Nov. 14, 1967 YUKIO KOYANAGI 3,352,970

CATHODE RAY TUBES AND APPARATUS USING THE SAME

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Fig. 1

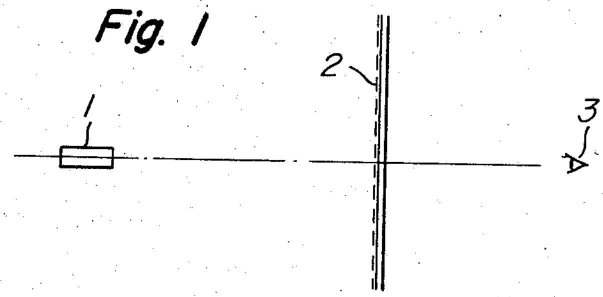


Fig. 2

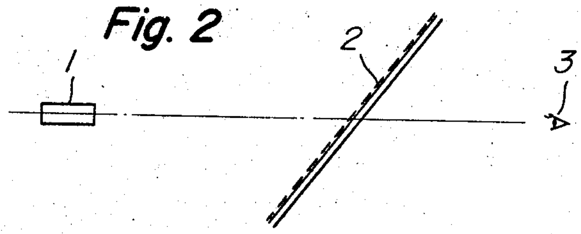
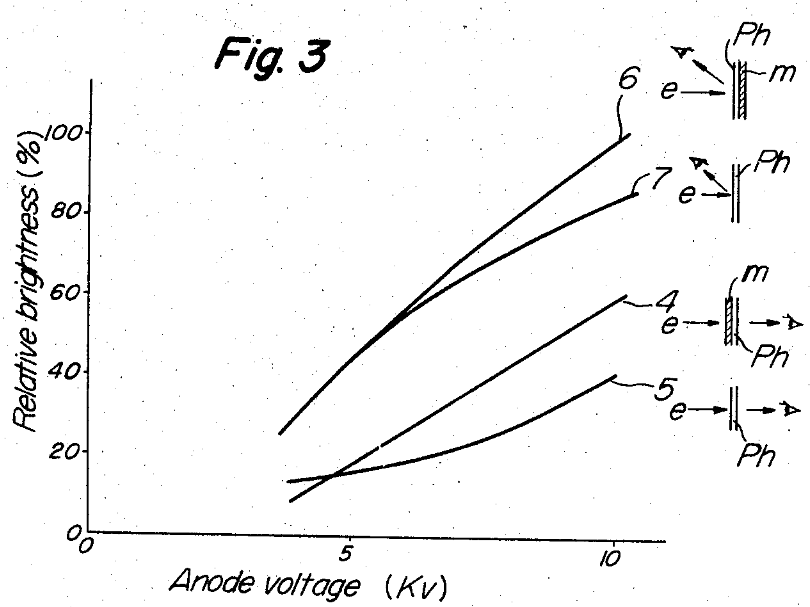


Fig. 3



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CATHODE RAY TUBES AND APPARATUS USING THE SAME

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Fig. 4

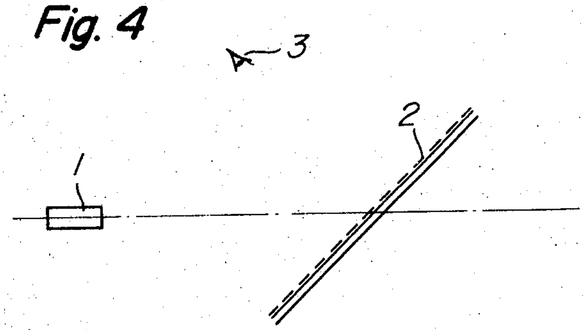


Fig. 5

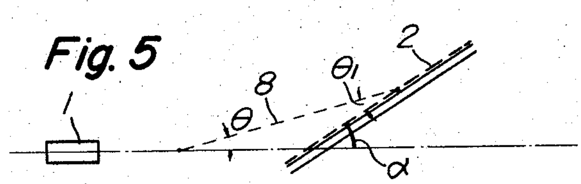


Fig. 6

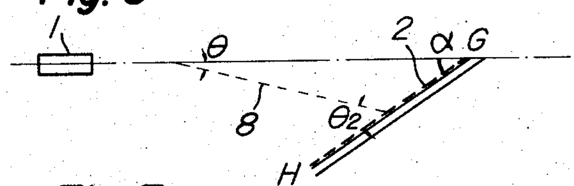
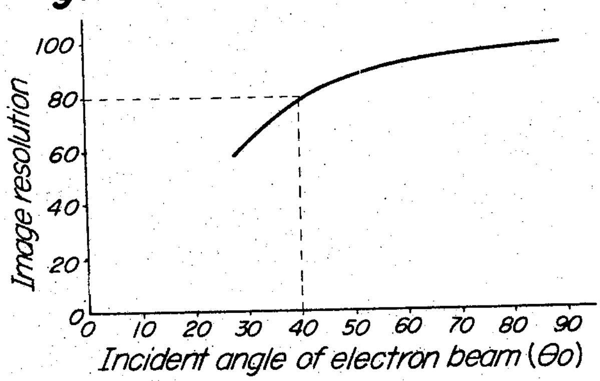


Fig. 7



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CATHODE RAY TUBES AND APPARATUS USING THE SAME

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Fig. 8

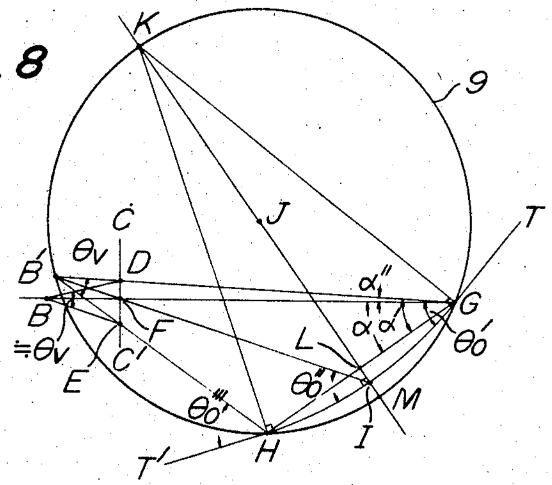


Fig. 9

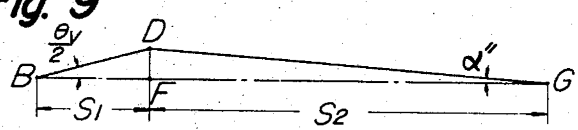


Fig. 10

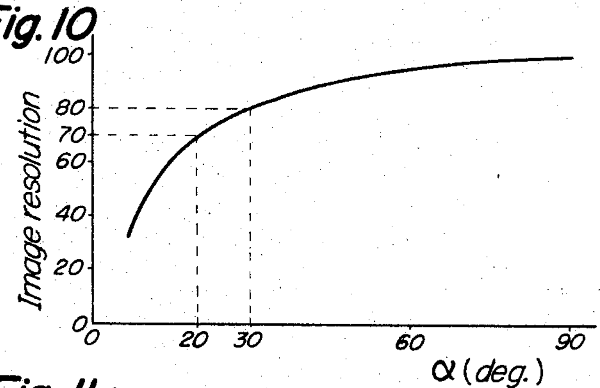
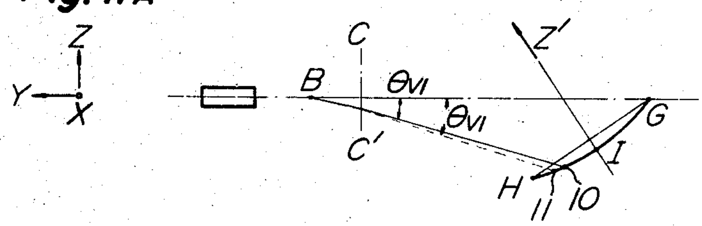


Fig. 11A



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CATHODE RAY TUBES AND APPARATUS USING THE SAME

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Fig. 11B

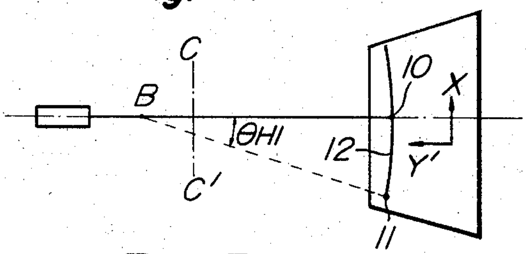


Fig. 12

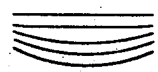


Fig. 13A

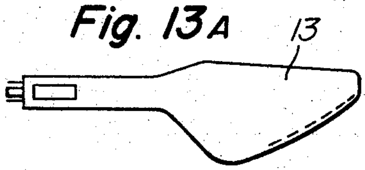


Fig. 14

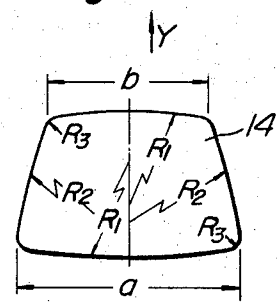


Fig. 13B

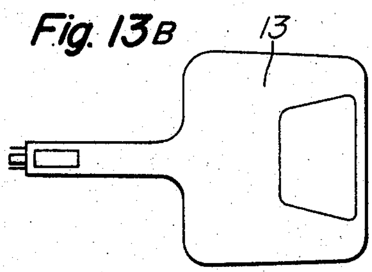
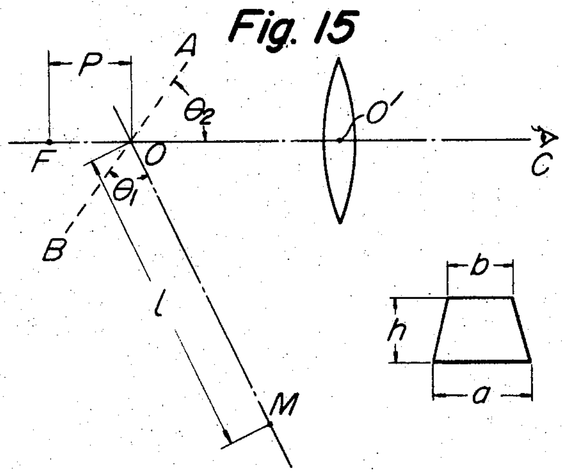


Fig. 15



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United States Patent Office

Patented Nov. 14, 19..

3,352,970

CATHODE RAY TUBES AND APPARATUS USING THE SAME

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Claims priority, application Japan, Apr. 12, 1963, 38/19,304; Apr. 15, 1963, 38/19,543; June 24, 1963, 38/33,599, 38/33,600; July 1, 1963, 38/49,832; July 5, 1963, 38/50,488, 38/50,489; Dec. 28, 1963, 39/21
2 Claims. (Cl. 178—7.85)

ABSTRACT OF THE DISCLOSURE

A cathode ray tube comprising an electro-conductive film layer on the inner surface of the bulb at a position displaced from the central axial line of the electron beam from the electron gun and a fluorescent screen provided on the film layer. The fluorescent screen is inclined at an acute angle with respect to the axis of the electron beam with the edge of the screen remote from the gun being positioned near the axial line of the electron beam.

This invention relates to cathode ray tubes and an apparatus using the same, such as television receivers.

The primary object of the present invention is to provide a cathode ray tube of relatively small horizontal depth with little deflecting power, particularly suitable for use in a portable television receiving set.

There are other objects and particularities of the present invention, which will be made obvious from the following detailed descriptions of the invention, with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic representation of the conventional system showing how the television image is presented to the human eyes;

FIG. 2 is a diagrammatic representation showing a manner of modifying the conventional system shown in FIG. 1 in order to have the horizontal depth of the system decreased relatively to the area of the fluorescent screen;

FIG. 3 is a curve diagram showing relations between anode voltage and relative brightness for various fluorescent screen systems with one and the same electron-beam current;

FIGS. 4, 5 and 6 show how the fundamental idea of the present invention is obtained;

FIG. 7 is a curve diagram showing the relation between the incident angle of electron beam to the fluorescent screen and the image resolution according to the present invention;

FIGS. 8 and 9 are diagrammatic representations for use in explanation of how the above-mentioned incident angle can be made substantially uniform throughout the whole area of the fluorescent screen according to the present invention;

FIG. 10 is a curve diagram showing the relation between the angle (α) of the inclination of fluorescent screen with respect to the central axis of the electron beam and the image resolution;

FIGS. 11 and 12 show how the scanning line distortion takes place and remedied according to the present invention;

FIG. 13 shows an example of a cathode ray tube bulb embodying the present invention, by side elevation A and front elevation B;

FIG. 14 is a front elevation of an example of a fluorescent screen according to the present invention; and

FIG. 15 is a diagram showing, as an example, how the fluorescent image may be magnified in the present invention.

Conventional cathode ray tubes for television use have, in general, electron guns arranged on axial lines perpendicular to fluorescent screens, and the fluorescent screens present images to human eyes at the side opposite to the electron guns, as shown in FIG. 1 in which **1** designates the electron gun, **2** the fluorescent screen, and **3** the human eye.

It has been tried to have the fluorescent screen **2** inclined relative to the axial line of electron gun **1**, as shown in FIG. 2, for shortening the horizontal depth of the apparatus containing a cathode ray tube therein, but in such an arrangement, the distance from the electron gun **1** t the screen **2** varies remarkably according to positions o the screen, and in addition, the electron beam inciden obliquely to the screen, so that images of good resoluti are difficult to obtain. If the deflection angle is m smaller in order to decrease the deflecting power with area of the fluorescent screen unchanged, the diamete the electron-beam spot is made larger, resulting in lo ing of the image resolution.

In order to improve the image resolution, one endeavor either to so modify the electron gun to ge smaller electron beam, or to decrease the beam c The former can be accomplished by employin known periodic focus guns or electromagnetic f system, and the latter may be accomplished, if m provided for decreasing the magnitude of the beam current with raised efficiency of the f screen for obtaining the same brightness of t For this purpose, the present invention provides viewing by human eyes of the side of the screen upon which electron beams impinge.

In FIG. 3, relative brightnesses are shown the same electron beam current for variable ages in various viewing systems. Curve **4** is f in which electron beam *e* impinges metal and human eyes look at the opposite phos and curve **5** is for the system wherein a me provided. To the contrary, curve **6** is for cording to the present invention, in whi beam directly impinges phosphor layer Ph layer *m* on the opposite side, and hum direct the phosphor layer Ph, and curve lar system having no metal back layer. that, for one and the same brightness v can remarkably be decreased with low according to the present invention. provision of a portable television rec low power consumption, together w small deflection angle to be describe

As for example, by an arrangemer it has been confirmed that the bri obtained with an anode voltage of 5 current of 15 μA is substantially tained with 6 kv. anode voltage a current in a conventional cathode

When the electron beam impin phor layer, there is a problem of layer by ion bombardment. In damage, bent guns and ion trap but it is not desirable to dispos to electron guns when high i The present invention contem cent screen out of the centr beam when the latter is not the deflected electron beam electric field, as diagramm FIG. 6. In each of these fig gun, **2** the fluorescent scree has been bent by an angle θ relative to the central axial line of the electron beam, after it was deflected by deflecting means, not shown. θ_1 and θ_2 are the incident angles of electron beams to the fluorescent screens **2** in FIGS. 5 and 6, respectively.

In comparing the two modes of arrangement as shown in FIGS. 5 and 6, for an equal angle (α) of inclination of the fluorescent screens relative to the central axial lines of the electron beams, θ_1 is always smaller than θ_2, and it is clearly understood that the arrangement as shown in FIG. 6 is preferable with respect to image resolution.

Let it be assumed that image resolution is

$$\propto\sqrt{\sin\theta_0} \tag{1}$$

where θ_0 is the incident angle of the electron beam to the fluorescent screen. This relation is plotted in FIG. 7. It is noted that, for an incident angle less than about 40°, the image resolution decreases abruptly. This is the reason why the arrangement shown in FIG. 6 is preferable to that of FIG. 5.

When the fluorescent screen is a plane as shown in FIG. 6, the angle of incident θ_0 increases from one end to the other end H. In order to obtain the highest image resolution at the central portion of fluorescent screen, the focussing electrode voltage is set to focus at the center of fluorescent screen, and consequently, the image resolution is extremely lowered at the portion near the end G. It is thus readily understood that the incident angle of electron beam to the fluorescent screen should preferably be substantially uniform through the whole area of fluorescent screen. For this purpose, the shape of the fluorescent screen may be decided as explained hereinafter.

Referring to FIG. 8, B is the center of deflection of beam, $\overline{CC'}$ the center line of the centering operation after the electron beam has been deflected, and G, H opposite ends of the fluorescent screen. $\overline{BDG}$, $\overline{BFI}$, designate the loci of the electron beams. The intersection B′ of extensions of $\overline{GD}$ and $\overline{HE}$ is the center of deflection of the electron beam. A circle with center at J and passing through points B′ and ... imagined, and the point of its intersection K with the bisecting line of $\overline{GH}$ is obtained. If an arc ... with the center at K, the radius being $\overline{KG}$

$$\angle KGB'=\angle KHB' \tag{2}$$

... ΔKHB′ have a common base $\overline{KB'}$, and are ... and the same circle.) If tangent lines T ... drawn with respect to arc GIH at points H ... respectively,

$$\angle KGT=\angle LHT=90° \tag{3}$$

... incident angle at point G is

$$\theta_0=90°-\angle KGB' \tag{4}$$

... is

$$\theta_0'''=90°-\angle KHB' \tag{5}$$

$$\therefore\theta_0'=\theta_0''' \tag{6}$$

$$\overline{KI}=\overline{KM} \tag{7}$$

$$=\theta_0'''=\theta_0'' \tag{8}$$

... is assumed as representing the incident angles of the electron beam ... screen are substantially uniform ...

... hereinbefore, the incident angle ... the fluorescent screen according ... should preferably be larger than ... important matter of the present ... angle of inclination α of the fluorescent screen with respect to the central axial line of the electron beam.

If $\angle DBE=\angle DB'E=\theta_V$, in triangles HB′G and KGH,

$$\angle HB'G=\angle HKG=\theta_V \tag{9}$$

$$\angle HGK=\alpha'+(90°-\theta_0')=\angle GHK \tag{10}$$

(∴ΔKGH is an isosceles triangle)

$$\angle HGK+\angle GHK+\angle GKH=180° \tag{11}$$

$$\therefore\alpha'=\frac{2\theta_0'-\theta_V}{2} \tag{12}$$

If the distance between the deflection center B and the point of intersection F of the centering axial line and the electron-beam axial line is **S1**, and the distance between points F and G is **S2**, then, as is clear from FIG. 9,

$$\alpha''=\frac{S1}{S2}\cdot\frac{\theta_V}{2} \tag{13}$$

The angle α between line GH and the electron-beam axial line is

$$\alpha=\alpha'-\alpha''=\frac{2\theta_0'-\theta_V}{2}-\frac{S1}{S2}\cdot\frac{\theta_V}{2} \tag{14}$$

FIG. 10 shows the relation between angle α and image resolution. This shows that the image resolution is lowered by 30% in comparison to the case when the electron beam impinges at a right angle to the fluorescent screen, at $\alpha=20°$, and this angle is considered the lower limit above which compensation is possible by means of the electron gun and decrease in electron beam current. The upper limit of α is 40°, as is decided by easy viewing of the fluorescent image and horizontal depth of the apparatus.

Thus, for cathode ray tubes under consideration, α should be selected between 20° and 40°.

Now, there have been decided the shape and disposition of the sectional view of the fluorescent screen at the plane perpendicular to the screen and containing the central axial line of the electron beam.

Next, it is required to decide the shape of the fluorescent screen in the direction perpendicular to the above-identified section plane. In order to clarify the description, geometrical directions are referred to as shown in FIG. 11. Y shows the direction of the central axial line of the electron beam, X the direction perpendicular to the plane containing the central axial line of the electron beam and perpendicular to the plane of the fluorescent screen, and Z the direction perpendicular to the plane containing both X and Y. In addition, Y′ is the projection of Y on the fluorescent screen, and Z′ is the direction vertical to the fluorescent screen.

If it is assumed that the section of the fluorescent screen in the X-direction is linear, the electron beam in plane Z–Y and bent by angle θ_{VI} relative to plane X–Y impinges the fluorescent screen at point **10**, and the electron beam bent by angle θ_{VI} relative to plane X–Y and by angle θ_{H1} relative to plane Z–Y impinges the fluorescent screen at point **11**. The locus of points **12** show the impingement of the beam when the angle θ_{H1} is changed. As is clear from FIG. 11, the above-mentioned tendency is remarkable when the section of the fluorescent screen in X-direction is made a circular arc having its center in Z′-direction, while, on the contrary, if a circular arc having its center in the direction opposite to Z′-direction is adopted, it is modified to approach to a straight line. However, the latter construction would cause breakage of cathode-ray tube glass under the atmospheric pressure. Consequently, the most desirable shape of the section of the fluorescent screen in X-direction is linear. In this case, there occurs a scanning line distortion as shown by **12** in FIG. 11, but this may be compensated for by providing a magnetic field of the centering magnet as shown in FIG. 12.

Most of the elements required for deciding the shape of the cathode ray tube according to the present invention have now been clarified. FIG. 13A shows the shape of the cathode ray tube seen from the X-direction, having the minimum volume, and capable of satisfying the above-explained various conditions, durable to the atmospheric pressure, and enabling proper viewing of the fluorescent image.

The shape of the cathode ray tube as seen from the Z-direction depends upon the shape of the fluorescent screen to a certain extent. The shape of the fluorescent screen is not necessarily approximately rectangular by the reason hereinafter described, but may be nearly a trapezoid, if necessary. In case when the shape of the fluorescent screen is as shown in FIG. 14, and when it is viewed from the Z′-direction, and if the right-hand end line of the fluorescent screen is considered as having a definite angle of inclination in the X–Z′ plane, the line of its intersection with the plane of the glass window decides the shape of the cathode ray tube as seen from the Z-direction. The plane of the window is desirable to be geometrical plane as far as is allowed by the strength of the glass bulb subjected to the atmospheric pressure, from the standpoint of image distortion, and it is nearly a plane substantially lying in X–Y plane. When the position and shape of the window are decided as above-mentioned, the line of intersection hereinabove referred to becomes line **14** in FIG. 14. Consequently, the shape of the cathode ray tube as seen from the Z-direction is as shown in FIG. 13B.

When the fluorescent screen is trapezoidal with a similar cross-sectional shape of the glass bulb, the glass bulb may have sharp corners providing weak points, as well as, inner places of inconvenient working, such as metal-backing. For this reason, it is desirable to make the fluorescent screen with a rectangular shape.

Referring to FIG. 14, **R1** is for providing tolerance in order not to have the inclination of the deflecting system observed clearly by scanning lines, and R2 is decided to prevent the ends of the fluorescent screen from being apparently concaved, when the fluorescent screen of part-cylindrical shape is seen from the X-, and Z-directions. R_3 is provided for giving tolerance for neck-shadow. Instead of providing edges as above, an extra electrode may, for example, be disposed within the cathode ray tube for limiting the electron beam after having been deflected to a definite shape.

The upper and lower lateral lengths a and b (see FIGS. 14 and 15) of the fluorescent screen are decided by the extent of electrical compensation by means of the wave-shapes of deflecting current or the like, or of magnetic compensation by means of compensating magnets, except optical means for compensation of the shape of the fluorescent screen.

The fluorescent screen is viewed through transparent glass window portion **13** in FIG. 13. This portion must not have any optical distortion, but its color or transparency may be changed if necessary or desirable. On the inner side of the glass window portion **13**, there should be provided an electrically-conductive transparent film for the purpose of static shielding. The film should evenly adhere to the inner face of glass portion **13** and it forms an electrostatic capacity between itself and the electro-conductive film provided on the outside of the glass bulb except for glass portion **13**.

The fluorescent screen is formed on the above-mentioned electro-conductive film and transparent inner film. As shown in FIG. 3, the metal back is not so effective when used at about 5 kv. anode voltage, and consequently, the metal back may be omitted in order to simplify manufacturing steps. When the anode voltage is higher, the metal back is effective and may advantageously be employed. When the anode voltage is sufficiently low, the fluorescent screen may be formed directly on the bulb glass.

In order to compensate for the trapezoidal distortion hereinbefore described by virtue of deflection, it is difficult to accomplish the required compensation into good linearity by the electrical method of compensation only to a large extent. It is, therefore, considered to effect the required compensation by combination of electrical compensation and optical compensation, or solely by optical compensation.

Assuming that the shape of the raster on the fluorescent screen is as shown in FIG. 15, having lateral widths a and b, and height h, with the apparent center of deflection M, the center of fluorescent screen O, and the length l of $\overline{OM}$, with angle of inclination θ_1 of the fluorescent screen relative to its axis $\overline{OM}$, an optical magnifying system of focal length $f=\overline{O'F}$ may be provided on the axial line inclined to the fluorescent screen by an angle θ_2, the distance between focal point F and point O being P. When no electric or magnetic deflection correcting means is provided in the cathode ray tube, the raster on the fluorescent screen will be distorted. The relation between the lengths a on the upper edge A of the screen and b on the lower edge B of the screen is defined by:

$$\frac{a}{b}=\frac{l+\frac{h}{2}\cos\theta_1}{l-\frac{h}{2}\cos\theta_1} \tag{15}$$

on the other hand, the magnification $m1$ at the upper edge A and $m2$ at the lower edge B by the optical magnifying system are:

$$m1=\frac{f}{P+\frac{h}{2}\cos\theta_2}$$

$$m2=\frac{f}{P-\frac{h}{2}\cos\theta_2}$$

Therefore, to compensate for the trapezoidal or keystone distortion, the arrangement has to satisfy the following:

$$\frac{a}{b}=\frac{m_2}{m_1}=\frac{P+\frac{h}{2}\cos\theta_2}{P-\frac{h}{2}\cos\theta_2} \tag{16}$$

Thus, substituting Equation 15 into Equation 16,

$$\frac{l+\frac{h}{2}\cos\theta_1}{l-\frac{h}{2}\cos\theta_1}=\frac{P+\frac{h}{2}\cos\theta_2}{P-\frac{h}{2}\cos\theta_2}$$

then,

$$\frac{l}{P}=\frac{\cos\theta_1}{\cos\theta_2} \tag{17}$$

is obtained. Thus, the arrangement will be free from keystone distortion when the relationship defined by Equation 17 is established therein. Various kinds of optical magnification may be used, among which concave mirrors and convex lenses are utilized, in general.

It has now been understood that, according to the present invention, the cathode ray tube may be of simple construction with a relatively small horizontal depth, suitable for use in a portable television receiver, and the like. In addition, its power consumption is low, while its image resolution is good. If it is combined with an optical magnifying system, as a Fresnel lens, with the axis of the optical system inclined to the vertical axis of the fluorescent screen, electrical compensation of the deflection can easily be effected, and also easy-viewing of a fluorescent image is obtained.

What we claim is:

1. A cathode ray tube comprising a closed glass bulb, an electron gun at one end of said bulb directing an electron beam along a central axial line of said bulb to a portion of the inner surface at opposite end of said bulb, an electroconductive film layer on said inner surface of said bulb at a position out of alignment with but adjacent to the central axial line of said electron beam at said opposite end of said bulb, a fluorescent screen provided on said film layer, said fluorescent screen being inclined to said axial line at an acute angle with the side edge of said fluorescent screen which is the most remote from said electron gun being positioned closely adjacent said central axial line of said electron beam, the shape of a vertical section of said screen in a plane containing said central axial line of the electron beam being a circular arc the center of which is at the point of intersection of a circle passing through the opposite ends of said section and the apparent center of electron beam deflection, and the perpendicular bisecting line to a line connecting said opposite ends of the fluorescent screen passing through said center, and the radius of said circular arc being equal to the length of a straight line connecting said point of intersection to one end of said fluorescent screen.

2. A cathode ray tube apparatus comprising a cathode ray tube, said tube comprising a closed bulb having an electron gun therein, said gun projecting an electron beam at a portion of the inner surface of said bulb spaced therefrom along a central axial line of said electron beam, an electroconductive film layer on said inner bulb surface adjacent the point where said electron beam impinges on said inner surface, and a fluorescent screen provided on said film layer, said fluorescent screen being inclined to the axial line of said electron beam at an acute angle with the side of said fluorescent screen remote from said electron gun being positioned near said central axial line of

said electron beam, an optical system disposed inclined to said fluorescent screen for compensating for the trapezoidal distortion of raster, said optical system being formed by an optical lens satisfying an equation

$$\frac{l}{P}=\frac{\cos \theta_1}{\cos \theta_2}$$

where θ_1 is the angle of inclination of the optical axis relative to the electron beam axis, θ_2 is the angle of inclination of the optical axis relative to said fluorescent screen, P is the distance between the center of said fluorescent screen and the focal point of said optical lens, and l the distance between said center of the fluorescent screen and the center of deflection of the electron beam.

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