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Barkow et al.

[11] **3,721,930**

[45] **March 20, 1973**

[54] **DEFLECTION YOKE FOR USE WITH IN-LINE ELECTRON GUNS**

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[52] **U.S. Cl.** **335/213,** 335/210

[51] **Int. Cl.** **H01f 7/00**

[58] **Field of Search** 335/210, 213; 313/76

[56] **References Cited**

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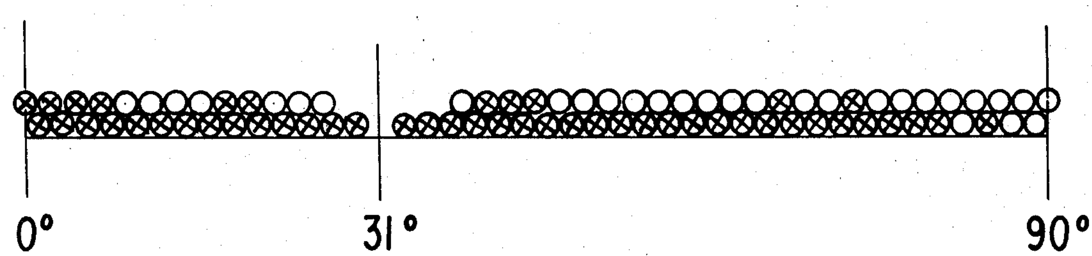
Primary Examiner—George Harris
Attorney—Eugene M. Whitacre et al.

[57] **ABSTRACT**

A deflection yoke for a television picture tube utilizing coplanar horizontal in-line electron guns includes vertical and horizontal coil windings selected for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism which underconverges the electron beams along the vertical deflection axis such that the beams are substantially converged at all points on a scanned raster of the picture tube. The desired convergence characteristics are achieved by winding the vertical and horizontal coil conductors such that the conductor distribution in each quadrant of a cross-section of the yoke is least in a region between 25° and 45° measured from the vertical deflection axis of the yoke.

6 Claims, 9 Drawing Figures



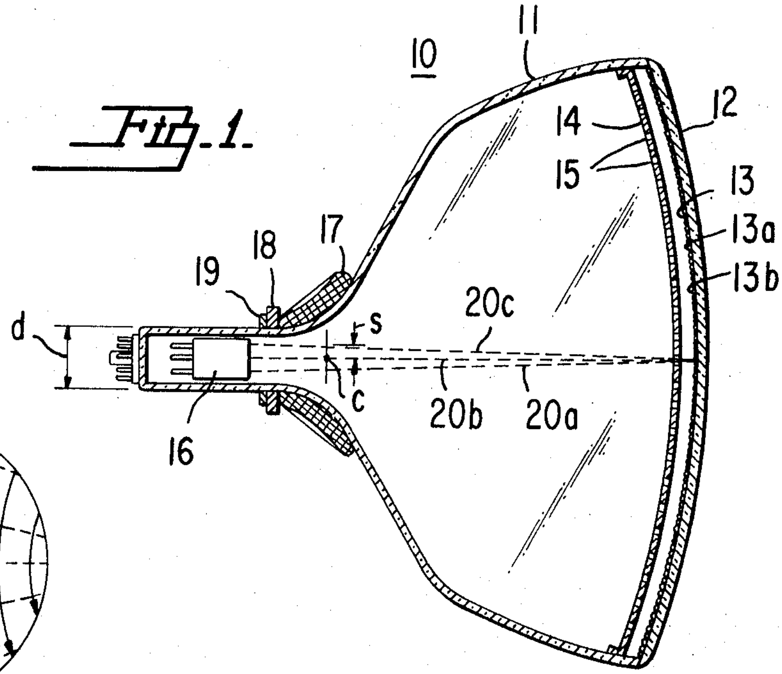


FIG. 1.

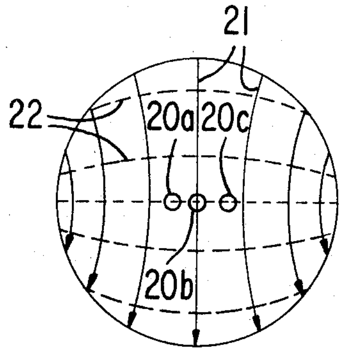


FIG. 2.

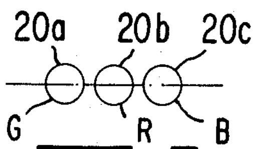


FIG. 3a.

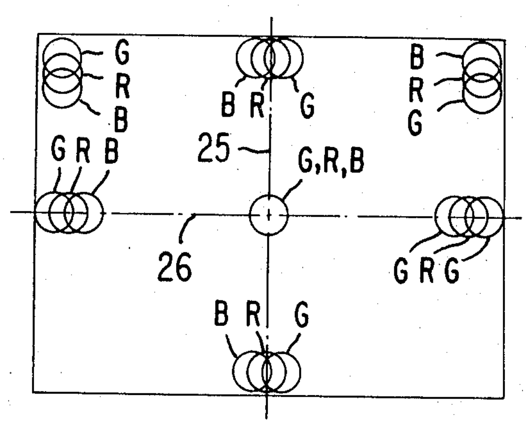


FIG. 3b.

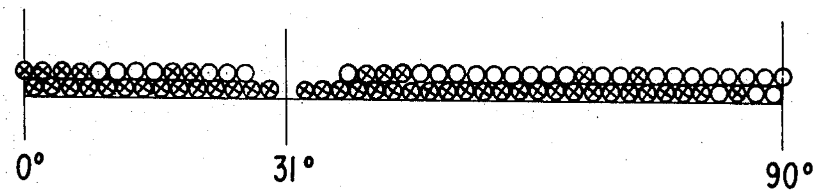


FIG. 5.

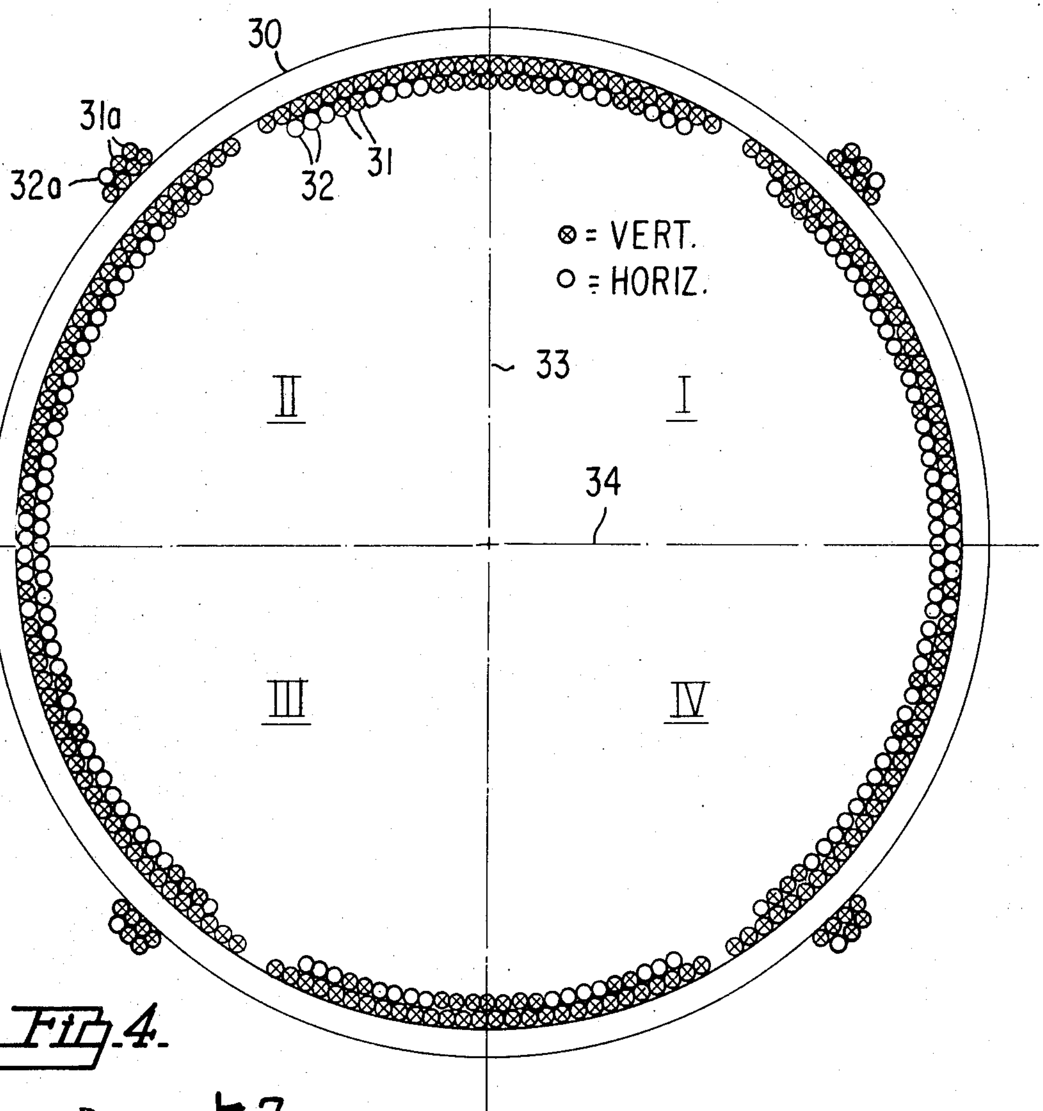


Fig. 4

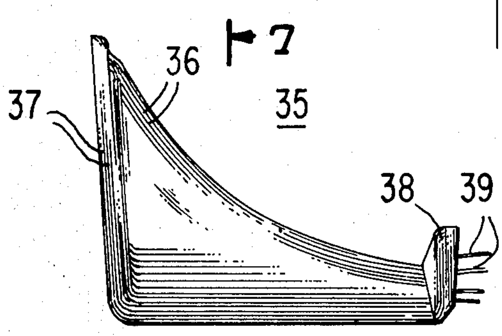


Fig. 6

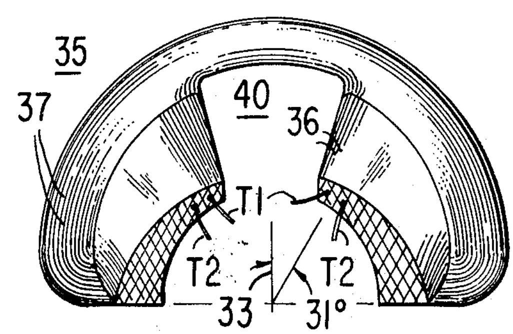


Fig. 7

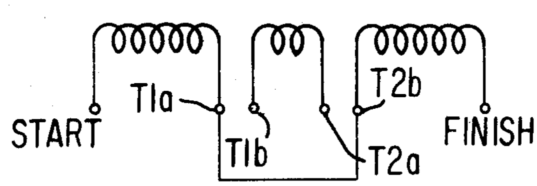


Fig. 8

DEFLECTION YOKE FOR USE WITH IN-LINE ELECTRON GUNS

BACKGROUND OF THE INVENTION

This invention relates to deflection yokes for use with coplanar in-line electron beams.

Color image display systems, such as color television receivers, for example, generally utilize a cathode ray tube as the display device. A color television picture tube includes a pattern of different color phosphor elements deposited on the inside surface of a transparent faceplate of the tube for forming a viewing screen. There are usually three different color phosphor elements, red, green and blue, which are excited by three electron beams produced by an electron gun assembly disposed inside a neck portion at the other end of the tube. The beams are modulated by video signals and are scanned over the viewing screen to form a raster and thereby reproduce a televised scene. Most often an electromagnetic deflection yoke including two pairs of horizontal and two pairs of vertical deflection coils suitably energized by scanning currents at line and field scanning rates provides the magnetic deflection field for deflecting the beams horizontally and vertically over the raster.

The color television picture tube also includes a color selection structure such as a shadow mask or aperture grill disposed a short distance from the phosphor elements for ensuring that portions of each color representative beam land only on their respective color phosphor elements. This condition is necessary to ensure color purity. In addition to the requirement of color purity, it is necessary that the three beams converge on the viewing screen as they are scanned over the raster. Misconvergence of the beams shows up as an undesirable color fringing around edges of objects in a televised scene. Misconvergence may be measured as a separation between the ideally superimposed red, green and blue lines of a crosshatch pattern observed on the viewing screen as a suitable test signal is coupled to the television receiver.

The electron beams are usually converged at the center of the viewing screen by a suitable static convergence apparatus in which the positions of magnets relative to the three beams are adjusted for bending the beams such that they do converge at the center of the screen. As the beams are deflected from the center of the screen they converge at points falling short of the screen because the screen is relatively flat and the beams tend to converge at points on a sphere having a radius smaller than the distance from the beam deflection plane to the center of the screen.

Misconvergence may also be caused by deflection yoke aberrations such as astigmatism which can nonuniformly and undesirably affect the separated beams in the yoke deflection field.

Misconvergence of the beams is commonly corrected by the use of dynamic convergence correction apparatus disposed around the neck of the picture tube and which includes electromagnets energized by line and field rate scanning waveforms to dynamically vary the convergence correction applied to the beams. Such apparatus is complicated and costly.

A color television picture tube may utilize an electron beam gun assembly producing three coplanar in-line horizontal beams in conjunction with a viewing

screen including phosphor elements disposed in adjacent vertical strips. The advantages of systems utilizing a picture tube of this type are disclosed in detail in copending application Ser. No. 217,780, filed concurrently herewith for A. M. Morrell et al and entitled "-Self-converging color Television Display System" and copending application Ser. No. 217,772, filed concurrently herewith for Josef Gross et al and entitled "Self-Converging Color Image Display System." Systems utilizing a picture tube of this type may produce a picture with satisfactory convergence with greatly simplified convergence apparatus providing a suitable deflection yoke is also utilized with the system.

An object of this invention is to provide an improved deflection yoke for use with a color image display device utilizing coplanar in-line electron guns.

In accordance with the invention a deflection yoke for use with a color image display device utilizing an electron gun assembly producing three coplanar horizontal in-line beams is provided. The yoke includes a pair of vertical and a pair of horizontal deflection coils, the coil winding distribution of which is selected for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of the beams along the vertical deflection axis and underconvergence of the beams along the horizontal deflection axis.

In one embodiment the yoke comprises a pair each of vertical an horizontal deflection coils toroidally wound around a magnetically permeable core. The coil winding density distribution of the yoke is selected such that the conductor density distribution is least in a region between 25° and 45° measured from the vertical deflection axis in each quadrant of the yoke.

In another embodiment the yoke comprises a pair each of vertical and horizontal saddle-type coils. The coil winding density distribution of the yoke is selected such that the conductor density distribution is least in a region between 25° and 45° measured from the vertical deflection axis in each quadrant of the yoke.

A more detailed description of the invention is given in the following detailed description and accompanying drawings of which:

FIG. **1** is a sectional view of a color image display system embodying a deflection yoke according to the invention;

FIG. **2** illustrates the net deflection field nonuniformities produced by the deflection yoke of FIG. **1**;

FIGS. **3***a* and **3***b* illustrate a convergence condition of electron beams of the system of FIG. **1** under the influence of the deflection field illustrated in FIG. **2**;

FIG. **4** illustrates the winding distribution at the rear of a toroidal deflection yoke suitable for use in the system of FIG. **1**;

FIG. **5** linearly illustrates the winding distribution of one quadrant of the yoke of FIG. **4**;

FIG. **6** illustrates a saddle-type coil suitable for use in the deflection yoke of FIG. **1**;

FIG. **7** is a transverse cross-sectional view of the coil of FIG. **6**; and

FIG. **8** is an electrical schematic diagram of the coil shown in FIGS. **6** and **7**.

FIG. **1** is a sectional view of a color image display system embodying a deflection yoke according to the invention. A color television picture tube **10** includes an evacuated glass envelope **11**. The front portion of the envelope **11** is a viewing screen and faceplate **12** on the inside of which is deposited a plurality of red, green and blue phosphor elements **13**, **13***a* and **13***b*. Disposed within the tube spaced a relatively short distance from the phosphor elements is an aperture mask **14** including a plurality of apertures **15**. The apertures **15** are so registered with relation to the phosphor elements that they serve to screen the electron beams such that portions of the beams pass through apertures **15** to impinge only on their respective color phosphor elements. Within the other end of glass envelope **11** is an electron beam gun assembly **16** for producing three in-line electron beams lying in a horizontal plane.

Disposed around the outside of glass envelope **11** along a flared portion thereof is a deflection yoke **17** according to the invention adapted to be energized by a suitable source of scanning currents, not shown, for producing a magnetic field which will deflect the electron beams horizontally and vertically to form a scanned raster on the viewing screen. A deflection plane C, the plane from which the beams undergoing deflection and reaching the viewing screen appear to emanate, is located half way along the longitudinal axis of the yoke at right angles thereto. A more detailed description of the deflection yoke **17** will be given in conjunction with FIGS. **4** and **6**.

Disposed behind the deflection yoke **17** on the next portion of glass envelope **11** is a static convergence assembly **18**. Static convergence assembly **18** includes magnets whose positions are adjustable such that they compensate for any error in beam alignment and cause the beams to converge at a point in the center of the viewing screen when the beams are not deflected. A suitable static assembly for use with in-line electron gun assembly **16**, is disclosed in copending application Ser. No. 217,757, filed concurrently herewith by Robert L. Barbin and entitled "Magnetic Beam Adjusting Arrangements." Disposed behind the beam convergence assembly **18** is a beam purity control device **19** of conventional design which serves the purpose of causing the beams to land on their respective color phosphor elements.

FIG. **2** illustrates the net deflection field nonuniformities produced by the deflection yoke of FIG. **1**. Although the horizontal and vertical magnetic field nonuniformities will vary from point to point along the longitudinal axis of the tube, the net or predominant deflection field is as shown in FIG. **2**.

A deflection field for deflecting the beams in a horizontal direction, which field is produced by a pair of horizontal deflection coils, is illustrated by the solid lines of flux **21** which extend in a generally vertical direction. It should be noted that this magnetic field is pincushion shaped, the lines of flux **21** being convex when viewed from the center of the figure. This horizontal deflection field produces negative horizontal isotropic astigmatism of the electron beams. Isotropic astigmatism is effective along an axis of deflection. Negative astigmatism along the horizontal deflection axis tends to converge the horizontal in-line beams. Conversely, positive astigmatism along the vertical deflection axis tends to converge the horizontal in-line beams. Also shown in FIG. **2** are lines of flux **22** representing a magnetic deflection field for deflecting the beams in a vertical direction, which field is produced by a pair of vertical deflection coils of deflection yoke **17**. It should be noted that the vertical deflection field is generally barrel-shaped, the lines of flux **22** being concave viewed from the center of the figure. The vertical deflection field produces positive vertical isotropic astigmatism of the beams. The purpose of selecting the yoke for producing the particular deflection fields described will be disclosed in conjunction with FIG. **3**.

FIG. **3** illustrates a convergence pattern of the electron beams of the system of FIG. **1** under the influence of the deflection field of FIG. **2**. FIG. **3***a* illustrates the relative positions of the green, red and blue beams **20***a*, **20***b* and **20***c* respectively as they would appear at the deflection plane (plane C in FIG. **1**) of the yoke viewed from the faceplate end of the picture tube.

FIG. **3***b* illustrates in exaggerated form the convergence condition of the beams in the corners of the scanned raster and along vertical and horizontal deflection axes **25** and **26**, respectively. It should be noted that each electron beam illuminates several phosphor elements of a particular color at the same time. The phosphor elements are of course separated from each other but this is not shown. FIG. **3***b* illustrates the convergence of the whole beams at various regions on the viewing screen.

At the center of the raster the green, red and blue beams are converged. This center convergence is accomplished by the alignment of the beams provided by the construction of the electron gun assembly **16** and the action of the static convergence assembly **18** shown in FIG. **1**. Along the horizontal deflection axis **26** the green, red and blue beams are shown underconverged, that is, there is a separation of the beams along the horizontal axis and their order is the same as that of the beams in the deflection plane as shown in FIG. **3***a*. This condition exists at both ends of the raster along the horizontal axis **26**. It is to be understood that the underconvergence of the beams on the horizontal axis extremities is reduced as a function of the distance from the center of the raster at which point the beams are converged. The underconvergence of the horizontal beams is caused by the negative horizontal isotropic astigmatism of the yoke which characteristic is illustrated in FIG. **2**.

At the extremities of the vertical axis **25** in FIG. **3***b* the red, green and blue beams are shown overconverged that is, the blue and green beams have crossed at some point such that at the viewing screen the blue and green beams are on opposite sides relative to their orientation of the deflection plane of the yoke. This overconvergence of the beams along the vertical axis is reduced as a function of the distance from the center of the raster at which point the beams are converged. The overconvergence of the beams along the vertical axis is caused by the positive vertical isotropic astigmatism characteristic of the yoke which characteristic is illustrated in FIG. **2**.

It has been discovered in accordance with the invention that by proportioning the relative amounts of positive and negative astigmatism in the deflection coils, a deflection field can be produced which will cause the horizontal in-line beams to substantially converge in the corners of the raster as well as at all other points of the raster as illustrated in FIG. 3*b*. By utilizing a deflection yoke according to the invention, which exhibits the described astigmatism characteristics, the beams can be made to substantially converge at all points in the raster without requiring dynamic convergence correction apparatus.

An ideal line-focus yoke has negative horizontal isotropic astigmatism and positive vertical isotropic astigmatism and is free of anisotropic corner astigmatism or trap. This pattern of astigmatism is necessary for maintaining convergence of the three horizontal in-line beams along the horizontal and vertical deflection axes. Convergence would simultaneously be carried in the corners of the raster and ideally result in convergence of the beams at all points on the raster. As a practical matter, it has been determined that this ideal line-focus condition can be realized only with picture tubes having a diagonal viewing screen measurement of about 14 inches or less. With picture tubes having larger viewing screen diagonal measurements a line-focus condition will not be realized and a trap condition such as described in conjunction with FIG. 3*b* will result. With trap present, a feature of the invention provides that the positive and negative astigmatism must be proportioned between the vertical and horizontal deflection coils by properly selecting the conductor winding distribution such that the trap error is balanced against the on-axes errors and a substantial convergence condition is achieved at all points on the raster.

Substantial convergence as used herein refers to a convergence condition that is commercially acceptable. It is common practice for a television receiver manufacturer to set a misconvergence limit requirement in the design specifications of a particular television receiver. It is always desirable to keep the misconvergence as close to zero as possible, but as a practical matter the manufacturing variations make zero misconvergence practically impossible to attain. A design goal set by one manufacturer is that the misconvergence of the beams measured at a distance of one half inch from the edges of the scanned raster should be less than **50** mils on a picture tube having a viewing screen diagonal measurement of **15** inches. The design limit increases for larger viewing screen sizes and would be about 62 mils on a picture tube having a viewing screen diagonal measurement of 25 inches. As a practical matter the above-mentioned manufacturing variations, particularly variations in the color picture tube and deflection yoke, result in a distribution of convergence errors from one receiver to another. Many receivers will have far less than the 50 mil design goal. On the other hand, other receivers made from the same batch of parts on the same production line will have a greater misconvergence. Receivers actually sold commercially have been found to have misconvergence errors greater than 125 mils. As used herein the term substantial convergence means a misconvergence not greater than 125 mils. The misconvergence of the beams may be observed by the separation of the ideally superimposed red, blue and green lines of a crosshatch pattern on lines appearing on the viewing screen as a suitable test signal is coupled to the television receiver.

FIG. **4** illustrates the winding distribution at the rear of a toroidal deflection yoke according to the invention and suitable for use in the system of FIG. **1**. FIG. **4** illustrates the cross-sectional winding distribution at the rear or small diameter portion of the yoke. At this portion of the yoke the conductors of the second layer lie on the top of and between the conductors of the first layer. It is to be understood that at the front end or large diameter end of the yoke the conductors form a single layer, with the conductors in the second layer being interleaved directly between adjacent conductors of the first layer. Vertical conductors **31** and horizontal conductors **32** are wound in toroidal fashion about a ferrite core **30**. The conductors **31** and **32** are active deflection field producing conductors. A portion of the return conductors **31***a* and **32***a* are shown on the outside circumference of core **30**. It is to be understood that these return conductors also extend all the way around the yoke. The conductor winding distribution in all of the quadrants I, II, III and IV bounded by the vertical and horizontal deflection axes **33** and **34** respectively, is similar, resulting in a deflection yoke with symmetrical winding distribution in all of the quadrants. The vertical and horizontal conductors are generally interleaved as illustrated for producing the desired magnetic field characteristics.

FIG. **5** illustrates in a linear manner the winding distribution of one quadrant of the yoke of FIG. **4**. In accordance with the invention the proper amounts of positive and negative astigmatism as described above are proportional between the horizontal and vertical coils. Proportioning the astigmatism between the coils by selecting the conductor distribution as illustrated in FIGS. **4** and **5** accomplishes a particular balance of misconvergence that is, underconvergence of the beams along the horizontal axis and overconvergence of the beams along the vertical axis and relatively little misconvergence and trap in the corners of the raster. In accordance with the invention the winding distribution of the yoke having its astigmatism proportioned between the coils as described above is further selected to have a minimum conductor density distribution in a region extending between 25° and 45° measured from the vertical deflection axis **33**. In the specific embodiment shown the area of minimum conductor density distribution extends around a point located 31° from the vertical deflection axis **22**. It has been determined that placing the area of minimum conductor density distribution in this region results in substantial convergence of the beams in the corners of the raster as well as along the axes. It is to be understood that the range of minimum conductor density distribution will depend on the type of picture tube selected and in general will not extend over the whole region between 25° and 45° from the vertical deflection axis. The result of this balancing of astigmatism and placement of the minimum conductor density distribution in the above described region is a yoke scanning a raster in which the beams are substantially converged at all points without the requirement of complicated dynamic convergence correction apparatus.

FIG. **6** illustrates a saddle-type coil suitable for use in the deflection yoke of FIG. **1**. For most purposes it is known that a deflection yoke utilizing saddle-type coils may be substituted for a deflection yoke utilizing toroidally wound coils for use with a color television picture tube. The teaching of the invention is also applicable to saddle coils as well as toroidal deflection coils. In

FIG. **6** a saddle-shaped coil **35** comprises active magnetic field producing side conductors **36** which are joined at the front of the yoke by end turns comprising transverse conductors **37** and which are joined at the rear of the yoke by transverse end turns **38**. Although not shown in the view in FIG. **6** the side conductors and front and rear end turns define a coil window in which there are no conductors. As is known in the art the saddle-type coil winding machine may be stopped after a preselected number of turns have been wound around the coil arbor for the purpose of measuring with a conductor so that the coil may be electrically tapped. Such tap conductors **39** are illustrated in FIG. **6**.

FIG. **7** is a transverse cross-sectional view of the coil **35** of FIG. **6**. The coil window **40** is partially illustrated in FIG. **7**. In the cross-sectional portion of the coil are shown conductors **T1** and **T2** illustrating two different taps which have been pulled from the coil during the winding thereof. As illustrated, the similar point between the two taps on either side of the coil is **31** degrees from the vertical deflection axis **22**.

FIG. **8** is an electrical schematic diagram of the coil shown in FIGS. **6** and **7**. It can be seen that a portion of the conductors between taps **T1** and **T2** have been electrically bypassed during the interconnection of the taps of the coil. Thus, even through the conductors are physically in place in the coil to help retain its shape they are electrically disconnected from the coil. Thus, in a region extending between the angles of 25° to 45° measured from the vertical deflection axis of the yoke the active field producing conductor distribution density is least. Thus, a deflection yoke utilizing saddle-type coils may have its winding distribution selected to proportion the astigmatism between its coils in the same manner as described above and to have a minimum of conductor density distribution in a region between 25° and 45° from the vertical axis. A deflection yoke utilizing saddle-type deflection coils having electrically bypassed turns is described in U.S. Pat. No. 3,588,566 issued to Robert L. Barbin on June 28, 1971. However, in addition the saddle-type coils described herein according to the invention produce the desired balance of positive and negative astigmatism and have the least concentration of conductor turns in that transverse cross-section of the coils extending between 25° and 45° measured from the vertical deflection axis. In a deflection yoke utilizing saddle-type coils a pair of diametrically opposed vertical deflection coils are disposed 90° from a pair of diametrically opposed horizontal deflection coils within the yoke core. Therefore, although the taps in the desired region are shown for only one of the four deflection coils utilized in the yoke it is to be understood that the other three coils are similarly tapped such that the conductor distribution density of each coil is least in a region between 25° and 45° measured from the vertical deflection axis of the yoke.

We claim:

1. A deflection yoke adapted for use in a color image display system in which a picture tube includes an electron gun assembly for producing a plurality of coplanar in-line beams which converge at and are scanned over a raster on the viewing screen of said picture tube, said yoke comprising:

a pair of vertical deflection coils and a pair of horizontal deflection coils for deflecting said beams vertically and horizontally, the conductor distribution of said coils being selected for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of said beams along the vertical deflection axis and underconvergence of said beams along the horizontal deflection axis as observed on the viewing screen of said picture tube as said beams are scanned over said raster.

2. A deflection yoke adapted for use in a color image display system in which a picture tube includes an electron gun assembly for producing a plurality of coplanar in-line beams which converge at and are scanned over a raster on the viewing screen of said picture tube, said yoke comprising:

a ferrite core;

a pair of vertical and a pair of horizontal deflection coils toroidally wound around said core for deflecting said beams vertically and horizontally, the conductor distribution of said coils being selected for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of said beams along the vertical deflection axis and underconvergence of said beams along the horizontal deflection axis as observed on the viewing screen of said picture tube as said beams are scanned over said raster.

3. A deflection yoke adapted for use in a color image display system in which a picture tube includes an electron gun assembly for producing a plurality of coplanar in-line beams which converge at and are scanned over a raster on the viewing screen of said picture tube, said yoke comprising:

a ferrite core;

a pair of vertical deflection coils and a pair of horizontal deflection coils toroidally wound around said core for deflecting said beams vertically and horizontally, the conductor density distribution in each quadrant of a transverse cross-section of said yoke bounded by the horizontal and vertical deflection axes being least in an angular portion extending between 25° and 45° measured from said vertical deflection axis for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of said beams along the vertical deflection axis and underconvergence of said beams along the horizontal deflection axis as observed on the viewing screen of said picture tube as said beams are scanned over said raster.

4. A deflection yoke adapted for use in a color image display system in which a picture tube includes an electron gun assembly for producing a plurality of coplanar in-line beams which converge at and are scanned over a raster on the viewing screen of said picture tube, said yoke comprising:

a ferrite core;

a pair of saddle-type vertical deflection coils and a pair of saddle-type horizontal deflection coils disposed around the inside of said core for deflecting said beams vertically and horizontally, the conductor distribution of said coils being selected for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of said beams along the vertical deflection axis and underconvergence of said beams along the horizontal deflection axis as observed on the viewing screen of said picture tube as said beams are scanned over said raster.

5. A deflection yoke adapted for use in a color image display system in which a picture tube includes an electron gun assembly for producing a plurality of coplanar in-line beams which converge at and are scanned over a raster on the viewing screen of said picture tube, said yoke comprising:

a ferrite core;

a pair of saddle-type vertical deflection coils and a pair of saddle-type horizontal deflection coils disposed around the inside surface of said core and adapted to be energized for deflecting said beams vertically and horizontally, the active field producing conductor density distribution of a cross-section of said coils being least in an angular portion extending between 25° and 45° from the vertical deflection axis for producing positive vertical isotropic astigmatism and negative horizontal isotropic astigmatism for producing overconvergence of said beams along the vertical deflection axis and underconvergence of said beams along the horizontal deflection axis as observed on the viewing screen of said picture tube as said beams are scanned over said raster.

6. A deflection coil according to claim 5 wherein each of said coils includes conductors in said region extending between 25° and 45° which are connected separately from conductors in other than said region such that scanning current is bypassed around said conductors in said region between 25° and 45° for producing said least active field producing conductor distribution density in said region between 25° and 45°.

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