and last aperture electrode **120** are held at high positive potentials, but the potentials on these electrodes are made variable in accordance with modified deflection voltages, to be described. The voltage on electrode **118** is normally much lower than that on last aperture **120**.

Included in correction system **110** are portions of the focusing arrangement of gun **108**, two slit

electrodes **122** and **124**, both having horizontal slits, and a third slit electrode **126** the slit of which is vertical. (A single horizontal slit can alternatively be arranged to precede two vertical slits, with appropriate circuit adjustments. The slit adjacent the rear deflection plates preferably is parallel to the rear edges of those plates.) Slit electrodes **122** and **126** are both held at constant potential, conveniently that of electrode **116**, and the internal conductive coating **128** of the cathode-ray tube is also conveniently held at this potential. A balanced vertical deflection source **130** and a balanced horizontal deflection source **132** are also connected at their center points to the D.-C. source that energizes slit electrode **126**. Deflection voltage sources **130** and **132** are connected to rectifying, combining and wave-shaping unit **134**. This unit ideally provides a voltage varying as a function of the radial beam deflection. As an approximation, the sweep voltages can be rectified, added in a series circuit, limited to the peak value of either one, and this resultant can be put through a wave-shaper. Alternatively the two voltages can be applied to separate balanced modulators having a common carrier, relatively shifted 90° in the two modulators, and the output of the two modulators can be added and then amplitude-detected. This provides a varying voltage corresponding to the instantaneous radial deflection which is then put through an appropriate wave-shaper. In another alternative a flat resistor having a central conductive button and a peripheral conductive ring can be used in a small auxiliary cathode-ray tube as a voltage divider the movable contact of which is the deflected electron beam. The particular details of combining unit **134** that is used form no part of the present invention.

Voltage from unit **134** is combined with the D.-C. from source **136** and applied to spherical focus electrode **118**. A rectifying and combining unit **138** for adding and wave-shaping the separately rectified sweep voltages, variably reduces the D.-C. potential on last anode **120**. Another rectifying, amplifying and wave-shaping circuit **140**, energized by horizontal deflection source **132**, is used to variably reduce the D.-C. potential on second horizontal slit **124**. In the block diagram shown the signal output of unit **140**, superimposed on the rectified and wave-shaped signal developed in unit **138**, is applied to last anode **120**.

In operation the beam is directed at the center of the screen in the absence of deflection signals and the potentials on spherical focus electrodes **116**, **118** and **120** are made proper for producing point focus. The potential on all the slit electrodes with no deflection is the same as that on last anode **120** and as the mean of the deflection system, so that there is no further change of the beam focus in traversing those elements.

When only a horizontal deflection voltage appears the potential on electrode **124** is reduced. Due to the potential gradient along the electron path, vertically slit electrode **126** causes the focus of the electron rays of the beam to be extended primarily in the horizontal direction. There is an important vertical effect at electrode **124**, even though the fields traversed by the electron beam on entering and leaving electrode **124** may be equal and opposite. This is eliminated by applying the voltage from unit **140** through unit **138** to last anode **120**. Deflection source **130** at this time adds nothing to the output of combining unit **138**. The spherical focus is adjusted by the changed voltage on electrode **118** due to supply

134. However there is a change in spherical focus between electrodes 118 and 120 due to the lowering of the voltage on anode 120, and this makes possible the total elimination of variable supply 134 with critical design of the electrode assembly, provided that the relative dimensions, spacing and D.-C. voltages are carefully designed.

When only a vertical deflection voltage appears, the potential on last anode 120 is reduced and the beam focus is extended predominantly in the vertical direction as explained in connection with Fig. 3. The spherical focus is also properly changed by changed potential on electrode 118 to perfect the corrective beam-conditioning in advance of the deflection system. Electrode 124 is at this time at the same potential as electrodes 122 and 126 and therefore does not further affect the beam.

In the presence of crossed deflection fields, the two crossed components of the beam-focus correction are severally provided as described above. In unit 138 the rectified and shaped signals are added, to reduce the voltage on anode 120 further than on 124 for proper correction of the crossed cylindrical components. The signal on electrode 118 provides the proper spherical correction.

The focus-correcting arrangements described are primarily intended to avoid the spot distortion caused by usual deflection systems; but where the spot distortion is altered by special deflection system designed principally to reduce image distortion or for other purposes, the foregoing arrangements provide an independent control over beam focus. It will be recognized that the improved focus of a variably deflected circular electron beam achieved with my invention, while of importance primarily in tubes having a photoelectric or a fluorescent screen, is also applicable to other types of tubes having, for example, a target embodying distinct conductive areas. And whereas several embodiments have been illustrated as preferred, it will be recognized that others will occur to those skilled in the art.

What I claim is:

1. A cathode-ray device having a cathode for providing an electron stream, a target, means for causing transverse deflection of the electron stream across said target, electrodes forming said stream into a beam and additional electrodes establishing electrically variable spherical and cylindrical electron lenses providing a substantially fixed straight-line electron path between said cathode and said deflection means and effective when energized to variably control the focus of the beam and to extend the focus in non-circular symmetry as a function of the stream deflection said electrodes including a final electrode disposed in advance of the deflection means which electrode can be connected to a fixed potential point as others of said electron lens electrodes are varied in potential.

2. A cathode-ray device according to claim 1 wherein said cylindrical electron lens is established by electrodes including an electrode having a transversely symmetrical aperture elongated transverse to the electron stream.

3. A cathode-ray device according to claim 1 including in addition an intensity control electrode between said cathode and said stream focusing lenses.

4. Cathode-ray apparatus including a cathode-ray device having a cathode, a screen, transverse deflection means and plural beam focusing and shaping elements between said cathode and said deflection means, one of said elements being circularly asymmetrical, deflection supply means for energizing said deflection means, and wave-shaping circuits interconnecting said deflection supply means and said focusing and beam-shaping elements for variably circularly enlarging the electron beam and for causing circular asymmetry as a function of the deflection, in advance of the deflection field.

5. A cathode-ray system according to claim 4 wherein a constant potential supply is connected between that element of the focusing and correcting elements which is closest to said deflection elements and the point of mean potential in said deflection supply means.

6. A cathode-ray system according to claim 4 including in addition an intensity control electrode between said cathode and said focusing and beam shaping elements, and a constant voltage supply between said cathode and the first of said focusing and shaping electrodes adjacent said intensity control electrode.

7. Cathode-ray apparatus including a cathode-ray device having a cathode, a screen, a transverse deflection system for variably directing an electron stream from said cathode to various portions of said screen, a plurality of electrodes between said cathode and said deflection system for focusing the electron stream in circular symmetry or asymmetry as a function of the deflection, at least one of said electrodes having a transversely long and narrow aperture, and an intensity control electrode between said cathode and said focusing electrodes, in combination with deflection supply means for said system, constant potential supply means for those focusing electrodes immediately adjacent said intensity control electrode and adjacent said transverse deflection system, and wave-shaping voltage supplies coupling said deflection supply means to certain of said focusing electrodes.

8. A cathode-ray tube having a cathode for providing an electron stream, a screen at which the stream is to be focused at an area of minimum circular size irrespective of deflection, means between said cathode and said screen for producing neutrally perpendicular symmetrical transverse deflection fields, and a plurality of aligned electrodes between said cathode and said deflecting means for shaping the electron stream into a beam focused at said screen in an area of minimum circular size irrespective of the inherent non-circular focusing effect of the deflection fields, said electrodes including plural circularly symmetric electrodes and an adjacent series of three electrodes, the first two of which have transversely elongated slots parallel to one deflection field and the third having an elongated slot parallel to the other deflection field.

9. Cathode ray apparatus including a cathode-ray device having a cathode, a screen, a transverse deflection couple between said cathode and said screen, beam-focusing and focus-correcting electrodes between said cathode and said deflecting couple including at least one unipotential electrode having a transversely elongated passage, a deflection signal source for said deflection couple, and connecting and wave-shaping circuits between said source and said electrodes.

10. A cathode-ray device including a cathode-ray tube having a cathode for providing an electron stream, a screen, a pair of mutually perpendicular deflection couples for determining the traverse of the electron stream over said screen, and electron-focusing and focus-correcting electrodes embodying circular and transversely elon-

gated passages positioned between said cathode and said deflection couples, deflection signal supplies for said deflection couples, a correction signal source connected to a said circularly symmetrical electrode for providing a voltage varying as functions of the signals from said deflection supplies, and connections between one of said deflection supplies and another of said focus-correcting electrodes.

11. The method of correcting for the defocusing effect of a deflection field in a cathode-ray device causing non-circular enlargement of the normally circular incidence of the beam preferentially at the screen or target, which comprises the steps of providing a normally circular electron beam and spreading the beam in the direction of the deflection as a function of the deflection field before it enters the deflection field.

12. The method of correcting for the spot distortion of the beam in a cathode-ray device at the screen or target caused by the deflection field, which comprises the steps of adjusting the beam focus three-dimensionally and two-dimensionally before it reaches the deflection field, each as a respective function of the deflection field.

13. The method of correcting for the distortion of a normally circular electron beam due to an electrostatic deflection field, which comprises the step of electrostatically extending the focus of the beam predominantly in one transverse plane in advance of the deflection field and as a function of the field.

14. The method of correcting for the non-circular distortion of a normally circular electron beam caused by a magnetic deflection field, which comprises the step of magnetically changing the beam focus predominantly in one transverse direction as a function of the deflection field.

15. The method of correcting for the non-circular defocusing effect of a pair of crossed deflection fields which comprises the step of extending the beam focus in the separate directions of the deflection fields before entering those fields as functions of the deflection field intensities.

16. The method of correcting the focus-distortion of a cathode ray that is incidental to deflection comprising the step of cylindrically adjusting the focus of the electron beam in advance of the deflection field as a function of the deflection.

17. Cathode-ray apparatus comprising a cathode-ray tube having a cathode for providing an electron beam, a screen at which the beam is desirably focused at an area of minimum circular size irrespective of deflection, a transverse deflection couple between said cathode and said screen, plural accelerating and focusing electrodes between said cathode and said deflection couple, at least one of said electrodes having a transversely elongated passage acting with an axially adjacent electrode to modify the focus of the electron beam in the manner of a cylindrical lens, a source of deflection voltage, and wave-shaping and proportioning circuits between said deflection voltage source and at least one of said electrodes for variably adjusting its voltage as a function of the deflection voltage.

18. Cathode-ray apparatus including a cathode-ray tube having a cathode and the first anode for providing a normally circular electron beam, a screen at which the beam is intended to be focused at an area of minimum circular size independent of deflection, a pair of transverse deflection couples mutually perpendicular to each other, a plural-electrode electron optical system between said first anode and said deflection couples the last electrode of which is connected to the mean potential point of said deflection couples and, through a constant potential source, to said cathode, said electron optical system including a circularly symmetrical electrode energized as a function of the combined deflection fields, and an electrode having a transversely elongated aperture forming part of a cylindrical lens energized as function of said composite fields.

19. Cathode-ray apparatus including a cathode-ray tube having a cathode, a target, a transverse deflection couple between said cathode and said target, and a focusing system between said cathode and said couple for focusing the cathode ray from said cathode on said target in an area of minimum circular size, said system including an axial flat-field electromagnet.

20. Cathode-ray apparatus including a cathode-ray tube having a cathode and a first anode for providing an electron beam normally circular in cross section, a screen at which the beam is intended to be focused at an area minimum circular size independent of deflection, a pair of transverse deflection devices between said cathode and said screen disposed to produce transverse deflection fields perpendicular to each other, each deflection device having a respective deflection signal supply, a multiple-electrode electron optical system between said first anode and said deflection devices, the last electrode of said electron optical system being connected to the mean point of the deflection signal supply of the deflection device nearest to said last electrode, said electron optical system including electrodes establishing a variable spherical electron lens and electrodes forming plural cylindrical electron lenses effectively extending parallel respectively to the fields of the deflection devices, a wave-shaping circuit between one of said cylindrical lens electrodes and one of said deflection signal supplies, a first combining and wave-shaping circuit connected for energization by both said deflection supplies and connected to a second of the electrodes forming said cylindrical lenses, and a further combining and wave-shaping circuit connected for energization by both said deflection signal supplies and connected to a spherical lens electrode, all for the purpose of adjusting cylindrical and spherical focus of the electron beam entering the deflection fields to correct for defocusing due to the crossed deflection fields.

21. A cathode ray device having a cathode for providing an electron stream, a target, deflection field producing means disposed between said cathode and said target, electrodes forming said stream into a beam, a beam-intensity control electrode, and electrodes establishing electrically variable spherical and cylindrical electron lenses, all said electrodes being disposed between said cathode and said deflection means, and providing a substantially fixed straight line electron beam path, said electron lens electrodes including an electrode having an aperture elongated transverse of the electron beam path which aperture is symmetrical about a pair of mutually perpendicular axes in the plane perpendicular to the electron path, said electrodes including a final electrode that can be connected to a fixed potential point separate from others of the electrodes that can be varied in potential, said spherical and cylindrical lenses being effective when energized to variably control the focus of the beam and to extend the focus in non-circular sym-

metry as a function of the electron beam deflection.

22. A cathode-ray device comprising a screen, means for forming and projecting an electron beam along a certain path toward said screen, beam-deflecting means including beam-deflection power supply means effective to cause the beam to scan substantially the entire screen, an electron lens system including a cylindrical electron lens component and spherical electron lens means along said certain path of said beam and both coupled through shaping circuits to said beam-deflection power supply means for energization thereby and effective to minimize the variation in size of the beam when deflected over the area of the screen.

23. A cathode-ray device comprising a screen, means for forming and projecting an electron beam along a certain path toward said screen, vertical electrostatic deflection means and horizontal electrostatic deflection means positioned along said path, separate beam-deflection power supplies for said vertical deflection means and said horizontal deflection means, a cylindrical electron lens component along said certain beam path, a spherical electron lens component separate from said cylindrical electron lens component along the beam path, and coupling and shaping circuits between both of said electron lenses and both of said power supplies.

24. A cathode-ray device comprising an electron target, means for forming and projecting an electron beam along a certain path toward said target, means for deflecting said beam laterally in a first direction including a deflection power supply, means for deflecting said beam laterally in a direction perpendicular to the first direction and including a separate deflection power supply, said deflecting means intrinsically causing variation in shape of the beam incidental to deflection, and a corrective electron lens system including a cylindrical component and a spherical component both coupled through shaping circuits to both of said beam deflection power supplies.

25. A cathode-ray device comprising a screen, means for projecting an electron beam along a path toward said screen, beam-deflecting means including beam-deflection power supply means effective to cause the beam to scan substantially the entire screen, a cylindrical electron lens distinct from said deflecting means, and spherical electron lens means, said lens and lens means both being coupled through shaping circuits to said beam-deflection power supply means and effective to compensate for the inherent beam-defocusing effect of said deflecting means.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,779,794	Ackerman	Oct. 28, 1930
2,089,692	Drewanz et al.	Aug. 10, 1937
2,101,669	Bruche et al.	Dec. 7, 1937
2,103,645	Schlesinger	Dec. 28, 1937
2,114,610	Schlesinger	Apr. 19, 1938
2,137,353	Schlesinger	Nov. 22, 1938
2,196,838	Rogowski et al.	Apr. 9, 1940
2,212,640	Hogan	Aug. 27, 1940
2,217,197	Davisson	Oct. 8, 1940
2,227,020	Schlesinger	Dec. 31, 1940
2,252,441	Schlesinger	Aug. 12, 1941
2,296,102	Gray	Sept. 15, 1942
2,332,622	Calbick	Oct. 26, 1943

FOREIGN PATENTS

Number	Country	Date
111,112	Australia	July 23, 1940