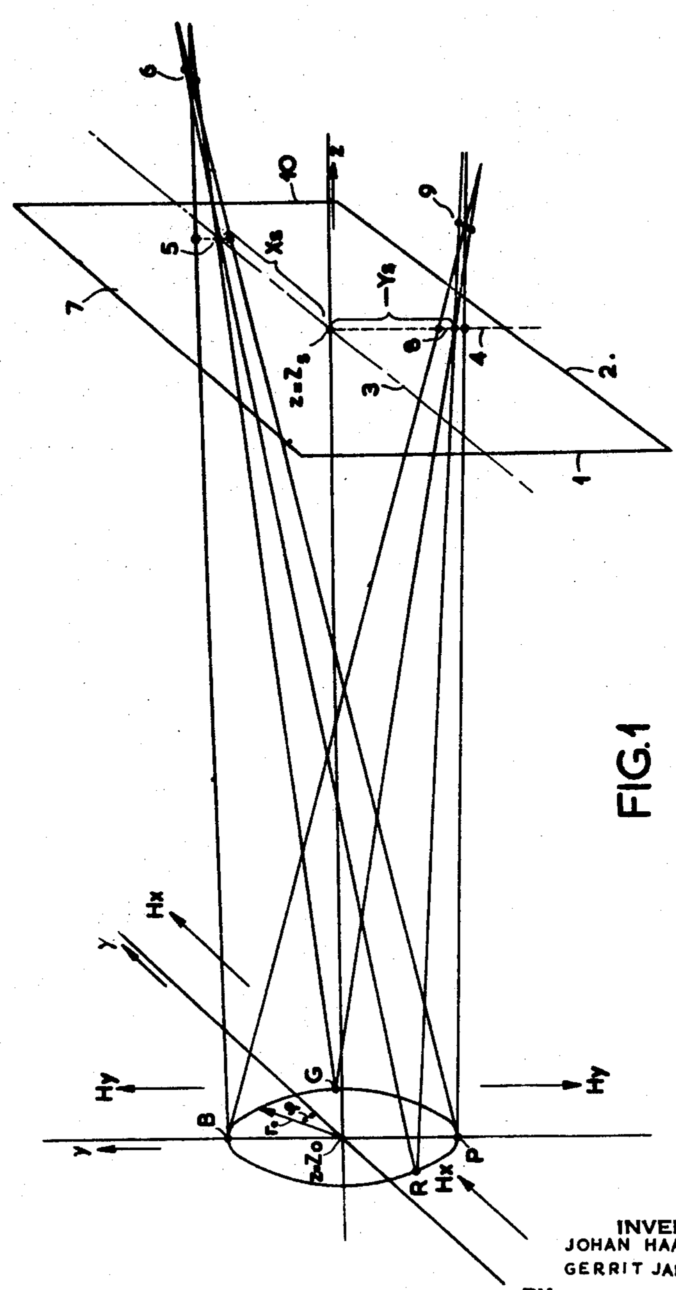

FIG. 1

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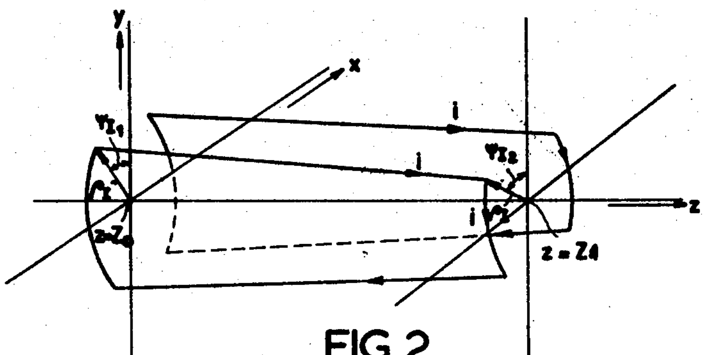

FIG. 2

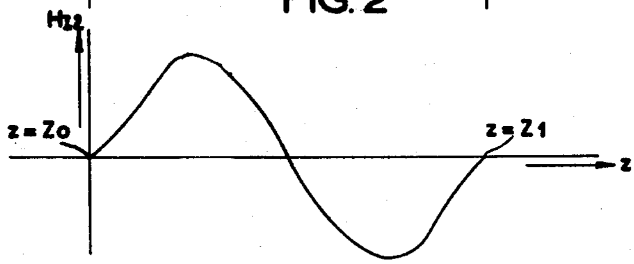

FIG. 3

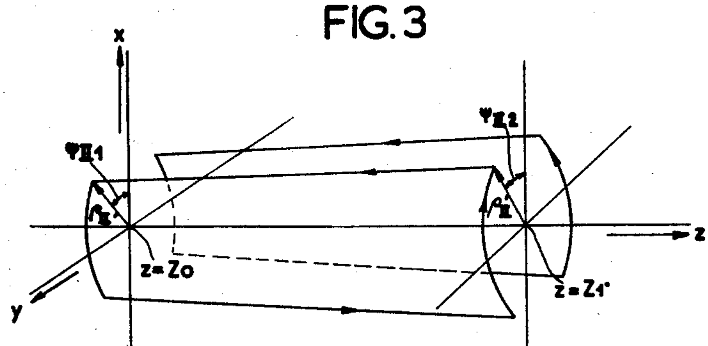

FIG. 4

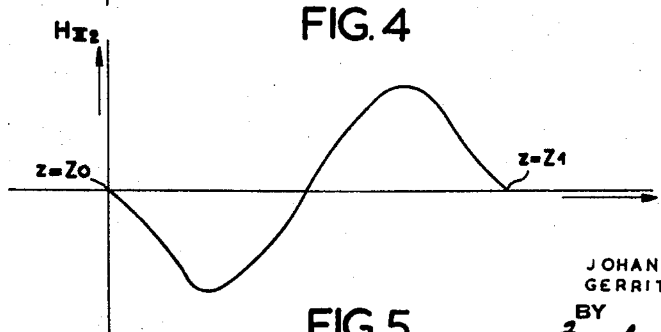

FIG. 5

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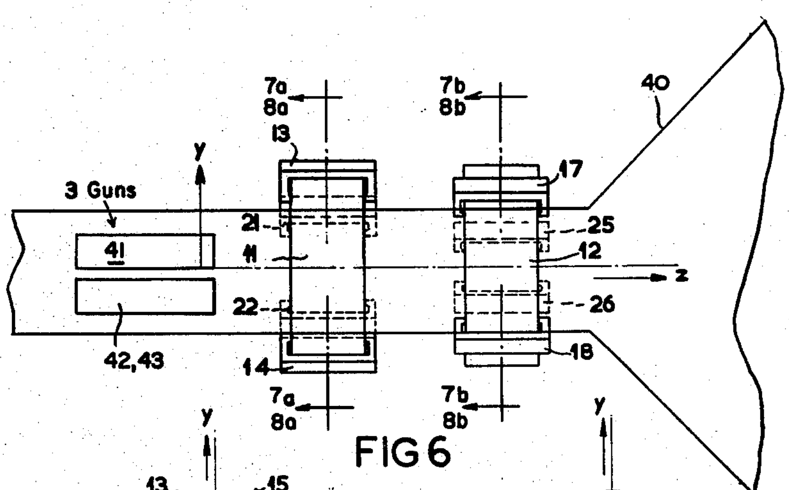

FIG 6

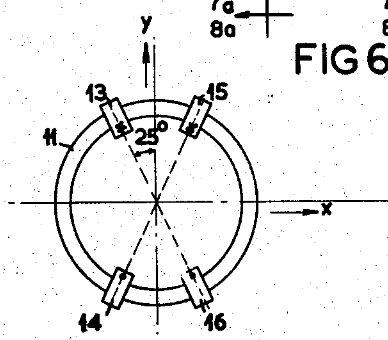

FIG. 7a

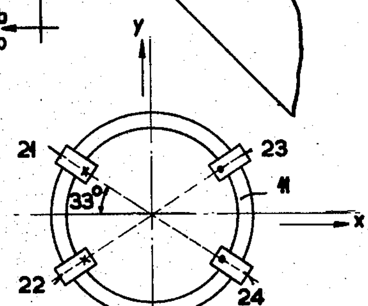

FIG. 8a

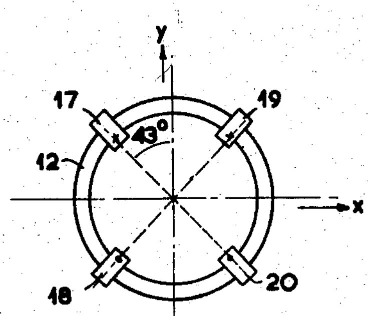

FIG 7b

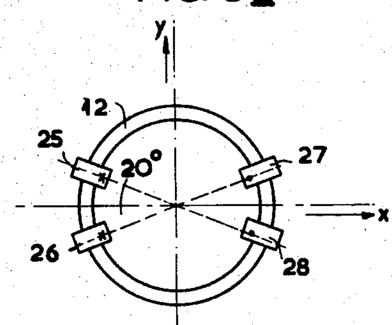

FIG 8b

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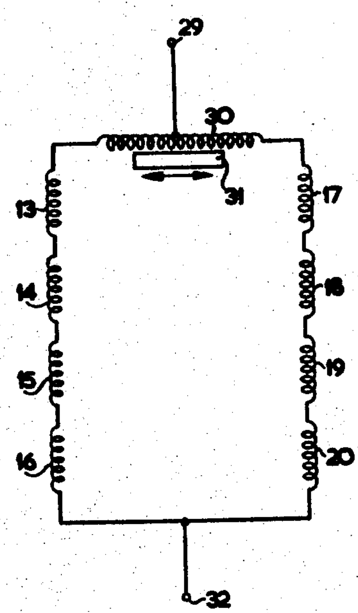

FIG.9

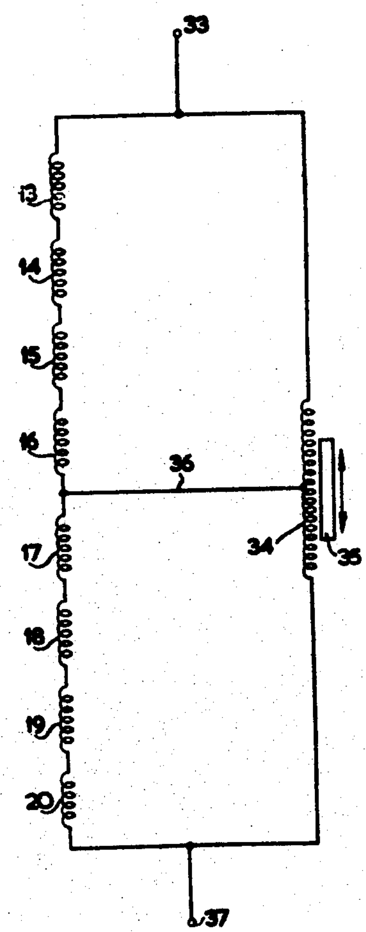

FIG.10

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United States Patent Office

2,945,157

Patented July 12, 1960

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2,945,157

PICTURE TUBES FOR THREE-COLOUR TELEVISION SYSTEMS COMPRISING DEFLECTION COILS

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Filed Oct. 16, 1958, Ser. No. 767,675

Claims priority, application Netherlands Dec. 11, 1957

10 Claims. (Cl. 315—13)

This invention relates to picture tubes for three-colour television systems comprising deflection coils and a substantially flat screen which is substantially at right angles to the axis of the tube, and in which three electron beams, emanating from three electron guns arranged at the corner points of a triangle located in a plane parallel to and opposite the said screen, are deflected in two directions substantially at right angles to each other.

As is well-known, for colour television purposes, the three beams are controlled so that each beam strikes a determined phosphor element provided on or behind the screen, whereby each element fluoresces in another colour.

In the so-called mask tube, said control is effected in a manner such that the three beams each pass through an aperture of the mask at relatively different angles of incidence and then strike the blue, red and green phosphor elements provided in punctiform on the plate located behind the mask. The term "screen" is to be understood in this case to mean the above-mentioned mask which must be struck by the three beams in each case at substantially the same point. It is known that, even though it is ensured by means of static convergency that the three beams strike the mask at one point if no deflection currents flow through the deflection coils, the beams upon being deflected by no means overlap each other on the mask as a result of the aberration faults then occurring.

In known systems, this disadvantage is obviated by the use of dynamic convergence, whereby by means of additional deflection coils and additional convergence currents the beams are influenced individually and caused to overlap on the mask, independent of the extent of the deflection. Consequently, in this case the use of three separate convergence circuits and three additional sets of deflection coils is required, which is expensive and causes difficulty in adjustment.

It has therefore previously been suggested to manufacture picture tubes in which the three electron guns are located in a plane containing the axis of the tube and in which the deflection of the three electron beams in one of the two directions is parallel to this plane. With coils of proper structure, it is thus possible to cause the three electron beams substantially to overlap throughout the mask of the picture tube, but such positioning of the electron guns is attended with the configuration of the phosphor elements provided on the plate behind the mask being such that the picture to be reproduced acquires a linear structure, while also the space in the neck of the picture tube must be larger than if, as is usually the case, the three guns are positioned at the corner points of an equilateral triangle.

The picture device according to the invention mitigates this disadvantage and is characterized in that for the direction of deflection which is parallel to a plane containing two of the three guns, the meridional image plane substantially coincides with the screen of the picture tube and for the other direction of deflection the sagittal image plane substantially coincides with said screen.

A further embodiment of the said picture device is characterized in that, by means of dynamic convergency, exerted only upon the electron beam produced by the gun located outside the plane containing the said two other guns, it is ensured that this electron beam, during deflection throughout the screen, on the screen overlaps the two other electron beams which, due to the coinciding of said image planes with the screen of the picture tube, are caused to overlap each other on the screen, independent of the extent of the deflection.

In order that the invention may be readily carried into effect, one embodiment will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows diagrammatically a deflection system in which the points of incidence of the three electron beams and the resultant pictures are shown;

Fig. 2 shows a possible embodiment of the deflection coils for deflection in the vertical direction;

Fig. 3 shows a portion of the field strength to be described hereinafter, which is produced by means of the coils of Fig. 2;

Fig. 4 shows a possible embodiment of the deflection coils for deflection in the horizontal direction;

Fig. 5 shows a portion of the field strength to be described hereinafter, which is produced by means of the coils of Fig. 4;

Figs. 6, 7 and 8 show other embodiments of the coils in horizontal and vertical directions, and

Figs. 9 and 10 show possible circuit diagrams for connecting the coils of Figs. 7 and 8.

Referring now to Fig. 1, this figure shows a rectangular system of co-ordinates, wherein the z-axis represents the axis of the picture tube and the positive z-direction is the direction in which the electrons are travelling, whereas x and y are the directions in which the electrons are deflected. In this figure, it is assumed that the electron beams B, R and G produced by three electron guns, which must strike the blue, red and green phosphor elements respectively, are not yet deflected at $z=Z_0$. It is also assumed that, by means of focussing and static convergence, the three beams are adjusted so as to strike the mask of the picture tube at the same area, that is to say at the area $x=0$, $y=0$, $z=Z_s$, if no current flows through the deflection coils.

The points of incidence of the beams at the area $z=Z_0$ are also marked with B, R and G in Fig. 1 and from this figure it appears that, when reckoning with polar co-ordinates, it is possible to indicate the co-ordinates of incidence in the plane $z=Z_0$ by:

$$r_B=r \qquad \varphi_B=90°$$
$$r_R=r \qquad \varphi_R=210°$$
$$r_G=r \qquad \varphi_G=330°$$

The mask is represented diagrammatically by lines **1**, **2**, **7** and **10** and is located in the plane $z=Z_s$ at right angles to the axis of the tube. When the three beams are deflected, it is necessary that, upon passing through the mask, they invariably pass through substantially one point, independent of the extent of the deflection.

Assuming, for example, that the beams are deflected towards the point $x=X_s$, $y=-Y_s$, $z=Z_s$. The beams B, R and G would then all three have to pass through this point, but as a result of aberration they pass through the points:

$$x_B=X_s\pm\Delta x_B \qquad (1a)$$
$$x_R=X_s\pm\Delta x_R \qquad (1b)$$
$$x_G=X_s\pm\Delta x_G \qquad (1c)$$
$$Y_B=-Y_s\pm\Delta y_B \qquad (2a)$$
$$Y_R=-Y_s\pm\Delta y_R \qquad (2b)$$
$$Y_G=-Y_s\pm\Delta y_G \qquad (2c)$$

If there is deflection only in the x-direction and if the error in this direction has been reduced to zero (that is to say $\Delta x_B=\Delta x_R=\Delta x_G=0$) then there is developed a line instead of a point which line by definition is called a meridional image or focal line and the plane containing this meridional focal line is called the meridional image plane.

If, however, upon deflection in the x-direction, the error in the y-direction has been reduced to zero (that is to say $\Delta y_B=\Delta y_R=\Delta y_G=0$) then there is developed a line instead of a point which line by definition is called a sagittal image or focal line and the plane containing this sagittal focal line is called the sagittal image plane.

Similarly, when upon deflection in the y-direction the error in the x-direction has been reduced to zero, the term sagittal focal line and, if the error is zero in the y-direction, the term meridional focal line will be used.

Thus, in Fig. 1, in which also a fourth beam emanating point P is shown for the sake of clarity, upon deflection in the positive x-direction, line **5** is the meridional focal line (that is to say **5** is the position of the beams B, R, G and P located in the meridional image plane) and line **6** is the sagittal focal line (that is to say **6** is the position of the beams B, R, G and P located in the sagittal image plane) whereas upon deflection in the negative y-direction, line **8** is the sagittal focal line and **9** is the meridional focal line.

Thus one can say:

(1) In the sagittal image plane the focal line is located in the direction of deflection,

(2) In the meridional image plane the focal line is located at right angles to the direction of deflection.

As a rule, the sagittal and meridional image planes are curved, non-coincident surfaces. Hereinafter it will be shown that if, according to the invention, for deflection in the x-direction which is parallel to the plane containing the red and green guns:

(1) The curvature of the meridional image plane is reduced to zero;

(2) This meridional image plane is caused to coincide with the mask;

(3) The so-called coma errors are substantially reduced; the red and green beams strike the mask at the same areas independent of the deflection in the x-direction, so that only the blue beam must be caused to overlap on the screen the red and green beams by means of dynamic convergence.

Similarly, it can be shown that if, according to the invention, for deflection in the y-direction:

(1) The curvature of the sagittal image plane is reduced to zero;

(2) This sagittal image plane is caused to coincide with the mask;

(3) The so-called coma errors are substantially reduced; the red and green beams strike the mask at the same areas independent of the deflection in the y-direction, so that only the blue beam must be caused to overlap on the screen the red and green beams by means of dynamic convergence.

Upon deflection in a magnetic field, so-called astigmatic errors occur, which may be determined with the aid of the formulae:

$$\Delta x=(A_4X_s^2+B_5Y_s^2)\frac{r}{Z_s-Z_o}\cos\varphi+(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o}\sin\varphi \quad (3)$$

$$\Delta y=(B_4Y_s^2+A_5X_s^2)\frac{r}{Z_s-Z_o}\sin\varphi+(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o}\cos\varphi \quad (4)$$

(See for the derivation of said formulae J. Haantjes, J. and G. J. Lubben, Philips Research Report 12, pages 46–48, February 1957) wherein A_n and B_n ($n=4, 5, 6$) are integral functions of the field strength and of the deflection, X_s is the extent of deflection in the x-direction at the area $z=Z_s$, and Y_s is the extent of deflection in the y-direction at the area $z=Z_s$.

Z_o, Z_s, r and φ are the co-ordinates shown in Fig. 1.

When the co-ordinates of incidence for the blue beam are substituted in the Formulae 3 and 4, the aberrations from the Formulae 1a and 2a are:

$$\Delta x_B=(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o} \quad (5a)$$

$$\Delta y_B=(B_4Y_s^2+A_5X_s^2)\frac{r}{Z_s-Z_o} \quad (6a)$$

Similarly, by substituting the co-ordinates of incidence of the red and green beams, the other aberrations are found, viz.:

$$\Delta x_R=-\frac{1}{2}\sqrt{3}(A_4X_s^2+B_5Y_s^2)\frac{r}{Z_s-Z_o}-\frac{1}{2}(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o} \quad (5b)$$

$$\Delta y_R=-\frac{1}{2}(B_4Y_s^2+A_5X_s^2)\frac{r}{Z_s-Z_o}-\frac{1}{2}\sqrt{3}(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o} \quad (6b)$$

$$\Delta x_G=\frac{1}{2}\sqrt{3}(A_4X_s^2+B_5Y_s^2)\frac{r}{Z_s-Z_o}-\frac{1}{2}(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o} \quad (5c)$$

$$\Delta y_G=-\frac{1}{2}(B_4Y_s^2+A_5X_s^2)\frac{r}{Z_s-Z_o}+\frac{1}{2}\sqrt{3}(A_6+B_6)X_sY_s\frac{r}{Z_s-Z_o} \quad (6c)$$

Considering only the deflection in the y-direction, then $Y_s\neq0$ and $X_s=0$, so that the Formulae 5 and 6 change to:

$$\Delta x_B=0 \quad (5'a)$$

$$\Delta y_B=B_4Y_s^2\frac{r}{Z_s-Z_o} \quad (6'a)$$

$$\Delta x_R=-\frac{1}{2}\sqrt{3}B_5Y_s^2\frac{r}{Z_s-Z_o} \quad (5'b)$$

$$\Delta y_R=-\frac{1}{2}B_rY_s^2\frac{r}{Z_s-Z_o} \quad (6'b)$$

$$\Delta x_G=+\frac{1}{2}\sqrt{3}B_5Y_s^2\frac{r}{Z_s-Z_o} \quad (5'c)$$

$$\Delta y_G=-\frac{1}{2}B_4Y_s^2\frac{r}{Z_s-Z_o} \quad (6'c)$$

From the Formulae 5′ and 6′ it may be seen that, if $B_5=0$, the aberration in the x-direction becomes zero and only an aberration in the y-direction subsists. According to the definition given hereinbefore, this is the sagittal focal line and since the radius of curvature of the sagittal image plane, in which this sagittal focal line is situated, is given approximately by the formula

$$\rho_s = \frac{1}{2B_5}$$

it follows therefrom that, by causing B_5 to approach zero, the sagittal image plane changes to a flat plane which coincides with the mask of the picture tube.

Now, an aberration in the y-direction remains, but this is the same for the red and green beams so that these beams strike the mask at the same points independent of the values of B_r and Y_s. By influencing the blue beam in proportion to Y_s^2, this beam may also be caused to strike the mask at the same points as the red and green beams. It thus suffices to pass a parabolic current of the raster frequency through one set of additional deflection coils (if Y_s is the deflection in vertical direction) and the field of said coils must then act only upon the blue beam and is directed in parallel to the x-axis.

For the x-direction $Y_s=0$ and $X_s \neq 0$, so that the aberrations are:

$$\Delta x_B = 0 \qquad (5''a)$$

$$\Delta y_B = A_5 X_s^2 \frac{r}{Z_s - Z_o} \qquad (6''a)$$

$$\Delta x_R = -\frac{1}{2}\sqrt{3} A_4 X_s^2 \frac{r}{Z_s - Z_o} \qquad (5''b)$$

$$\Delta y_R = -\frac{1}{2} A_5 X_s^2 \frac{r}{Z_s - Z_o} \qquad (6''b)$$

$$\Delta x_G = \frac{1}{2}\sqrt{3} A_4 X_s^2 \frac{r}{Z_s - Z_o} \qquad (5''c)$$

$$\Delta y_G = -\frac{1}{2} A_5 X_s^2 \frac{r}{Z_s - Z_o} \qquad (6''c)$$

If $A_4=0$, the aberration in the x-direction is again reduced to zero and, despite the aberration in the y-direction, the red and green beams strike the mask at the same areas independent of the values of A_5 and X_s. The blue beam can again be caused to overlap the red and green beams by passing a parabolic current of line frequency (if X_s is the deflection in a horizontal direction) through a second set of additional deflection coils, and said coils also must produce a field directed in parallel to the x-axis. Since in either case a field is to be produced directed in parallel to the x-axis, it suffices to use one set of additional coils which must be traversed by a current proportional to both X_s^2 and Y_s^2.

Since, in the last-mentioned case, only an aberration in the y-direction remains, whereas there is deflection in the x-direction, a meridional focal line is now concerned. The radius of curvature of the meridional image plane, in which the said meridional focal line is situated, may be represented approximately by the formula

$$\rho_m = \frac{1}{2A_4}$$

so that this meridional image plane also changes to a flat plane, if $A_4 \to 0$, which flat plane coincides with the mask of the picture tube.

If there is deflected in both the x-direction and the y-direction, all that has been described above remains true, but there is an additional aberration in both the x- and y- directions as a result of most of the right-hand terms in the Formulae 3 and 4. This aberration may always be reduced to zero by providing that the term $A_6+B_6=0$.

During deflection there also occur so-called coma-errors, which may be determined with the aid of the formulae:

$$\Delta x = A_7 X_s \left(\frac{r}{Z_s - Z_o}\right)^2 \cos^2\varphi + A_8 X_s \left(\frac{r}{Z_s - Z_o}\right)^2 \sin^2\varphi + 2B_8 Y_s \left(\frac{r}{Z_s - Z_o}\right)^2 \sin\varphi\cos\varphi \qquad (7)$$

$$\Delta y = B_7 Y_s \left(\frac{r}{Z_s - Z_o}\right)^2 \sin^2\varphi + B_8 Y_s \left(\frac{r}{Z_s - Z_o}\right)^2 \cos^2\varphi + 2A_8 X_s \left(\frac{r}{Z_s - Z_o}\right)^2 \sin\varphi\cos\varphi \qquad (8)$$

wherein A_n and B_n ($n=7, 8$) again are integral functions of the field strength and of the deflection and the other symbols have the same meaning as in the Formulae 3 and 4.

From (7) and (8) it appears that the non-coincidence of the blue, red and green beams as a result of coma errors can be obviated only if $A_7=A_8=B_7=B_8=0$.

The requirements found above are elaborated for constructing the coils for said deflection system.

For obviating the astigmatism in the y-direction, it is necessary that $B_5=0$ or:

$$B_5 = -\frac{1}{2}\int_{Z_0}^{Z_s} \frac{Y'^2}{Y_s^2} dz + k^2 \int_{Z_0}^{Z_s} \frac{H_{I0}^2 (z-Z_s)^2}{Y_s^2} dz - 2k \int_{Z_0}^{Z_s} \frac{H_{I2} Y (z-Z_s)^2}{Y_s^2} \cdot dz = 0 \qquad (9)$$

H_{I0} and H_{I2} are the coefficients of the power series,

$$H_x = H_{I0} + H_{I2} y^2 + \ldots = H_{I0}\left(1 + \frac{H_{I2}}{H_{I0}} y^2 + \ldots\right) \qquad (10)$$

wherein H_x is the field strength in the x-direction in the plane $x=0$. H_{I0} has the same sign (in this case assumed as positive) along the z-axis between the values $z=Z_0$ and $z=Z_1$, whereas the sign of H_{I2} varies between the same values as a function of z. In this case $z=Z_0$ is the beginning and $z=Z_1$ is the end of the deflection coil system, k is a proportionality constant and the terms Y and Y' represent the extent of the deflection and the variation thereof in the y-direction as given by the relations $Y=Y(z)$ and

$$Y' = \frac{dY}{dz}$$

for which there applies: $Y=Y'=0$ if $z=Z_0$. The first two terms of (9) provide together a positive contribution, so that the third term must provide a negative contribution. For a positive H_x, Y is negative with the direction of propagation of the electrons, chosen in this example, so that, since the contribution of the deflection is maximum at the end of the coils, the contribution of H_{I2} must also be negative at the end of the coils.

For obviating the astigmatism in the x-direction, it is necessary that $A_4=0$ or:

$$A_4 = \frac{3}{2}\int_{Z_0}^{Z_s} \frac{X'^2}{X_s^2} dz - 2k \int_{Z_0}^{Z_s} \frac{H_{I2} X (z-Z_s)^2}{Y_s^2} dz = 0 \qquad (11)$$

H_{II2} is a coefficient of the power series,

$$H_y = H_{II0} + H_{II2} x^2 + \ldots = H_{II0}\left(1 + \frac{H_{II2}}{H_{II0}} x^2 + \ldots\right) \qquad (12)$$

wherein H_y is the field strength in the y-direction in the plane $y=0$. For H_{II0} there applies, under similar conditions as for H_{I0}, that the sign along the z-axis remains the same (in this case also assumed as positive) and under similar conditions as for H_{I2} there applies that the sign of H_{II2} varies as a function of z, while X and X' represent the extent of the deflection and its variation in the x-direction as given by: $X=X(z)$ and

$$X'=\frac{dX}{dz}$$

for which there applies: $X'=X=0$ if $z=Z_0$. The first term of (11) provides a positive contribution so that the second term must provide a negative contribution. For a positive H_y, X is positive with the directions chosen in this example so that H_{II2} must be positive at the end of the coils.

The conditions $A_6+B_6=0$ is satisfied if

$$A_6+B_6=k\int_{Z_0}^{Z_s}\frac{H_{II0}\cdot Y}{X_sY_s}dz-k\int_{Z_0}^{Z_s}\frac{H_{I0}X}{X_sY_s}dz$$
$$+2k\int_{Z_0}^{Z_s}\frac{H_{II2}Y(z-Z_s)^2}{X_sY_s}dz-2k\int_{Z_0}^{Z_s}\frac{H_{I2}X(z-Z_s)^2}{X_sY_s}dz=0$$

The first two terms provide a positive contribution so that the last two terms must provide a negative contribution.

Now, Y and Y_s are negative at the end of the coils whereas X_s is positive. According to the foregoing, H_{II2} must be positive at this area, so that the total contribution of the third term is positive. For the fourth term there applies X and X_s positive, Y_s negative, while H_{I2}, as explained above, is negative. The fourth term thus provides a negative contribution and if the sum of the third and fourth terms is to be negative, it is necessary that

$$|H_{I2}|>|H_{II2}|$$

In order to obviate the coma errors, it is necessary and sufficient that the terms $A_7=A_8=B_7=B_8=0$. Now:

$$B_7=\frac{3}{2}+k\int_{Z_0}^{Z_s}\frac{H_{I2}(z-Z_s)^3}{X_s}dz \qquad (13)$$

$$B_8=1-B_7 \qquad (14)$$

Consequently, the condition $B_7=B_8=0$ can never be fulfilled but a satisfactory result is obtained if

$$\int_{Z_0}^{Z_s}\frac{H_{I2}(z-Z_s)^3}{X_s}dz=0$$

If for H_{I2} a function is chosen as shown in Fig. 3, the above-mentioned condition is satisfied, while H_{I2} provides a negative contribution towards the end of the coils ($z=Z_1$).

Such a course of the field strength may be obtained with a set of coils as shown in Fig. 2. These coils serve to deflect in the y-direction and for deflection in the negative direction they must convey a current i, the direction of which is indicated by arrows. An H_x field is produced as given by the Formula 10 and an H_{I2} field as shown in Fig. 3, since there applies with great approximation:

$$h_I=\frac{H_{I2}}{H_{I0}}=\frac{-3+4\cos^2\psi I}{\rho_I}$$

wherein ρ_I and ψ_I are the magnitudes indicated in Fig. 2.

$$\{\rho_I=\text{constant},\ \psi_I=\psi_I(z)\}$$

As previously mentioned, H_{I0} is positive, so that, if H_{I2} has to satisfy the form shown in Fig. 3, it is necessary that $h_I>0$ in the vicinity of $z=Z_0$ and that $h_I<0$ in the vicinity of $z=Z_1$, while for z midway between Z_0 and Z_1, it is necessary that $h_I=0$. The last-mentioned condition is fulfilled if $\psi_I=30°$. For $z\rightarrow Z_1$ there applies that $\psi_I>30°$ and for z in the vicinity of Z_0 there applies that $\psi_I<30°$.

In a similar manner it is found from

$$A_7=\frac{3}{2}-k\int_{Z_0}^{Z_s}\frac{H_{II2}(z-Z_s)^3}{Y_s}dz \qquad (15)$$

$$A_8=1-A_7 \qquad (16)$$

that the condition $A_7=A_8=0$ cannot be satisfied, but that in this case also it suffices if

$$\int_{Z_0}^{Z_s}\frac{H_{II2}(z-Z_s)^3}{Y_s}dz=0$$

For this purpose, a function must be chosen for H_{II2} as shown in Fig. 5. In this case the last-mentioned integral becomes zero and, furthermore, H_{II2} provides a positive contribution towards the end of the coils ($z=Z_1$).

The course of the field strength shown in Fig. 5 may be obtained with a set of coils as shown in Fig. 4. For this set of coils the same is true as for the coils of Fig. 2. An H_y field is produced in accordance with Formula 12 and an H_{II2} field as shown in Fig. 5, since there applies with great approximation:

$$h_{II}=\frac{H_{II2}}{H_{II0}}=\frac{-3+4\cos^2\psi_{II}}{\rho_{II}}$$

wherein ρ_{II} and ψ_{II} are the magnitudes indicated in Fig. 4. The conditions are fulfilled if $h_{II}<0$ in the vicinity of $z=Z_0$, $h_{II}>0$ in the vicinity of $z=Z_1$ and again $h_{II}=0$ approximately midway between Z_0 and Z_1.

For this there applies $\psi_{II}=30°$ at the centre, $\psi_{II}<30°$ for $z\rightarrow Z_1$ and $\psi_{II}>30°$ for z in the vicinity of Z_0. Furthermore, it is necessary to fulfill the condition

$$|H_{I2}|>|H_{II2}|$$

which may be achieved if for approximately equal values for H_{I0} and H_{II0} the angles ψ_I and ψ_{II} are chosen so that there always applies $|h_I|>|h_{II}|$.

For the sake of completeness, it is to be noted that the shape of the halves of the coils is dependent upon the radius ρ, upon the length of the coils Z_1-Z_0 and upon the distance to the mask Z_s-Z_0.

If ψ_I is called ψ_{I1} at the area Z_0 and ψ_{I2} at the area Z_1 and if the angle ψ_{II} is called ψ_{II1} at the area Z_0 and ψ_{II2} at the area Z_1, then each half of the coil for the vertical deflection (y-direction) at a distance $Z_s-Z_0=44$ cms. from the screen of the tube acquires the dimensions:

$$Z_1-Z_0=12.5 \text{ cms.};\ \rho_I=3 \text{ cms.}$$

$$\psi_{I1}=11°30';\ \psi_{I2}=36°30'$$

For the horizontal (x-direction) this is:

$$Z_1-Z_0=12.5 \text{ cms.};\ \rho_{II}=3 \text{ cms.}$$

$$\psi_{II1}=34°30';\ \psi_{II2}=27°30'$$

Another embodiment is shown in Figs. 6, 7 and 8.

In these figures, **11** and **12** indicate annular ferromagnetic cores, which may be arranged around the neck of a picture tube (**40**) and on which coils **13** to **20** are toroidally wound which serve for deflection in the vertical direction and coils **21** to **28** which serve for deflection in the horizontal direction. Ring **12** is closer to the screen than ring **11**. In Fig. 6 the z-axis is also the axis of the picture tube, the coils **13**, **14**, **17** and **18** only being shown in full lines and the coils **21**, **22**, **25**, and **26** in dashed lines. The three guns are shown at the left, with the blue gun **41** located on the Y axis, and the red gun **42** below it. The green gun **43** (see Fig. 1) is in line with and behind the red gun **42** and will not be seen.

Figs. 7 and 8 show cross-sections of the cores **11** and **12** and in these cross-sections the orientations of the coils and the directions of the currents are shown. Thus, the (x) sign indicates that the current at this area flows in the direction of the positive z-axis, whereas a (.) sign indicates that the current at this area flows in the direction of the negative z-axis.

For these coils also there apply the formulae:

$$h_I=\frac{-3+4\cos^2\psi_I}{\rho_I} \text{ and } h_{II}=\frac{-3+4\cos^2\psi_{II}}{\rho_{II}}$$

wherein ψ is half the acute angle between two coils having the same direction of current.

In Fig. 7a, $\psi_{I1}=25°$ and in Fig. 7b $\psi_{I2}=43°$, whereas in Figs. 8a and 8b the different angles are given by:

$$\psi_{II1}=33° \text{ and } \psi_{II2}=20°$$

For these values again the condition is fulfilled: $|h_I|>|h_{II}|$ and the functions H_{I2} and H_{II2} are obtained as shown in Figures 3 and 5. Since the cores **11** and **12** contain all the coils, for this system of deflection coils $\rho_I=\rho_{II}=\rho$, wherein ρ is the mean radius of the cores.

A possible method of circuiting the various coils for deflection in the vertical direction is shown in Figs. 9 and 10. In these latter figures, the coils are represented by inductor symbols and given the same reference numerals as in Figs. 6 to 8. Figs. 6 to 8 show the structural arrangement of the coils relative to the tube, whereas Figs. 9 and 10 show suitable circuit arrangements for energizing the coils.

In Fig. 9, the coils **13** to **16** arranged on the core **11** are connected in series, as are the coils **17** to **20** arranged on the core **12**. The two series-branches are connected together at their lower ends to a terminal **32** and at their upper ends, via the variable inductance **30**, to a terminal **29**.

By shifting a core **31**, the sawtooth current supplied to the terminals **29** and **32** may be distributed over the two branches in an arbitrary manner. It will be evident that the connection to the coils must be such that the direction of the current in each part has the proper polarity in the direction of the z-axis. The coil **30** is required to be adjusted so that it does not act upon the deflection of the beams.

Fig. 10 shows another method of connecting the same coils. In this case the two series-branches are connected in series, a tapping between the coils **16** and **17** being connected via a lead **36** to a tapping on a variable inductance **34**. The sawtooth current is supplied to terminals **33** and **37** and, by shifting a core **35**, the current may be distributed arbitrarily over the various branches so that the correct number of ampere turns for each branch may be obtained.

The method of connecting for deflection in the horizontal direction may be similar in either case.

It is to be noted that, in the example under consideration, the red and green beams always coincide and the blue beam is influenced by means of dynamic convergence. However, it will be evident that it is alternatively possible to cause overlapping of two other beams, dependent upon the positioning of the deflection coils. It is necessary only that the deflection in one of the two directions is parallel to the plane in which two of the three guns are located.

It will also be evident that, if the error in the x-direction cannot be reduced completely to zero, it is necessary to apply dynamic convergence also to the red and green beams. True, in this case, again three additional deflection coils are required, but the energy required for the convergency of the red and green beams may be considerably less than if use is made of deflection coils which are not built up in accordance with the invention.

What is claimed is:

1. A color cathode-ray tube comprising a substantially planar screen located substantially perpendicular to the axis of and at one end of the tube, two electron guns arranged at the other end of the tube spaced from the tube axis and directed toward the screen and at which a straight line in a plane parallel to that of the screen joining the two guns is spaced from the axis, and a deflection coil system for deflecting the electron beams produced by the two guns in two orthogonal directions, one of said orthogonal directions extending parallel to the said straight line joining two of the said guns, said coil system being operable to cause the beams from said two guns to form a linearly elongated cross-section whose longest dimension is perpendicular to said one deflection direction and which is located in a meridional image plane which substantially coincides with the plane of said screen for said one deflection direction, and to form a linearly elongated cross-section whose longest dimension is parallel to the other deflection direction and which is located in a sagittal image plane which substantially coincides with the plane of said screen for said other deflection direction.

2. A three-color cathode-ray tube comprising a substantially planar screen located substantially perpendicular to the axis of and at one end of the tube, three electron guns arranged at the other end of the tube and symmetrically around the tube axis and directed toward the screen and at which straight lines in a plane parallel to that of the screen joining the three guns form a triangle, a deflection coil system for deflecting the electron beams produced by the three guns in two orthogonal directions, one of said orthogonal directions extending parallel to the straight line joining two of the said guns in the parallel plane, said coil system being operable to cause the beams from said two guns to form a linearly elongated cross-section whose longest dimension is perpendicular to said one deflection direction and which is located in a meridional image plane which substantially coincides with the plane of said screen for said one deflection direction, and to form a linearly elongated cross-section whose longest dimension is parallel to the other deflection direction and which is located in a sagittal image plane which substantially coincides with the plane of said screen for said other deflection direction, and convergence means acting on the beam from the third gun in accordance with its deflection to cause it to coincide with the other two beams at the screen.

3. A three-color cathode-ray tube comprising a substantially planar screen located substantially perpendicular to the axis of and at one end of the tube, three electron guns arranged at the other end of the tube and symmetrically around the tube axis and directed toward the screen and at which straight lines in a plane parallel to that of the screen joining the three guns form an equilateral triangle, and a deflection coil system for producing a deflecting field within the tube for deflecting the electron beams produced by the three guns in two orthogonal directions, said tube axis corresponding to the z-axis of a rectangular system of coordinates, one of said orthogonal directions extending parallel to the x-axis and to the straight line joining two of the said guns in the parallel plane, the other orthogonal direction extending parallel to the y-axis, said deflection system producing within the tube a deflecting field having a y-component H_y in said one deflection direction, as measured in the plane $x=0$, determined by a power series of x^2 of the form.

$$H_y=H_{II0}\left(1+\frac{H_{II2}}{H_{II0}}x^2+\ .\ .\ .\ \right)$$

and an x-component H_x in the other deflection direction, as measured in the plane $y=0$, determined by a power series of y^2 of the form

$$H_x=H_{I0}\left(1+\frac{H_{I2}}{H_{I0}}y^2+\ .\ .\ .\ \right)$$

and in which the integrals

$$\int_{Z_0}^{Z_s} H_{I2}(z-z_s)^3dz \text{ and } \int_{Z_0}^{Z_s} H_{II2}(z-z_s)^3dz$$

are substantially zero for both field components, where the coefficients H_{I0} and H_{II0} are positive and the coefficients H_I and H_{II2} are functions of z, z_0 is the coordinate of the end of the deflection system remote from the screen and z_s is the position of the screen in the coordinate system, the value of the terms $H_{I2}/H_{I0}=h_I$ for deflection in the y-direction at the end of said coil system adjacent said screen being negative and at the beginning of said coil system being positive, the value of the term

$$H_{II2}/H_{II0}=h_{II}$$

for deflection in the x-direction has the opposite polarities and h_I having an absolute value that exceeds h_{II}, wherein the coefficients H_{I0}, H_{II0}, H_{I2} and H_{II2} are determined by measuring the x-component H_x of the magnetic field in the plane $x=0$ at a particular y-point and substituting in the equation

$$H_x=H_{I0}+H_{I2}y^2$$

and by measuring the y-component H_y of the magnetic field in the plane $y=0$ at a particular x-point and substituting in the equation

$$H_y=H_{II0}+H_{II2}x^2$$

whereby the meridional image plane for said one direction of deflection produced by said deflecting field is substantially coincident with the surface of the screen, and the sagittal image plane for the other direction of deflection is also substantially coincident with the surface of the screen.

4. In combination; a cathode-ray tube having a substantially planar apertured screen extending substantially at right angles to the longitudinal axis of the tube and three electron guns arranged symmetrically around the tube axis for producing three electron beams directed toward the screen; and electromagnetic deflection means located between said electron guns and said screen for producing a deflecting field within the tube for deflecting said electron beams in two substantially perpendicular directions, whereby said beams may be caused jointly to scan said screen, one of said perpendicular directions extending parallel to a straight line in a plane parallel to the screen joining two of the guns, said deflection means including first and second ferromagnetic annular members surrounding the tube with the second member being closer to the screen than the first member, a first coil system for deflecting said beam in said one direction of deflection comprising a first set of four coils wound toroidally on the first annular member and a second set of four coils wound toroidally on the second annular member, a second coil system for deflecting said beam in the other direction comprising a third set of four coils wound toroidally on the first annular member and a fourth set of four coils wound toroidally on the second annular member, two coils of each set of four coils being mounted substantially diametrically opposite one another and being connected so as to be traversed by deflection current in opposite senses, whereby said deflection means produce a deflection field in which the meridional image plane for said one direction is substantially coincident with the surface of said screen, and the sagittal image plane for the other direction of deflection is also substantially coincident with the surface of said screen.

5. The combination set forth in claim 4 wherein the first and second sets of coils produce a field having a magnitude equal to

$$\frac{-3+4\cos^2\psi_{II}}{\rho_{II}}$$

which magnitude is predominately negative for the first set and predominately positive for the second set, and the third and fourth sets produce a field having a magnitude equal to

$$\frac{-3+4\cos^2\psi_I}{\rho_I}$$

which latter magnitude is predominately positive for the third set and predominately negative for the fourth set wherein ψ_{II} is the angle between lines drawn from the first and second sets toward the tube axis and the said one deflection direction, ψ_I is the angle between lines drawn from the third and fourth sets toward the tube axis and the other deflection direction, and ρ_{II} and ρ_I are the radii, respectively, of the first and second annular members.

6. The combination set forth in claim 5 wherein the coils of each set are connected in series each with a portion of an impedance and the two sets and their associated portion of the impedance are connected in parallel, said impedance being variable to control the relative magnitude of the current through the coil sets.

7. The combination set forth in claim 5 wherein the coils of both sets are connected in series, and all the coils are connected in parallel with a variable impedance, an intermediate portion of said impedance being connected to the junction of the two sets of coils.

8. The combination of claim 5 wherein means are provided for acting only on the beam from the third gun for converging it in accordance with its deflection to cause it to coincide at the screen with the other two beams.

9. In combination; a cathode-ray tube having a substantially planar apertured screen extending substantially at right angles to the longitudinal axis of the tube and three electron guns arranged symmetrically around the tube axis for producing three electron beams directed toward the screen; and electromagnetic deflection means located between said electron guns and said screen for producing a deflecting field within the tube for deflecting said electron beams in two substantially perpendicular directions, whereby said beams may be caused jointly to scan said screen, one of said perpendicular directions extending parallel to a straight line in a plane parallel to the screen joining two of the guns, said deflection means including a first pair of coil halves diametrically surrounding the tube for deflection in said one direction and a second pair of coil halves diametrically surrounding the tube between and symmetrically relative to the first pair for deflection in the other direction, the coils of said first pair having a shape producing a field at which the value

$$h_{II}=\frac{-3+4\cos^2\psi_{II}}{\rho_{II}}$$

measured at the coil end adjacent the screen is predominately positive but at the beginning of the coil is predominately negative, the coils of said second pair having a shape producing a field at which the value

$$h_I=\frac{-3+4\cos^2\psi_I}{\rho_I}$$

at said coil ends is predominately negative but predominately positive at the beginning, wherein ρ_{II}, and ρ_I are the radii, respectively, from the tube axis to the coil halves, ψ_{II} is the angle between ρ_{II} and the said one direction, and ψ_I is the angle between ρ_I and the other direction.

10. The combination set forth in claim 9 wherein the coil halves of both pairs are trapezoidal in shape with the first pair having its wide end adjacent the screen and with the second pair having its narrow end adjacent the screen.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,945,157 July 12, 1960

Johan Haantjes et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 19, before "point" insert -- from --.

Signed and sealed this 4th day of July 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

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