

WO 91/02373



PCT/US90/04556

1

Method and apparatus for controlling dynamic convergence of a plurality of electron beams of a color cathode ray tube

This invention relates generally to color cathode ray tubes (CRTs) and is particularly directed to the control of multiple electron beams incident upon the faceplate of a color CRT.

Most color CRTs employ an in-line electron gun arrangement for directing a plurality of electron beams on the phosphorescing inner screen of its glass faceplate. The in-line electron gun approach offers various advantages over earlier "delta" electron gun arrangements particularly in simplifying the electron beam positioning control system as well as essentially eliminating the tendency of the electron beams to drift. However, in-line color CRT's employ a self-converging deflection yoke which applies a nonuniform magnetic field to the electron beams, resulting in an undesirable astigmatism in and defocusing of the electron beam spot displayed on the CRT's faceplate. In order to achieve three electron beam convergence at the screen edges and corners, the self-converging yoke applies a dynamic quadrupole magnetic field to the beams which over-focuses the beams in the vertical direction and under-focus them in the horizontal direction. This is an inherent operating characteristic of the in-line yoke design.

One approach to eliminate this astigmatism and deflection defocus employs a quadrupole lens with the CRT's focusing electrode which is oriented 90° from the self-converging yoke's quadrupole field. A dynamic voltage, synchronized with electron beam deflection, is applied to the quadrupole lens to compensate for the astigmatism caused by the deflection system. This dynamic voltage also allows for dynamic focusing of the electron beams over the entire CRT screen. The astigmatism of the electron beam caused by the quadrupole lens tends to offset the astigmatism caused by the color CRT's self-converging deflection yoke and generally improves the performance of the CRT.

THIS SHEET HAS BEEN
REPLACED

SUBSTITUTE SHEET

An articles entitled "Progressive-Scanned 33-in. 110° Flat-Square Color CRT" by Suzuki et al published in SID 87 Digest, at page 166, discloses a dynamic astigmatism and focus (DAF) gun wherein spot astigmatism and deflection defocusing is simultaneously corrected using a single dynamic voltage. The electron gun employs a quadrupole lens to which the dynamic voltage is applied and which includes a plurality of generally vertically elongated apertures in a first section of a focusing electrode and a second pair of aligned, generally horizontally oriented elongated apertures in a second section of the focusing electrode. Each electron beam first transits a vertically aligned aperture, followed by passage through a generally horizontally aligned aperture in the single quadrupole lens for applying astigmatism correction to the electron beam.

An article entitled "Quadrupole Lens For Dynamic Focus and Astigmatism Control in an Elliptical Aperture Lens Gun" by Shiral et al, also published in SID 87 Digest, at page 162, discloses a quadrupole lens arrangement comprised of three closely spaced electrodes, where the center electrode is provided with a plurality of keyhole apertures and the outer electrodes are provided with a plurality of square recesses each with a circular aperture in alignment with each of the respective electron beams. A dynamic voltage V_d is applied to the first and third electrodes so as to form a quadrupole field to compensate for the astigmatism caused by the self-converging yoke deflection system. Although this allows for a reduction in the dynamic voltage applied to the quadrupole, this voltage still exceeds 1 KV in this approach. While these two articles describe improved approaches for beam focusing and astigmatism compensation, they too suffer from performance limitations particularly in the case of those CRTs having a flat faceplate and foil tension shadow mask, where the flat geometry imposes

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

substantially greater challenges than those encountered with a curved faceplate.

An electron gun employing a quadrupole lens to which a dynamic voltage is applied generally also includes a Beam Forming Region (BFR) refraction lens design intended to correct for the lack of dynamic convergence of the red and blue outer electron beams. The horizontal beam landing locations of the red and blue beams in color CRTs having an in-line electron gun arrangement change with variations in the focus voltage applied to the electron gun. While the dynamic quadrupole lens compensates for astigmatism caused by the self-converging electron beam deflection yoke, prior art quadrupole lens arrangements do not address the lack of horizontal convergence of the two outer electron beams.

In a more general sense, this invention addresses the problem of how to electrically converge off-axis beams in a three-beam color cathode ray tube, particularly a color cathode ray tube of the type having an in-line gun.

There exists a number of techniques in the prior art for electrically converging off-axis electron beams in a color cathode ray tube. One technique offsets the axes of apertures in facing electrodes. Offsetting the axes of the cooperating apertures creates an asymmetrical field which bends an electron beam in a direction dependent upon the asymmetry and strength of the field. Examples of electron guns having such offset-aperture-type beam bending are U.S. Patent Nos. 3,772,554; 4,771,216 and 4,058,753.

A second approach is to use coaxial apertures, but angle the gap between the facing electrodes to produce the necessary asymmetrical field. Examples of electron guns having such "angled gap" technique for producing the necessary asymmetrical field are disclosed in U.S. Patent Nos. 4,771,216 and 4,058,753.

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

A third approach is to create the asymmetrical field for the off-axis beam or beams by creating a wedge-shaped gap between the addressing electrodes. Examples of this third approach for electrically converging off-axis beams are disclosed in U.S. Patent Nos. 3,772,554 and 4,058,753.

Each of these three approaches suffers from difficulties in mandrelling the electrodes during assembly. One aspect of the present invention is to provide improved means in an electron gun for refracting or bending an electron beam, useful for converging off-axis beams in a color CRT gun.

As discussed above, certain modern high performance electron guns have a dynamic quadrupole lens to compensate for beam astigmatism introduced by an associated self-converging yoke. Incorporation of such dynamic quadrupole astigmatism correctors in electron guns of the type having a common focusing field for all three beams introduces convergence errors due to the converging effect produced by such common lens on the off-axis beam.

In one sense, this invention concerns improved quadrupolar lenses independent of their application or particular implementation, and more particularly concerns a way to bend an electron beam passing through a quadrupolar lens field. Dynamic control of beam angle as a function of potentials applied to the quadrupolar lens is achievable using the present invention.

In accordance with a further aspect of this invention, means are provided for correcting or reducing such convergence errors. As will be explained, this is accomplished by unbalancing the quadrupolar lens fields through which the off-axis beams pass. The unbalancing is accomplished in a preferred embodiment by the creation of an asymmetrical field component which has a refractive effect on the off-axis beams, causing them to converge or diverge as a function of the strength and degree of

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



asymmetry of the asymmetrical fields applied to the off-axis beams. As will also be explained in more detail hereinafter, in a preferred embodiment the asymmetrical fields are produced by providing an aperture pattern in one or more of the facing electrodes employed to create the quadrupolar lens field for the off-axis beams which is shaped to create an asymmetry in the field affecting the off-axis (outer) beams.

In one embodiment to be described (FIGS. 17-20), a novel electrode has a center opening and two outer openings arranged in-line along an electrode axis orthogonal to the gun axis. The outer openings have profile distortions which are symmetrical about the electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axes through the outer beam openings. In one preferred embodiment, the opening profile distortions each take the form of an inwardly or outwardly extending opening enlargement (a notch, for example). In another arrangement (FIG. 22, to be described) the asymmetrical field is produced in an electrode having a horizontal aperture extending across all three beams, the terminal portions of which are vertically larger than the center portions of the horizontal aperture so as to create the aforesaid opening enlargement and asymmetrical field.

This aspect of the invention may be employed in unipotential (Einzel) type quadrupolar lenses, or quadrupolar lenses of the bipotential or other type. The profile distortion provided to create the field asymmetry for the off-axis beams may be located in any or all of the electrodes which constitute the quadrupolar lens. If the profile distortion is located in the electrode or electrodes having relatively higher voltage, the profile enlargement extends away from the center beam opening; if located in the electrode or electrodes having lower applied potential, the opening enlargement which creates

the asymmetrical field extends inwardly toward the center beam opening.

In a broader context, as noted above, the invention concerns a quadrupolar lens for an electron gun having the capability of bending a beam passing through the lens, independent of the application or manner of implementing the quadrupolar lens. In this context, the invention concerns the provision of a quadrupolar lens having at least two facing apertured electrodes, one adapted to receive a relatively higher excitation potential, the electrodes being constructed and arranged such that a quadrupolar field component is created therebetween for the beam when different excitation potentials are applied to the facing electrodes. The quadrupolar field component such as to cause the beam to be diverted from a straight line path as a function of the different applied potentials. The unbalancing, as described, is preferably by provision of an asymmetrical field component in the quadrupolar lens which, in turn, is preferably created by the provision of an aperture pattern in one or both of the facing electrodes, all as outlined above and as will be described in detail hereinafter.

Such a quadrupole lens with beam bending capability may be employed in electron guns in general, but not limited to the type described above and to be described hereinafter wherein the quadrupole lens provides astigmatism correction to offset astigmatism produced by an associated self-converging yoke.

In still a broader context, this invention provides an improved means for electrically bending or diverting the path of an electron beam, independent of its use in a quadrupolar or any other particular type of lens. In the background of the invention set forth above, mention is made of three types of electron-refractive devices which each create an asymmetrical field in the path of an electron beam to divert it from a straight line

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

path. One employs offset apertures, another an angled electrode gap, and a third a wedge-shaped gap between the operative electrodes. Applicants here provide a fourth way -- namely, by the provision of an aperture pattern in one or more of both of the facing electrode(s) which is so shaped relative to the aperture pattern in the facing electrode as to create an asymmetrical pattern in the facing electrode as to create an asymmetrical field influencing the passed electron beams. Thus the beam bender of the present invention may be used in substitution for any of the above three types of beam benders in any application in which they are found, as well as other applications which call for electrical beam divergence. The present invention has the advantage over the aforescussed three types of beam benders found in the prior art in that it is more easily mandrelled during electron gun assembly than any of those arrangements.

In this most general context, the invention may be thought of as comprising means for generating a beam of electrons, and beam bending means for producing an asymmetrical field in the path of the beam for diverting the beam from a straight line path. The beam bending means comprises at least two facing electrodes adapted to receive different excitation potentials and having coaxial beam-passing openings, at least one of the openings being symmetrical about a first electrode axis, but asymmetrical about an orthogonal second axis to thereby produce the said asymmetrical field.

Such a beam bender may be adapted for dynamic convergence by employing it in the off-axis beams and applying a varying potential to one or both of the operative facing electrodes to cause the strength of the asymmetrical field to vary as a function of the applied voltage. In application to a three beam in-line gun color CRT having dynamic convergence, a variable voltage

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

SUBSTITUTE SHEET

correlated with the deflection of the beam across the screen may be applied to one or all of the electrodes.

Thus, one feature of the present invention involves dynamically compensating for astigmatism and beam focusing errors in an in-line, multi-beam color CRT without introduction of convergence errors.

Another feature of the present invention is to provide a quadrupole lens adapted for use in virtually any of the more common in-line color CRTs and which affords precise control of electron beam convergence/divergence.

Another feature of the present invention is to compensate for the non-uniform magnetic field of a self-converging deflection yoke in a color CRT by dynamically controlling horizontal and vertical divergence/convergence of the CRT electron beams.

A still further feature of the present invention is to allow for a reduction in the dynamic focusing voltage provided to a quadrupole electron beam focusing lens for a color CRT and minimize problems involving additional high voltage application through a CRT neck pin.

Another feature of the present invention is to correct for outer electron beam (typically the red and blue beams) dynamic misconvergence in in-line color CRTs having dynamic astigmatism compensation.

Further features and advantages of the present invention will best be understood by reference to the following detailed description of preferred embodiments taken in conjunction with the accompanying drawings, where like reference characters identify like elements throughout the various figures, in which:

FIG. 1 is a perspective view of a dynamic quadrupole lens for an in-line color CRT in accordance with the principles of the present invention;

FIG. 2 is a graphic representation of the variation over time of the dynamic voltage applied to the quadrupole lens of the present invention;

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



FIG. 3 is a simplified planar view of a phosphor screen on the inner surface of a CRT glass faceplate illustrating various deflection positions of the electron beams thereon;

FIGS. 4a and 4b are sectional views of an electron beam respectively illustrating vertical convergence/horizontal divergence (negative astigmatism effect) and vertical divergence/horizontal convergence (positive astigmatism effect) effected by the dynamic quadrupole lens of the present invention;

FIG. 5 is a simplified sectional view illustrating the electrostatic potential lines and electrostatic force applied to an electron in the space between two charged electrodes;

FIGS. 6 through 12 illustrate additional embodiments of a dynamic quadrupole lens for focusing a plurality of electron beams in an in-line color CRT in accordance with the principles of the present invention;

FIGS. 13a and 13b respectively illustrate sectional views of a prior art bipotential type ML electron focusing lens and the manner in which the dynamic quadrupole lens of the present invention may be incorporated in such a prior art electron beam focusing lens;

FIGS. 14a and 14b are sectional views of a prior art Einzel-type ML electron focusing lens and the same focusing lens design incorporating a dynamic quadrupole lens in accordance with the present invention, respectively;

FIGS. 15a, 15b, 15c and 15d respectively illustrate sectional views of a prior art QPF-type ML electron focusing lens and three versions of such a QPF-type ML lens incorporating a dynamic quadrupole lens in accordance with the present invention;

FIGS. 16a and 16b respectively illustrate sectional views of a prior BU-type ML electron focusing

lens and the same type of electron focusing lens incorporating the inventive dynamic quadrupole lens of the present invention;

FIG. 17 is a perspective view of an electron beam misconvergence correction arrangement in accordance with the present invention as employed in a dynamic quadrupole lens for an in-line color CRT;

FIG. 18 is a lengthwise sectional view of an electron beam misconvergence correction arrangement as shown in FIG. 17;

FIG. 19 is a plan view of an offset keyhole electrode design for use in an in-line multi-electron beam focusing arrangement in an electron gun in accordance with the present invention;

FIG. 20 is an end-on view of the focusing electrode of FIG. 19;

FIG. 21 is a perspective view of an electron beam misconvergence correction arrangement incorporating generally circular, notched outer apertures in a center electrode in accordance with another embodiment of the present invention;

FIG. 22 is a plan view of another embodiment of an electrode in accordance with the present invention, where the electrode has a higher voltage than an adjacent focusing electrode;

FIG. 23 is a schematic illustration of a focusing lens structure in a three-beam in-line gun wherein the outer electron beams are electrically converged by the present invention; and

FIG. 24 is a simplified schematic diagram of yet another embodiment of the present invention wherein an asymmetric field component is formed by distorting the outer beam apertures in a pair of adjacent focusing electrodes maintained at different voltages.

Referring to FIG. 1, there is shown a perspective view of a dynamic quadrupole lens 20 for use in an in-line





electron gun in a color CRT. The manner in which the dynamic quadrupole lens of the present invention may be integrated into various existing electron gun arrangements is illustrated in FIGS. 13a and 13b through 16a and 16b, and is described in detail below. Various alternative embodiments of the dynamic quadrupole lens of the present invention are illustrated in FIGS. 10 through 16 and are discussed below. Details of the embodiment of the dynamic quadrupole lens 20 illustrated in FIG. 1 are discussed in the following paragraphs, with the principles of the present invention covered in this discussion applicable to each of the various embodiments illustrated in FIGS. 6 through 12. The present invention may be used to correct for astigmatism in CRTs having electron guns with a focusing field common to all three beams such as the Combined Optimum Tube and Yoke (COTY) CRTs, as well as non-COTY CRTs as described below. A COTY-type main lens is used in an in-line electron gun and allows the three electron guns to have a larger vertical lens while sharing the horizontal open space in the main lens for improved spot size. The terms "electrode", "grid" and "plate" are used interchangeably in the following discussion.

The dynamic quadrupole lens 20 includes first, second, and third electrodes 28, 30 and 32 arranged in mutual alignment. The first electrode 28 includes an elongated aperture 28a extending a substantial portion of the length of the electrode. Disposed along the length of the aperture 28a in a spaced manner are three enlarged portions of the aperture.

The second electrode 30 includes three keyhole-shaped apertures 30a, 30b and 30c arranged in a spaced manner along the length of the electrode. As in the case of the first electrode 28, the third electrode 32 includes an elongated aperture 32a extending along a substantial portion of the length thereof and including three spaced enlarged portions. Each of the

aforementioned keyhole-shaped apertures 30a, 30b and 30c has a longitudinal axis which is aligned generally vertically as shown in FIG. 1, or generally transverse to the longitudinal axes of the apertures in the first and third electrodes 28 and 32. With the first, second, and third electrodes 28, 30 and 32 arranged generally parallel and in linear alignment, the respective apertures of the electrodes are adapted to allow the transit of three electron beams 22, 24 and 26, each shown in the figure as a dashed line.

The second electrode 30 is coupled to a constant voltage source 34 and is charged to a fixed potential VF_1 . The first and third electrodes 28, 32 are coupled to a variable voltage source 36 for applying a dynamic voltage VF_2 to these electrodes. The terms "voltage" and "potential" are used interchangeably in the following discussion. The present invention is described in detail in the following paragraphs with the dynamic and static voltages applied as indicated, although the principles of this invention also encompass applying a dynamic voltage to the second intermediate electrode 30 while maintaining the first and third electrodes 28, 32 at a fixed voltage.

Referring to FIG. 2, there is shown a graphic representation of the relative voltages at which the second electrode 30 and the first and third electrodes 28, 32 are maintained over time. As shown in FIG. 2, the VF_1 voltage is maintained at a constant value, while the VF_2 voltage varies in a periodic manner with electron beam sweep. The manner in which the VF_2 dynamic voltage varies with electron beam sweep can be explained with reference to FIG. 3 which is a simplified planar view of a CRT faceplate 37 having a phosphorescing screen 38 on the inner surface thereof. The dynamic focusing voltage VF_2 applied to the first and third electrodes 28, 32 varies in a periodic manner between a minimum value at point A and a maximum value at point C as shown in FIG. 2. The minimum

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



value at point A corresponds to the deflection of the electron beams positioned along a vertical center line of the CRT screen 38 such as shown at point A' as the electron beams are deflected horizontally across the screen. As the electron beams are further deflected toward the right edge of the CRT screen in the vicinity of point B, the dynamic voltage VF_2 increases to the value of the fixed focus voltage VF_1 as shown at point B in FIG. 2. Further deflection of the electron beams toward the right edge of the CRT screen 38 at point C' occurs as the dynamic focus voltage VF_2 increases to its maximum value at point C in FIG. 3 which is greater than VF_1 . The dynamic voltage VF_2 then decreases to the value of the fixed focus voltage VF_1 as the electron beams are deflected leftward in FIG. 3 toward point B' which is intermediate the center and lateral edge locations on the CRT screen 38. The dynamic voltage VF_2 varies relative to the fixed voltage VF_1 in a similar manner when the electron beams are deflected to the left of point A' in FIG. 3 to cover the other half of the CRT screen. In some color CRTs currently in use, such as those of the COTY type, the dynamic focus voltage is varied in a periodic manner but does not go below the fixed focus voltage VF_1 . This type of dynamic focus voltage is labeled VF_2 in FIG. 2 and is shown in dotted line form therein. The dynamic focus voltage is applied to the first and third electrodes 28, 32 synchronously with the deflection yoke current to change the quadrupole fields applied to the electron beam so as to either converge or diverge the electron beams, depending upon their position on the CRT screen, in correcting for deflection yoke-produced astigmatism and beam defocusing effects as described below.

Referring to FIGS. 4a and 4b, there is shown the manner in which the spot of an electron beam 40 may be controlled by the electrostatic field of a quadrupole lens. The arrows in FIGS. 4a and 4b indicate the

direction of the forces exerted upon an electron beam by the electrostatic field. In FIG. 4a, the quadrupole lens is horizontally diverging and vertically converging causing a negative astigmatism of the electron beam 40. This negative astigmatism corrects for the positive astigmatism of the beam introduced by a COTY-type main lens. Negative astigmatism correction is introduced when the beam is positioned in the vicinity of the vertical center of the CRT screen in a COTY-type main lens. In FIG. 4b, the quadrupole lens is vertically diverging and horizontally converging for introducing a positive astigmatism correction in the electron beam. Positive astigmatism correction compensates for the negative astigmatism of the electron beam spot caused by the self-converging magnetic deflection yoke as the electron beam is deflected adjacent to a lateral edge of the CRT's screen. Positive and negative astigmatism correction is applied to the electron beams in a COTY-type of CRT. In a non-COTY-type of CRT, only positive astigmatism is applied in the electron beams. The manner in which the present invention compensates for astigmatism in both types of CRTs is discussed in detail below.

Operation of the dynamic quadrupole lens 20 for an in-line color CRT as shown in FIG. 1 will now be described with reference to Table I. Table I briefly summarizes the effect of the electrostatic field of the dynamic quadrupole lens 20 applied to an electron beam directed through the lens. The electrostatic force applied to the electrons in an electron beam by the electrostatic field of the dynamic quadrupole lens is shown in FIG. 5.

Referring to FIG. 5, there is shown a simplified illustration of the manner in which an electrostatic field, represented by the field vector $\vec{E}$, applies a force, represented by the force vector $\vec{F}$, to an electron. An electrostatic field is formed between two charged

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



electrodes, with the upper electrode charged to a voltage of V_1 and the lower electrode charged to a voltage of V_2 , where V_1 is greater than V_2 . The electrostatic field vector $\vec{E}$ is directed toward the lower electrode, while the force vector $\vec{F}$ is directed toward the upper electrode because of the electron's negative charge. FIG. 5 provides a simplified illustration of the electrostatic force applied to an electron, or an electron beam, directed through apertures in adjacent charged electrodes which are maintained at different voltages. It can be seen that the relative width of the two apertures in the electrodes as well as the relative polarity of the two electrodes determines whether the electron beam is directed away from the A-A' axis (divergence), or toward the A-A' axis (convergence).

With reference to FIG. 1 in combination with Table I, the horizontal slots 28a, 32a in the first and third electrodes 28, 32 cause vertical divergence of the electron beam when they are maintained at a voltage greater than the second electrode 30 such as when the electron beams are positioned adjacent to a lateral edge of the CRT screen. With the second electrode 30 maintained at a lower voltage V_F , than the other two electrodes when the electron beams are located adjacent the CRT screen's lateral edge, as shown at point C in FIG. 2, the vertically aligned apertures of the second electrode effect a horizontal convergence of the electron beams which reinforces the vertical divergence correction of the other two electrodes. This combination of vertical divergence and horizontal convergence of an electron beam 40 is shown in FIG. 4b and represents a positive astigmatism correction which compensates for the negative astigmatism introduced in the electron beam by the CRT's self-converging magnetic deflection yoke.

When the electron beams are positioned between the center and a lateral edge of the CRT screen, all three

electrodes are at the same voltage and the dynamic quadrupole lens does not introduce either an astigmatism or a focus correction factor in the electron beams. In non-COTY CRTs, the three electrodes are also maintained at the same voltage when the electron beams are positioned on a vertical center portion of the CRT screen as shown graphically in FIG. 2 for the dynamic focus voltage VF_2 . In this case, because all three electrodes are again maintained at the same voltage, the dynamic quadrupole lens does not introduce a correction factor in the electron beams to compensate for deflection yoke astigmatism and defocusing effects. In COTY-type CRTs, the dynamic focusing voltage VF_2 applied to the first and third electrodes 28, 30 is less than the fixed voltage VF_1 of the second electrode 30 in the vicinity of the center of the CRT screen. With the polarity of the electrodes changed, the first and third electrodes 28, 32 introduce a vertical convergence in the electron beams as shown in Table I. The second electrode 30, now at a higher voltage than the other two electrodes, introduces a horizontal divergence by virtue of its generally vertically aligned apertures. The vertical convergence effected by the first and third electrodes 28, 32 and the horizontal divergence caused by the second electrode 30 introduces a negative astigmatism correction in the electron beams as shown in FIG. 4a. The negative astigmatism correction compensates for the positive astigmatism effects of a COTY-type main lens on the electron beams in the center of the CRT screen.

Although the first and third electrodes 28, 32 are each shown with a single elongated, generally horizontally aligned aperture, the present invention also contemplates providing each of these electrodes with a plurality of spaced, aligned apertures each having a horizontally oriented longitudinal axis and adapted to pass a respective one of the electron beams. In addition,



while the operation of the present invention has thus far been described with the dynamic quadrupole lens positioned after electron beam cross over, or between cross over and the CRT screen, the dynamic quadrupole lens may also be positioned before beam cross over, or between the electron beam source and cross over. The effect of the dynamic quadrupole lens on the electron beams is reversed in these two arrangements as shown in Table I.

Referring to FIGS. 6 through 12, there are shown various alternative embodiments of the dynamic quadrupole lens of the present invention. In the dynamic quadrupole lens 50 of FIG. 6, the first and third electrodes 51 and 53 include respective elongated, generally rectangular apertures 51a and 53a through which the three electron beams are directed. The second electrode 52 includes a plurality of spaced, generally rectangular shaped apertures 52a, 52b and 52c. Each of the rectangular apertures 52a, 52b and 52c is aligned lengthwise in a generally vertical direction.

The dynamic quadrupole lens 60 of FIG. 8 is similar to that of FIG. 6 in that the first and third electrodes 61 and 63 each include a respective rectangular, horizontally oriented aperture 61a and 63a. However, in the dynamic quadrupole lens 60 of FIG. 8, the second electrode 62 includes three circular apertures 62a, 62b and 62c. Where circular apertures are employed, the second electrode 62 will not function as a quadrupole lens element, although the first and third electrodes 61 and 63 will continue to so operate. The three apertures 62a, 62b and 62c may also be elliptically shaped with their major axes oriented generally vertically, in which case the second electrode 62 will function as a quadrupole lens element to converge or diverge the electron beams, as the case may be.

The dynamic quadrupole lens 55 of FIG. 7 is a combination of the lenses shown in FIGS. 1 and 8 in that

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

the second electrode 57 includes three circular, or elliptically shaped, apertures 57a, 57b and 57c, while the first and third electrodes 56 and 58 each include respective elongated, horizontally oriented apertures 56a and 58a. Each of the apertures 56a and 58a includes a plurality of spaced enlarged portions through which a respective one of the electron beams is directed. The dynamic quadrupole lenses 65 and 70 respectively shown in FIGS. 9 and 10 also include three spaced electrodes in alignment with three electron beams, wherein the electrodes include various combinations of apertures previously described and illustrated. In FIG. 9, the first and third electrodes 66 and 67 are each shown with a plurality of spaced elongated apertures having their longitudinal axes in common alignment with the in-line electron beams.

Referring to FIG. 11, there is shown yet another embodiment of a dynamic quadrupole lens 75 in accordance with the principles of the present invention. The dynamic quadrupole lens 75 includes first and third electrodes 76 and 78, which are each in the general form of an open frame through which the electron beams pass, and a second electrode 77 having three spaced, generally vertically oriented apertures through each of which a respective one of the electron beams is directed. The first and third electrodes 76 and 78 do not include an aperture through which electron beams are directed, or may be considered to have an infinitely large aperture disposed within a charged electrode. Any any rate, it has been found that it is the dynamic focusing voltage applied to the first and third electrodes 76 and 78 which functions in combination with the charge on the second electrode 77, and the apertures therein, to provide electron beam convergence/divergence control in compensating for electron beam astigmatism and defocusing. The dynamic quadrupole lens 80 of FIG. 12 is similar to that shown in

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

FIG. 11, except that the three apertures in the second electrode 82 are generally rectangular in shape and operate in conjunction with the first and third dynamically charged electrodes 81 and 83.

The dynamic quadrupole lens 75 operates in the following manner. In a COTY-type CRT, the second electrode 77 will be at a higher voltage than the first and third electrodes 76, 78 when the electron beams are positioned near the center of the CRT screen. The second electrode 77 will thus cause a horizontal divergence resulting in a negative astigmatism correction as shown in FIG. 4a. The first and third electrodes 76, 78 cause a vertical convergence of the electron beams to further effect negative astigmatism correction. When the electron beams are adjacent to a lateral edge of the CRT screen, the second electrode 77 will be at a lower voltage than the first and third electrodes 76, 78 resulting in horizontal convergence and vertical divergence of the electron beams as shown in Table I and as illustrated in FIG. 4b as a positive astigmatism correction. Thus, electron beam astigmatism and defocusing are corrected for by the dynamic quadrupole lenses of FIGS. 11 and 12, although the compensating effects of this electrode arrangement are not as great as in the previously discussed embodiments wherein all three electrodes are provided with apertures.

Referring to FIG. 13a, there is shown a conventional bipotential type main lens (ML) electron gun 90. The bipotential type ML electron gun 90 includes a cathode K which provides electrons to the combination of a control grid electrode G1, a screen grid electrode G2, a first accelerating and focusing electrode G3, and a second accelerating and focusing electrode G4. A focusing voltage V_{F1} is applied to the first accelerating and focusing electrode G3, and an accelerating voltage V_A as

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

applied to the second accelerating and focusing electrode G4.

FIG. 13b shows the manner in which a dynamic quadrupole lens 92 may be incorporated in a conventional bipotential type ML electron gun. The dynamic quadrupole lens 92 includes adjacent plates of a G₃₁ electrode and a G₃₂ electrode to which a dynamic focusing voltage VF₂ is applied. The dynamic quadrupole lens 92 further includes a G₃₂ electrode, or grid, which is maintained at a fixed voltage VF₁. The cathode as well as various other control grids which are illustrated in FIG. 13a have been omitted from FIG. 13b, as well as the remaining figures, for simplicity. Thus, a bipotential type ML electron gun may be converted to an electron gun employing the dynamic quadrupole lens of the present invention by separating its first accelerating and focusing electrode G₃ into two components and inserting a third fixed voltage electrode G₃₂ between the two accelerating and focusing electrode components G₃₁ and G₃₂.

Referring to FIG. 14a, there is shown a conventional Einzel-type ML electron gun 94 which includes G₃, G₄ and G₅ accelerating and focusing electrodes.

Referring to FIG. 14b, there is shown the manner in which a dynamic quadrupole lens 96 in accordance with the present invention may be incorporated in a conventional Einzel-type ML electron gun. In the electron gun arrangement of FIG. 14b, the G₄ electrode is divided into two lens components G₄₁ and G₄₃, and a third focusing electrode G₄₂ is inserted between the adjacent charged plates of the G₄₁ and G₄₃ electrodes. A fixed focus voltage VF₁ is applied to the G₄₂ electrode, while a dynamic focus voltage VF₂ is applied to the G₄₁ and G₄₃ electrodes. The dynamic quadrupole lens 96 within the Einzel-type ML electron gun thus includes adjacent charged plates of the G₄₁ and G₄₃ accelerating and focusing electrodes in combination with an intermediate





G4₂ electrode which is maintained at a fixed focus voltage VF₁.

Referring to FIG. 15a, there is shown a conventional QPF type ML electron gun 98. The QPF type ML electron gun 98 includes G₂, G₃, G₄, G₅ and G₆ electrodes. A fixed focus voltage VF is applied to the G₃ and G₅ electrodes.

FIG. 15b illustrates the manner in which a dynamic quadrupole lens 100 in accordance with the present invention may be incorporated in the G₄ electrode of a QPF type ML electron gun. In the arrangement of FIG. 15b, the G₄ electrode is comprised of G₄₁, G₄₂ and G₄₃ electrodes. The G₂ and G₄₂ electrodes are maintained at a voltage VG₂₀, while the G₄₁ and G₄₃ electrodes are maintained at a voltage VG₂₁. The VG₂₀ voltage is fixed, while the VG₂₁ voltage varies synchronously with electron beam sweep across the CRT screen.

Referring to FIG. 15c, there is shown the manner in which a dynamic quadrupole lens 102 in accordance with the present invention may be incorporated in the G₅ electrode of a conventional QPF type ML electron gun. In the arrangement of FIG. 15c, the G₅ accelerating and focusing electrode of a conventional QPF type ML electron gun has been divided into three control electrodes G₅₁, G₅₂ and G₅₃. A fixed focus voltage VF₁ is applied to the G₃ and G₅₂ electrodes, while a dynamic focus voltage VF₂ is applied to the G₅₁ and G₅₃ electrodes. A VG₂ voltage is applied to the G₂ and G₄ electrodes. The dynamic quadrupole lens 102 is comprised of the G₅₂ electrode in combination with the adjacent plates of the G₅₁ and G₅₃ electrodes. In FIG. 15d, the G₃ electrode is shown coupled to the VF₂ focus voltage rather than the VF₁ focus voltage as in FIG. 15c. In the arrangement of FIG. 15d, two spatially separated quadrupoles each apply an astigmatism correction to the electron beams. A first quadrupole is comprised of the upper plate of the G₃

electrode, the lower plate of the G5₁ electrode, and the G4 electrode disposed therebetween. A dynamic focus voltage VF2 is provided to the G3, G5₁ and G5₃ electrodes. The second quadrupole is comprised of the upper plate of the G5₁ electrode, the lower plate of the G5₃ electrode, and the G5₂ electrode disposed therebetween. The G5₃ and G6 electrodes form an electron beam focusing region, while the combination of electrodes G2 and G3 provide a convergence correction for the two outer electron beams as the beams are swept across the CRT screen with changes in the electron beam focus voltage. This is commonly referred to as a FRAT (focus refraction alignment test) lens.

Referring to FIG. 16, there is shown a conventional BU type ML electron gun 104. The BU type ML electron gun 104 includes G3, G4, G5 and G6 electrodes. An anode voltage VA is applied to the G4 and G6 electrodes, while a dynamic focus voltage VF is applied to the G3 and G5 electrodes.

FIG. 16b shows the manner in which a dynamic quadrupole lens 106 in accordance with the present invention may be incorporated in a conventional BU type ML electron gun. The G5 electrode of the prior art BU type ML electron gun is reduced to two electrodes G5₁ and G5₃ with a third electrode G5₂ inserted therebetween. The dynamic quadrupole lens 106 thus is comprised of adjacent plates of the G5₁ and G5₃ electrodes in combination with the G5₂ electrode. A fixed focus voltage VF1 is applied to the G3 and G5₂ electrodes, while the anode voltage VA is applied to the G4 and G6 electrodes. A dynamic focusing voltage VF₂ is applied to the G5₁ and G5₃ electrodes in the electron gun.

A further preferred embodiment of the invention is disclosed in FIGS. 17-20. Referring to FIG. 17, there is shown a perspective view of a dynamic quadrupole lens



120 for use in an in-line electron gun in a color CRT incorporating a second electrode 130 in accordance with the present invention. The dynamic quadrupole lens 120 includes first, second and third electrodes 128, 130 and 132 arranged in mutual alignment. The first electrode 128 includes an elongated aperture 128a extending a substantial portion of the length of the electrode. Disposed along the length of the aperture 128a in a spaced manner are three openings in the form of enlarged portions of the aperture. As in the case of the first electrode 128, the third electrode 132 also includes an elongated aperture 132a extending along a substantial portion of the length thereof and including three spaced openings in the form of enlarged portions of the aperture 132a. The first and third electrodes 128 and 132 are aligned so that first, second and third electron beams 122, 124 and 126 respectively transit the corresponding enlarged portions of the elongated apertures 128a and 132a within the first and third electrodes. The first and third electrodes 128, 132 are coupled to a variable voltage source 136 for applying a dynamic voltage VF_2 to these electrodes.

The second electrode 130 is disposed intermediate the first and third electrodes 128, 132 and includes three keyhole-shaped apertures 130a, 130b and 130c arranged in a spaced manner along the length of the electrode. Each of the aforementioned keyhole-shaped apertures 130a, 130b and 130c has a longitudinal axis which is aligned generally vertically as shown in FIG. 17, or generally transverse to the longitudinal axes of the apertures in the first and third electrodes 128 and 132. With the first, second and third electrodes 128, 130 and 132 arranged generally parallel in a linear alignment, the respective apertures of the electrodes are adapted to allow the transit of the three electron beams 122, 124 and 126, each shown in the figure as a dashed line. The second electrode 30 is

This Sheet Has Been Replaced

THIS SHEET HAS BEEN
REPLACED

SUBSTITUTE SHEET

coupled to a constant voltage source 134 and is charged to a fixed potential V_{F_1} .

Referring also to FIGS. 19 and 20, additional details of the second electrode 130 which concern an aspect of this invention will now be described. Each of the three keyhole-shaped apertures 130a, 130b and 130c in the second electrode 130 includes an enlarged center portion through which a respective one of the electron beams is directed. As shown in the figures, the two outer keyhole-shaped apertures 130a and 130c are provided with respective opening profile distortions or opening enlargements in the form of notches 130d and 130e on inner portions thereof and are in the general form of an offset keyhole. The opening enlargements (here notches) 130d and 130e in the offset keyhole-shaped apertures 130a and 130c unbalance the horizontal focusing strength of the two outer offset keyholes to produce an asymmetrical field component having a refraction lens effect, where the strength of the refraction lens on the two outer electron beams is proportional to the dynamic drive voltage V_{DYN} applied to the first and third electrodes 128 and 132. The refraction lens effect of the notched inner portions of the two outer keyhole-shaped apertures 130a and 130c moves the outer (here red and blue) electron beams inwardly or outwardly along the horizontal direction across the CRT's faceplate to reduce or cancel the dynamic outer beam misconvergence effect caused by the use of a common focusing field for all three beams. The outer electron beams are horizontally displaced either inwardly or outwardly depending upon the voltages on the first and third electrodes 128 and 132 relative to the voltage of the second electrode 130.

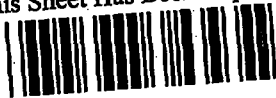
Referring to FIG. 18, there is shown a sectional view of the arrangement of FIG. 17 including a quadrupole focusing type main lens (ML) electron gun 140 incorporating the focusing electrode 130 of the present

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



invention. In the arrangement of FIG. 18, the first, second and third electrodes 128, 130 and 132 form a dynamic quadrupole to compensate for electron beam astigmatism and defocusing caused by the electron beam deflection yoke. A fixed focusing voltage V_{F1} is applied to the second electrode 130 while a dynamic focusing voltage $V_{F2} + V_{DYN}$ as applied to the first and third electrodes 128 and 132. A cathode K emits electrons which are controlled by various grids including a screen grid electrode G2. The electrons are then directed to a first accelerating and focusing electrode G3. The G3 electrode is comprised of a G3 lower section, a G3 upper section, and the aforementioned dynamic quadrupole region disposed therebetween. The respective apertures 128a, 130a and 132a in the first, second and third electrodes 128, 130 and 132 are aligned to allow the transit of each of the three electron beams as discussed above and shown in FIG. 17. A second accelerating and focusing electrode G4 is disposed adjacent to the G3 upper portion, with a COTY-type main lens (ML) dynamic focus region (or stage) formed by the G3 and G4 electrodes.

While a second electrode 130 having a pair of outer keyhole-shaped apertures 130a and 130c each with an inner notch is disclosed and illustrated herein as forming a portion of a dynamic quadrupole electron beam focusing lens, as noted above, the opening profile distortion feature of the present invention is not limited to use in a dynamic quadrupole lens and may be used simply by itself in virtually any type of conventional electron gun. Even when not used in a dynamic quadrupole lens, the offset keyhole design of the inventive focusing electrode 130 exerts a refractive lens effect on the off-axis (outer) electron beams, with the strength of the refraction (asymmetrical) lens being proportional to the dynamic focusing voltage applied to the main lens focusing stage, to horizontally displace the outer (here red and blue)

beams so as to reduce or cancel the dynamic red/blue misconvergence effect of the multi-beam electron gun. When not employed in a quadrupole electron beam focusing lens, the inventive electrode 130 is disposed intermediate the G3 lower and upper electrode portions, with the first and third electrodes 128, 132 absent from such an electron beam focusing arrangement.

FIG. 21 is a perspective view of another embodiment of an electron beam misconvergence correction arrangement 150 including first, second and third electrodes 152, 154 and 156. The second (middle) electrode 154 includes three generally circular spaced apertures 154a, 154b and 154c. The outer two apertures 154a and 154c include respective inwardly opening enlargements in the form of directed notches 154d and 154e. These notches provide an unbalanced horizontal focusing field to produce the refraction lens effect, where the strength of the refraction lens on the two outer electron beams is proportional to the dynamic drive voltage applied to the first and third electrodes 152 and 156. This electrode 160 is introduced for use in a lens arrangement wherein it receives the higher applied potential.

Referring to FIG. 22, there is shown a plan view of an electrode 160 in accordance with another embodiment of the present invention. The electrode 160 is adapted for use in a dual quadrupole electron beam focusing arrangement as described above for the first and third electrodes, where the first and third electrodes are maintained at a higher voltage than a second, middle electrode. A dynamic focusing voltage is applied to the electrode 160 which includes an elongated aperture 162 therein. As in previous embodiments, the elongated aperture 162 is provided with a plurality of spaced beam-passing openings in the form of openings (enlarged portions) 162a, 162b and 162c along the length thereof.

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



An electron beam is directed through each of the openings 162a, 162b and 162c along the length of the elongated aperture 162 in the electrode 160. With the electrode 160 maintained at a higher voltage than an adjacent, middle electrode (not shown), the elongated aperture 162 is provided with a pair of extensions 162e and 162d, each at a respective end of the elongated aperture 162. The end extensions 162e and 162d of the elongated aperture 162 provide an unbalanced horizontal focusing field effect on the two outer electron beams to correct the focus-convergence interaction between the red and blue beams arising from changes in the magnitude of the dynamic focus voltage. The difference between electrode 160 and previously described embodiments is in the width (or height) of the extensions 162e and 162d relative to the width of the elongated aperture 162. In a preferred embodiment of electrode 160, the extensions 162e, 162d each have a width of $Y = 0.115$ mil, while the width of aperture 162 is 0.065 mil. The greater widths of the extensions 162d, 162e on each end of the elongated aperture 162 weakens the electrostatic field exerted on the two outer electron beams allowing for reduced outer electron beam deflection in correcting the focus-convergence interaction arising from changes in the focus voltage.

As suggested above, the present invention can be viewed in a broad context as providing means for electrically refracting or bending an electron beam in various applications in electron guns not limited to the preferred embodiments described above. FIG. 23 is a schematic illustration of the use of a focusing lens structure in a three-beam in-line gun in which the outer beams are electrically converged by use of the present invention. Specifically, FIG. 23 illustrates a pair of facing electrodes 170, 172 for converging three electron beams 174, 176 and 178. Electrode 170 has apertures 180,

182 and 184 which cooperate with apertures 186, 188 and 190 in adjacent electrode 172. Electrode 172 is adapted to receive a relatively lower potential and electrode 170 is adapted to receive a relatively higher potential.

In accordance with the present invention, the electrode 172 receiving the relatively lower potential has an aperture pattern so configured so as to create symmetrical field components for the outer beams 174, 178 which have the effect of bending or refracting the outer beams 174, 178 toward a distant common point.

As explained in more detail and claimed in our co-pending application, serial No. (DF-6269), a dynamic voltage may be applied to one or both of the electrodes 170, 172 to cause the beam convergence angle to vary as a function of beam deflection.

In accordance with the present invention, the asymmetrical field component acting upon the outer beams 174, 178 is produced by enlarging the apertures 186, 190 in a direction toward the center aperture 188. The opening enlargements are shown as taking the form of rounded protuberances 192, 194, respectively, in the profile of the apertures 186, 190. Many other opening distortion geometries may be utilized in accordance with the present invention, dependent upon the nature and degree of unbalancing of the fields on the outer beams which is desired.

FIG. 24 illustrates yet another embodiment of the present invention wherein the asymmetrical field component is formed by distorting the openings for the outer beams in both electrode 196 receiving a relatively higher voltage and electrode 198 receiving a relatively lower voltage. Specifically, the electrode 196 has outer beam passing openings 200, 202 which have opening enlargements 204, 206 extending outwardly away from the center beam opening 208. The electrode 198 adapted to receive the lower potential has outer beam apertures 210 and 212

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

having opening enlargements 214, 216 which extend inwardly toward the center beam opening 218. The FIG. 24 embodiment illustrates that opening enlargements may be employed in both the high voltage and lower voltage electrodes as well as in either alone and that these opening enlargements may assume various forms.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects. For example, while the present invention has been described as applying a dynamic voltage to first and third electrodes and a fixed voltage to a second electrode spaced therebetween, this invention also contemplates applying a dynamic voltage to the second electrode while maintaining the spaced first and third electrodes at a fixed voltage. Therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective based on the prior art.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

SUBSTITUTE SHEET

TABLE I

SLOT LOCATION	MAJOR AXIS OF SLOT	FORCE DIRECTION ON THE E-BEAM	OPTICAL EFFECT ON THE E-BEAM AFTER CROSS OVER	COMMENTS
HIGHER VOLTAGE SIDE	VERTICAL (Y-DIRECTION)	X-AWAY FROM AXIS Y-NO EFFECT	HORIZ. DIV.	A.) FIELD VECTOR "E" IS IN DIRECTION FROM HIGH VOLTAGE SIDE (EQUIPOTENTIAL LINES) B.) FORCE VECTOR "F" ON ELECTRON IS EQUAL TO $-e$ E
	HORIZ. (X-DIRECTION)	X-NO EFFECT Y-AWAY FROM AXIS	VERT. DIV.	
LOWER VOLTAGE SIDE	VERTICAL (Y-DIRECTION)	X-TOWARD AXIS Y-NO EFFECT	HORIZ. CONV.	
	HORIZ. (X-DIRECTION)	X-NO EFFECT Y-TOWARD AXIS	VERT. CONV.	

This Sheet Has Been Replaced



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

CLAIMS

1. A color cathode ray tube system having a color tube with a phosphor screen, said system including a three-beam, in-line gun for exciting said screen, said gun including, cathode means and focus lens means for developing a center beam and two outer beams and for forming three focused electron beam spots at the screen of the tube, and electrostatic quadrupole-developing means configured and arranged to develop a horizontally unbalanced quadrupole field in the path of each of said outer beams when appropriately excited, and system signal generating means for developing a signal having amplitude variations correlated with the scan of the beams across the screen and for applying said signal to said electrostatic quadrupole-developing means to cause said beams to converge and diverge as a function of the strength of said signal.

2. The system of claim 1 wherein said quadrupole-developing means includes electrode means having outer beam apertures shaped to create field-strength-dependent asymmetrical outer beam fields whose strength varies as said signal varies.

3. The system of claim 1, wherein said developing means includes at least two facing electrodes, one adapted to receive a relatively higher excitation potential and the other a relatively lower excitation potential, and including respective openings each having a profile which interacts with an opening in a facing electrode such as to create a quadrupolar field therebetween when different excitation potentials are applied to said facing electrodes, a first one of said electrodes having a center opening and two outer openings arranged in a line along an electrode axis extending orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center





aperture, but asymmetrical about respective vertical axis through the outer openings to create asymmetrical outer beam fields.

4. The system of claim 3 wherein said dynamic quadrupolar lens is of the unpotential type comprising three electrodes, and wherein said first one of said electrodes is the center electrode.

5. A three-beam in-line electron gun system for a color cathode ray tube having a screen and a self-converging yoke which imparts an undesirable astigmatism to the beams in off-center regions of the screen, said system including an electron beam source for developing three electron beams, focusing means for focusing said three electron beams at the screen of the tube, said focusing means being so constructed and arranged that changes in focusing field strength undesirably alter beam convergence, correcting lens means located within or coupled to said focusing means for developing an astigmatic field component in the path of each of said beams when said lens means is appropriately excited, and means for modulating the strength of said astigmatic field component as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the screen, said modulating of said astigmatic field component also modulating said focusing field strength and undesirably creating errors in the convergence of said beams, said correcting lens means including electrode means having a beam passing opening pattern shaped to create asymmetrical outer beam fields effective to at least partially compensate for said deflection-related beam convergence errors.

6. The system of claim 5 wherein said correcting lens means comprises a dynamic quadrupole lens of the unipotential type comprising first, center and third electrodes.



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



7. The system of claim 6 wherein said center electrode is adapted to receive a lower potential than said first and third electrodes, and wherein said center electrode has a center opening and two outer openings arranged in a line along an electrode axis orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

8. The system of claim 7 wherein said aperture distortions each take the form of a notch extending inwardly toward said center aperture.

9. A three-beam in-line color CRT electron gun including an electron lens for influencing said electron beams, including at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said electrodes having a center opening and two outer openings arranged in line along an electrode axis orthogonal to the gun axis, said outer apertures having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

10. A three-beam in-line electron gun for a color cathode ray tube, including means for generating three beams of electrons aligned in a common plane - a center beam and two outer beams, and beam bending means for producing asymmetrical fields in the paths of said outer beams for diverting said outer beams from respective straight line paths toward a common point of convergence, comprising at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said





electrodes having a center opening and two outer openings arranged in line along an electrode horizontal axis orthogonal to the gun axis, said outer openings having opening distortions which are symmetrical about said electrode horizontal axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings to thereby produce said asymmetrical fields for said outer beams.

11. The electron gun of claim 10 wherein said one electrode is said electrode adapted to receive said lower potential and its outer beam openings have said opening distortion in the form of an opening enlargement extending inwardly towards said center opening.

12. The electron gun of claim 10 wherein said one of said electrodes is said electrode adapted to receive said higher potential and its outer beam openings have said opening distortion in the form of an opening enlargement extending outwardly away from said center opening.

13. In a three-beam in-line electron gun system for a color cathode ray tube having a screen and a self-converging yoke which imparts an undesirable astigmatism to the beams in off-center regions of the screen, apparatus including an electron beam source for developing three electron beams, focusing means for focusing said three electron beams at the screen of the tube, said focusing means being so constructed and arranged that changes in focusing field strength undesirably alter beam convergence, correcting lens means located within or coupled to said focusing means for developing an astigmatic field component in the path of each of said beams when said lens means is appropriately excited, and means for modulating the strength of said astigmatic field component as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the





screen, said modulating of said astigmatic field component also modulating said focusing fields strength and undesirably creating errors in the convergence of said beams, said correcting lens means including means for unbalancing the outer beam astigmatic field component such as to cause said outer beams to converge or diverge as a function of the strength of said astigmatic field components for at least partially compensating for said deflection-related beam convergence errors.

14. The electron gun of claim 13 wherein said means for unbalancing comprises a distortion in the profile of one or both of associated coaxial beam-passing openings in said facing electrodes.

15. For use in a color cathode ray tube system having a color tube with a cathodoluminescent screen, a system adapted for use with a deflection yoke having an asymmetrical yoke field for self-converging said beams which undesirably astigmatizes said beams in off-center regions of the screen, said system including an in-line electron gun for developing three electron beams for exciting said screen, said gun including, for each of said beams, means including cathode means for developing said beam, focus lens means including focus electrode means for receiving said electron beam and forming a focused electron beam spot at the screen of the tube, said focus lens means having a plurality of electrode means spaced along a lens axis, beam correcting means incorporated in said focus electrode means for developing in the path of said beam when said beam correcting means is appropriately excited, an astigmatic field component, and system signal generating means for developing a signal having amplitude variations correlated with a scan of the beams across the screen and means for applying said signal to said beam correcting means to cause, as a function of beam deflection angle, the strength of said astigmatic field component to vary to produce a dynamic





astigmatism-correction effect to at least partially compensate for the beam-astigmatizing effect of said yoke, said focus lens means being so constructed and arranged that operation of said beam correcting means causes undesired deflection-related misconvergence of said beams as they are swept, said beam correcting means including misconvergence compensation means for at least partially compensating for said undesired beam misconvergence, comprising at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said electrodes having a center opening and two outer openings arranged in line along an electrode axis orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

16. The system of claim 15 wherein said misconvergence compensation means comprises an asymmetric dynamic quadrupolar lens of the unipotential type comprising first, center and third electrodes, the center electrode being adapted to receive a relatively lower excitation potential than the first and third electrodes, the center electrode having its outer apertures with said profile distortions.

17. The system of claim 15 wherein said center electrode outer beam openings have said opening distortion in the form of an opening enlargement extending inwardly toward said center aperture.

18. A color cathode ray tube system having a color tube with a cathodoluminescent screen, said system including an in-line electron gun for developing three electron beams for exciting said screen, said gun including, for each of said beams, means including cathode means for developing beam, focus lens means for receiving



SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED



said electron beam and forming a focused electron beam spot at the screen of the tube, said focus lens means having a plurality of electrode means spaced along a lens axis including focus electrode means, yoke means for deflecting said electron beams, said yoke means having an asymmetrical field for self-converging said beams which undesirably astigmatizes said beams in off-center regions of the screen, beam correcting means incorporated in said focus electrode means for developing in the path of said beam when appropriately excited a first astigmatic accelerating field component and a second astigmatic decelerating field component wherein said beam correcting means includes three or more electrodes, the first of which has for said beam a horizontally elongated aperture, and system signal generating means for developing a signal having amplitude variations correlated with a scan of the beam across the screen and means for applying said signal to said beam correcting means to cause, as a function of beam deflection angle, the strength of said first and second astigmatic field components to vary to produce a dynamic astigmatism-correction effect to at least partially compensate for the beam-astigmatizing effect of said yoke.

19. A method of providing dynamic convergence control in an electron gun for a color cathode ray tube having a screen, said method including the steps of developing three electron beams, focusing said three electron beams at the screen of the tube, using a multi-element lens, the first element of which has three horizontally elongated apertures, developing in the path of each of said beams when appropriately excited at least one astigmatic field component, and modulating the strength of said first astigmatic field component as a function of beam deflection angle.

20. The method of claim 19, wherein the electron gun system has a self-converging yoke which imparts an



This Sheet Has Been Replaced



WO 91/02373

PCT/US90/04556

-38-

undesirable astigmatism to the beams in off-center regions of the screen, said method including the step of developing in the path of each of said beams when appropriately excited, in back-to-back arrangement, a first astigmatic field component and a second astigmatic decelerating field component, and modulating the strength of said astigmatic field components as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the screen.

21. The method of claim 19 or 20, wherein the multi-element lens comprises a three element lens.



* C L M S *

THIS SHEET HAS BEEN
REPLACED

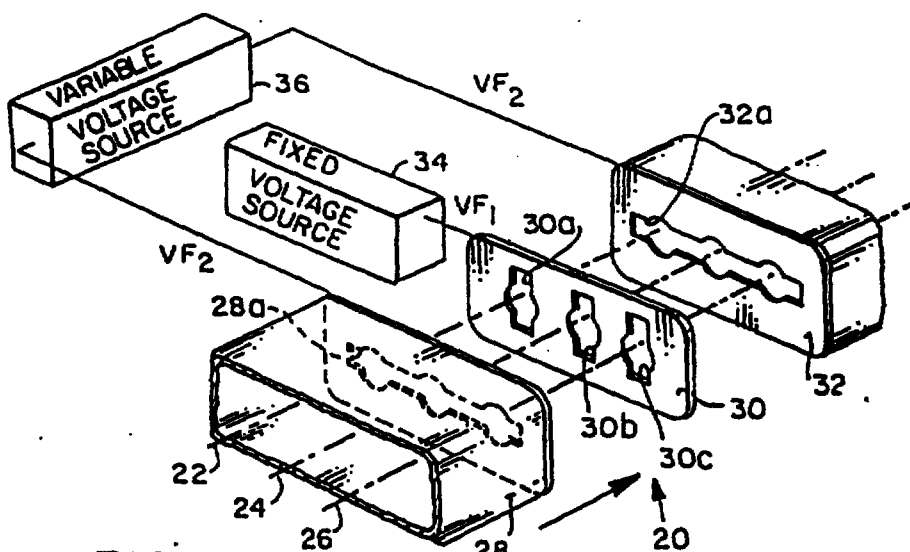


FIG. 1

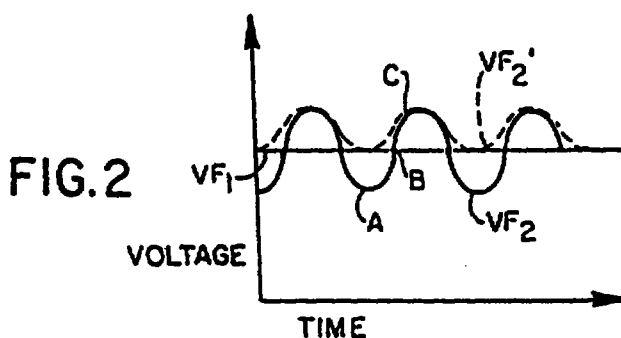


FIG. 2

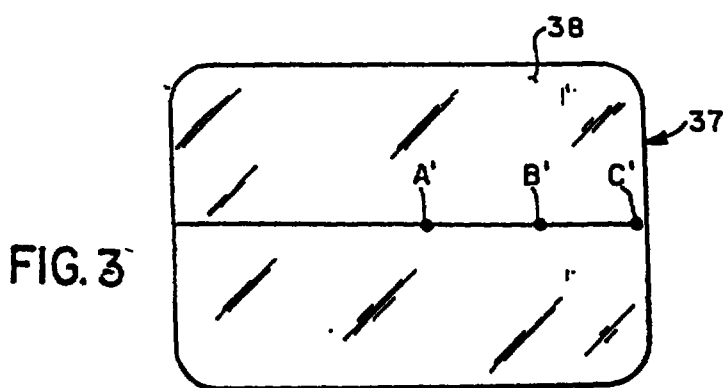


FIG. 3

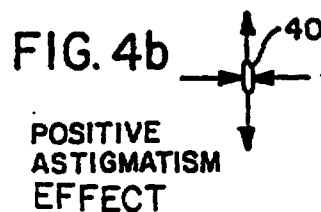
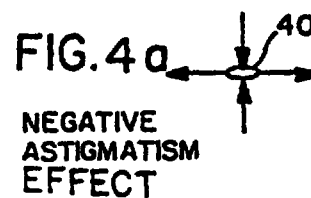
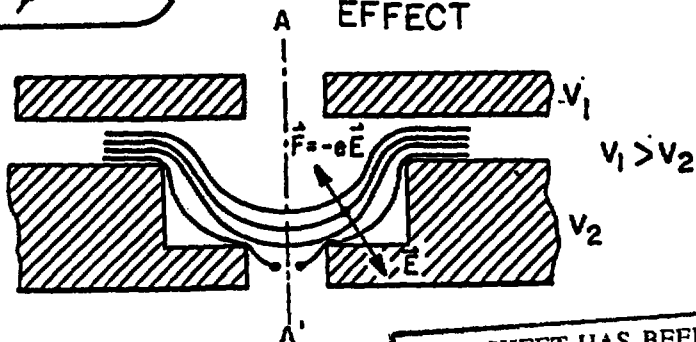


FIG. 5



THIS SHEET HAS BEEN REPLACED

This Sheet Has Been Replaced

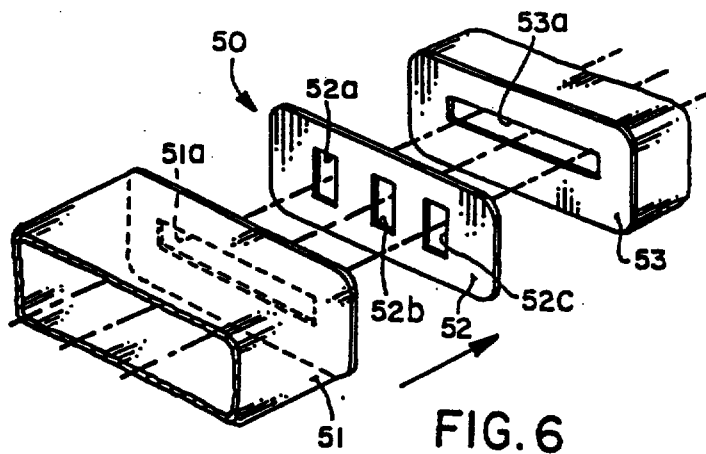


FIG. 6

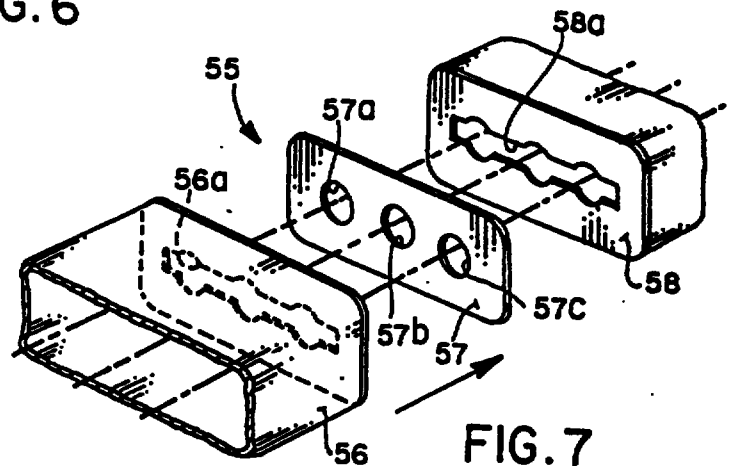


FIG. 7

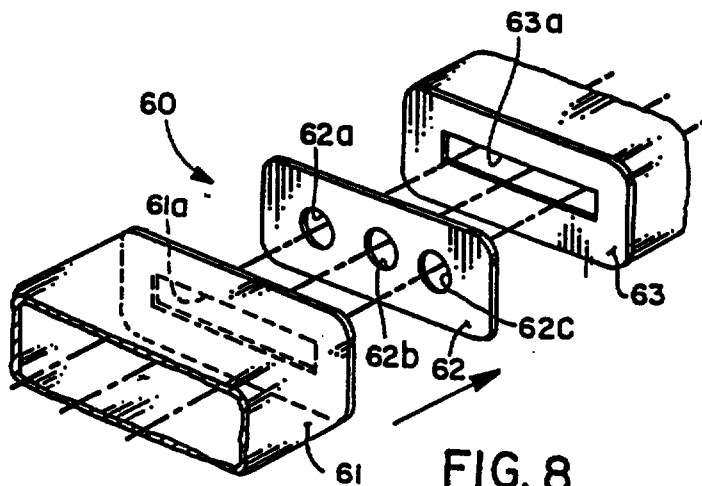


FIG. 8

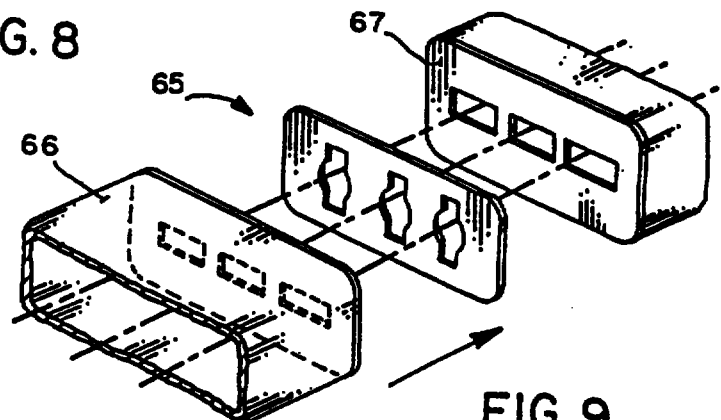


FIG. 9

This Sheet Has Been Replaced

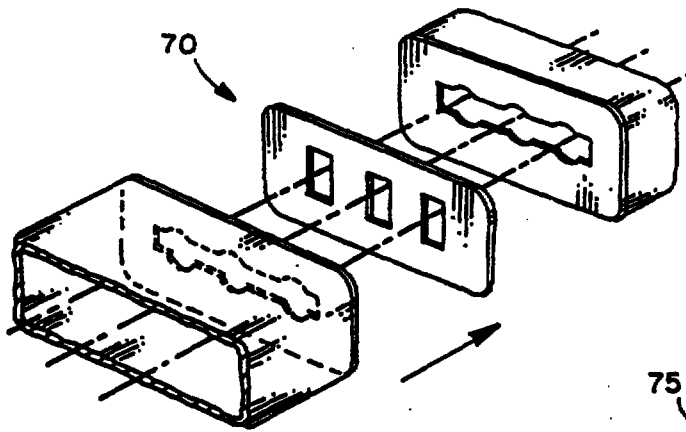


FIG. 10

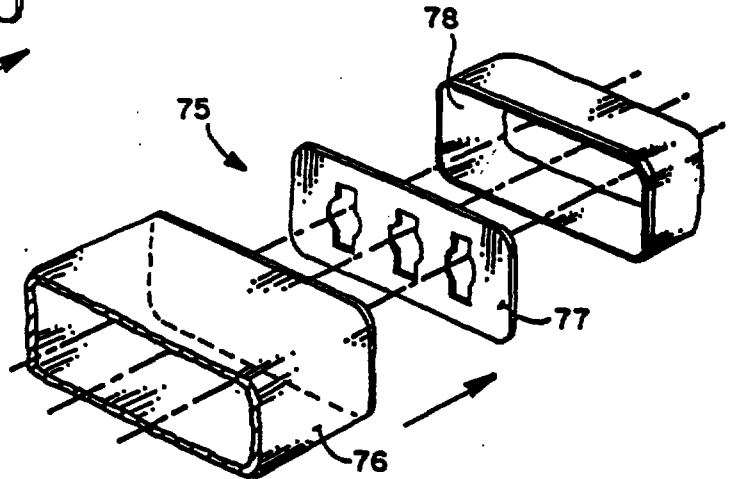


FIG. 11

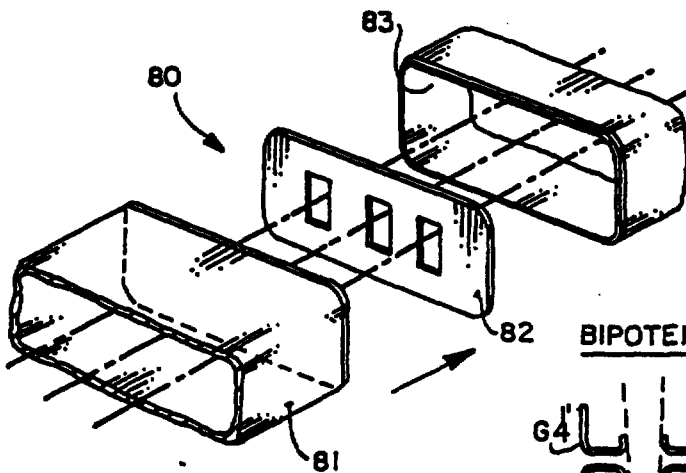


FIG. 12

BIPOTENTIAL TYPE ML DESIGN

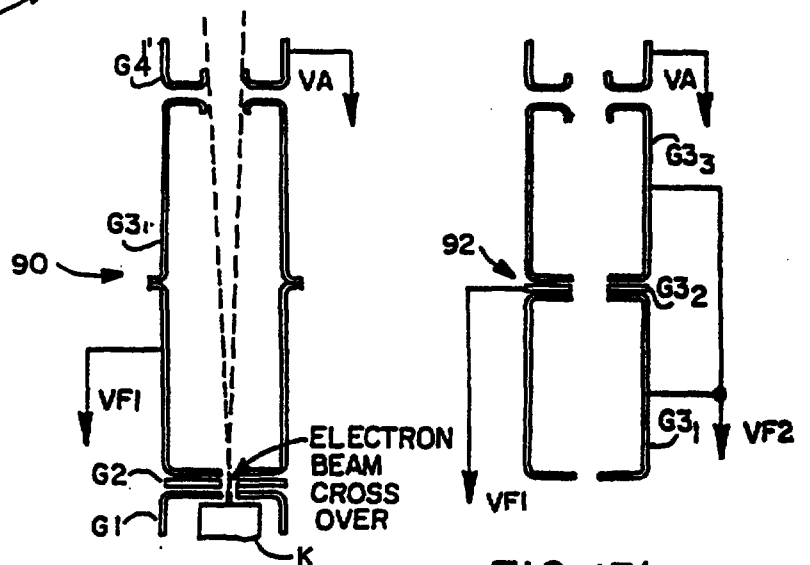
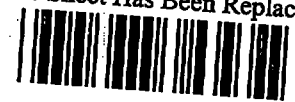


FIG. 13a

FIG. 13b

THIS SHEET HAS BEEN REPLACED

This Sheet Has Been Replaced



EINZEL TYPE ML DESIGN

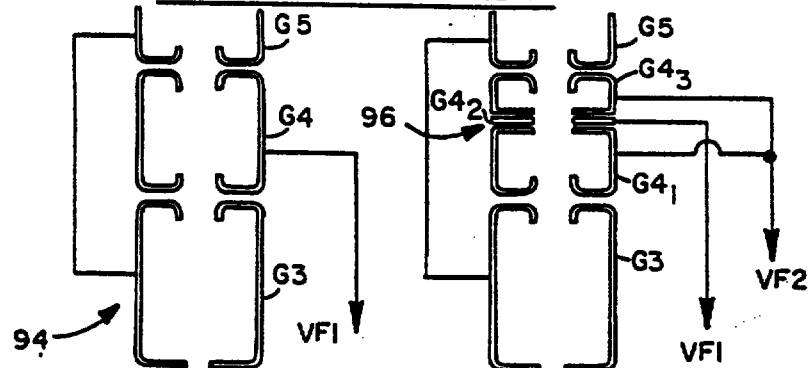


FIG. 14a

FIG. 14b

QPF TYPE ML DESIGN

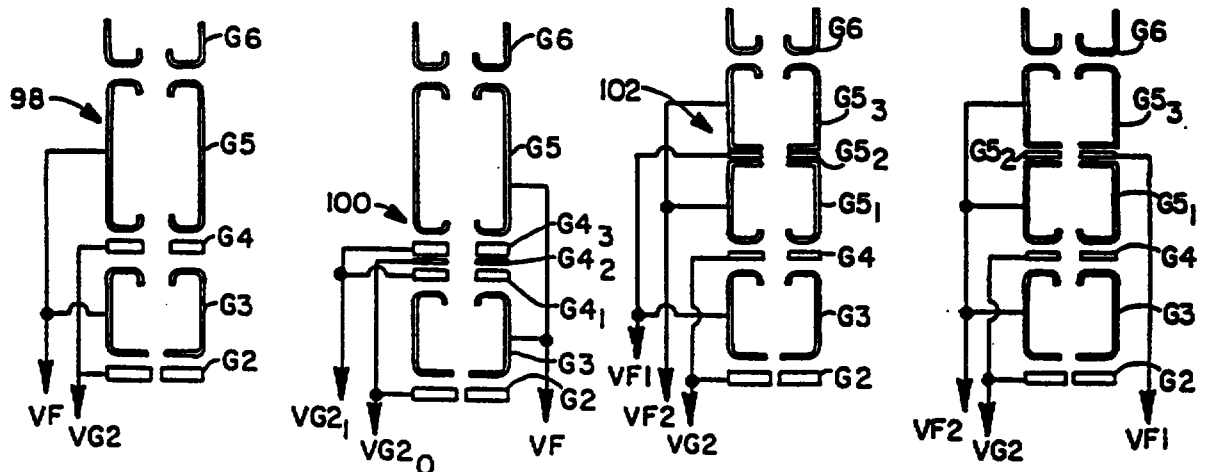


FIG. 15a

FIG. 15b

FIG. 15c

FIG. 15d

BU TYPE ML DESIGN

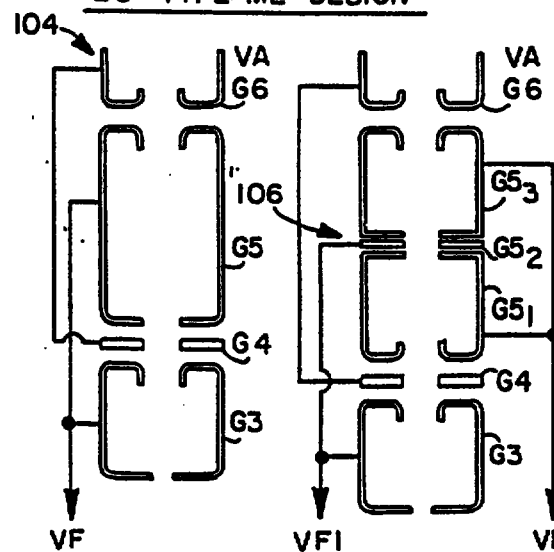


FIG. 16a

FIG. 16b

SUBSTITUTE SHEET

This Sheet Has Been Replaced



5/7

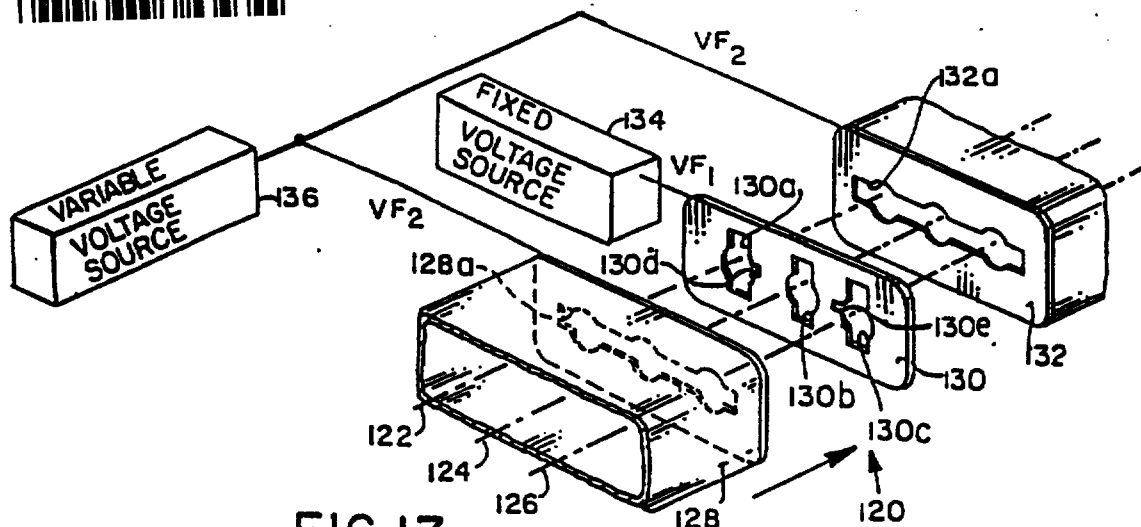


FIG. 17

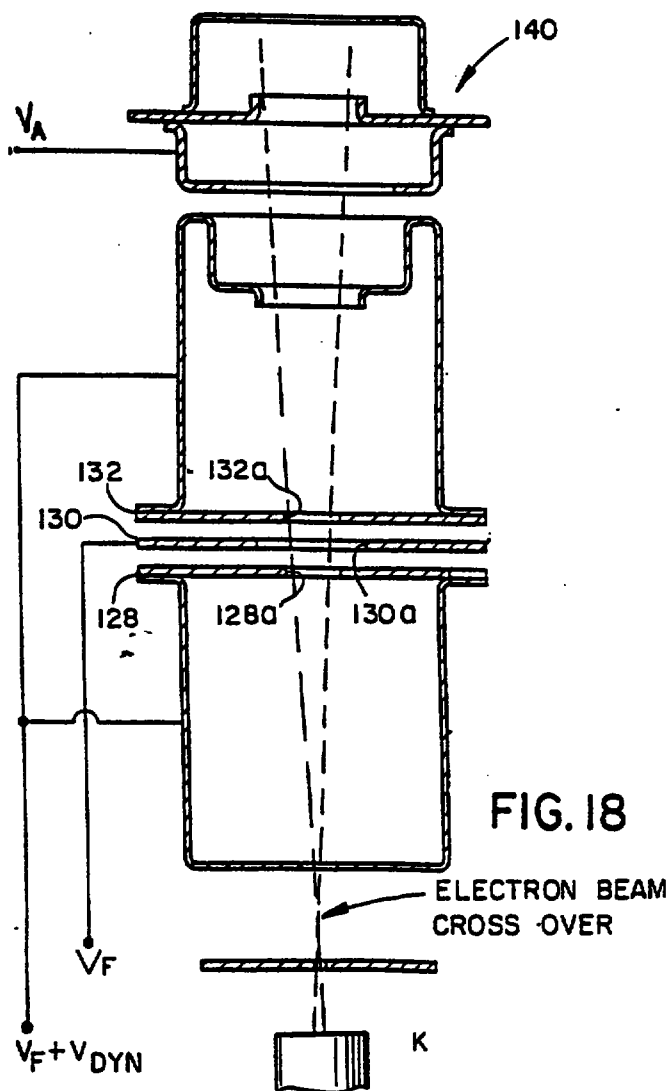


FIG. 18

FIG. 20

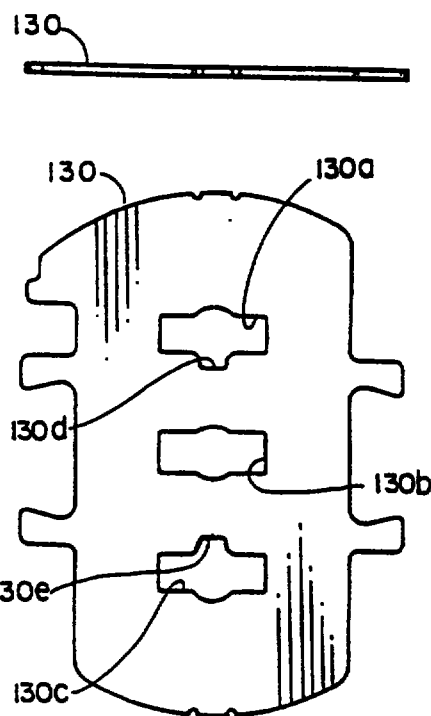


FIG. 19

THIS SHEET HAS BEEN REPLACED

This Sheet Has Been Replaced

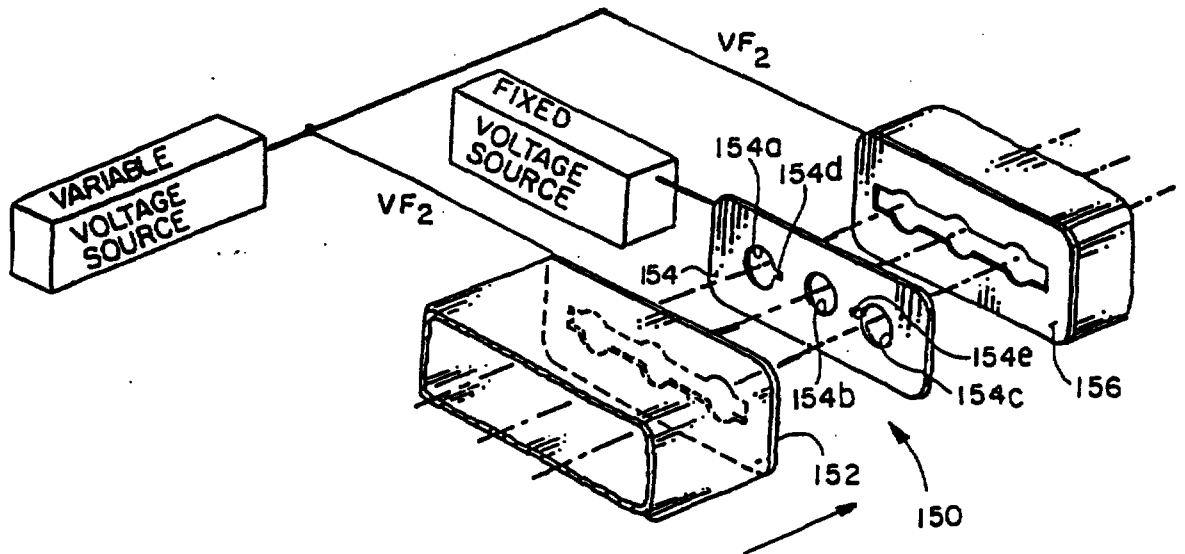


FIG. 21

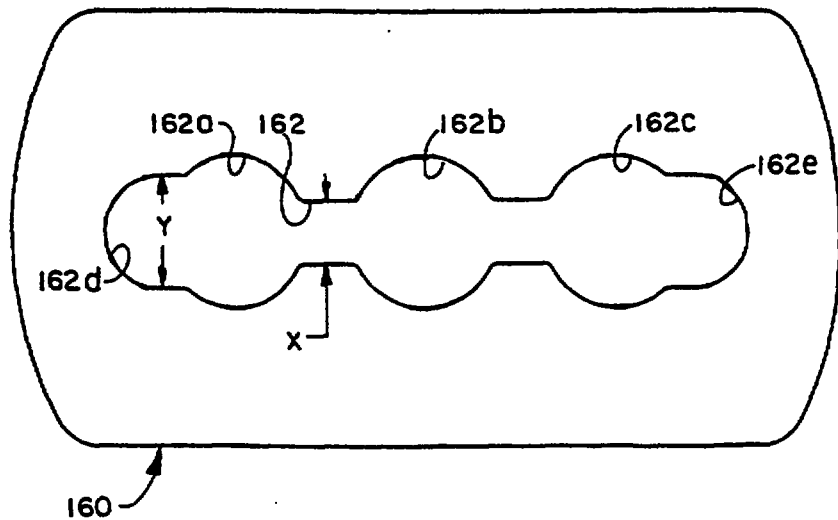


FIG. 22

SUBSTITUTE SHEET

THIS SHEET HAS BEEN REPLACED

This Sheet Has Been Replaced.



FIG. 23

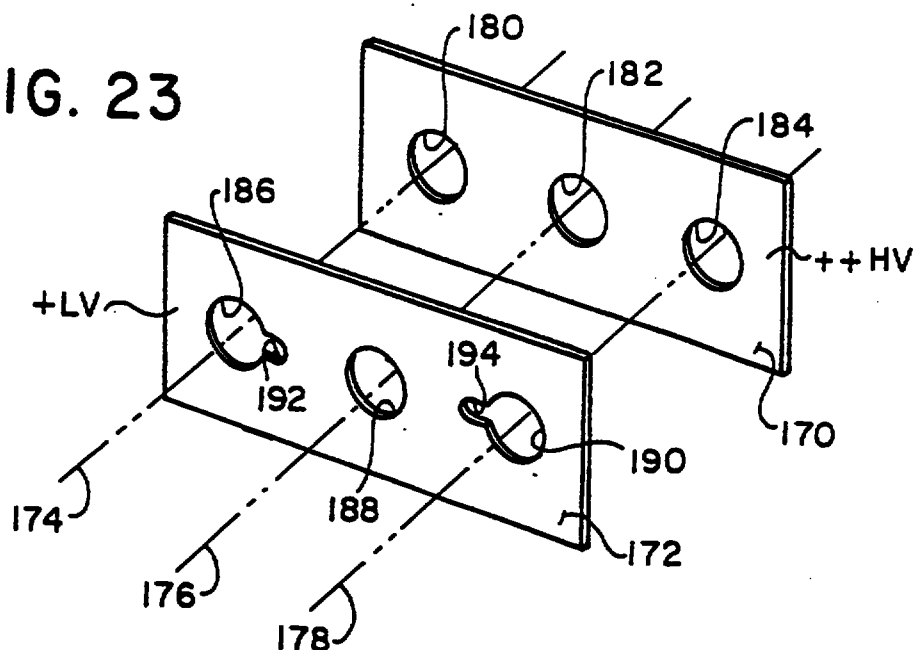
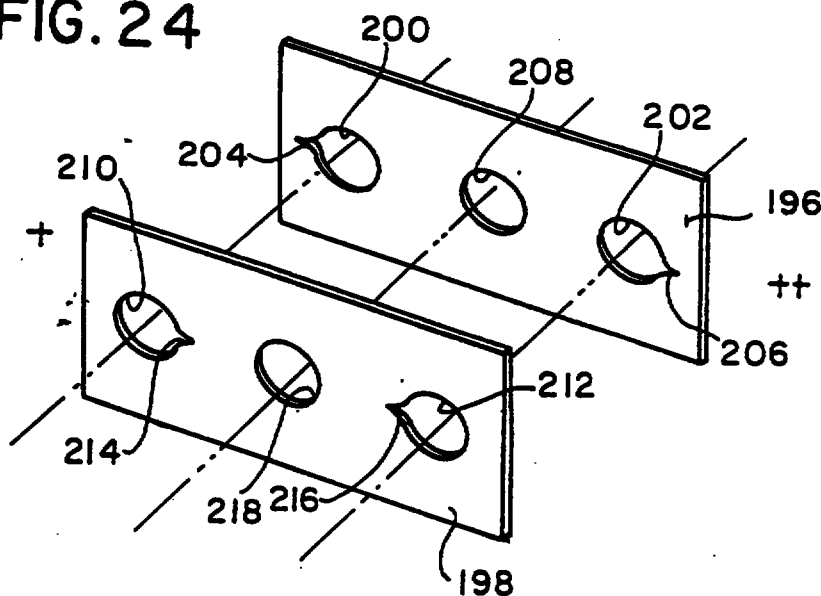


FIG. 24



8-2250703

SUBSTITUTE SHEET

THIS SHEET HAS BEEN
REPLACED

03 MAR 1997

1

Method and apparatus for controlling dynamic convergence of a plurality of electron beams of a color cathode ray tube

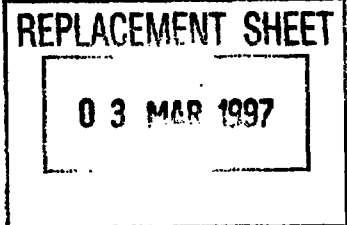
This invention relates generally to color cathode ray tubes (CRTs) and is particularly directed to the control of multiple electron beams incident upon the faceplate of a color CRT.

Most color CRTs employ an in-line electron gun arrangement for directing a plurality of electron beams on the phosphorescing inner screen of its glass faceplate. The in-line electron gun approach offers various advantages over earlier "delta" electron gun arrangements particularly in simplifying the electron beam positioning control system as well as essentially eliminating the tendency of the electron beams to drift. However, in-line color CRT's employ a self-converging deflection yoke which applies a nonuniform magnetic field to the electron beams, resulting in an undesirable astigmatism in and defocusing of the electron beam spot displayed on the CRT's faceplate. In order to achieve three electron beam convergence at the screen edges and corners, the self-converging yoke applies a dynamic quadrupole magnetic field to the beams which over-focuses the beams in the vertical direction and under-focus them in the horizontal direction. This is an inherent operating characteristic of the in-line yoke design.

One approach to eliminate this astigmatism and deflection defocus employs a quadrupole lens with the CRT's focusing electrode which is oriented 90° from the self-converging yoke's quadrupole field. A dynamic voltage, synchronized with electron beam deflection, is applied to the quadrupole lens to compensate for the astigmatism caused by the deflection system. This dynamic voltage also allows for dynamic focusing of the electron beams over the entire CRT screen. The astigmatism of the electron beam caused by the quadrupole lens tends to offset the astigmatism caused by the color CRT's self-converging deflection yoke and generally improves the performance of the CRT.

An articles entitled "Progressive-Scanned 33-in. 110⁰ Flat-Square Color CRT" by Suzuki et al published in SID 87 Digest, at page 166, discloses a dynamic astigmatism and focus (DAF) gun wherein spot astigmatism and deflection defocusing is simultaneously corrected using a single dynamic voltage. The electron gun employs a quadrupole lens to which the dynamic voltage is applied and which includes a plurality of generally vertically elongated apertures in a first section of a focusing electrode and a second pair of aligned, generally horizontally oriented elongated apertures in a second section of the focusing electrode. Each electron beam first transits a vertically aligned aperture, followed by passage through a generally horizontally aligned aperture in the single quadrupole lens for applying astigmatism correction to the electron beam.

An article entitled "Quadrupole Lens For Dynamic Focus and Astigmatism Control in an Elliptical Aperture Lens Gun" by Shiral et al, also published in SID 87 Digest, at page 162, discloses a quadrupole lens arrangement comprised of three closely spaced electrodes, where the center electrode is provided with a plurality of keyhole apertures and the outer electrodes are provided with a plurality of square recesses each with a circular aperture in alignment with each of the respective electron beams. A dynamic voltage V_d is applied to the first and third electrodes so as to form a quadrupole field to compensate for the astigmatism caused by the self-converging yoke deflection system. Although this allows for a reduction in the dynamic voltage applied to the quadrupole, this voltage still exceeds 1 KV in this approach. While these two articles describe improved approaches for beam focusing and astigmatism compensation, they too suffer from performance limitations particularly in the case of those CRTs having a flat faceplate and foil tension shadow mask, where the flat geometry imposes



-3-

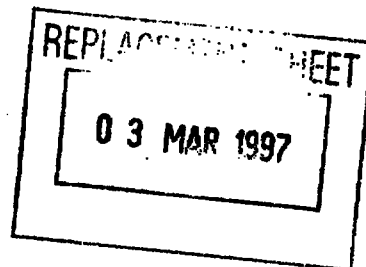
substantially greater challenges than those encountered with a curved faceplate.

An electron gun employing a quadrupole lens to which a dynamic voltage is applied generally also includes a Beam Forming Region (BFR) refraction lens design intended to correct for the lack of dynamic convergence of the red and blue outer electron beams. The horizontal beam landing locations of the red and blue beams in color CRTs having an in-line electron gun arrangement change with variations in the focus voltage applied to the electron gun. While the dynamic quadrupole lens compensates for astigmatism caused by the self-converging electron beam deflection yoke, prior art quadrupole lens arrangements do not address the lack of horizontal convergence of the two outer electron beams.

In a more general sense, this invention addresses the problem of how to electrically converge off-axis beams in a three-beam color cathode ray tube, particularly a color cathode ray tube of the type having an in-line gun.

There exists a number of techniques in the prior art for electrically converging off-axis electron beams in a color cathode ray tube. One technique offsets the axes of apertures in facing electrodes. Offsetting the axes of the cooperating apertures creates an asymmetrical field which bends an electron beam in a direction dependent upon the asymmetry and strength of the field. Examples of electron guns having such offset-aperture-type beam bending are U.S. Patent Nos. 3,772,554; 4,771,216 and 4,058,753.

A second approach is to use coaxial apertures, but angle the gap between the facing electrodes to produce the necessary asymmetrical field. Examples of electron guns having such "angled gap" technique for producing the necessary asymmetrical field are disclosed in U.S. Patent Nos. 4,771,216 and 4,058,753.



-4-

A third approach is to create the asymmetrical field for the off-axis beam or beams by creating a wedge-shaped gap between the addressing electrodes. Examples of this third approach for electrically converging off-axis beams are disclosed in U.S. Patent Nos. 3,772,554 and 4,058,753.

Each of these three approaches suffers from difficulties in mandrelling the electrodes during assembly. One aspect of the present invention is to provide improved means in an electron gun for refracting or bending an electron beam, useful for converging off-axis beams in a color CRT gun.

As discussed above, certain modern high performance electron guns have a dynamic quadrupole lens to compensate for beam astigmatism introduced by an associated self-converging yoke. Incorporation of such dynamic quadrupole astigmatism correctors in electron guns of the type having a common focusing field for all three beams introduces convergence errors due to the converging effect produced by such common lens on the off-axis beam.

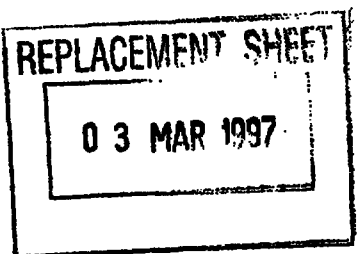
In one sense, this invention concerns improved quadrupolar lenses independent of their application or particular implementation, and more particularly concerns a way to bend an electron beam passing through a quadrupolar lens field. Dynamic control of beam angle as a function of potentials applied to the quadrupolar lens is achievable using the present invention.

In accordance with a further aspect of this invention, means are provided for correcting or reducing such convergence errors. As will be explained, this is accomplished by unbalancing the quadrupolar lens fields through which the off-axis beams pass. The unbalancing is accomplished in a preferred embodiment by the creation of an asymmetrical field component which has a refractive effect on the off-axis beams, causing them to converge or diverge as a function of the strength and degree of

asymmetry of the asymmetrical fields applied to the off-axis beams. As will also be explained in more detail hereinafter, in a preferred embodiment the asymmetrical fields are produced by providing an aperture pattern in one or more of the facing electrodes employed to create the quadrupolar lens field for the off-axis beams which is shaped to create an asymmetry in the field affecting the off-axis (outer) beams.

In one embodiment to be described (FIGS. 17-20), a novel electrode has a center opening and two outer openings arranged in-line along an electrode axis orthogonal to the gun axis. The outer openings have profile distortions which are symmetrical about the electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axes through the outer beam openings. In one preferred embodiment, the opening profile distortions each take the form of an inwardly or outwardly extending opening enlargement (a notch, for example). In another arrangement (FIG. 22, to be described) the asymmetrical field is produced in an electrode having a horizontal aperture extending across all three beams, the terminal portions of which are vertically larger than the center portions of the horizontal aperture so as to create the aforesaid opening enlargement and asymmetrical field.

This aspect of the invention may be employed in unipotential (Einzel) type quadrupolar lenses, or quadrupolar lenses of the bipotential or other type. The profile distortion provided to create the field asymmetry for the off-axis beams may be located in any or all of the electrodes which constitute the quadrupolar lens. If the profile distortion is located in the electrode or electrodes having relatively higher voltage, the profile enlargement extends away from the center beam opening; if located in the electrode or electrodes having lower applied potential, the opening enlargement which creates



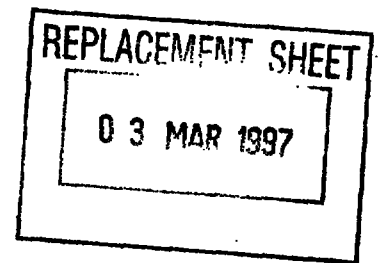
-6-

the asymmetrical field extends inwardly toward the center beam opening.

In a broader context, as noted above, the invention concerns a quadrupolar lens for an electron gun having the capability of bending a beam passing through the lens, independent of the application or manner of implementing the quadrupolar lens. In this context, the invention concerns the provision of a quadrupolar lens having at least two facing apertured electrodes, one adapted to receive a relatively higher excitation potential, the electrodes being constructed and arranged such that a quadrupolar field component is created therebetween for the beam when different excitation potentials are applied to the facing electrodes. The quadrupolar field component such as to cause the beam to be diverted from a straight line path as a function of the different applied potentials. The unbalancing, as described, is preferably by provision of an asymmetrical field component in the quadrupolar lens which, in turn, is preferably created by the provision of an aperture pattern in one or both of the facing electrodes, all as outlined above and as will be described in detail hereinafter.

Such a quadrupole lens with beam bending capability may be employed in electron guns in general, but not limited to the type described above and to be described hereinafter wherein the quadrupole lens provides astigmatism correction to offset astigmatism produced by an associated self-converging yoke.

In still a broader context, this invention provides an improved means for electrically bending or diverting the path of an electron beam, independent of its use in a quadrupolar or any other particular type of lens. In the background of the invention set forth above, mention is made of three types of electron-refractive devices which each create an asymmetrical field in the path of an electron beam to divert it from a straight line

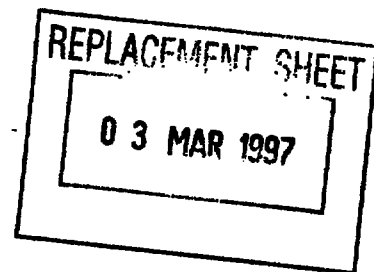


-7-

path. One employs offset apertures, another an angled electrode gap, and a third a wedge-shaped gap between the operative electrodes. Applicants here provide a fourth way -- namely, by the provision of an aperture pattern in one or more of both of the facing electrode(s) which is so shaped relative to the aperture pattern in the facing electrode as to create an asymmetrical pattern in the facing electrode as to create an asymmetrical field influencing the passed electron beams. Thus the beam bender of the present invention may be used in substitution for any of the above three types of beam benders in any application in which they are found, as well as other applications which call for electrical beam divergence. The present invention has the advantage over the aforesaid three types of beam benders found in the prior art in that it is more easily mandrelled during electron gun assembly than any of those arrangements.

In this most general context, the invention may be thought of as comprising means for generating a beam of electrons, and beam bending means for producing an asymmetrical field in the path of the beam for diverting the beam from a straight line path. The beam bending means comprises at least two facing electrodes adapted to receive different excitation potentials and having coaxial beam-passing openings, at least one of the openings being symmetrical about a first electrode axis, but asymmetrical about an orthogonal second axis to thereby produce the said asymmetrical field.

Such a beam bender may be adapted for dynamic convergence by employing it in the off-axis beams and applying a varying potential to one or both of the operative facing electrodes to cause the strength of the asymmetrical field to vary as a function of the applied voltage. In application to a three beam in-line gun color CRT having dynamic convergence, a variable voltage



-8-

correlated with the deflection of the beam across the screen may be applied to one or all of the electrodes.

Thus, one feature of the present invention involves dynamically compensating for astigmatism and beam focusing errors in an in-line, multi-beam color CRT without introduction of convergence errors.

Another feature of the present invention is to provide a quadrupole lens adapted for use in virtually any of the more common in-line color CRTs and which affords precise control of electron beam convergence/divergence.

Another feature of the present invention is to compensate for the non-uniform magnetic field of a self-converging deflection yoke in a color CRT by dynamically controlling horizontal and vertical divergence/convergence of the CRT electron beams.

A still further feature of the present invention is to allow for a reduction in the dynamic focusing voltage provided to a quadrupole electron beam focusing lens for a color CRT and minimize problems involving additional high voltage application through a CRT neck pin.

Another feature of the present invention is to correct for outer electron beam (typically the red and blue beams) dynamic misconvergence in in-line color CRTs having dynamic astigmatism compensation.

Further features and advantages of the present invention will best be understood by reference to the following detailed description of preferred embodiments taken in conjunction with the accompanying drawings, where like reference characters identify like elements throughout the various figures, in which:

FIG. 1 is a perspective view of a dynamic quadrupole lens for an in-line color CRT in accordance with the principles of the present invention;

FIG. 2 is a graphic representation of the variation over time of the dynamic voltage applied to the quadrupole lens of the present invention;

03 MAR 1997

-9-

FIG. 3 is a simplified planar view of a phosphor screen on the inner surface of a CRT glass faceplate illustrating various deflection positions of the electron beams thereon;

FIGS. 4a and 4b are sectional views of an electron beam respectively illustrating vertical convergence/horizontal divergence (negative astigmatism effect) and vertical divergence/horizontal convergence (positive astigmatism effect) effected by the dynamic quadrupole lens of the present invention;

FIG. 5 is a simplified sectional view illustrating the electrostatic potential lines and electrostatic force applied to an electron in the space between two charged electrodes;

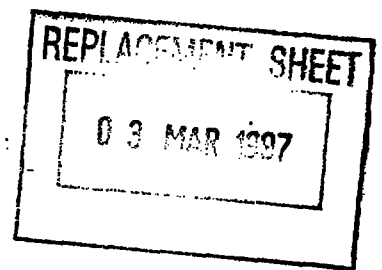
FIGS. 6 through 12 illustrate additional embodiments of a dynamic quadrupole lens for focusing a plurality of electron beams in an in-line color CRT in accordance with the principles of the present invention;

FIGS. 13a and 13b respectively illustrate sectional views of a prior art bipotential type ML electron focusing lens and the manner in which the dynamic quadrupole lens of the present invention may be incorporated in such a prior art electron beam focusing lens;

FIGS. 14a and 14b are sectional views of a prior art Einzel-type ML electron focusing lens and the same focusing lens design incorporating a dynamic quadrupole lens in accordance with the present invention, respectively;

FIGS. 15a, 15b, 15c and 15d respectively illustrate sectional views of a prior art QPF-type ML electron focusing lens and three versions of such a QPF-type ML lens incorporating a dynamic quadrupole lens in accordance with the present invention;

FIGS. 16a and 16b respectively illustrate sectional views of a prior BU-type ML electron focusing



-10-

lens and the same type of electron focusing lens incorporating the inventive dynamic quadrupole lens of the present invention;

FIG. 17 is a perspective view of an electron beam misconvergence correction arrangement in accordance with the present invention as employed in a dynamic quadrupole lens for an in-line color CRT;

FIG. 18 is a lengthwise sectional view of an electron beam misconvergence correction arrangement as shown in FIG. 17;

FIG. 19 is a plan view of an offset keyhole electrode design for use in an in-line multi-electron beam focusing arrangement in an electron gun in accordance with the present invention;

FIG. 20 is an end-on view of the focusing electrode of FIG. 19;

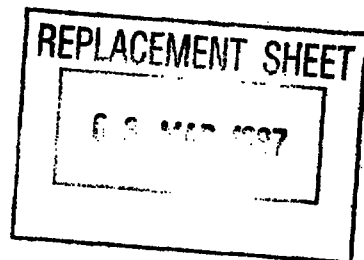
FIG. 21 is a perspective view of an electron beam misconvergence correction arrangement incorporating generally circular, notched outer apertures in a center electrode in accordance with another embodiment of the present invention;

FIG. 22 is a plan view of another embodiment of an electrode in accordance with the present invention, where the electrode has a higher voltage than an adjacent focusing electrode;

FIG. 23 is a schematic illustration of a focusing lens structure in a three-beam in-line gun wherein the outer electron beams are electrically converged by the present invention; and

FIG. 24 is a simplified schematic diagram of yet another embodiment of the present invention wherein an asymmetric field component is formed by distorting the outer beam apertures in a pair of adjacent focusing electrodes maintained at different voltages.

Referring to FIG. 1, there is shown a perspective view of a dynamic quadrupole lens 20 for use in an in-line



-11-

electron gun in a color CRT. The manner in which the dynamic quadrupole lens of the present invention may be integrated into various existing electron gun arrangements is illustrated in FIGS. 13a and 13b through 16a and 16b, and is described in detail below. Various alternative embodiments of the dynamic quadrupole lens of the present invention are illustrated in FIGS. 10 through 16 and are discussed below. Details of the embodiment of the dynamic quadrupole lens 20 illustrated in FIG. 1 are discussed in the following paragraphs, with the principles of the present invention covered in this discussion applicable to each of the various embodiments illustrated in FIGS. 6 through 12. The present invention may be used to correct for astigmatism in CRTs having electron guns with a focusing field common to all three beams such as the Combined Optimum Tube and Yoke (COTY) CRTs, as well as non-COTY CRTs as described below. A COTY-type main lens is used in an in-line electron gun and allows the three electron guns to have a larger vertical lens while sharing the horizontal open space in the main lens for improved spot size. The terms "electrode", "grid" and "plate" are used interchangeably in the following discussion.

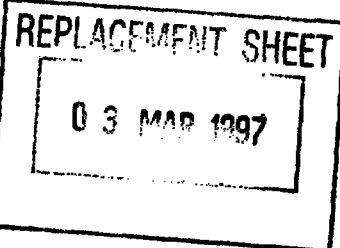
The dynamic quadrupole lens 20 includes first, second, and third electrodes 28, 30 and 32 arranged in mutual alignment. The first electrode 28 includes an elongated aperture 28a extending a substantial portion of the length of the electrode. Disposed along the length of the aperture 28a in a spaced manner are three enlarged portions of the aperture.

The second electrode 30 includes three keyhole-shaped apertures 30a, 30b and 30c arranged in a spaced manner along the length of the electrode. As in the case of the first electrode 28, the third electrode 32 includes an elongated aperture 32a extending along a substantial portion of the length thereof and including three spaced enlarged portions. Each of the

aforementioned keyhole-shaped apertures 30a, 30b and 30c has a longitudinal axis which is aligned generally vertically as shown in FIG. 1, or generally transverse to the longitudinal axes of the apertures in the first and third electrodes 28 and 32. With the first, second, and third electrodes 28, 30 and 32 arranged generally parallel and in linear alignment, the respective apertures of the electrodes are adapted to allow the transit of three electron beams 22, 24 and 26, each shown in the figure as a dashed line.

The second electrode 30 is coupled to a constant voltage source 34 and is charged to a fixed potential VF_1 . The first and third electrodes 28, 32 are coupled to a variable voltage source 36 for applying a dynamic voltage VF_2 to these electrodes. The terms "voltage" and "potential" are used interchangeably in the following discussion. The present invention is described in detail in the following paragraphs with the dynamic and static voltages applied as indicated, although the principles of this invention also encompass applying a dynamic voltage to the second intermediate electrode 30 while maintaining the first and third electrodes 28, 32 at a fixed voltage.

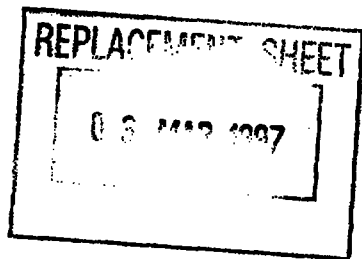
Referring to FIG. 2, there is shown a graphic representation of the relative voltages at which the second electrode 30 and the first and third electrodes 28, 32 are maintained over time. As shown in FIG. 2, the VF_1 voltage is maintained at a constant value, while the VF_2 voltage varies in a periodic manner with electron beam sweep. The manner in which the VF_2 dynamic voltage varies with electron beam sweep can be explained with reference to FIG. 3 which is a simplified planar view of a CRT faceplate 37 having a phosphorescing screen 38 on the inner surface thereof. The dynamic focusing voltage VF_2 applied to the first and third electrodes 28, 32 varies in a periodic manner between a minimum value at point A and a maximum value at point C as shown in FIG. 2. The minimum



-13-

value at point A corresponds to the electron beams positioned along a vertical centerline of the CRT screen 38 such as shown at point A' as the electron beams are deflected horizontally across the screen. As the electron beams are further deflected toward the right in FIG. 3 in the vicinity of point B, the dynamic voltage VF_2 increases to the value of the fixed focus voltage VF_1 as shown at point B in FIG. 2. Further deflection of the electron beams toward the right edge of the CRT screen 38 at point C' occurs as the dynamic focus voltage VF_2 increases to its maximum value at point C in FIG. 3 which is greater than VF_1 . The dynamic voltage VF_2 then decreases to the value of the fixed focus voltage VF_1 as the electron beams are deflected leftward in FIG. 3 toward point B' which is intermediate the center and lateral edge locations on the CRT screen 38. The dynamic voltage VF_2 varies relative to the fixed voltage VF_1 in a similar manner when the electron beams are deflected to the left of point A' in FIG. 3 to cover the other half of the CRT screen. In some color CRTs currently in use, such as those of the COTY type, the dynamic focus voltage is varied in a periodic manner but does not go below the fixed focus voltage VF_1 . This type of dynamic focus voltage is labeled VF_2 in FIG. 2 and is shown in dotted line form therein. The dynamic focus voltage is applied to the first and third electrodes 28, 32 synchronously with the deflection yoke current to change the quadrupole fields applied to the electron beam so as to either converge or diverge the electron beams, depending upon their position on the CRT screen, in correcting for deflection yoke-produced astigmatism and beam defocusing effects as described below.

Referring to FIGS. 4a and 4b, there is shown the manner in which the spot of an electron beam 40 may be controlled by the electrostatic field of a quadrupole lens. The arrows in FIGS. 4a and 4b indicate the



-14-

direction of the forces exerted upon an electron beam by the electrostatic field. In FIG. 4a, the quadrupole lens is horizontally diverging and vertically converging causing a negative astigmatism of the electron beam 40. This negative astigmatism corrects for the positive astigmatism of the beam introduced by a COTY-type main lens. Negative astigmatism correction is introduced when the beam is positioned in the vicinity of the vertical center of the CRT screen in a COTY-type main lens. In FIG. 4b, the quadrupole lens is vertically diverging and horizontally converging for introducing a positive astigmatism correction in the electron beam. Positive astigmatism correction compensates for the negative astigmatism of the electron beam spot caused by the self-converging magnetic deflection yoke as the electron beam is deflected adjacent to a lateral edge of the CRT's screen. Positive and negative astigmatism correction is applied to the electron beams in a COTY-type of CRT. In a non-COTY-type of CRT, only positive astigmatism is applied in the electron beams. The manner in which the present invention compensates for astigmatism in both types of CRTs is discussed in detail below.

Operation of the dynamic quadrupole lens 20 for an in-line color CRT as shown in FIG. 1 will now be described with reference to Table I. Table I briefly summarizes the effect of the electrostatic field of the dynamic quadrupole lens 20 applied to an electron beam directed through the lens. The electrostatic force applied to the electrons in an electron beam by the electrostatic field of the dynamic quadrupole lens is shown in FIG. 5.

Referring to FIG. 5, there is shown a simplified illustration of the manner in which an electrostatic field, represented by the field vector $\vec{E}$, applies a force, represented by the force vector $\vec{F}$, to an electron. An electrostatic field is formed between two charged

electrodes, with the upper electrode charged to a voltage of V_1 and the lower electrode charged to a voltage of V_2 , where V_1 is greater than V_2 . The electrostatic field vector $\vec{E}$ is directed toward the lower electrode, while the force vector $\vec{F}$ is directed toward the upper electrode because of the electron's negative charge. FIG. 5 provides a simplified illustration of the electrostatic force applied to an electron, or an electron beam, directed through apertures in adjacent charged electrodes which are maintained at different voltages. It can be seen that the relative width of the two apertures in the electrodes as well as the relative polarity of the two electrodes determines whether the electron beam is directed away from the A-A' axis (divergence), or toward the A-A' axis (convergence).

With reference to FIG. 1 in combination with Table I, the horizontal slots 28a, 32a in the first and third electrodes 28, 32 cause vertical divergence of the electron beam when they are maintained at a voltage greater than the second electrode 30 such as when the electron beams are positioned adjacent to a lateral edge of the CRT screen. With the second electrode 30 maintained at a lower voltage V_F , than the other two electrodes when the electron beams are located adjacent the CRT screen's lateral edge, as shown at point C in FIG. 2, the vertically aligned apertures of the second electrode effect a horizontal convergence of the electron beams which reinforces the vertical divergence correction of the other two electrodes. This combination of vertical divergence and horizontal convergence of an electron beam 40 is shown in FIG. 4b and represents a positive astigmatism correction which compensates for the negative astigmatism introduced in the electron beam by the CRT's self-converging magnetic deflection yoke.

When the electron beams are positioned between the center and a lateral edge of the CRT screen, all three

03 MAR 1997

-16-

electrodes are at the same voltage and the dynamic quadrupole lens does not introduce either an astigmatism or a focus correction factor in the electron beams. In non-COTY CRTs, the three electrodes are also maintained at the same voltage when the electron beams are positioned on a vertical center portion of the CRT screen as shown graphically in FIG. 2 for the dynamic focus voltage VF_2 . In this case, because all three electrodes are again maintained at the same voltage, the dynamic quadrupole lens does not introduce a correction factor in the electron beams to compensate for deflection yoke astigmatism and defocusing effects. In COTY-type CRTs, the dynamic focusing voltage VF_2 applied to the first and third electrodes 28, 30 is less than the fixed voltage VF_1 of the second electrode 30 in the vicinity of the center of the CRT screen. With the polarity of the electrodes changed, the first and third electrodes 28, 32 introduce a vertical convergence in the electron beams as shown in Table I. The second electrode 30, now at a higher voltage than the other two electrodes, introduces a horizontal divergence by virtue of its generally vertically aligned apertures. The vertical convergence effected by the first and third electrodes 28, 32 and the horizontal divergence caused by the second electrode 30 introduces a negative astigmatism correction in the electron beams as shown in FIG. 4a. The negative astigmatism correction compensates for the positive astigmatism effects of a COTY-type main lens on the electron beams in the center of the CRT screen.

Although the first and third electrodes 28, 32 are each shown with a single elongated, generally horizontally aligned aperture, the present invention also contemplates providing each of these electrodes with a plurality of spaced, aligned apertures each having a horizontally oriented longitudinal axis and adapted to pass a respective one of the electron beams. In addition,

while the operation of the present invention has thus far been described with the dynamic quadrupole lens positioned after electron beam cross over, or between cross over and the CRT screen, the dynamic quadrupole lens may also be positioned before beam cross over, or between the electron beam source and cross over. The effect of the dynamic quadrupole lens on the electron beams is reversed in these two arrangements as shown in Table I.

Referring to FIGS. 6 through 12, there are shown various alternative embodiments of the dynamic quadrupole lens of the present invention. In the dynamic quadrupole lens 50 of FIG. 6, the first and third electrodes 51 and 53 include respective elongated, generally rectangular apertures 51a and 53a through which the three electron beams are directed. The second electrode 52 includes a plurality of spaced, generally rectangular shaped apertures 52a, 52b and 52c. Each of the rectangular apertures 52a, 52b and 52c is aligned lengthwise in a generally vertical direction.

The dynamic quadrupole lens 60 of FIG. 8 is similar to that of FIG. 6 in that the first and third electrodes 61 and 63 each include a respective rectangular, horizontally oriented aperture 61a and 63a. However, in the dynamic quadrupole lens 60 of FIG. 8, the second electrode 62 includes three circular apertures 62a, 62b and 62c. Where circular apertures are employed, the second electrode 62 will not function as a quadrupole lens element, although the first and third electrodes 61 and 63 will continue to so operate. The three apertures 62a, 62b and 62c may also be elliptically shaped with their major axes oriented generally vertically, in which case the second electrode 62 will function as a quadrupole lens element to converge or diverge the electron beams, as the case may be.

The dynamic quadrupole lens 55 of FIG. 7 is a combination of the lenses shown in FIGS. 1 and 8 in that

the second electrode 57 includes three circular, or elliptically shaped, apertures 57a, 57b and 57c, while the first and third electrodes 56 and 58 each include respective elongated, horizontally oriented apertures 56a and 58a. Each of the apertures 56a and 58a includes a plurality of spaced enlarged portions through which a respective one of the electron beams is directed. The dynamic quadrupole lenses 65 and 70 respectively shown in FIGS. 9 and 10 also include three spaced electrodes in alignment with three electron beams, wherein the electrodes include various combinations of apertures previously described and illustrated. In FIG. 9, the first and third electrodes 66 and 67 are each shown with a plurality of spaced elongated apertures having their longitudinal axes in common alignment with the in-line electron beams.

Referring to FIG. 11, there is shown yet another embodiment of a dynamic quadrupole lens 75 in accordance with the principles of the present invention. The dynamic quadrupole lens 75 includes first and third electrodes 76 and 78, which are each in the general form of an open frame through which the electron beams pass, and a second electrode 77 having three spaced, generally vertically oriented apertures through each of which a respective one of the electron beams is directed. The first and third electrodes 76 and 78 do not include an aperture through which electron beams are directed, or may be considered to have an infinitely large aperture disposed within a charged electrode. Any any rate, it has been found that it is the dynamic focusing voltage applied to the first and third electrodes 76 and 78 which functions in combination with the charge on the second electrode 77, and the apertures therein, to provide electron beam convergence/divergence control in compensating for electron beam astigmatism and defocusing. The dynamic quadrupole lens 80 of FIG. 12 is similar to that shown in

03 MAR 1997

-19-

FIG. 11, except that the three apertures in the second electrode 82 are generally rectangular in shape and operate in conjunction with the first and third dynamically charged electrodes 81 and 83.

The dynamic quadrupole lens 75 operates in the following manner. In a COTY-type CRT, the second electrode 77 will be at a higher voltage than the first and third electrodes 76, 78 when the electron beams are positioned near the center of the CRT screen. The second electrode 77 will thus cause a horizontal divergence resulting in a negative astigmatism correction as shown in FIG. 4a. The first and third electrodes 76, 78 cause a vertical convergence of the electron beams to further effect negative astigmatism correction. When the electron beams are adjacent to a lateral edge of the CRT screen, the second electrode 77 will be at a lower voltage than the first and third electrodes 76, 78 resulting in horizontal convergence and vertical divergence of the electron beams as shown in Table I and as illustrated in FIG. 4b as a positive astigmatism correction. Thus, electron beam astigmatism and defocusing are corrected for by the dynamic quadrupole lenses of FIGS. 11 and 12, although the compensating effects of this electrode arrangement are not as great as in the previously discussed embodiments wherein all three electrodes are provided with apertures.

Referring to FIG. 13a, there is shown a conventional bipotential type main lens (ML) electron gun 90. The bipotential type ML electron gun 90 includes a cathode K which provides electrons to the combination of a control grid electrode G1, a screen grid electrode G2, a first accelerating and focusing electrode G3, and a second accelerating and focusing electrode G4. A focusing voltage V_{F1} is applied to the first accelerating and focusing electrode G3, and an accelerating voltage V_A as

03 MAR 1997

-20-

applied to the second accelerating and focusing electrode G4.

FIG. 13b shows the manner in which a dynamic quadrupole lens 92 may be incorporated in a conventional bipotential type ML electron gun. The dynamic quadrupole lens 92 includes adjacent plates of a G3₁ electrode and a G3₂ electrode to which a dynamic focusing voltage VF2 is applied. The dynamic quadrupole lens 92 further includes a G3₂ electrode, or grid, which is maintained at a fixed voltage VF1. The cathode as well as various other control grids which are illustrated in FIG. 13a have been omitted from FIG. 13b, as well as the remaining figures, for simplicity. Thus, a bipotential type ML electron gun may be converted to an electron gun employing the dynamic quadrupole lens of the present invention by separating its first accelerating and focusing electrode G3 into two components and inserting a third fixed voltage electrode G3₂ between the two accelerating and focusing electrode components G3₁ and G3₁.

Referring to FIG. 14a, there is shown a conventional Einzel-type ML electron gun 94 which includes G3, G4 and G5 accelerating and focusing electrodes.

Referring to FIG. 14b, there is shown the manner in which a dynamic quadrupole lens 96 in accordance with the present invention may be incorporated in a conventional Einzel-type ML electron gun. In the electron gun arrangement of FIG. 14b, the G4 electrode is divided into two lens components G4₁ and G4₃, and a third focusing electrode G4₂ is inserted between the adjacent charged plates of the G4₁ and G4₃ electrodes. A fixed focus voltage VF1 is applied to the G4₂ electrode, while a dynamic focus voltage VF2 is applied to the G4₁ and G4₃ electrodes. The dynamic quadrupole lens 96 within the Einzel-type ML electron gun thus includes adjacent charged plates of the G4₁ and G4₃ accelerating and focusing electrodes in combination with an intermediate

03 MAR 1997

-21-

G4₂ electrode which is maintained at a fixed focus voltage VF1.

Referring to FIG. 15a, there is shown a conventional QPF type ML electron gun 98. The QPF type ML electron gun 98 includes G2, G3, G4, G5 and G6 electrodes. A fixed focus voltage VF is applied to the G3 and G5 electrodes.

FIG. 15b illustrates the manner in which a dynamic quadrupole lens 100 in accordance with the present invention may be incorporated in the G4 electrode of a QPF type ML electron gun. In the arrangement of FIG. 15b, the G4 electrode is comprised of G4₁, G4₂ and G4₃ electrodes. The G2 and G4₂ electrodes are maintained at a voltage VG2₀ while the G4₁ and G4₃ electrodes are maintained at a voltage VG2₁. The VG2₀ voltage is fixed, while the VG2₁ voltage varies synchronously with electron beam sweep across the CRT screen.

Referring to FIG. 15c, there is shown the manner in which a dynamic quadrupole lens 102 in accordance with the present invention may be incorporated in the G5 electrode of a conventional QPF type ML electron gun. In the arrangement of FIG. 15c, the G5 accelerating and focusing electrode of a conventional QPF type ML electron gun has been divided into three control electrodes G5₁, G5₂ and G5₃. A fixed focus voltage VF1 is applied to the G3 and G5₂ electrodes, while a dynamic focus voltage VF2 is applied to the G5₁ and G5₃ electrodes. A VG2 voltage is applied to the G2 and G4 electrodes. The dynamic quadrupole lens 102 is comprised of the G5₂ electrode in combination with the adjacent plates of the G5₁ and G5₃ electrodes. In FIG. 15d, the G3 electrode is shown coupled to the VF2 focus voltage rather than the VF1 focus voltage as in FIG. 15c. In the arrangement of FIG. 15d, two spatially separated quadrupoles each apply an astigmatism correction to the electron beams. A first quadrupole is comprised of the upper plate of the G3

electrode, the lower plate of the G5₁ electrode, and the G4 electrode disposed therebetween. A dynamic focus voltage VF₂ is provided to the G3, G5₁ and G5₃ electrodes. The second quadrupole is comprised of the upper plate of the G5₁ electrode, the lower plate of the G5₃ electrode, and the G5₂ electrode disposed therebetween. The G5₃ and G6 electrodes form an electron beam focusing region, while the combination of electrodes G2 and G3 provide a convergence correction for the two outer electron beams as the beams are swept across the CRT screen with changes in the electron beam focus voltage. This is commonly referred to as a FRAT (focus refraction alignment test) lens.

Referring to FIG. 16, there is shown a conventional BU type ML electron gun 104. The BU type ML electron gun 104 includes G3, G4, G5 and G6 electrodes. An anode voltage VA is applied to the G4 and G6 electrodes, while a dynamic focus voltage VF is applied to the G3 and G5 electrodes.

FIG. 16b shows the manner in which a dynamic quadrupole lens 106 in accordance with the present invention may be incorporated in a conventional BU type ML electron gun. The G5 electrode of the prior art BU type ML electron gun is reduced to two electrodes G5₁ and G5₃ with a third electrode G5₂ inserted therebetween. The dynamic quadrupole lens 106 thus is comprised of adjacent plates of the G5₁ and G5₃ electrodes in combination with the G5₂ electrode. A fixed focus voltage VF₁ is applied to the G3 and G5₂ electrodes, while the anode voltage VA is applied to the G4 and G6 electrodes. A dynamic focusing voltage VF₂ is applied to the G5₁ and G5₃ electrodes in the electron gun.

A further preferred embodiment of the invention is disclosed in FIGS. 17-20. Referring to FIG. 17, there is shown a perspective view of a dynamic quadrupole lens

120 for use in an in-line electron gun in a color CRT incorporating a second electrode 130 in accordance with the present invention. The dynamic quadrupole lens 120 includes first, second and third electrodes 128, 130 and 132 arranged in mutual alignment. The first electrode 128 includes an elongated aperture 128a extending a substantial portion of the length of the electrode. Disposed along the length of the aperture 128a in a spaced manner are three openings in the form of enlarged portions of the aperture. As in the case of the first electrode 128, the third electrode 132 also includes an elongated aperture 132a extending along a substantial portion of the length thereof and including three spaced openings in the form of enlarged portions of the aperture 132a. The first and third electrodes 128 and 132 are aligned so that first, second and third electron beams 122, 124 and 126 respectively transit the corresponding enlarged portions of the elongated apertures 128a and 132a within the first and third electrodes. The first and third electrodes 128, 132 are coupled to a variable voltage source 136 for applying a dynamic voltage VF_2 to these electrodes.

The second electrode 130 is disposed intermediate the first and third electrodes 128, 132 and includes three keyhole-shaped apertures 130a, 130b and 130c arranged in a spaced manner along the length of the electrode. Each of the aforementioned keyhole-shaped apertures 130a, 130b and 130c has a longitudinal axis which is aligned generally vertically as shown in FIG. 17, or generally transverse to the longitudinal axes of the apertures in the first and third electrodes 128 and 132. With the first, second and third electrodes 128, 130 and 132 arranged generally parallel in a linear alignment, the respective apertures of the electrodes are adapted to allow the transit of the three electron beams 122, 124 and 126, each shown in the figure as a dashed line. The second electrode 30 is

coupled to a constant voltage source 134 and is charged to a fixed potential VF_1 .

Referring also to FIGS. 19 and 20, additional details of the second electrode 130 which concern an aspect of this invention will now be described. Each of the three keyhole-shaped apertures 130a, 130b and 130c in the second electrode 130 includes an enlarged center portion through which a respective one of the electron beams is directed. As shown in the figures, the two outer keyhole-shaped apertures 130a and 130c are provided with respective opening profile distortions or opening enlargements in the form of notches 130d and 130e on inner portions thereof and are in the general form of an offset keyhole. The opening enlargements (here notches) 130d and 130e in the offset keyhole-shaped apertures 130a and 130c unbalance the horizontal focusing strength of the two outer offset keyholes to produce an asymmetrical field component having a refraction lens effect, where the strength of the refraction lens on the two outer electron beams is proportional to the dynamic drive voltage V_{DYN} applied to the first and third electrodes 128 and 132. The refraction lens effect of the notched inner portions of the two outer keyhole-shaped apertures 130a and 130c moves the outer (here red and blue) electron beams inwardly or outwardly along the horizontal direction across the CRT's faceplate to reduce or cancel the dynamic outer beam misconvergence effect caused by the use of a common focusing field for all three beams. The outer electron beams are horizontally displaced either inwardly or outwardly depending upon the voltages on the first and third electrodes 128 and 132 relative to the voltage of the second electrode 130.

Referring to FIG. 18, there is shown a sectional view of the arrangement of FIG. 17 including a quadrupole focusing type main lens (ML) electron gun 140 incorporating the focusing electrode 130 of the present

invention. In the arrangement of FIG. 18, the first, second and third electrodes 128, 130 and 132 form a dynamic quadrupole to compensate for electron beam astigmatism and defocusing caused by the electron beam deflection yoke. A fixed focusing voltage V_{F1} is applied to the second electrode 130 while a dynamic focusing voltage $V_{F2} + V_{DYN}$ as applied to the first and third electrodes 128 and 132. A cathode K emits electrons which are controlled by various grids including a screen grid electrode G2. The electrons are then directed to a first accelerating and focusing electrode G3. The G3 electrode is comprised of a G3 lower section, a G3 upper section, and the aforementioned dynamic quadrupole region disposed therebetween. The respective apertures 128a, 130a and 132a in the first, second and third electrodes 128, 130 and 132 are aligned to allow the transit of each of the three electron beams as discussed above and shown in FIG. 17. A second accelerating and focusing electrode G4 is disposed adjacent to the G3 upper portion, with a COTY-type main lens (ML) dynamic focus region (or stage) formed by the G3 and G4 electrodes.

While a second electrode 130 having a pair of outer keyhole-shaped apertures 130a and 130c each with an inner notch is disclosed and illustrated herein as forming a portion of a dynamic quadrupole electron beam focusing lens, as noted above, the opening profile distortion feature of the present invention is not limited to use in a dynamic quadrupole lens and may be used simply by itself in virtually any type of conventional electron gun. Even when not used in a dynamic quadrupole lens, the offset keyhole design of the inventive focusing electrode 130 exerts a refractive lens effect on the off-axis (outer) electron beams, with the strength of the refraction (asymmetrical) lens being proportional to the dynamic focusing voltage applied to the main lens focusing stage, to horizontally displace the outer (here red and blue)

beams so as to reduce or cancel the dynamic red/blue misconvergence effect of the multi-beam electron gun. When not employed in a quadrupole electron beam focusing lens, the inventive electrode 130 is disposed intermediate the G3 lower and upper electrode portions, with the first and third electrodes 128, 132 absent from such an electron beam focusing arrangement.

FIG. 21 is a perspective view of another embodiment of an electron beam misconvergence correction arrangement 150 including first, second and third electrodes 152, 154 and 156. The second (middle) electrode 154 includes three generally circular spaced apertures 154a, 154b and 154c. The outer two apertures 154a and 154c include respective inwardly opening enlargements in the form of directed notches 154d and 154e. These notches provide an unbalanced horizontal focusing field to produce the refraction lens effect, where the strength of the refraction lens on the two outer electron beams is proportional to the dynamic drive voltage applied to the first and third electrodes 152 and 156. This electrode 160 is introduced for use in a lens arrangement wherein it receives the higher applied potential.

Referring to FIG. 22, there is shown a plan view of an electrode 160 in accordance with another embodiment of the present invention. The electrode 160 is adapted for use in a dual quadrupole electron beam focusing arrangement as described above for the first and third electrodes, where the first and third electrodes are maintained at a higher voltage than a second, middle electrode. A dynamic focusing voltage is applied to the electrode 160 which includes an elongated aperture 162 therein. As in previous embodiments, the elongated aperture 162 is provided with a plurality of spaced beam-passing openings in the form of openings (enlarged portions) 162a, 162b and 162c along the length thereof.

03 MAR 1997

-27-

An electron beam is directed through each of the openings 162a, 162b and 162c along the length of the elongated aperture 162 in the electrode 160. With the electrode 160 maintained at a higher voltage than an adjacent, middle electrode (not shown), the elongated aperture 162 is provided with a pair of extensions 162e and 162d, each at a respective end of the elongated aperture 162. The end extensions 162e and 162d of the elongated aperture 162 provide an unbalanced horizontal focusing field effect on the two outer electron beams to correct the focus-convergence interaction between the red and blue beams arising from changes in the magnitude of the dynamic focus voltage. The difference between electrode 160 and previously described embodiments is in the width (or height) of the extensions 162e and 162d relative to the width of the elongated aperture 162. In a preferred embodiment of electrode 160, the extensions 162e, 162d each have a width of $Y = 0.115$ mil, while the width of aperture 162 is 0.065 mil. The greater widths of the extensions 162d, 162e on each end of the elongated aperture 162 weakens the electrostatic field exerted on the two outer electron beams allowing for reduced outer electron beam deflection in correcting the focus-convergence interaction arising from changes in the focus voltage.

As suggested above, the present invention can be viewed in a broad context as providing means for electrically refracting or bending an electron beam in various applications in electron guns not limited to the preferred embodiments described above. FIG. 23 is a schematic illustration of the use of a focusing lens structure in a three-beam in-line gun in which the outer beams are electrically converged by use of the present invention. Specifically, FIG. 23 illustrates a pair of facing electrodes 170, 172 for converging three electron beams 174, 176 and 178. Electrode 170 has apertures 180,

MAR 1997

-28-

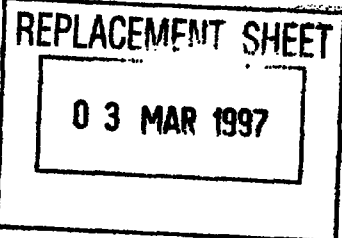
182 and 184 which cooperate with apertures 186, 188 and 190 in adjacent electrode 172. Electrode 172 is adapted to receive a relatively lower potential and electrode 170 is adapted to receive a relatively higher potential.

In accordance with the present invention, the electrode 172 receiving the relatively lower potential has an aperture pattern so configured so as to create symmetrical field components for the outer beams 174, 178 which have the effect of bending or refracting the outer beams 174, 178 toward a distant common point.

As explained in more detail and claimed in our co-pending application, serial No. (DF-6269), a dynamic voltage may be applied to one or both of the electrodes 170, 172 to cause the beam convergence angle to vary as a function of beam deflection.

In accordance with the present invention, the asymmetrical field component acting upon the outer beams 174, 178 is produced by enlarging the apertures 186, 190 in a direction toward the center aperture 188. The opening enlargements are shown as taking the form of rounded protuberances 192, 194, respectively, in the profile of the apertures 186, 190. Many other opening distortion geometries may be utilized in accordance with the present invention, dependent upon the nature and degree of unbalancing of the fields on the outer beams which is desired.

FIG. 24 illustrates yet another embodiment of the present invention wherein the asymmetrical field component is formed by distorting the openings for the outer beams in both electrode 196 receiving a relatively higher voltage and electrode 198 receiving a relatively lower voltage. Specifically, the electrode 196 has outer beam passing openings 200, 202 which have opening enlargements 204, 206 extending outwardly away from the center beam opening 208. The electrode 198 adapted to receive the lower potential has outer beam apertures 210 and 212



-29-

having opening enlargements 214, 216 which extend inwardly toward the center beam opening 218. The FIG. 24 embodiment illustrates that opening enlargements may be employed in both the high voltage and lower voltage electrodes as well as in either alone and that these opening enlargements may assume various forms.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects. For example, while the present invention has been described as applying a dynamic voltage to first and third electrodes and a fixed voltage to a second electrode spaced therebetween, this invention also contemplates applying a dynamic voltage to the second electrode while maintaining the spaced first and third electrodes at a fixed voltage. Therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective based on the prior art.

03 MAR 1997

- 30 -

TABLE I

SLOT LOCATION	MAJOR AXIS OF SLOT	FORCE DIRECTION ON THE E-BEAM	OPTICAL EFFECT ON THE E-BEAM AFTER CROSS OVER	COMMENTS
HIGHER VOLTAGE SIDE	VERTICAL (Y-DIRECTION)	X-AWAY FROM AXIS Y-NO EFFECT	HORIZ. DIV.	A.) FIELD VECTOR "E" IS IN DIRECTION FROM HIGH VOLTAGE SIDE (EQUIPOTENTIAL LINES) B.) FORCE VECTOR "F" ON ELECTRON IS EQUAL TO -e E
	HORIZ. (X-DIRECTION)	X-NO EFFECT Y-AWAY FROM AXIS	VERT. DIV.	
	VERTICAL (Y-DIRECTION)	X-TOWARD AXIS Y-NO EFFECT	HORIZ. CONV.	
	HORIZ. (X-DIRECTION)	X-NO EFFECT Y-TOWARD AXIS	VERT. CONV.	
LOWER VOLTAGE SIDE				

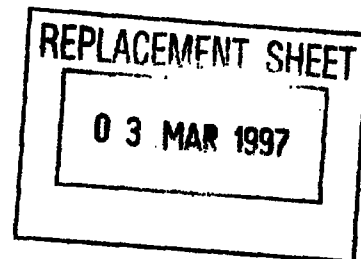
CLAIMS

1. A color cathode ray tube system having a color tube with a phosphor screen, said system including a three-beam, in-line gun for exciting said screen, said gun including, cathode means and focus lens means for developing a center beam and two outer beams and for forming three focused electron beam spots at the screen of the tube, and electrostatic quadrupole-developing means configured and arranged to develop a horizontally unbalanced quadrupole field in the path of each of said outer beams when appropriately excited, and system signal generating means for developing a signal having amplitude variations correlated with the scan of the beams across the screen and for applying said signal to said electrostatic quadrupole-developing means to cause said beams to converge and diverge as a function of the strength of said signal.

2. The system of claim 1 wherein said quadrupole-developing means includes electrode means having outer beam apertures shaped to create field-strength-dependent asymmetrical outer beam fields whose strength varies as said signal varies.

3. The system of claim 1, wherein said developing means includes at least two facing electrodes, one adapted to receive a relatively higher excitation potential and the other a relatively lower excitation potential, and including respective openings each having a profile which interacts with an opening in a facing electrode such as to create a quadrupolar field therebetween when different excitation potentials are applied to said facing electrodes, a first one of said electrodes having a center opening and two outer openings arranged in a line along an electrode axis extending orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center





-32-

aperture, but asymmetrical about respective vertical axis through the outer openings to create asymmetrical outer beam fields.

4. The system of claim 3 wherein said dynamic quadrupolar lens is of the unpotential type comprising three electrodes, and wherein said first one of said electrodes is the center electrode.

5. A three-beam in-line electron gun system for a color cathode ray tube having a screen and a self-converging yoke which imparts an undesirable astigmatism to the beams in off-center regions of the screen, said system including an electron beam source for developing three electron beams, focusing means for focusing said three electron beams at the screen of the tube, said focusing means being so constructed and arranged that changes in focusing field strength undesirably alter beam convergence, correcting lens means located within or coupled to said focusing means for developing an astigmatic field component in the path of each of said beams when said lens means is appropriately excited, and means for modulating the strength of said astigmatic field component as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the screen, said modulating of said astigmatic field component also modulating said focusing field strength and undesirably creating errors in the convergence of said beams, said correcting lens means including electrode means having a beam passing opening pattern shaped to create asymmetrical outer beam fields effective to at least partially compensate for said deflection-related beam convergence errors.

6. The system of claim 5 wherein said correcting lens means comprises a dynamic quadrupole lens of the unpotential type comprising first, center and third electrodes.



03 MAR 1997

-33-

7. The system of claim 6 wherein said center electrode is adapted to receive a lower potential than said first and third electrodes, and wherein said center electrode has a center opening and two outer openings arranged in a line along an electrode axis orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

8. The system of claim 7 wherein said aperture distortions each take the form of a notch extending inwardly toward said center aperture.

9. A three-beam in-line color CRT electron gun including an electron lens for influencing said electron beams, including at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said electrodes having a center opening and two outer openings arranged in line along an electrode axis orthogonal to the gun axis, said outer apertures having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

10. A three-beam in-line electron gun for a color cathode ray tube, including means for generating three beams of electrons aligned in a common plane - a center beam and two outer beams, and beam bending means for producing asymmetrical fields in the paths of said outer beams for diverting said outer beams from respective straight line paths toward a common point of convergence, comprising at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said



* C L M S *

electrodes having a center opening and two outer openings arranged in line along an electrode horizontal axis orthogonal to the gun axis, said outer openings having opening distortions which are symmetrical about said electrode horizontal axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings to thereby produce said asymmetrical fields for said outer beams.

11. The electron gun of claim 10 wherein said one electrode is said electrode adapted to receive said lower potential and its outer beam openings have said opening distortion in the form of an opening enlargement extending inwardly towards said center opening.

12. The electron gun of claim 10 wherein said one of said electrodes is said electrode adapted to receive said higher potential and its outer beam openings have said opening distortion in the form of an opening enlargement extending outwardly away from said center opening.

13. In a three-beam in-line electron gun system for a color cathode ray tube having a screen and a self-converging yoke which imparts an undesirable astigmatism to the beams in off-center regions of the screen, apparatus including an electron beam source for developing three electron beams, focusing means for focusing said three electron beams at the screen of the tube, said focusing means being so constructed and arranged that changes in focusing field strength undesirably alter beam convergence, correcting lens means located within or coupled to said focusing means for developing an astigmatic field component in the path of each of said beams when said lens means is appropriately excited, and means for modulating the strength of said astigmatic field component as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the



03 MAR 1997

-35-

screen, said modulating of said astigmatic field component also modulating said focusing fields strength and undesirably creating errors in the convergence of said beams, said correcting lens means including means for unbalancing the outer beam astigmatic field component such as to cause said outer beams to converge or diverge as a function of the strength of said astigmatic field components for at least partially compensating for said deflection-related beam convergence errors.

14. The electron gun of claim 13 wherein said means for unbalancing comprises a distortion in the profile of one or both of associated coaxial beam-passing openings in said facing electrodes.

15. For use in a color cathode ray tube system having a color tube with a cathodoluminescent screen, a system adapted for use with a deflection yoke having an asymmetrical yoke field for self-converging said beams which undesirably astigmatizes said beams in off-center regions of the screen, said system including an in-line electron gun for developing three electron beams for exciting said screen, said gun including, for each of said beams, means including cathode means for developing said beam, focus lens means including focus electrode means for receiving said electron beam and forming a focused electron beam spot at the screen of the tube, said focus lens means having a plurality of electrode means spaced along a lens axis, beam correcting means incorporated in said focus electrode means for developing in the path of said beam when said beam correcting means is appropriately excited, an astigmatic field component, and system signal generating means for developing a signal having amplitude variations correlated with a scan of the beams across the screen and means for applying said signal to said beam correcting means to cause, as a function of beam deflection angle, the strength of said astigmatic field component to vary to produce a dynamic



* C L M S *

03 MAR 1997

-36-

astigmatism-correction effect to at least partially compensate for the beam-astigmatizing effect of said yoke, said focus lens means being so constructed and arranged that operation of said beam correcting means causes undesired deflection-related misconvergence of said beams as they are swept, said beam correcting means including misconvergence compensation means for at least partially compensating for said undesired beam misconvergence, comprising at least two facing electrodes, a first electrode being adapted to receive a relatively higher excitation potential and a second electrode a relatively lower excitation potential, at least one of said electrodes having a center opening and two outer openings arranged in line along an electrode axis orthogonal to the gun axis, said outer openings having profile distortions which are symmetrical about said electrode axis and a vertical axis through the center opening, but asymmetrical about respective vertical axis through the outer openings.

16. The system of claim 15 wherein said misconvergence compensation means comprises an asymmetric dynamic quadrupolar lens of the unipotential type comprising first, center and third electrodes, the center electrode being adapted to receive a relatively lower excitation potential than the first and third electrodes, the center electrode having its outer apertures with said profile distortions.

17. The system of claim 15 wherein said center electrode outer beam openings have said opening distortion in the form of an opening enlargement extending inwardly toward said center aperture.

18. A color cathode ray tube system having a color tube with a cathodoluminescent screen, said system including an in-line electron gun for developing three electron beams for exciting said screen, said gun including, for each of said beams, means including cathode means for developing beam, focus lens means for receiving



* C L M S *

03 MAR 1997

-37-

said electron beam and forming a focused electron beam spot at the screen of the tube, said focus lens means having a plurality of electrode means spaced along a lens axis including focus electrode means, yoke means for deflecting said electron beams, said yoke means having an asymmetrical field for self-converging said beams which undesirably astigmatizes said beams in off-center regions of the screen, beam correcting means incorporated in said focus electrode means for developing in the path of said beam when appropriately excited a first astigmatic accelerating field component and a second astigmatic decelerating field component wherein said beam correcting means includes three or more electrodes, the first of which has for said beam a horizontally elongated aperture, and system signal generating means for developing a signal having amplitude variations correlated with a scan of the beam across the screen and means for applying said signal to said beam correcting means to cause, as a function of beam deflection angle, the strength of said first and second astigmatic field components to vary to produce a dynamic astigmatism-correction effect to at least partially compensate for the beam-astigmatizing effect of said yoke.

19. A method of providing dynamic convergence control in an electron gun for a color cathode ray tube having a screen, said method including the steps of developing three electron beams, focusing said three electron beams at the screen of the tube, using a multi-element lens, the first element of which has three horizontally elongated apertures, developing in the path of each of said beams when appropriately excited at least one astigmatic field component, and modulating the strength of said first astigmatic field component as a function of beam deflection angle.

20. The method of claim 19, wherein the electron gun system has a self-converging yoke which imparts an



* C L N S *

03 MAR 1997

-38-

undesirable astigmatism to the beams in off-center regions of the screen, said method including the step of developing in the path of each of said beams when appropriately excited, in back-to-back arrangement, a first astigmatic field component and a second astigmatic decelerating field component, and modulating the strength of said astigmatic field components as a function of beam deflection angle to at least partially compensate for said yoke-induced astigmatism in said off-center regions of the screen.

21. The method of claim 19 or 20, wherein the multi-element lens comprises a three element lens.



METHOD AND APPARATUS FOR CONTROLLING DYNAMIC CONVERGENCE OF
A PLURALITY OF ELECTRON BEAMS OF A COLOR CATHODE RAY TUBE

Abstract of the Disclosure

For use particularly in a color cathode ray tube electron gun, means for diverting an electron beam from a straight line path. The beam diverting means has general utility, but is disclosed as part of a quadrupole lens for correcting astigmatism introduced by an associated self-converging yoke. The beam bending feature in the dynamic quadrupole compensates for convergence errors undesirably introduced by the dynamic focus voltage.

FIGURE 17

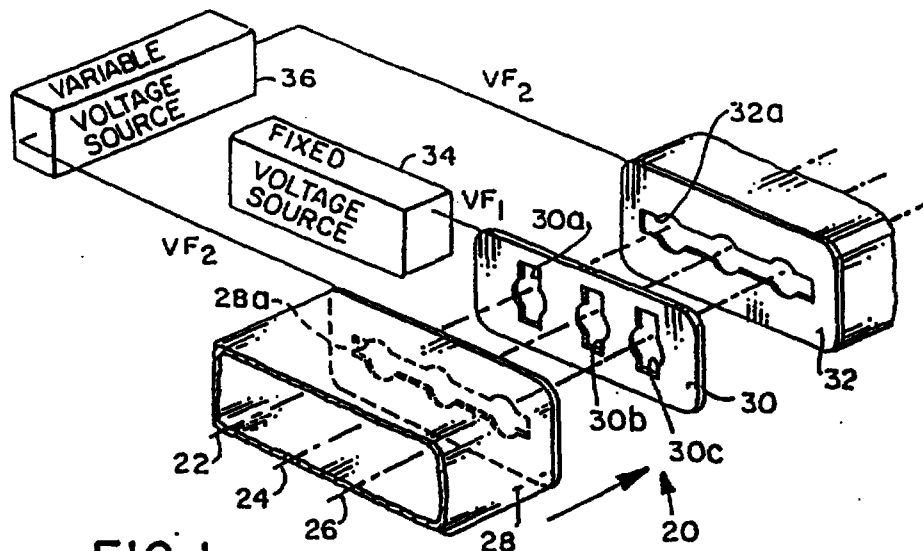


FIG. 1

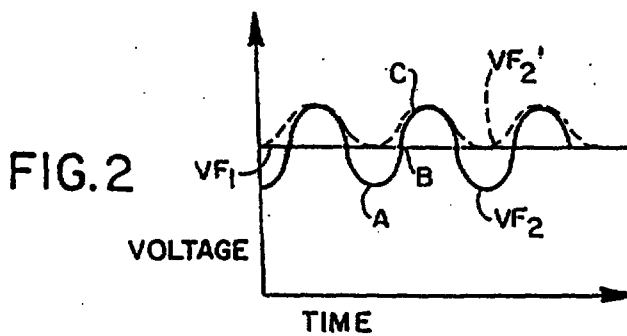


FIG. 2

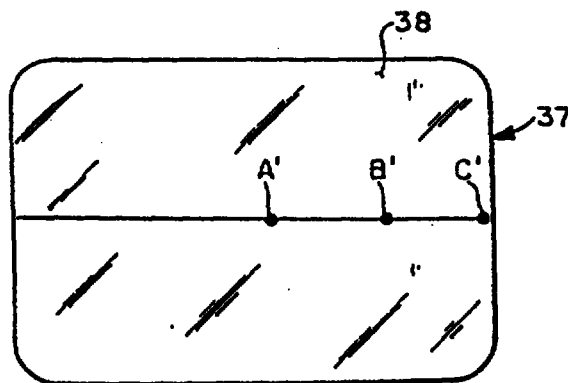


FIG. 3

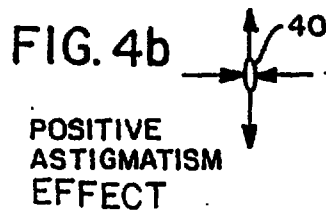
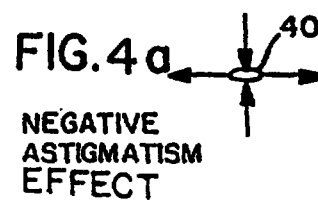
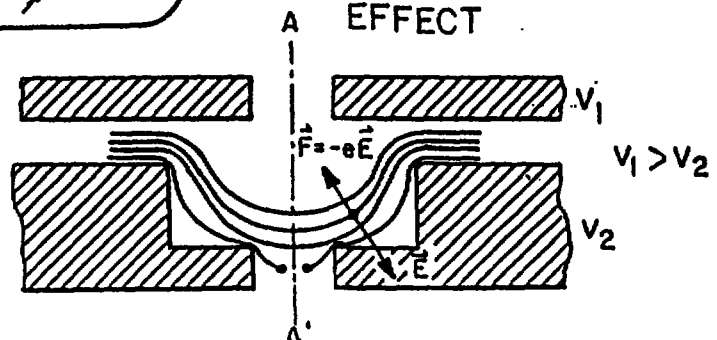


FIG. 5



REPLACEMENT S

03 MAR 1997

2

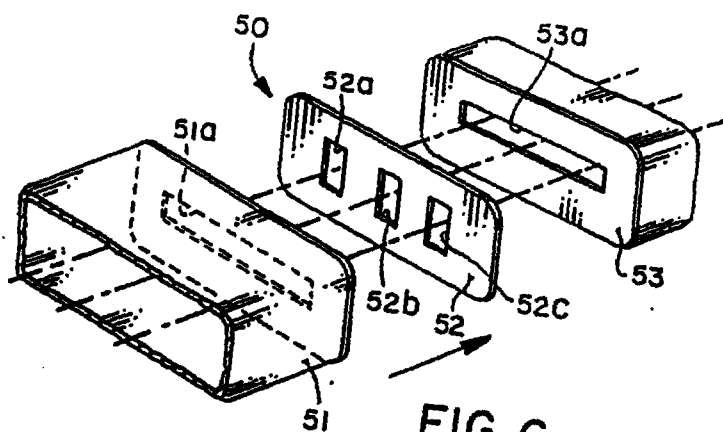


FIG. 6

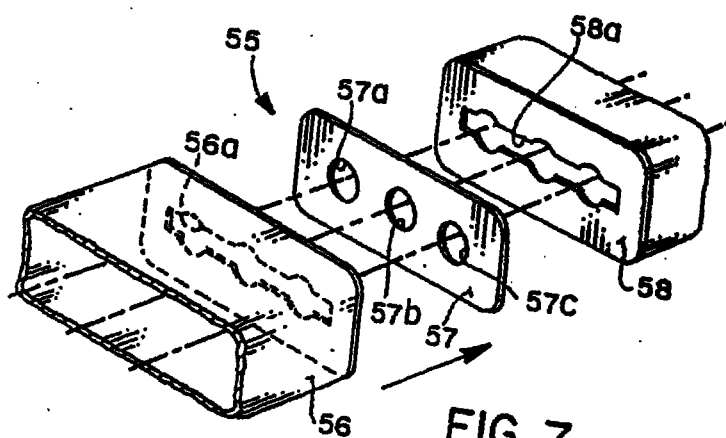


FIG. 7

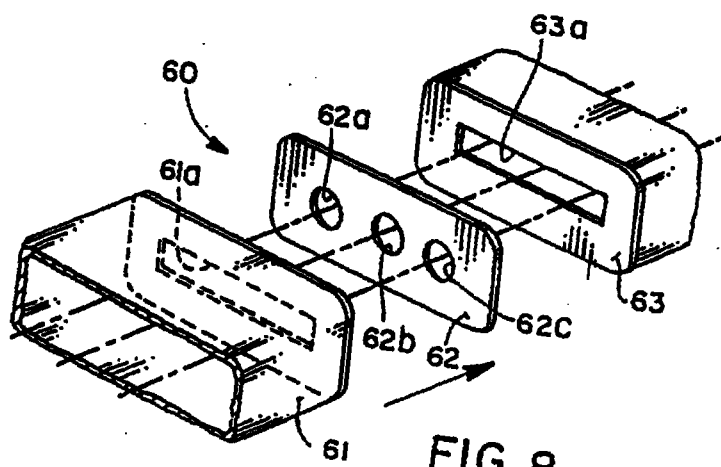


FIG. 8

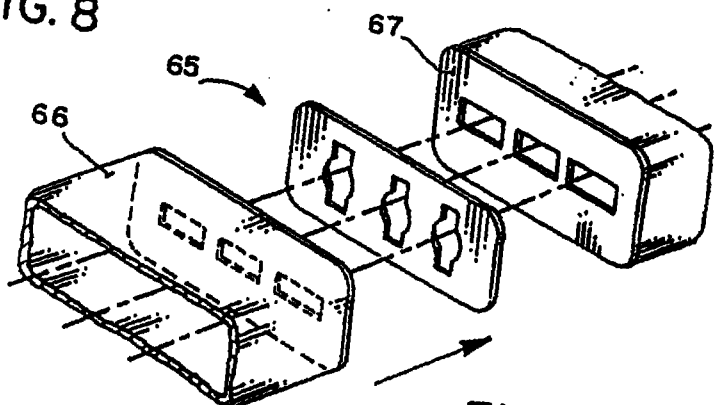


FIG. 9

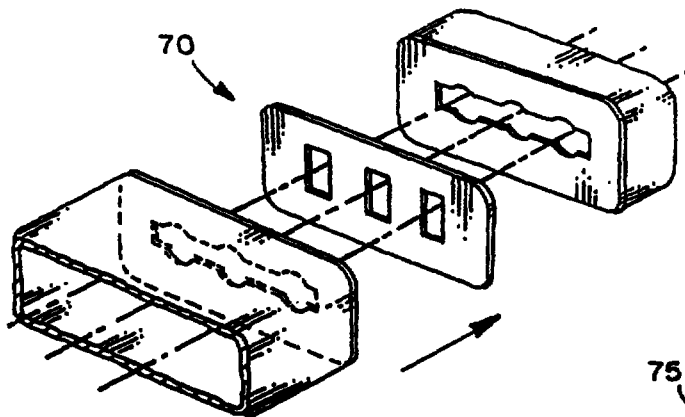


FIG. 10

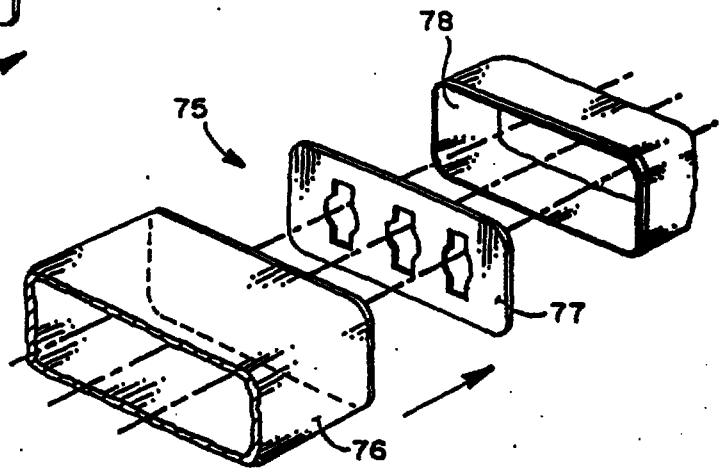


FIG. 11

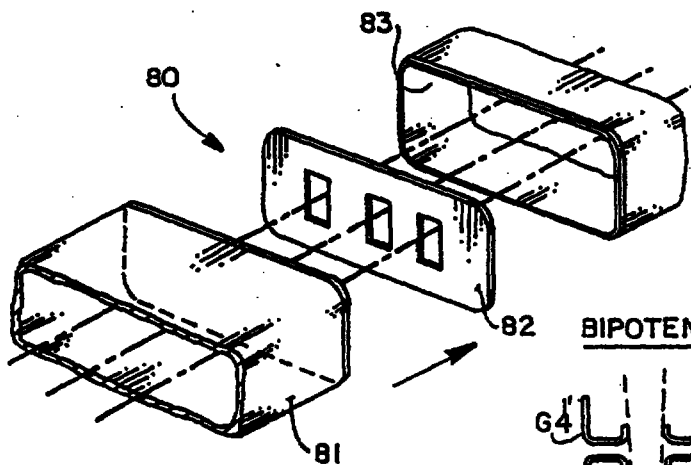


FIG. 12

BIPOTENTIAL TYPE ML DESIGN

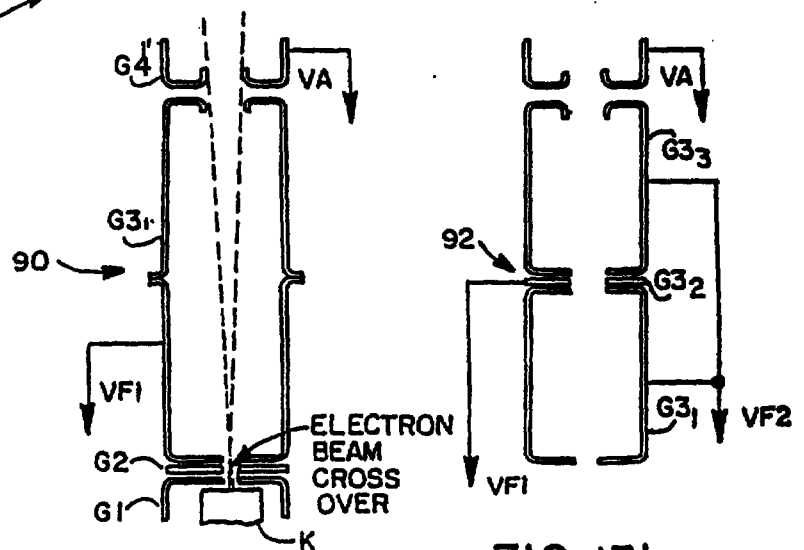


FIG. 13a

FIG. 13b

03 MAR 1997

EINZEL TYPE ML DESIGN

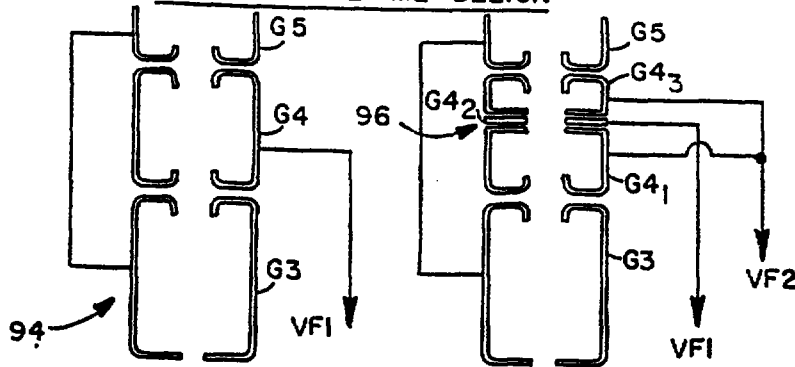


FIG. 14a

FIG. 14b

QPF TYPE ML DESIGN

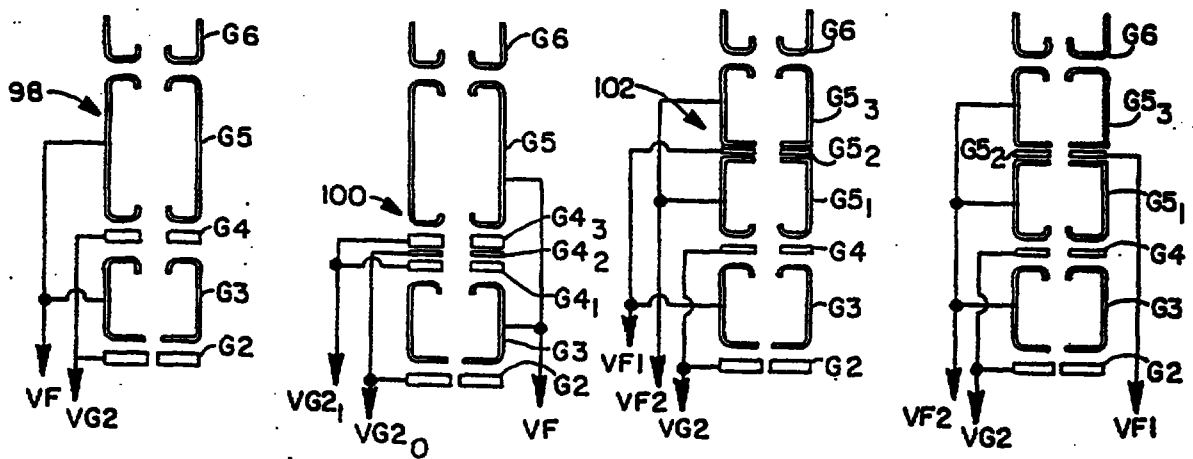


FIG. 15a

FIG. 15b

FIG. 15c

FIG. 15d

BU TYPE ML DESIGN

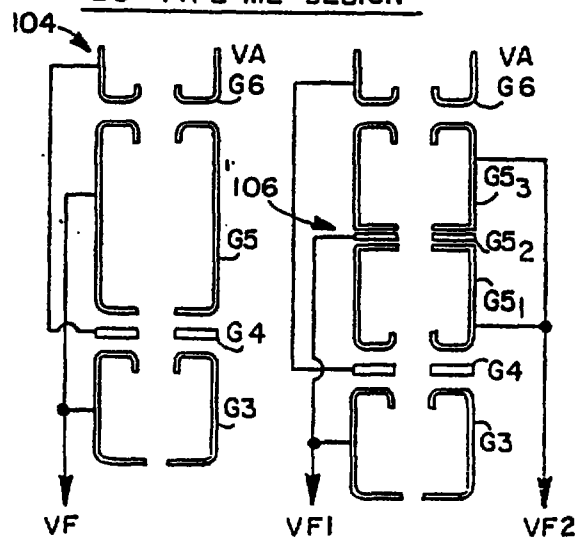


FIG. 16a

FIG. 16b

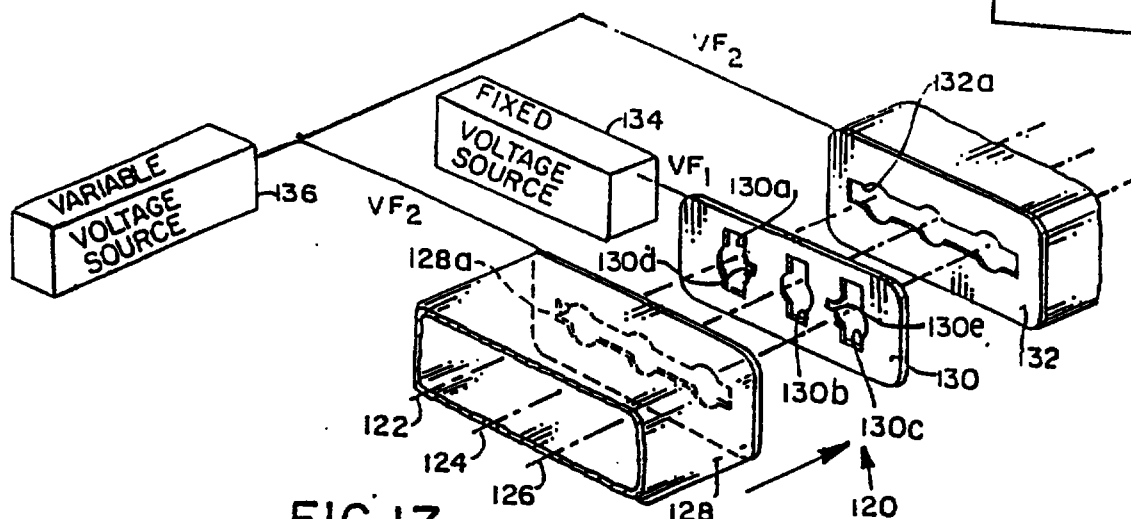


FIG. 17

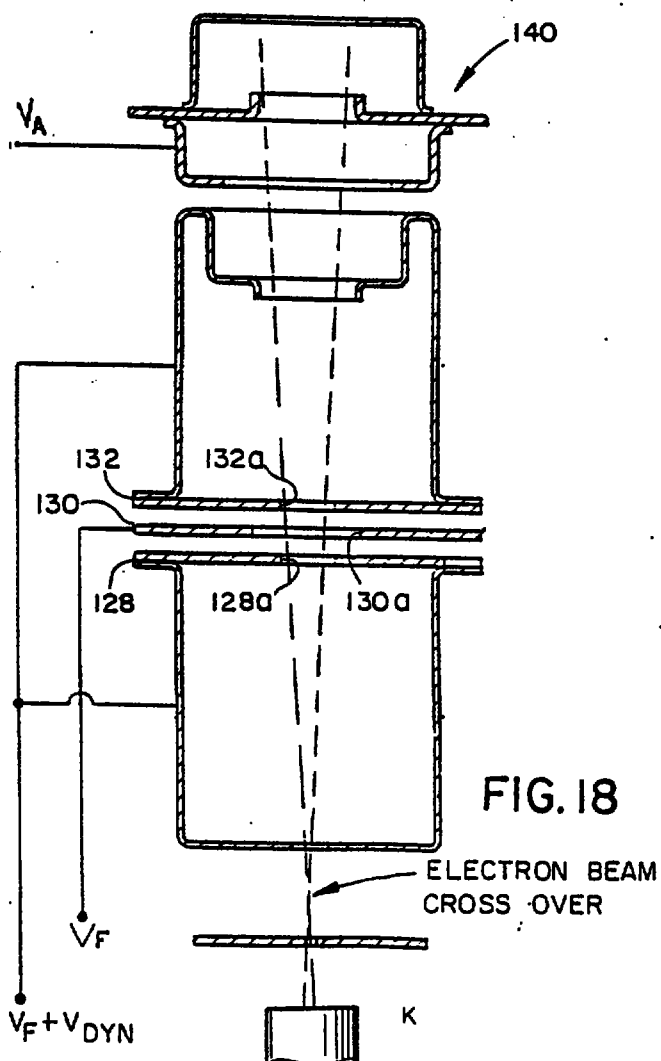


FIG. 18

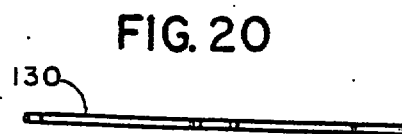


FIG. 20

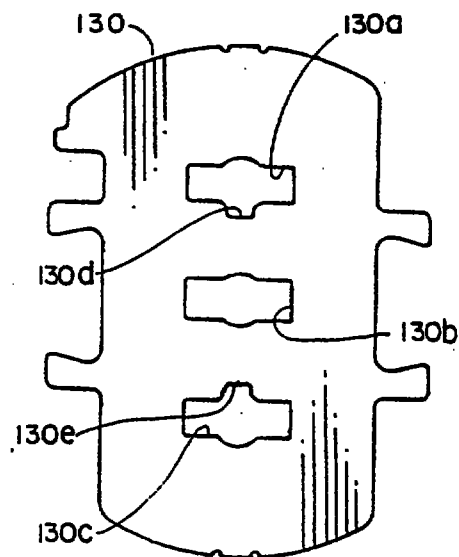


FIG. 19

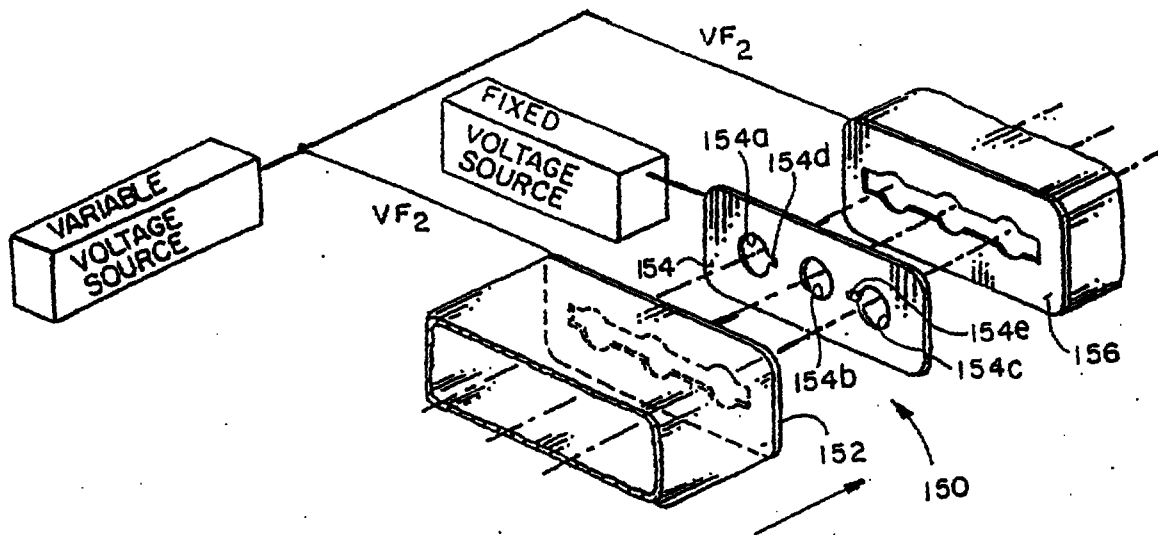


FIG. 21

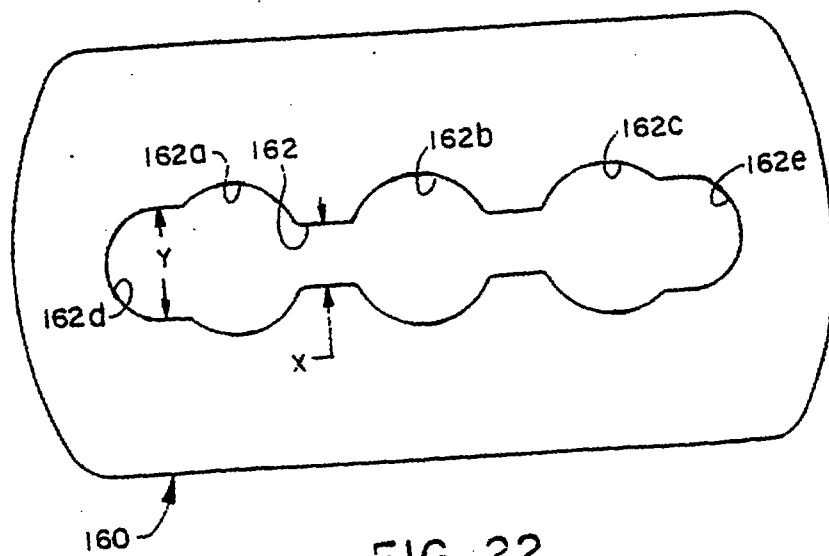


FIG. 22

FIG. 23

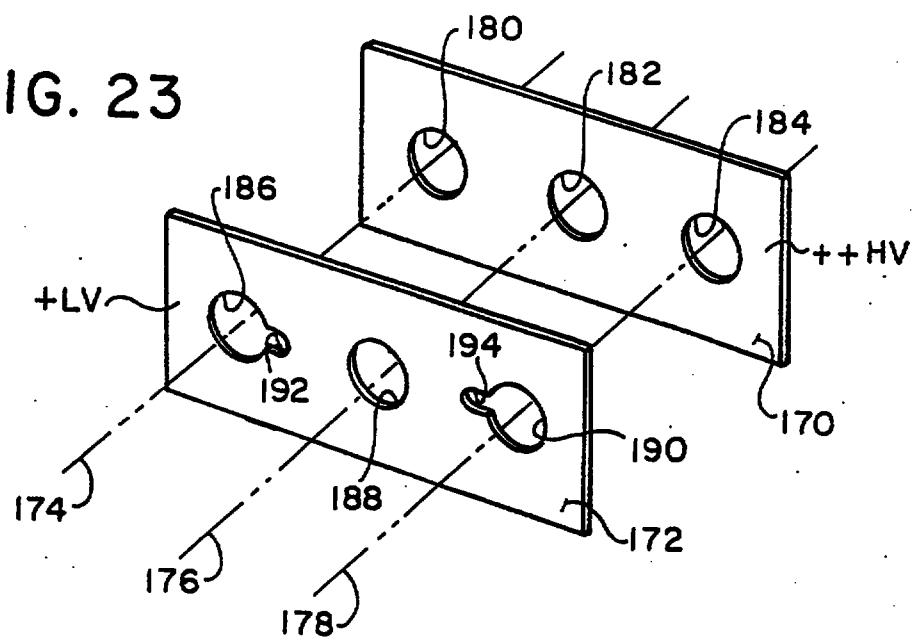


FIG. 24

