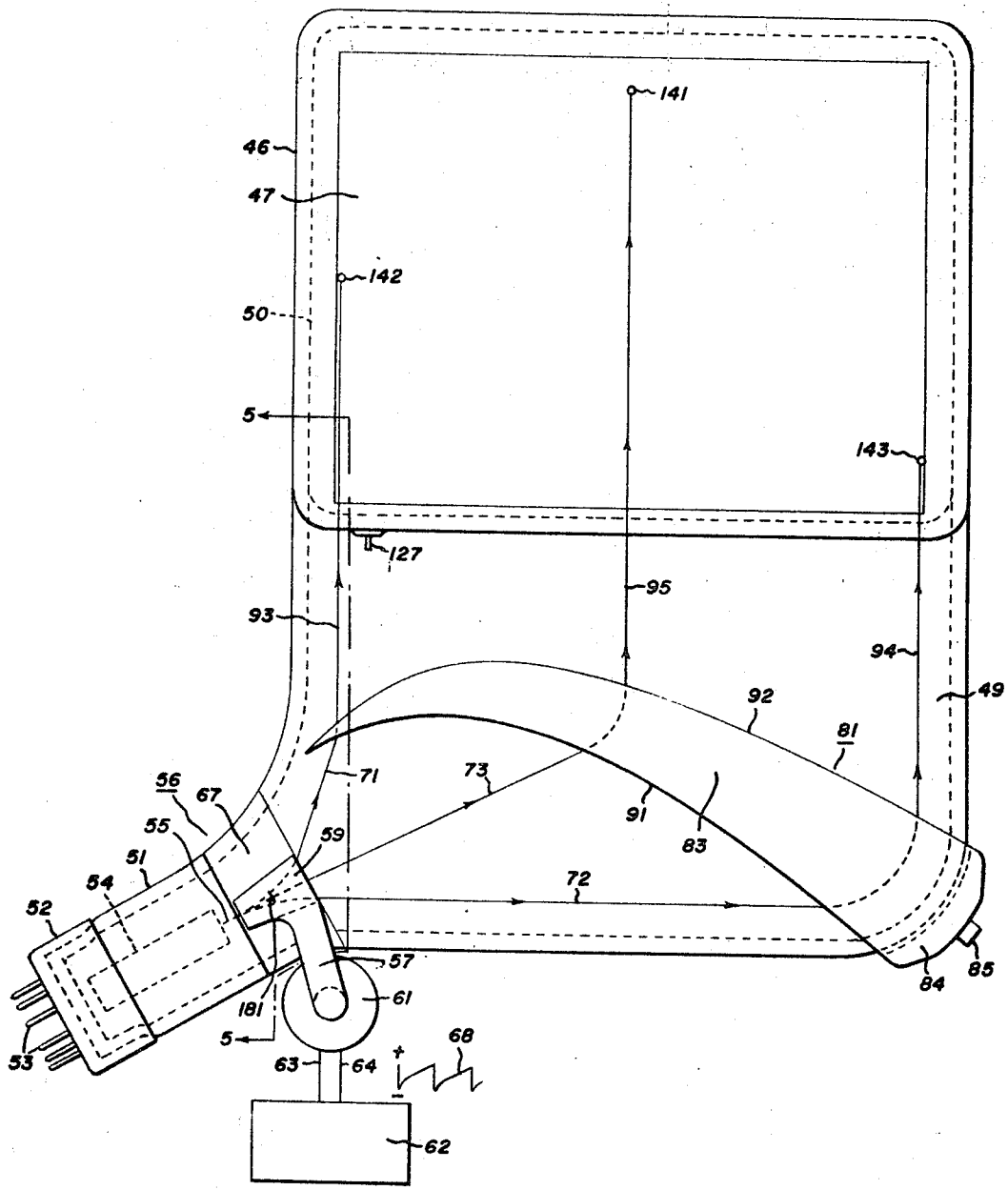
Aug. 12, 1969 S. E. HAVN 3,461,333

DEFLECTION SYSTEM FOR FLAT CATHODE RAY TUBE HAVING CANTED ELECTRON GUN IN PLANE PARALLEL TO DISPLAY SCREEN

Original Filed Sept. 29, 1961 5 Sheets-Sheet 1

FIG. 1.



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DEFLECTION SYSTEM FOR FLAT CATHODE RAY TUBE HAVING CANTED ELECTRON GUN IN PLANE PARALLEL TO DISPLAY SCREEN

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FIG.2.

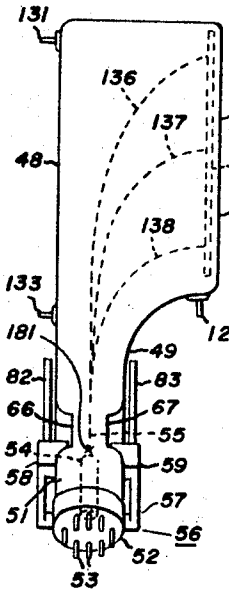


FIG.3.

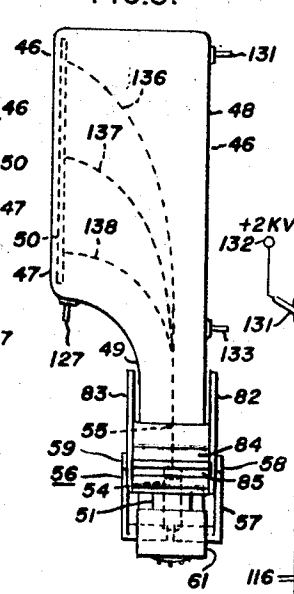


FIG.4.

FIG.5.

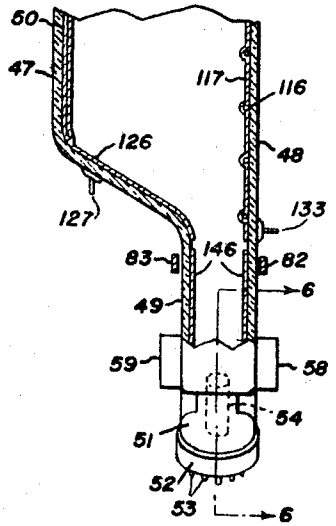
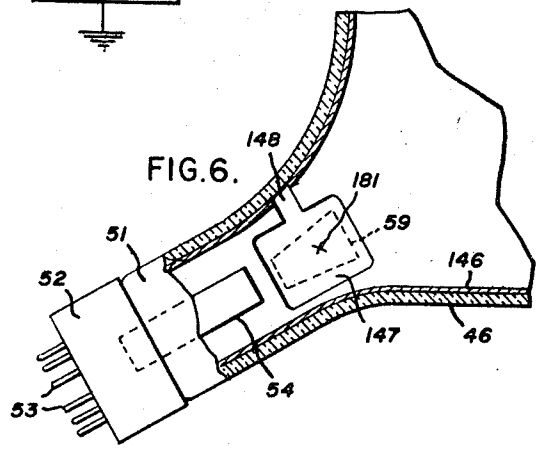


FIG.6.



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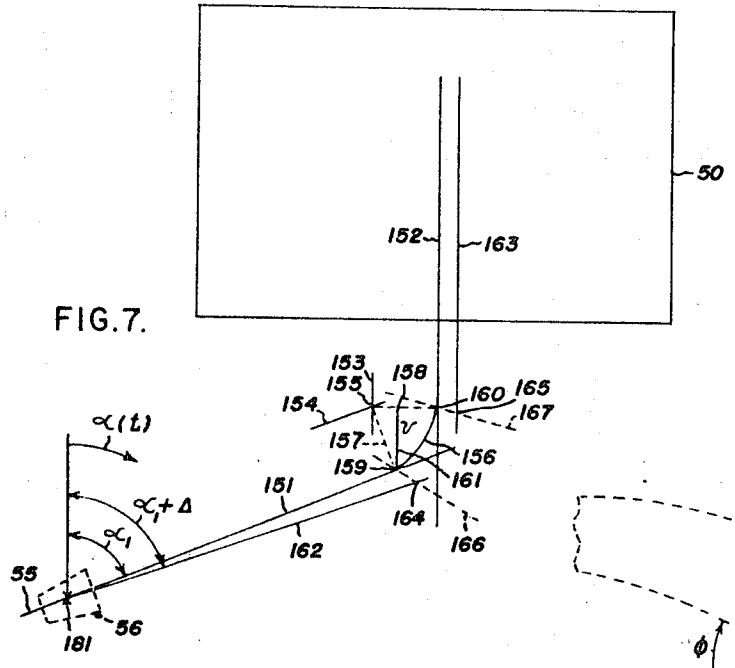


FIG.7.

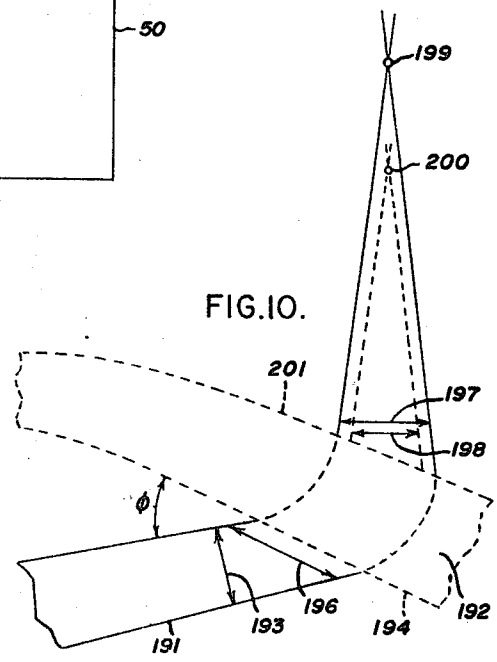


FIG.10.

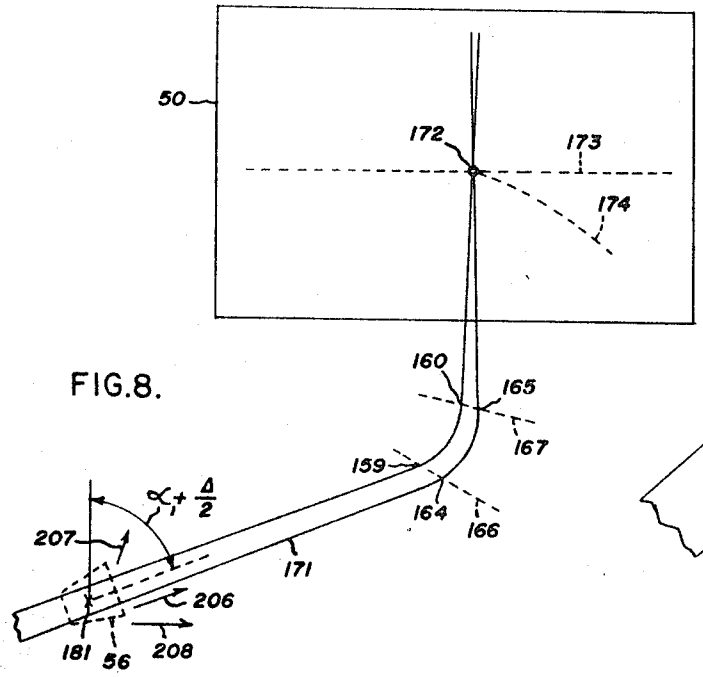


FIG.8.

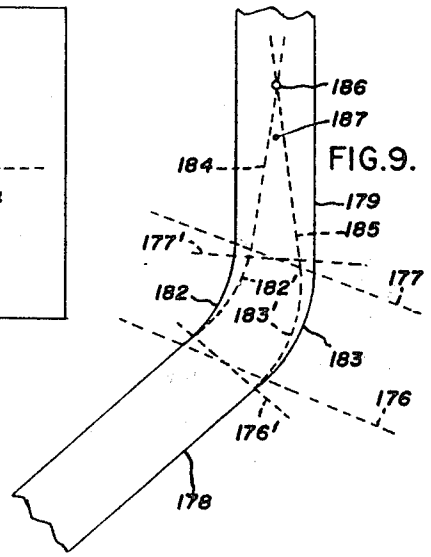
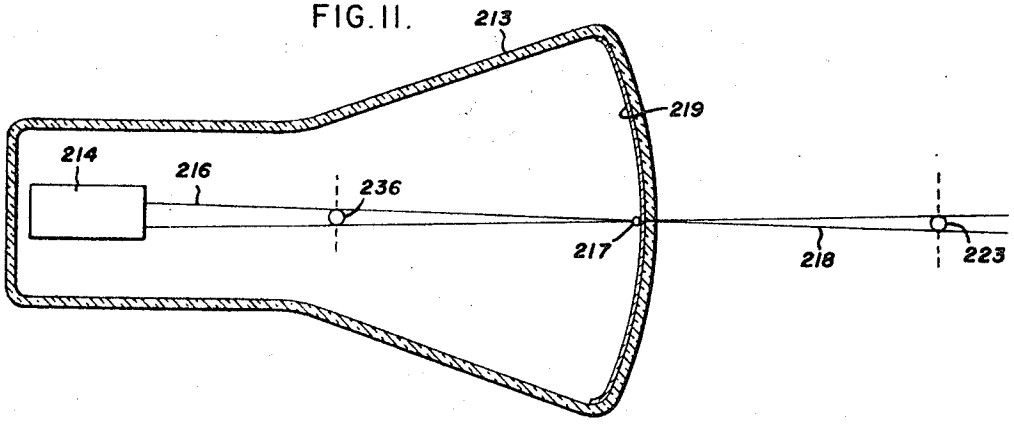


FIG.9.

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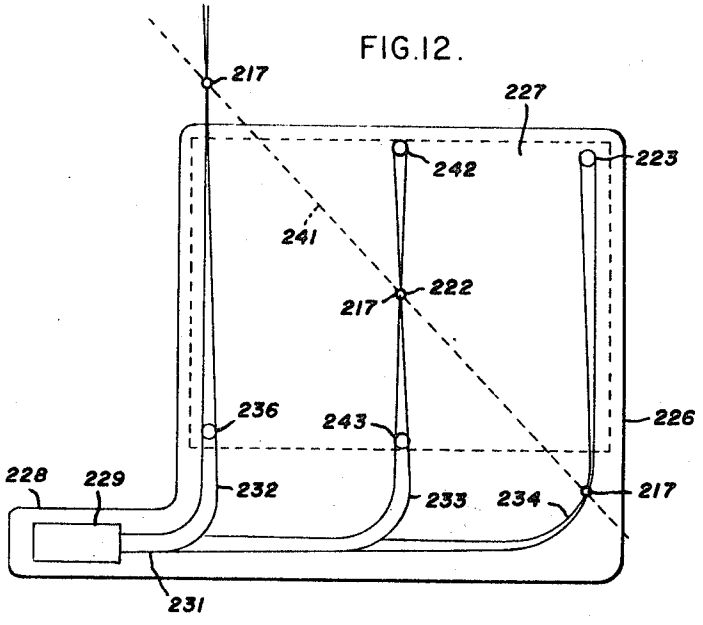
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FIG. 11.



PRIOR ART

FIG. 12.



PRIOR ART

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FIG.13.

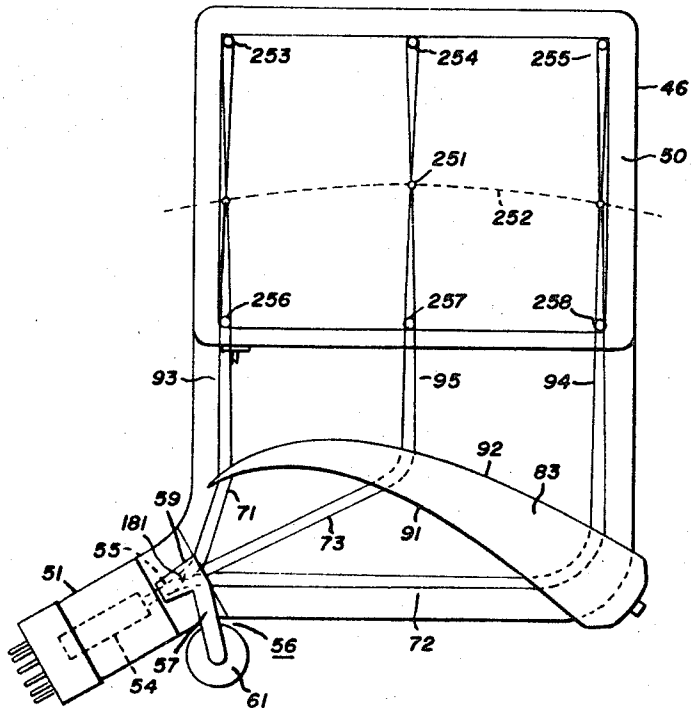
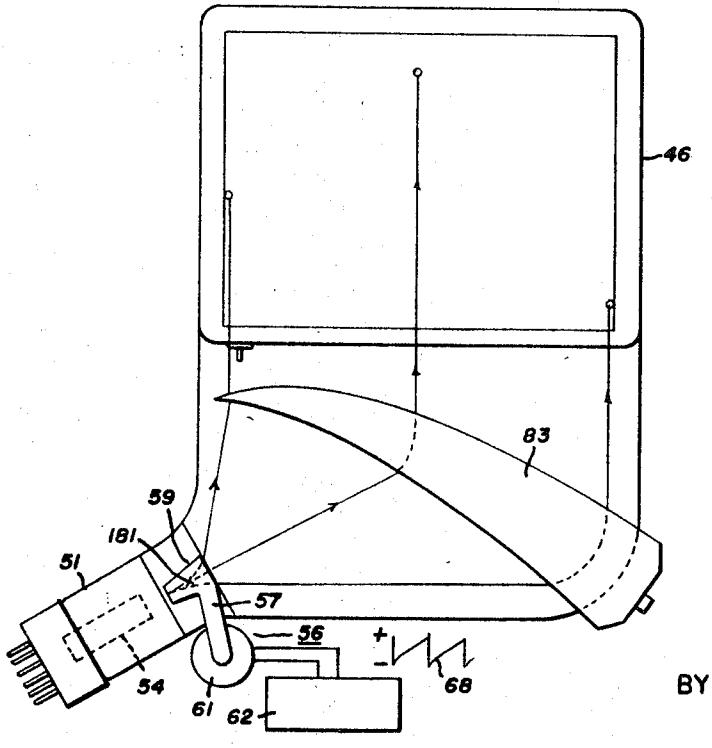


FIG.14.



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United States Patent Office 3,461,333
Patented Aug. 12, 1969

3,461,333

DEFLECTION SYSTEM FOR FLAT CATHODE RAY TUBE HAVING CANTED ELECTRON GUN IN PLANE PARALLEL TO DISPLAY SCREEN

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Continuation of application Ser. No. 141,863, Sept. 29, 1961. This application Apr. 10, 1967, Ser. No. 629,827
Int. Cl. H01j 29/70, 29/76
U.S. Cl. 313—77 6 Claims

ABSTRACT OF THE DISCLOSURE

A cathode ray tube having improved means for producing, deflecting and focusing an electron beam in a plane spaced from and generally parallel to the tube's image target plane. The image target has first and second orthogonal scan dimensions and the beam produced originates at a point that is displaced from and travels in an initial path that is canted relative to both of these dimensions. First and second scanning means are provided for respectively cyclically scanning the beam along the two scan dimensions. The first scanning means includes both dynamic and static deflection means. The dynamic deflection means is disposed across the initial path of the beam with its center of deflection displaced from both scan dimensions and dynamically deflects the beam along a plurality of angularly spaced diverging paths. The static deflection means comprises means for producing a substantially unidirectional magnetic field across the diverging paths and performs the dual function of statically deflecting the beam therefrom along a succession of collimated paths generally parallel to the second scan dimension and also varying the focal length of the beam as it travels along different ones of the collimated paths such that the focus of the beam focal points lies along a line generally parallel to the first scan dimension. The second scan means comprises dynamic deflection means disposed across the collimated paths for dynamically deflecting the beam therefrom toward the target area.

This is a continuation of application Ser. No. 141,863, filed Sept. 29, 1961.

This invention relates to cathode ray tubes, and more particularly to cathode ray tubes of the flat type having a relatively short distance between the front and back thereof. The invention primarily is concerned with an arrangement for producing and deflecting an electron beam in a plane behind and generally parallel to the viewing screen of a flat cathode ray tube, in such a manner as to achieve good focusing and other desirable characteristics of the electron beam at the viewing screen.

Various cathode ray tubes of the flat type which have been proposed in the prior art are constructed to provide a horizontal deflecting means for cyclically scanning an electron beam in a first or horizontal direction in a plane behind and parallel to a phosphor viewing screen, this electron beam extending in a generally vertical direction. Vertical deflecting means are also provided for variably directing the horizontally deflected electron beam frontwardly toward the screen in a cyclical scanning manner in a second or vertical scanning direction. Present television scanning standards require a horizontal scanning rate of 15,750 cycles per second and a vertical scanning rate of 60 cycles per second. These horizontal and vertical scansions of the electron beam define a raster on the viewing screen. The design and construction of a flat tube incur problems concerning electron beam focusing on the screen, linearity, and other problems, as will be explained hereinafter. It is to be understood that the terms

"horizontal" and "vertical" scanning are used in a relative sense, for convenience, to denote two mutually perpendicular directions of scanning at the viewing screen, and the "horizontal" scanning may in fact be vertical and the "vertical" scanning may in fact be horizontal, or the tube may be turned on its side, without departing from the scope and meaning of the language used herein.

An object of the present invention is to obviate the aforementioned problems of prior art flat cathode ray tubes.

Another object is to provide a flat cathode ray tube structure having improved performance and simplified construction.

An additional object is to provide improved arrangements for producing and deflecting an electron beam, and to provide such arrangements requiring only nominal amounts of electrical power.

A further object is to provide a flat cathode ray tube having improved focus of the electron beam at the viewing screen.

A still further object is to provide a flat cathode ray tube having a small size and utilizing readily obtainable deflection signals.

Still other objects will be apparent from the following description and claims, and from the drawing in which:

FIG. 1 is a front view of a cathode ray tube in accordance with the present invention;

FIG. 2 is a side view of the arrangement of FIG. 1, looking toward the left side thereof;

FIG. 3 is a side view of the arrangement of FIG. 1, looking toward the right side thereof;

FIG. 4 is a perspective view of a portion of the embodiment of FIGS. 1–3, shown partly broken away to reveal interior construction thereof;

FIG. 5 is a cross-sectional view of a portion of FIG. 1, taken on the line 5—5 thereof;

FIG. 6 is a cross-sectional view of a portion of FIG. 5, taken on the line 6—6 thereof, and showing details of an electron gun arrangement;

FIGS. 7–10 constitute a graphical explanation of the analytical procedure employed in the design of a cathode ray tube in accordance with the invention;

FIGS. 11 and 12 illustrate focusing of the electron beam at the viewing screen in some prior art types of cathode ray tubes;

FIG. 13 illustrates focusing of the electron beam at the viewing screen in a cathode ray tube in accordance with the present invention; and

FIG. 14 is a front view of a cathode ray tube in accordance with the invention, illustrating a modified construction.

The invention comprises, in its basic preferred embodiment, a source of a converging electron beam, and a lens arrangement for scanning the beam in a plane behind (or in front of) a viewing screen, the lens arrangement comprising a first deflection lens element in the path of the beam for variably deflecting the beam over an angle, and a second deflection lens element in the path of the beam as deflected by the first lens element, the second lens element comprising means for producing a unidirectional field for deflecting the beam in a direction behind (or in front of) the viewing screen, the lens arrangement having relatively different strengths of focus action on the converging electron beam at different regions of the deflected beam in order to control the location of the cross-over point of the electron beam so as to provide focus of the beam at the screen. In accordance with a preferred embodiment of the invention, the center of deflection of the electron beam as deflected by the first lens element is located below and sideways from the viewing screen, and the aforesaid second lens element is a unidirectional magnetic field having a tapered shape.

The invention further comprises specially shaped magnetic pole pieces for producing the aforesaid magnetic field, whereby improved focus is achieved. The invention also comprises a specially shaped tube envelope, and other features that will become apparent, for achieving an improved flat cathode ray tube.

The preferred embodiment of the invention, shown in FIGS. 1–3 of the drawing, comprises an evacuated envelope 46, preferably of glass, having a front wall 47 and a back wall 48. These front and back walls may be substantially mutually parallel, and the distance between them constitutes the relatively shallow overall depth of the flat tube. The front wall 47 of the envelope 46 is recessed at the lower portion 49 thereof, so that this portion of the tube has considerably less distance, preferably less than half the distance, between the front and back thereof than does the upper portion of the tube. A phosphor viewing screen 50, or other suitable target for an electron beam, is positioned within the envelope 46 adjacent to or on the front wall 47. The envelope 46 is provided with an inclined neck 51 extending from a corner of the lower portion 49 and generally in the plane thereof, as shown. A base 52, attached to the neck 51, is provided with electrical connector prongs 53. An electron gun 54 is provided within the neck 51 for projecting an electron beam 55 generally parallel to and in the general direction of the phosphor screen 50.

A two-stage horizontal deflection arrangement, which constitutes a lens arrangement for the electron beam 55, comprises a first stage 56, which constitutes a lens element for the electron beam, having a yoke 57 of magnetic material, this yoke being generally U-shaped and provided with a pair of pole pieces 58, 59 at the ends thereof. The yoke 57 and pole pieces 58, 59 may be constructed as an integral unit, or may be formed from separate pieces. A winding 61 is positioned around the yoke 57, and a source 62 of suitable horizontal deflection signals is connected to ends of the winding 61 by means of connection wires 63, 64. The first stage of the horizontal deflection assembly is positioned with respect to the envelope 46, so that the pole pieces 58, 59 thereof are on opposite sides of the envelope 46 in the general vicinity of the junction of the neck 51 and the remainder of the tube envelope, the pole piece 58 being in back of the envelope and the pole piece 59 being in front of the envelope, the entire first stage of the horizontal magnetic deflection system thus being located externally of the envelope 46. Preferably the envelope 46 is narrowed down at both the front and back thereof, as indicated at 66 and 67, so that the pole pieces 58, 59 will be positioned as closely as is feasible to the electron beam 55.

A representative signal supplied by the deflection circuit 62 is indicated at 68 in the drawing. This deflection signal, when applied to the winding 61, produces a cyclically changing magnetic field between the pole pieces 58 and 59, which causes the electron beam 55 to scan sequentially from a leftmost nearly vertical position 71 to a rightmost nearly horizontal position 72, the undeflected position of the electron beam being approximately centrally located as indicated at 73. The pole pieces 58, 59 may be suitably shaped to provide a desired degree of linearity of the electron beam scansion with respect to time, in conjunction with the wave form of the horizontal deflection signal 68.

The second stage or lens element 81 of the two-stage horizontal deflection arrangement comprises a pair of elongated suitably shaped pole pieces 82, 83 of magnetic material such as iron positioned generally mutually parallel to each other and extending generally across the lower portion of the envelope 46 at the back 48 and front 49 thereof, respectively, and tilted generally from upper left to lower right, as shown. The pole pieces 82, 83 are tapered and the wide ends thereof extend beyond the right edge of the envelope 46, as shown, so that a permanent magnet 84 may be positioned therebetween to provide a magnetic field in the space between the pole pieces 82 and 83. A magnetic shunt member 85, made of magnetic material such as iron, is provided across or between the pole pieces 82 and 83, and is rotatable, slideable, or otherwise positionable, to permit adjustment of the strength of the magnetic field between the pole pieces 82 and 83. Alternatively, if desired, a winding may be placed around the magnet 84, or otherwise positioned with respect to the pole pieces 82, 83, and may be connected to a source of adjustable current for adjusting the magnetic field strength. The entire second-stage assembly 81 is located externally of the envelope 46, as shown, and the magnetic field extends between the pole pieces 82 and 83 transversely to the plane in which the beam 55 is deflected by the first stage 56, whereby the electron beam 55 passes through this field after being deflected by the first stage 56 and before reaching the space behind the screen 50. The magnetic field between the pole pieces 82, 83 is unidirectional in magnetic polarity along the entire length thereof. The pole pieces 82, 83 are long enough so that the length of the magnetic field produced therebetween extends across the width of the screen 50 and across the entire space in which the electron beam 55 is usefully deflected by the horizontal deflection pole pieces 58, 59 of the first stage 56, i.e. from the leftmost beam position 71 to the rightmost beam position 72.

The second stage pole pieces 82 and 83 preferably are shaped as shown so that the leading and trailing edges 91, 92 thereof are both concave toward the approaching electron beam 55. However, other specific shapes of the pole pieces may be designed in accordance with the principles of the invention. These pole pieces 82, 83 are generally inclined from upper left to lower right, as shown in the drawing, and are wider at the righthand end which is relatively farther from the electron gun 54 than at the left-hand end thereof which is relatively nearer the electron gun 54.

The leading and trailing edges 91, 92 are tapered with respect to each other and this taper varies in a manner to achieve optimum focus as will be described.

FIG. 1 shows a tube in accordance with the invention drawn to exact size on the patent drawing (reduced to about ⅔ actual size on patent copies), with the second stage pole pieces 82, 83 shaped and oriented exactly in a manner found to produce satisfactory results. A way of designing these pole pieces will be described subsequently.

The magnetic field produced between the pole pieces 82, 83 deflects the electron beam 55 upwardly by varying predetermined amounts as a function of horizontal position of the deflected electron beam, so that the electron beam will always be vertically oriented when it leaves this magnetic field. That is, the principal or central rays of the electron beam will be vertical upon the beam leaving the magnetic field. For example, the vertical beam paths 93, 94, 95 are obtained, respectively, from the differently angled beam paths 71, 72, 73, because the beam when in the nearly vertical path 71 passes through a narrower magnetic field and hence is deflected less than when passing through a greater width of magnetic field as in the nearly horizontal path 72. The amount of deflection of the electron beam by the magnetic field between the pole pieces 82 and 83, may be affected by varying the magnetic field intensity along the length of the pole piece arrangement, as by varying the spacing between the pole pieces 82, 83 along their lengths. Toward the right-hand end of the horizontal beam deflection, as in the beam path 72, there is a substantial horizontal component, as well as a vertical component, of distance of beam travel in the magnetic field and hence the pole pieces need not be as wide at this region thereof as would otherwise appear necessary for deflecting the beam to a vertical direction. The beam, when in inter-

mediate paths, is deflected corresponding intermediate amounts. There are numerous combinations of shapes and positions of the magnetic field that will achieve the aforesaid vertical orientation of the electron beam.

After the horizontally scanned electron beam enters the region of the tube behind the viewing screen **50**, vertically oriented as described above, it is controlled by a vertical deflection system which causes the beam to be deflected toward the viewing screen **50** in a repetitive sequence whereupon the point of impingement of the beam on the screen moves from top to bottom thereof in a cyclical manner. Various arrangements are known for accomplishing the vertical deflection. A preferred vertical deflection system is shown in FIGS. 4 and 5 of the drawing, and is the subject matter of patent application Ser. No. 141,862 filed Sept. 29, 1961 and now U.S. Patent No. 3,155,872 issued Nov. 3, 1964 to the present inventor and Harry T. Freestone and assigned to the same assignee as the present invention.

Now referring briefly to the vertical deflection arrangement shown in FIGS. 4 and 5, a plurality of electrical conductors **116** extend horizontally in mutually parallel relationship and are positioned within the envelope **46** in a plane near or against the back **48** thereof. The conductors **116** are electrically interconnected by a series arrangement of resistors **117** which may be in the form of a strip of resistive material painted or otherwise deposited along the inside of the envelope **46** and against the conductors **116** a shown.

One or more elongated electrical conductors **118** are positioned horizontally and mutually parallel within the envelope **46** against or adjacent to the top side **119** thereof. These conductors **118** are interconnected by a series arrangement of resistors **121** which also connect the array of conductors **118** serially to the array of conductors **116**. The resistors **121** may comprise a continuation of the strip of resistive material which forms the resistors **117**.

A layer **126** of electrically conductive material, such as aluminum, is deposited or otherwise positioned against the back surface of the phosphor screen **50**. The conductive layer **126** is electrically attached to a terminal pin **127** extending through the envelope **46**, to which a source of positive direct potential, for example 10 kilovolts, may be connected as indicated at **128**. The front-most of the conductors **118** at the top of the tube is electrically connected to the conductive layer **126**, either directly or via a resistance **121**. The upper one of the conductors **116** is electrically connected to a terminal pin **131** which extends through the envelope **46** and to which may be connected a source of positive direct potential, for example 2 kilovolts, as indicated at **132**. The lower one of the conductors **116** is electrically connected to a terminal pin **133** which extends through the envelope **46** and may be connected to a source **134** of vertical deflection signals. A suitable vertical deflection signal, as produced by the source **134**, and indicated at **135**, may have, for example, a minimum value of about zero volts and a maximum value of about plus 8 kilovolts.

The values of the resistances **117** and **121** may be one megohm or greater. For example, these resistances may have equal values, or the values thereof may be graduated along the array of conductors, depending upon linearity considerations of the vertical deflection system.

At the commencement of a vertical scansion, the vertical deflection signal **135** has a plus 8 kilovolts, whereupon the electron beam **55** will be caused, by the electrostatic field produced by the vertical deflection array of conductors **116**, **118** and **126**, to assume a path as indicated by the numeral **136** in FIGS. 2 and 3 such that the electron beam is deflected toward the viewing screen **50** and impinges thereon at the upper part thereof. As the vertical deflection voltage **135** decreases in value, the electrostatic field produced by the vertical scanning array of conductors causes the electron beam **55** to deflect more sharply toward the phosphor screen **50**, as indicated by the path **137** in FIGS. 2 and 3. When the vertical deflection voltage **135** has a value of zero at the end of a vertical scanning cycle, the electric field pattern produced by the array of conductors causes the electron beam **55** to deflect relatively sharply so as to impinge upon the phosphor screen **50** at the lower part thereof, as indicated by the path **138** in FIGS. 2 and 3.

When the electron beam **55** follows the path **136** under the influence of the vertical deflection arrangement and the path **95** under the influence of the horizontal deflection arrangement, it will impinge against the phosphor screen **50** at the point **141**, as shown in FIG. 1. When the electron beam **55** follows the path **137** under the influence of the vertical deflection arrangement and the path **93** under the influence of the horizontal deflection arrangement, it will impinge upon the screen **50** at the point **142**. Similarly, when the electron beam follows the path **138** under the influence of the vertical deflection arrangement and the path **94** as determined by the horizontal deflection arrangement, it will impinge upon the screen **50** at a point **143**. With a horizontal scanning rate at a higher repetitive frequency than the vertical scanning rate, as is conventional in television practice, the point of impingement of the electron beam **55** on the phosphor screen **50** will describe a successive series of horizontal lines in descending order, thus forming a raster on the area of the screen **50**.

If desired, arrangements for vertical scanning of the electron beam, other than the preferred arrangement described herein, may be employed in conjunction with the horizontal scanning arrangement of the present invention.

Preferably, as shown in FIGS. 4–6, an electrically conductive coating **146** of aluminum, aguadag, or other suitable material, is deposited or otherwise applied to the inside surface of the tube envelope **46** in the lower region **49** thereof and in the neck **51**, in order to shield these regions from undesired fields and deflection influences on the electron beam **55** by external sources. This coating **146** also functions to maintain an equipotential region in the tube where the magnetic deflection occurs, so that more accurate magnetic control of the beam is achieved. Window openings **147** are provided in the coating **146** adjacent each of the horizontal deflection pole pieces **58** and **59** to prevent induced current losses in the coating **146** that would be caused by the varying magnetic field produced by these pole pieces. A slit **148** is provided in the coating **146** between and interconnecting the windows **147** to prevent there being closed electrically conductive loops around the peripheries of the windows **147** which, if present, would permit circulating currents to be set up by the varying horizontal deflection magnetic field, which currents would consume energy. No windows need be provided in the coating **146** in the vicinity of the magnetic pole pieces **82** and **83** because the magnetic field produced by these pole pieces is fixed rather than variable, and this fixed magnetic field does not produce currents in the conductive coating **146**.

The electron gun **54** and first-stage horizontal deflection pole pieces **58**, **59** are located so that the center of deflection of the horizontally deflected electron beam is below and sideways from the target area **50**, as shown at **181** in the figures of the drawing. That is, if the useful target area were projected downward or sideways, no part of it would pass over the deflection center **181** of the first magnetic field. Thus, the electron beam **55** always has a horizontal component of direction when it enters the second stage magnetic field of uniform magnetic polarity produced by the pole pieces **82** and **83**, whereby the electron beam will always be curved and rendered vertical by this magnetic field. This arrangement avoids picture distortion effects that would occur if the second stage magnetic field had a point of zero or reversing polarity through which the scanning electron beam must pass. Such a transition point in the second stage magnetic field would cause distortions in the deflection of the beam.

In describing and claiming the electron beam source and other components as being below the viewing screen or target area, it is to be understood that the term "below" is used for convenience as a reference direction and is meant to include equivalent positions or directions above or to a side of the viewing screen or target area.

After learning of the present invention, as described herein, one skilled in the art may design various sizes and embodiments of cathode ray tubes in accordance with the principles of the invention, by various means such as analytical or graphical design. For purposes of illustration, a graphical design technique will now be described.

In FIG. 7, the numeral **181** indicates the compromise center of deflection of the electron beam **55** as deflected by a magnetic field produced by the first deflection stage **56** of the horizontal deflection arrangement. Now assume the electron beam to be directed from the center of deflection **181**, by the first deflection stage **56**, at an angle α_1 with respect to the vertical, α being variable as a function of time, so that at a particular instant of time the central axis of the elecron beam follows along a path **151**. Now draw a vertical line **152** to indicate the path the central axis of the beam will follow after exiting from the second deflection stage. The position of this line is dictated by the selection of time t_1 within the horizontal interval. For example, if a linear relation is desired between the angle of beam deflection caused by the first deflection stage and the horizontal scanning of the electron beam behind the screen **50**, then α_1 may be the mid-angle of the horizontal deflection range caused by the first deflection stage, and the vertical line **152** will be midway between the left and right sides of the screen **50**. As a practical matter, this relationship preferably is chosen to be non-linear in a manner such that a readily obtainable wave shape of horizontal deflection signal will produce the required linear horizontal scanning of the beam behind the screen.

Assume a value of magnetic field strength or flux density for the second deflection stage which will cause the electron beam to curve on a radius r of reasonable dimension for the size of the tube being designed. For example, a radius r of 1.5 cm. has been found suitable for the cathode ray tube shown in the drawing. The value r is related to the magnetic flux density by the formula

$$r=\frac{\sqrt{\frac{2m}{e}V}}{B}$$

where

r=radius of curvature of the electron beam, in meters;
m=mass of an electron (9.11×10^{-31} kilograms);
e=electrical charge of an electron (1.602×10^{-19} coulombs);
V=potential of the electron beam, in volts, as determined by the last element of the electron gun (2,000 volts in a preferred embodiment); and
B=magnetic flux density, in Webers per square meter, as produced between the second deflection lens pole pieces by the magnet (0.01 Webers per square meter in the embodiment shown in the drawing).

Then, draw a vertical line **153** to the left of, parallel to, and at a distance r from, the vertical electron beam path line **152**. Draw a line **154** above, parallel to, and at a distance r from, the electron beam path line **151**. About the intersection **155** of the lines **153** and **154**, which is a center of deflection curvature, draw a circular arc **156** connecting the electron beam path lines **151** and **152**. The arc **156** shows the deflection path of the electron beam caused by the magnetic field of the second deflection stage. To determine precisely where the electron beam must enter and leave this magnetic field, draw a line **157** from the intersection **155** normal to the line **151**, and draw a line **158** from the intersection **155** normal to the line **152**. The point **159** of intersection of lines **157** and **151** is the point where the leading edge of the deflecting magnetic field must be, and the point **160** of intersection of lines **158** and **152** is the point where the trailing edge of the deflecting magnetic field must be, for the electron beam, when approaching this magnetic field at an angle α_1 to the vertical, as shown, to exit from this magnetic field in the vertical path **152**. The vertical distance v, shown by the line **161**, is the vertical dimension of the deflecting magnetic field between the beam entering and exiting points **159** and **160**, and is defined by the formula $v=r\sin\alpha$ where r is the radius of beam deflection caused by the magnetic field and α is the angle of the beam, with respect to the vertical, as the beam leaves the first deflection stage.

Now assume a slightly different angle of horizontal deflection of the electron beam as caused by the first deflection stage **56**, for example $\alpha_1+\Delta$, the increment Δ being such that the central axis **162** of this electron beam will approach the second deflection stage at a distance from the first beam axis **151** approximately equal to the width of an actual electron beam. Draw a vertical line **163** to indicate the path it is desired that the central axis of the beam will follow after exiting from the second deflection stage, as determined by $t_1+\Delta t$. Proceed, in the manner described above, to draw lines parallel to the lines **162** and **163**, and at a distance r therefrom, to obtain a second center of deflection curvature which will be spaced from the previoisly found center of curvature **155**. Draw lines from this second center of curvature normal to the lines **162** and **163**, respectively, to determine the points **164** and **165** where the leading and trailing edges of the second stage magnetic field must be to produce the desired beam deflection. The latter steps are not shown, to avoid congestion in FIG. 7.

Next, draw a line **166** through points **159** and **164**; this line **166** is tangent to the leading edge of the deflection stage magnetic field at the region where an electron beam at a deflection angle of

$$\alpha_1+\frac{\Delta}{2}$$

will enter this second stage magnetic field. Draw a line **167** through the points **160** and **165**; this line **167** is tangent to the trailing edge of the second deflection stage magnetic field at the region where the aforesaid electron beam at the deflection angle of

$$\alpha_1+\frac{\Delta}{2}$$

will leave this second stage magnetic field. The lines **166** and **167** represent the practical edges of the magnetic field, neglecting the fringe field effects.

The next step is to compute, analytically, the exact shape of an actual electron beam **171** as deflected at an angle

$$\alpha_1+\frac{\Delta}{2}$$

by the first deflection stage. FIG. 8 shows such a plot. Analytical methods of computing electron beam shapes and trajectories are well known. In making these computations, it should be observed that the actual center of deflection of the electron beam at the first deflection stage **56** will not necessarily be the same as the compromise center of deflection **181**. The electron beam **171** is a converging electron beam, and has a cross-over point at **172** which is the point of minimum diameter of the beam along its length. The best focus, i.e. the smallest spot size produced on the screen **50** by the electron beam striking the screen **50**, occurs when the beam is at the cross-over point when it strikes the screen. For best overall focus of the electron beam on the screen, the locus of the cross-over point of the horizontally deflected electron beam should lie on a line **173** extending approximately horizontally mid-way between the top and bottom of the screen **16**. As shown in FIG. 8, the point **172** of electron

beam focus is properly on the line 173. If, the first time the electron beam focus is thus computed, the focus is not on line 173, it should be made to fall on line 173 by varying one or more pertinent parameters, such as the original rate of convergence of the electron beam, the location of the beam source, the location and shape of the first deflection stage 56, and the angle $\alpha(t)$, of the beam produced by the electron gun.

Similar computations are then made of points on the leading and trailing edges of the second deflection stage magnetic field, and the locus of the electron beam cross-over points, for other values of deflection angle such as α_2 and $\alpha_2+\Delta$ etc., for the entire horizontal scanning range. The exact order in which these computations are made is not critical. If it is found that the locus of best focus deviates unduly from the line 173, for example along a line 174, it will be apparent that the chosen combination of parameters will not produce acceptable focus of the electron beam of the screen 50, and then one or more of the parameters must be changed and the computations of the leading and trailing edges of the second deflection stage magnetic field must be repeated. This procedure is repeated until a suitable set of parameters is obtained which will provide suitable overall size and shape; practical size, shape, orientation and magnetic strength of magnetic pole pieces for producing the second deflection stage magnetic field (these pole pieces will be slightly narrower than the magnetic field produced therebetween, due to well-known fringe effects which cause the magnetic field to bulge a bit beyond the edges of the pole pieces), a suitable linearly relationship of the deflected beam angle $\alpha(t)$ with respect to horizontal beam scansion behind the screen commensurate with a readily obtainable wave shape of horizontal deflection signal, and suitable focus of the electron beam at the screen.

Some electron beam deflection principles will now be described which will aid in choosing the parameters when making the aforesaid computations and graphic plots. First, referring to FIG. 9, it should be realized that, with the magnetic field tapered as produced by the tapered second deflection stage pole pieces in the preferred embodiment of the invention, i.e., tapered so as to become increasingly wider from left to right, so that the beam curves in a direction toward the more narrow end of the magnetic field, this tapered magnetic field acts as a convergent lens on the electron beam; i.e., it increases the beam convergence and hence shortens the distance along the length of the beam at which the cross-over point occurs. This is readily seen from FIG. 9, in which 176 and 177 are mutually parallel leading and trailing edges of a hypothetical second deflection stage magnetic field. Assume a hypothetical electron beam 178 having mutually parallel sides, i.e., a beam that is neither convergent nor divergent. The beam will be curved by the magnetic field and exit therefrom at 179 with mutually parallel sides. Thus the magnetic field has not provided any lens action on the electron beam. The reason for this is that the two curved paths 182, 183 of the sides of the beam in the magnetic field, have equal lengths.

Now assume the second deflection stage magnetic field to have mutually tapered leading and trailing edges 176' and 177', respectively. The inner and outer sides of the electron beam are now curved different amounts by the magnetic field, as shown at 182' and 183', the inner side 182' being curved relatively less to exit on a path 184 and the outer side 183' being curved relatively more to exit on a path 185. As is readily apparent, the tapered magnetic field has a convergent lens action on the electron beam, so that the deflected beam converges to a cross-over point at 186. Similarly, if the electron beam 178 is a converging electron beam as in actuality, the convergent lens action of the magnetic field having mutually tapered leading and trailing edges 176' and 177' will increase the beam convergence to give the beam a shorter focal length having a cross-over point at 187, for example.

From the foregoing, it is seen that the amount of convergence, and hence the focal length of the electron beam to the cross-over point, can be controlled or varied by choosing a proper taper, or rate of change of taper, of the second deflection stage magnetic field. In the preferred embodiment of the invention shown in the drawing, the sides of the second deflection stage pole pieces, and hence the magnetic field produced thereby, are so designed to shorten the focal length of the electron beam more at the left than at the right, so as to move the cross-over point of best focus relatively down at the left and up at the right, this being in the proper direction to correct the undesired slanted locus of best focus shown in FIG. 12. In the preferred embodiment, the taper of the second stage pole pieces has a point of maximum taper to the left of which the taper becomes relatively less. The reason for this is that the focal length of the system is determined by the sum of the focus actions taking place in the first and second deflection means.

Another electron beam deflection principle used in designing an arrangement in accordance with the invention will now be described with reference to FIG. 10, and concerns the lengthening of the focal length of the deflection lens system at the right-hand region of the horizontal deflection, in order to increase the distance along the electron beam at which the cross-over point occurs. Referring to FIG. 10, the converging beam 191 approaches the right-hand region of the second deflection stage magnetic field 192 at a relatively acute angle ϕ. The electron beam has a certain diameter or width 193 at the leading edge 194 of the magnetic field; however, the effective width of the beam coincident with the leading edge 194 is a larger value as shown at 196. Due to the relatively large curvature of the beam in this region of the magnetic field, the effectively larger entering beam width 196 causes the exiting beam width to be greater, as indicated at 197, than the beam width would be, as indicated at 198, if it were not for the combination of acute entrance angle ϕ and relatively large curvature of the beam in this region of the magnetic field 192. The vertically exiting electron beam with its broadened base dimension 197, converges to a cross-over point 199 which is higher than the cross-over point 200 the beam would have with a non-widened base dimension 198. This effect of increasing the focal length of the deflection system is greater than, and is slightly reduced by, the tendency for the focal length to shorten slightly due to a slightly increased convergence caused by the slight mutual taper between the leading and trailing edges 194 and 201 at this region of the magnetic field.

From the foregoing, it is seen that the focal length of the deflection system can be varied by proper combinations of angle of approach of the electron beam to the second deflection stage magnetic field and the amount of deflection given the beam by this field.

The first deflection stage 56 affects the focal length of the electron beam, by what is known as deflection focus. When the beam is deflected by the first deflection stage 56, its convergence is increased, and hence its focal length shortened, as a function of the amount of deflection. Now referring to FIG. 8, the non-deflected beam, which is directed in the direction 206, does not experience any deflection focus. When the beam is deflected to its most nearby vertical direction 207 by the first stage 56, it has the relatively strongest deflection focus, thus shortening its focal length. This effect is desirable, because the focal length of the beam must be shortened at the left-hand region of horizontal deflection in order to achieve good focus at the screen. Because of this, the second stage magnetic pole pieces need not be tapered as much at the left-hand or narrower ends thereof as would otherwise be necessary. When the beam is deflected to its most nearly horizontal direction 208 by the first stage 56, it is given a moderate amount of deflection focus and less than when deflected to the direction 207, because, in accordance with a feature of the invention, the electron gun which produces the beam

is tilted at an angle less than 45° with respect to the horizontal. The deflection focus when the beam is deflected to the direction 208, undesirably tends to shorten the focal length of the electron beam, which effect is overcome by the relatively greater effect, as described above with reference to FIG. 10 of increasing the focal length due to the widening of the electron beam at 197.

The foregoing explanation and drawings graphically illustrate the mechanisms functioning within the horizontal deflection system. The actual design of the structure entails the application of analytic techniques. The general technique of designing different cathode ray tubes in accordance with the invention is one of arriving at unique geometrical parameters of both electron gun orientation along with magnetic fields that result in a linear, collimated, and optimumly focused electron beam projected vertically behind the screen. The analytic procedure consists of the following:

(1) Select an approximate geometry of tube configuration and the first deflection means.

(2) Assume a practical drive waveshape for the dynamic magnetic deflection means (first deflection means). If a perfectly collimated and linear horizontal sweep is required, there is one and only one properly shaped second deflection stage magnetic field which will fulfill the requirements.

(3) The second deflection stage magnetic field is now determined analytically by conventional ray tracing techniques and the focal characteristics of the entire system are likewise checked analytically. If the focal characteristics or the geometry of the system are not satisfactory, one or more of the parameters in 1 or 2 will be changed.

(4) Continue iteration of above until optimum requirements are met.

The general structure arrived at through the above procedure, represents a unique and simple configuration which will permit the construction of a practical flat display horizontal deflection system capable of adequately fulfilling requirements of scan linearity and focus in such devices.

The desirability for improving the electron beam focus in flat cathode ray tubes, which is achieved in the present invention, will now be described with reference to FIGS. 11 and 12 of the drawing.

FIG. 11 is a side sectional view of a typical widely used type of prior art cathode ray tube 213 and shows, in an exaggerated manner for illustrative purposes, the side-view shape of a typical electron beam 216 produced by an electron gun 214. The beam 216, as it emerges from the gun 214, has sufficient cross-sectional area to provide adequate electron-beam energy, and the beam is converging, i.e. the outer bundles of electrons of the beam are converging, to a cross-over point 217 at which the electron beam has the smallest cross-sectional area and hence the sharpest focus, and thereafter the electron beam 216 diverges as indicated at 218. As a practical matter, the cross-over point 217 will have a finite cross-sectional area due to the effect of space charge of the electrons. In the well-known and widely used conventional type of cathode ray tube 213 in which the electron beam is directed substantially perpendicular to the phosphor screen 219, the electron gun 214 is designed to converge the beam 216 in such a manner that the cross-over point 217 will be approximately at the plane of the viewing screen 219, whereby small spot size and hence good focus is readily achieved over the entire area of the screen 219. However, in the typical prior art flat picture tube of FIG. 12 the convergence of the electron beam must be chosen so that, as a matter of compromise, the best focus lies at the center 222 of the screen and only at certain other points on the screen equidistant from the electron gun along the electron beam path, the focus being poor at other areas of the screen as will now be described.

A typical prior art flat cathode ray tube as shown in FIG. 12, looking toward the front thereof, consists of an evacuated envelope 226 provided with a phosphor viewing screen 227 on the inside of the front wall thereof, the envelope 226 including a neck portion 228 in which an electron gun 229 is positioned to provide an electron beam 231 in a horizontal direction below and slightly behind the screen 227. Horizontal beam deflection means, not shown, which may consist of an array of electrostatic deflection plates, is supplied with electric potentials causing the beam 231 to curve upwardly at successive intervals or locations so as to cause the beam 231 to scan horizontally behind the viewing screen 227. For example, the left-most position of the horizontally scanned electron beam is indicated at 232; the central position is indicated at 233; and the right-most horizontally scanned position is indicated at 234.

Vertical deflection means, not shown, and which may comprise an array of electrostatic deflection plates, is arranged behind the screen 227 to direct the electron beam 231 toward the screen 227 at successive vertical intervals. For example, if the electron beam when following the path 232 is directed toward the screen 227 at the lower region of the screen, the beam will impinge upon the screen at a point 236. If the beam, when following the path 233, is caused by the vertical deflection means to impinge centrally of the screen, it will thus impinge at the point 222; and if the vertical deflection means causes the beam, when following path 234, to bend toward the screen 227 near the upper portion thereof, the beam will impinge thereon at a point 223.

It will be evident that the electron beam path 323 is appreciably shorter in length than the beam path 234. If the electron beam 231 is a converging electron beam having a cross-over point, which is desirable because it provides adequate electron energy along with small cross-sectional area at the cross-over point for achieving good focus, it is found that, unless dynamic focusing correction is employed in the electron gun, uneven and poor focus of the beam occurs at the screen 227. The best focus of the electron beam is at the cross-over point, and the focus is increasingly poorer at increasing distances along the electron beam from the cross-over point.

As illustrated in FIGS. 11 and 12, the cross-sectional size of the electron beams 216 and 231 at points along the length thereof corresponding to the points of impingement 236 and 223 on the viewing screen 227 of FIG. 12, are considerably larger than that at the central point 222, and intermediate points therebetween have intermediate sizes of cross-sectional area. In FIG. 12, the tilted dashed line 241 indicates the locus of best focus of the converging electron beam on the screen 227. The beam at point 222 and at other points along the line 241 will have best focus; beam spots 242 and 243 generally will have acceptable focus, and the beam spots 236 and 223 will have unacceptable focus. It is known to employ a dynamic, i.e., a varying, focus technique at the electron gun or elsewhere to shift the cross-over point of the electron beam while scanning over the screen in order to improve the focus; however, this technique involves certain complications and there are practical limitations to its effectiveness.

An important feature of the invention is the attainment of improved focus of the electron beam on the screen, as will now be particularly described with reference to FIG. 13. The electron beam 55, as it leaves the electron gun 54, is tapered in a converging manner with a degree of convergence to produce the cross-over point or best focus at approximately the center 251 of the screen 50 when the beam is in its undeflected or neutral position 73.

There is a smooth change in the focus action of the two magnetic fields which causes decreasing convergence and hence a relative increase in focal length of the electron beam as the beam scans from left to right, so that the

point of best focus lies along a line **252** extending substantially horizontally across the center of the viewing screen **50**. Since the locus of best focus extends substantially horizontally across the center of the viewing screen **50**, the locations of relatively poorest focus will be at the top and bottom edges of the viewing screen **50**, as indicated at the points **253–258**; however, the focus or spot size at these points will be of acceptable size. By comparing the electron beam spot sizes of the tube of the present invention as shown in FIG. 13 with the spot sizes of the prior cathode ray tube shown in FIG. 12, it will be seen that the spot size distribution of the present invention is considerably more uniform and the spot size is generally smaller. This improvement in focus is obtained without the necessity of horizontal dynamic focus correction.

The above-described focus improvement applies to the dimension of the cross-section of the electron beam **55** in the plane of the horizontal or line deflection, i.e. horizontally of the electron beam when it strikes the viewing screen. The cross-over point of the electron beam is not affected in the cross-section dimension normal to the plane of horizontal deflection; the focus in this cross-sectional dimension of the beam is controlled by the vertical deflection system. The horizontal and vertical focus effects combine to provide a desirable spot size and shape of the electron beam where it impinges on the viewing screen.

With the above-described preferred arrangement of the invention in which the neutral position of the electron beam is approximately centered horizontally of the screen **50** as indicated by the electron beam path **95**, the horizontal deflection signal source **62** may be a conventional television deflection circuit producing a non-linear deflection signal as shown at **68** for successively deflecting the electron beam **55** to the left and to the right of its neutral position, whereby the electron beam scans cyclically from left to right behind the viewing screen **50** in a linear manner with respect to time. If it is desired to use horizontal deflection signals having a nonstandard wave shape, linear scanning of the electron beam behind the viewing screen can be achieved by a compensatory reshaping of the deflection pole pieces **58**, **59**. Since the function of the first stage **56** is to produce an angular deflection of the electron beam, any suitable equivalent deflection system, such as electrostatic deflection plates, may be used instead of the magnetic system shown, provided the deflection signal **68** has a suitable wave shape.

Although in the preferred embodiment of the invention, the electron gun **54** is tilted at an angle of less than 45 degrees with respect to the horizontal and is oriented so that the electron beam **55**, when unaffected by the first deflection stage **56**, i.e., when the signal **68** has zero value, follows the paths **73** and **95** to pass upwardly behind the screen **50** at approximately the center, if desired the electron gun may be tilted at other angles if the deflection signal **68** is given a suitable wave shape or if a fixed amount of bias current is supplied to the winding **61** to cause the beam **55** to have the desired neutral path **73–95**. Alternatively, a permanent magnet may be employed to provide magnetic bias.

Preferably, a high resistance material, such as chromic oxide, is coated over the inside of the glass envelope **46** at the window openings **147** to provide a leakage path from the window areas to the conductive coating **146**, to prevent stray electrical charges from developing on the envelope at the window areas **147**.

FIG. 14 shows, by way of example, a modified shape of the pole pieces **82**, **83** which results from designing the tube for use with a horizontal deflection signal **68** of modified wave shape.

The new arrangements of this invention for producing and deflecting an electron beam are found to be advantageous over prior art arrangements in several respects. Good, and relatively uniform, focus is achieved over the entire area of the viewing screen. The magnetic beam scanning arrangement can function at relatively high repetition frequencies, such as the horizontal scanning rate of television, without incurring the problems of providing for fast discharging of deflection elements as is the case with certain prior-art electrostatic deflection techniques. The first and second horizontal deflection stages of the invention cooperate to provide a continuous linear motion of the electron beam scanning behind the target area, whereas certain prior art scanning arrangements tend to provide nonlinear or distorted scanning which results in distortion of the image reproduced on the picture tube. The invention avoids the use of expensive and complex electrical commutating arrangements which have been proposed in the past for causing deflection of the electron beam in certain flat picture tubes. The required angle of deflection of the electron beam by the first-stage horizontal deflection magnetic field, in the present invention, is easily achieved with very low power, and generally is less than 90 degrees. The preferred embodiments of the invention have further advantages in that the neutral or unscanned position of the electron beam is approximately centrally aligned with respect to the viewing screen, without the need for applying any bias voltages or fields to the horizontal scanning means, and thus the horizontal deflection may be achieved by the use of a conventional television horizontal deflection signal. The shape of the tube envelope minimizes the volume of air that must be evacuated, minimizes the spacing between the magnetic pole pieces which provide the first and second lens elements, thereby increasing the efficiency and preciseness of the magnetic field lenses, and at the same time positions the screen forwardly of the electron beam source so as to permit accurate vertical scanning of the electron beam on the screen.

In addition to achieving the aforesaid advantages, the flat cathode ray tube of the present invention is capable of relatively inexpensive mass production as compared with certain prior art types of flat picture tubes.

While preferred embodiments and modifications of the invention have been shown and described, various other embodiments and modifications thereof will be apparent to those skilled in the art and will fall within the scope of invention as defined in the following claims. It is to be understood that, although the present invention has been described primarily as useful for the horizontal scanning system in a flat television picture tube, it may also be useful for achieving vertical scanning, and furthermore is useful in cathode ray tubes other than television picture tubes wherein it is desired to cause an electron beam to be scanned in the manner of the invention.

I claim:

1. A cathode ray tube comprising:

(a) an image target area having first and second orthogonal scan dimensions lying in a first plane;

(b) means for producing an electron beam in a second plane spaced from and generally parallel to said first plane and along an initial path canted with respect to said scan dimensions;

(c) first scanning means for cyclically scanning said beam within said second plane along said first scan dimension, said first scanning means including

(1) dynamic deflection means disposed across said initial path, with a center of deflection displaced from both said target area dimensions, for dynamically deflecting said beam along a plurality of angularly spaced diverging paths, and

(2) static deflection means comprising means for producing a substantially unidirectional magnetic field across said diverging paths of said beam for statically deflecting said beam along a succession of collimated paths generally parallel to said second scan dimension and for varying the focal length of said beam as it travels along different ones of said collimated paths such that the locus of the beam focal points lies along

a line generally parallel to said first scan dimension; and

(d) second scanning means for cyclically scanning the beam along said second scan dimension including dynamic deflection means disposed across said collimated paths for deflecting said beam from said second plane toward said target area.

2. The invention of claim 1, wherein the magnetic field produced by said field producing means has a leading edge and trailing edge disposed across said diverging paths of said beam and inclined at an angle relative to said first scan dimension.

3. The invention of claim 2, wherein the magnetic field produced by said field producing means includes a tapered end an a wider end with said tapered end being located closer to said target area and said center of deflection than said wider end.

4. The invention of claim 3, wherein the magnetic field produced by said field producing means is tapered in accordance with the formula

$$v = r \sin \alpha$$

wherein v is the distance measured along the direction parallel to said second scan dimension between the points at which a given electron beam leaving said first deflection means intersects said leading and trailing edges, r is the radius of deflection of said given beam caused by said field, and α is the angle of the path of said given beam relative to said second scan dimension as it leaves said first deflection means.

5. The invention of claim 4, wherein:

(a) said field producing means comprises a pair of opposing pole pieces disposed substantially parallel

to said first plane and on opposite sides of said second plane, and

(b) said pole pieces having a leading edge and a trailing edge substantially coincident with said leading and trailing edges of said magnetic field.

6. The invention of claim 5, wherein:

(a) said first scan dimension is generally horizontal,

(b) said second scan dimension is generally vertical,

(c) said second plane is spaced behind said first plane,

(d) said beam producing means and said dynamic deflection means of said first scanning means are displaced below and to the left of said target area, and

(e) said pole pieces are located below said target area with their tapered and wider ends respectively disposed below the left and right edges of said target area.

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