Feb. 18, 1958 W. H. BARKOW 2,824,267

DEFLECTION YOKE FOR MULTI-BEAM CATHODE RAY TUBE

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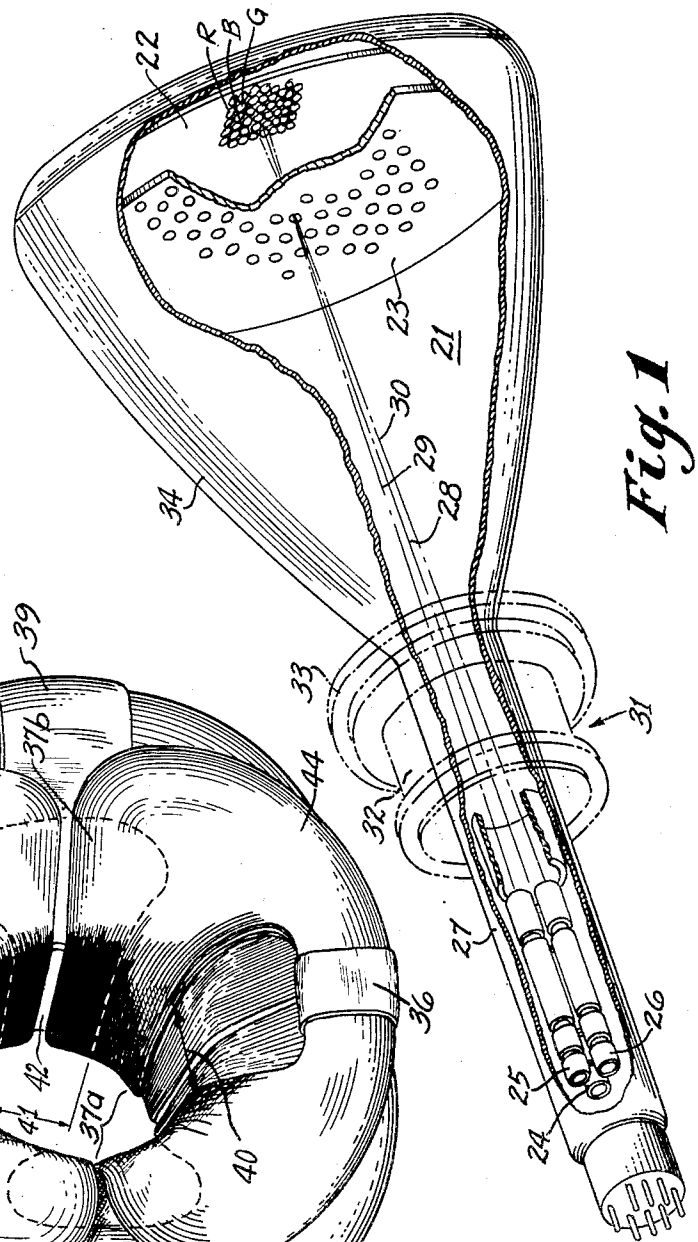


Fig. 1

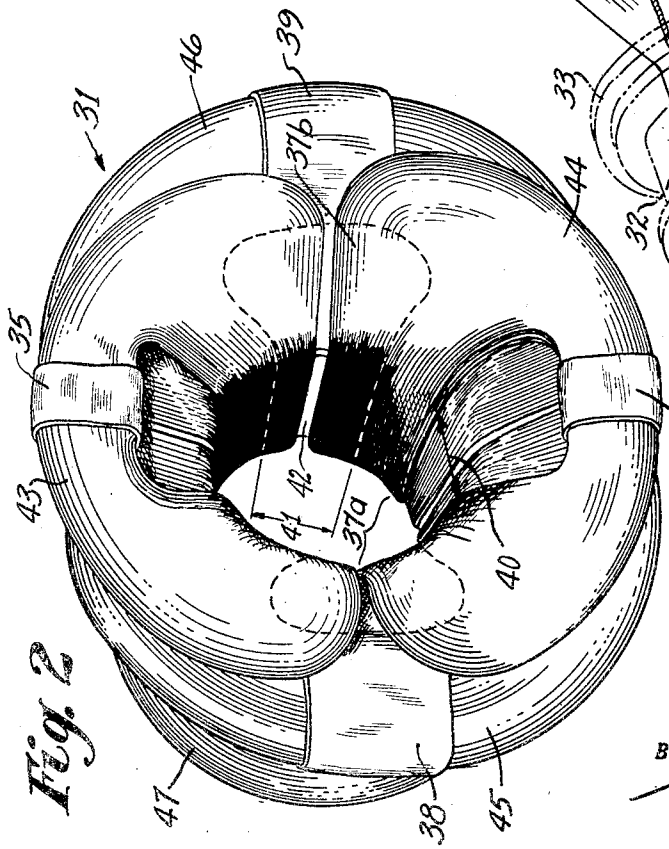


Fig. 2

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Fig. 3

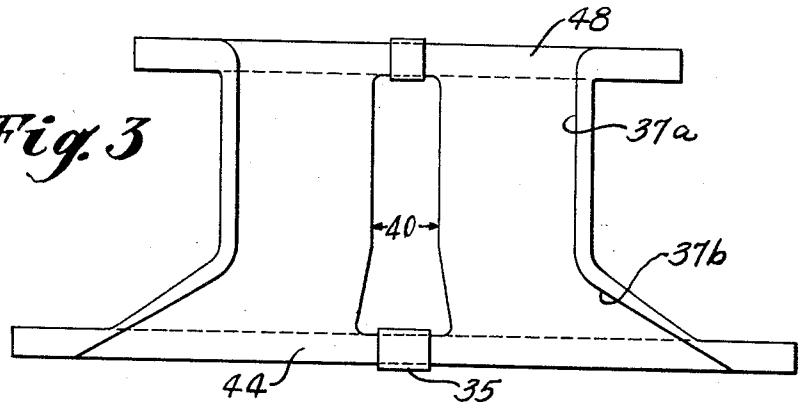
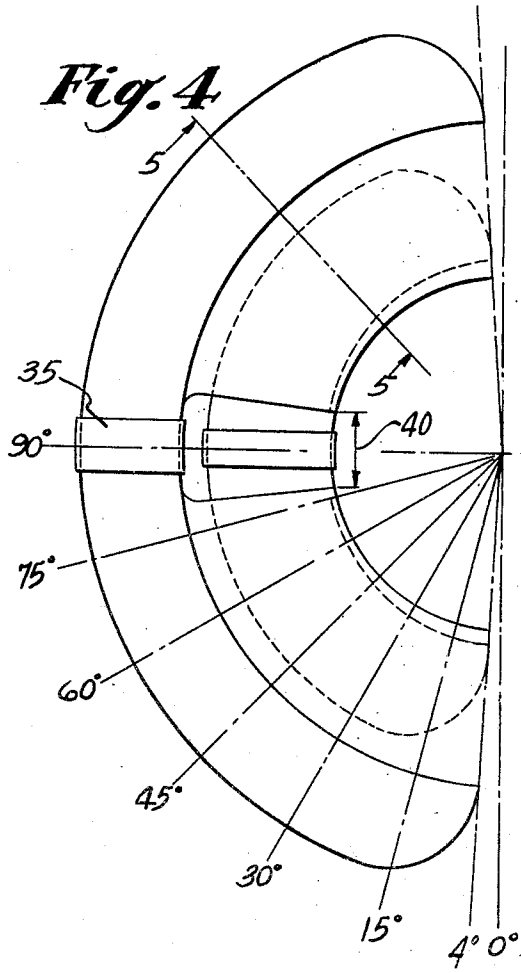


Fig. 4



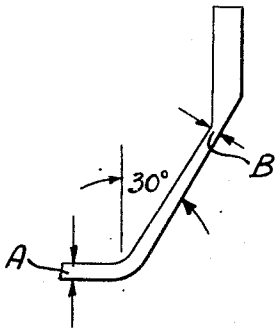


Fig. 5

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Fig. 6

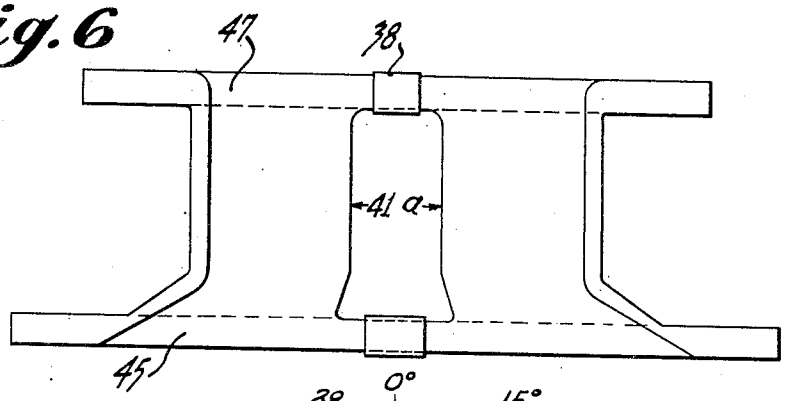


Fig. 7

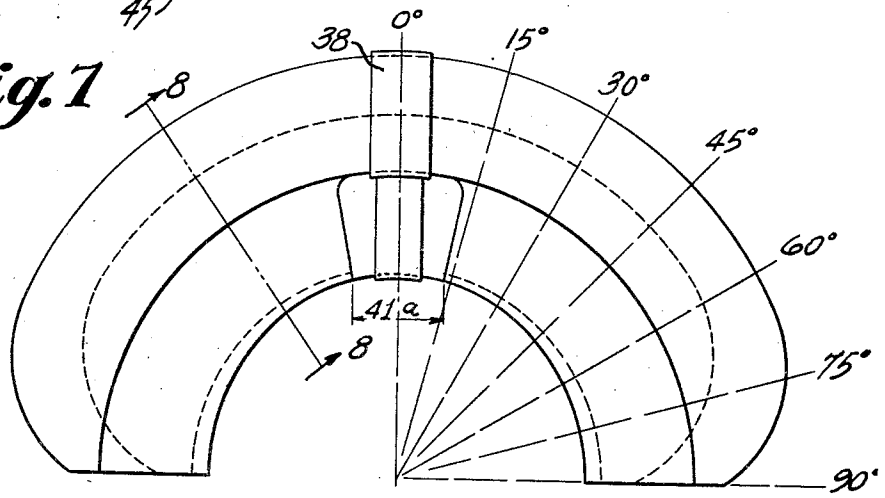


Fig. 8

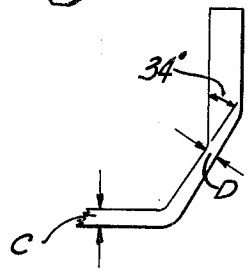


Fig. 9

ANGLE	COIL THICKNESS			
	A	B	C	D
4°	.125	.075	—	—
15°	.121	.073	.056	.043
30°	.107	.065	.070	.052
45°	.086	.052	.091	.067
60°	.068	.041	.109	.080
75°	.057	.034	.120	.087
90°	—	—	.125	.092

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Fig. 10

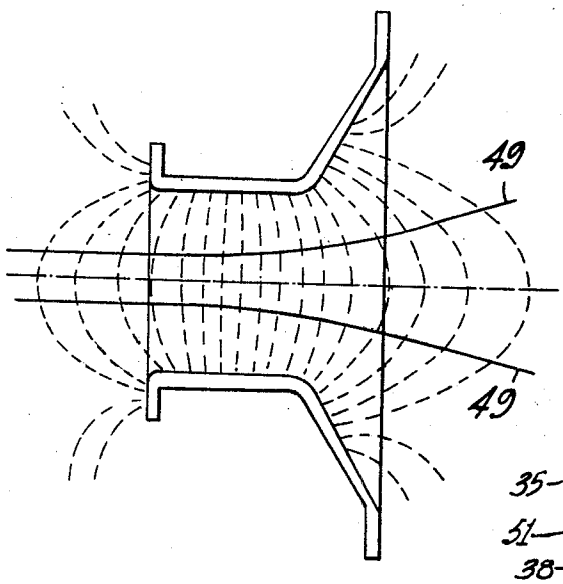


Fig. 11

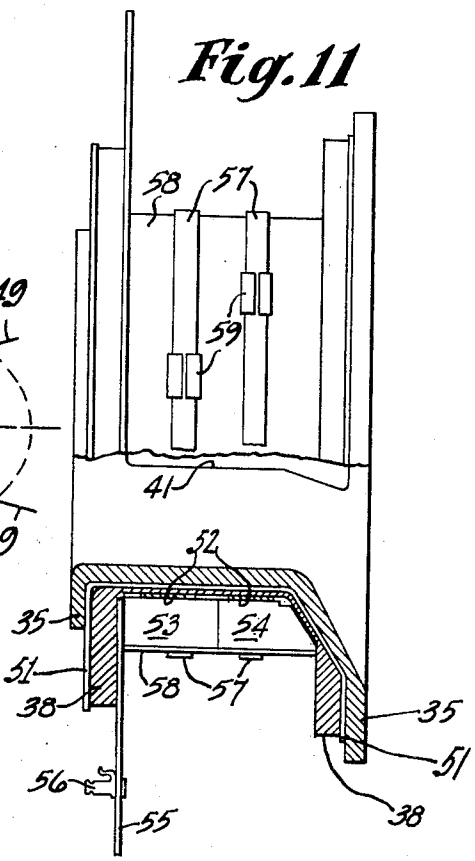
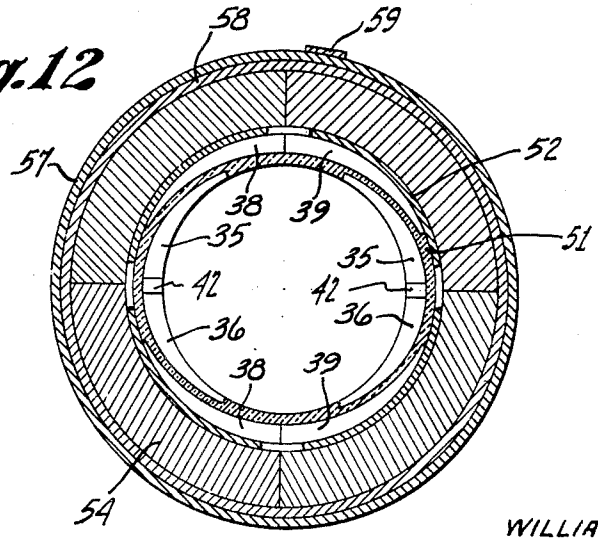


Fig. 12



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Fig. 13

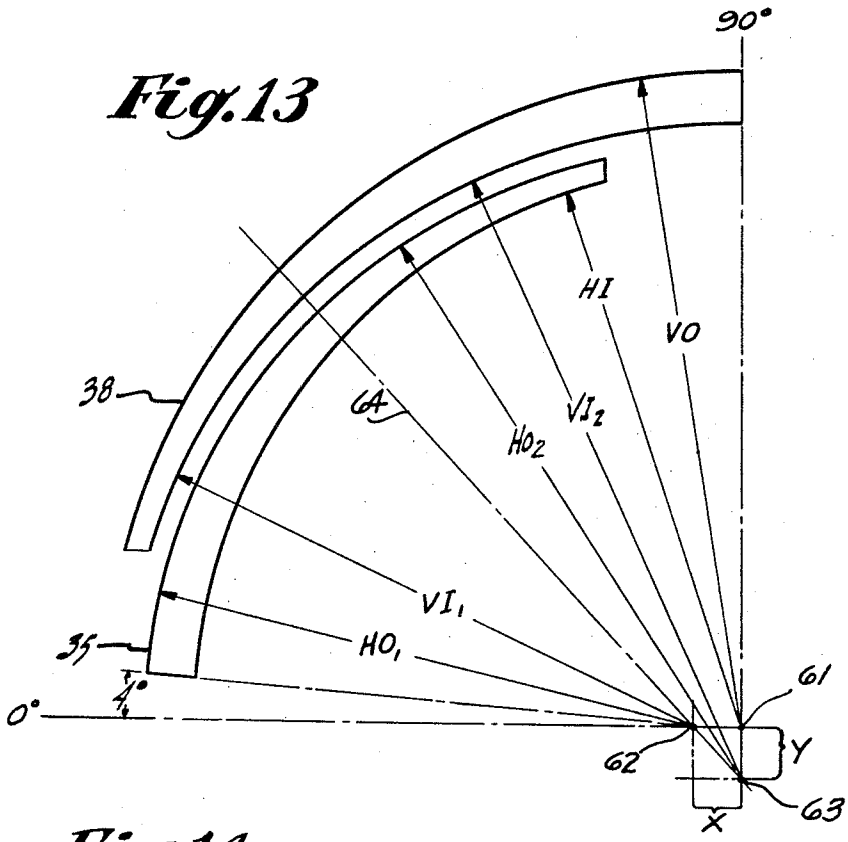
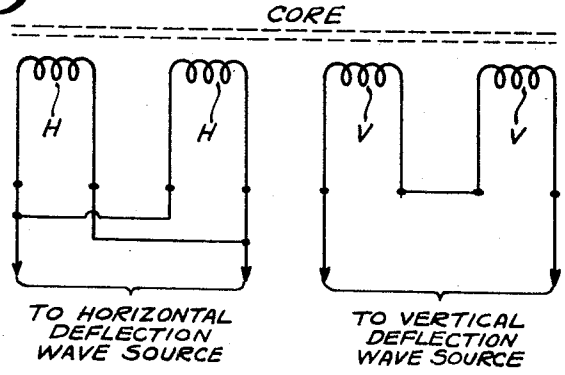


Fig. 14



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2,824,267

DEFLECTION YOKE FOR MULTI-BEAM CATHODE RAY TUBE

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Application November 2, 1953, Serial No. 389,578

5 Claims. (Cl. 317—200)

This invention relates to deflection yokes and particularly to yokes adapted for use with multi-beam cathode ray tubes such as a tri-color kinescope in a color television receiving apparatus.

In multi-beam cathode ray tubes such as a tri-color kinescope of the general type disclosed in a paper by H. B. Law titled "A three-gun shadow-mask color kinescope," published in the Proceedings of the I. R. E., October 1951, vol. 39, No. 10, at page 1186, the color selection is achieved by the angle at which the different electron beams approach the target electrode structure. The general principles of such a tube are illustrated in Patent No. 2,595,548, issued May 6, 1952, to A. C. Schroeder and titled "Picture Reproducing Apparatus." A tube of this character has a luminescent screen as part of the target electrode structure and in which different phosphor areas produce differently colored light when excited by electron beam components impinging upon it from different angles. Color selection of this type is facilitated by means of a perforated shadow mask, also forming part of the target electrode structure, through the apertures of which the electron beams must pass to reach the phosphor screen. The present invention relates to apparatus by means of which to control the deflection of the plurality of electron beams over the target electrode structure to scan a raster therein.

The invention also relates to a color kinescope of the type described in another paper titled "A one-gun shadow-mask color kinescope," by R. R. Law, published in the Proceedings of the I. R. E., vol. 39, No. 10, October 1951, at page 1194. The target electrode structure of the one gun color kinescope is essentially the same as that of the three gun color kinescope. Also, the luminescent phosphor screen of the target electrode is excited by electron beam components passing through a shadow mask as in the three gun color kinescope apparatus. In the case of the one gun color kinescope, however, the electron beam components are derived from a single electron beam which is caused to describe a substantially conic locus about a central axis and thereby to approach the target electrode structure from different angles in the succeeding intervals of time. The one gun shadow mask color kinescope also is the subject matter of a copending U. S. patent application of Russell R. Law, Serial No. 165,552, filed June 1, 1950, and titled "Color Television."

It will be appreciated that, in order for a color kinescope employing a plurality of electron beams or components thereof to achieve color selection at a target electrode structure by reason of the different angular approach of the beam components to the target electrode structure, it is required that the predetermined angles of approach be maintained over the entire raster scanned as the beams are deflected. Furthermore, it is essential that all of the beam components converge substantially in the apertures of the shadow mask of the target electrode structure at all points in the scanned raster. Otherwise, while color identity may be achieved by the maintenance of the predetermined angles of approach of the

beams to the target electrode, the different color components of the image to be reproduced may be out of registry, thereby producing an undesired and untrue reproduction of the image.

Inasmuch as in the type of color kinescope to which the present invention particularly relates the electron beam components originate at points which are symmetrically located about the central axis of the tube, and with a relatively small spacing therebetween, it is necessary that all of the beam components be deflected by the same apparatus. By reason of the fact that the beams are displaced at finite distances from one another and from the central axis of the kinescope, it is necessary, in order to maintain substantial uniformity in the angles at which the beams approach the target electrode structure, to instantaneously deflect the respective beam components by different amounts. These differences in the magntiude of the deflections of the respective beam components increase as a function of the raster scanning deflection angle. It also will be appreciated that the problem of maintaining a given angle of approach of the different beam components to the target electrode structure and also of effecting substantial convergence of the beam components in the plane of the masking electrode is made increasingly difficult by reason of the substantially flat character of the target electrode structure which presently is employed in this type of color kinescope and which is generally desirable for viewing of the reproduced image.

In deflecting the plurality of electron beam components in a color kinescope of the character described by means of a common deflection yoke, it is desirable, if not virtually essential in order to achieve the uniform angle of approach and convergence of the beams at the target electrode structure, to insure that the beams are not unduly influenced by any extraneous field components which tend to give an undesired deflection to one or more of the electron beam components. One commonly encountered extraneous field of the character referred to is that produced by the end conductors of the deflection yoke coils. These conductors tend to produce a longitudinal field extending substantially in the axial direction of the cathode ray tube. This type of field tends to cause the electrons to follow spiral paths so that, in the case of a plurality of electron beam components, there is a tendency for such a field to twist the beam components relative to the central axis of the beam array. Such twisting of the beams causes them to change their positions in space so that, upon arrival at the target electrode structure, even though they approach it at the desired angles and with the necessary convergence, the beam components which are modulated with the color representative signals are caused to impinge upon phosphors producing light of colors other than those represented by the respective signals. Consequently, extraneous fields of such a character tend to produce what is commonly termed as "color impurity."

Extraneous fields of the character described produced by the end conductors have varying effects, depending upon the raster scanning deflection of the electron beam components. The deleterious effects of such field are greater when the beam components are greatly deflected from the central axis of the tube, such as when corner areas of the raster are being scanned, because the axial field produced by the end conductors is of greater intensity in the immediate vicinity of the end conductors and the electron beam components are deflected to such regions when the corner portions of the raster are being scanned. It is seen that the maintenance of color purity again is a problem which varies as a function of the raster scanning deflection angle. Consequently, it will be appreciated that, not only is it necessary to maintain a substantially constant angle of approach of the beam com-

ponents to the target electrode structure and to effect convergence of the beam components substantially in the plane of the shadow mask or its equivalent, but it also is necessary to insure that the beam components maintain the same relative positions to one another and to the central axis of the beam array throughout all portions of the scanned raster. Therefore, it is necessary that any deflection apparatus for use in a multi-beam cathode ray tube of the character referred to be capable of achieving all of these results, at least to a practical degree, whereby a substantially accurate reproduction of an image is produced.

It, therefore. is an object of the present invention to provide a deflection yoke for the deflection of a plurality of beam components of a multi-beam cathode ray tube and which is of such a character as to achieve optimum convergence of the beam components at desired angles substantially at a target electrode throughout all points of a raster scanned by the beams at the electrode.

Another object of the invention is to provide a precision yoke for a multi-beam color kinescope and which is of such a character as to effect suitably wide angle deflection of the beam components and which is capable of maintaining accurate color reproduction throughout the raster scanned by the beam deflection.

Still another object of the invention is to provide a deflection yoke for a multi-beam color kinescope which has the high precision required to effect accurate color reproduction and which has a design to facilitate manufacture in quantities on a commercial scale.

A further object of the invention is to provide a deflection yoke for a cathode ray tube which is constructed and/or operated in such a manner as to minimize transient oscillations in the vertical winding resulting from horizontal retrace.

In accordance with this invention, there is provided a deflection yoke of such a character that the field produced thereby may be adjusted to such a high degree of precision as to enable its employment for the deflection of a plurality of electron beam components in a multi-beam cathode ray tube such as a tri-color kinescope. This improved type of deflection yoke has two portions, one of which is relatively straight and extends parallel to the longitudinal axis of the yoke and the other of which is flared, deviating from the central axis of the kinescope at the forward end of the yoke. The turns distribution of the straight section of the yoke is of such a character as to produce a field of a predetermined intensity distribution. Also, the configurations of the surfaces of the horizontal and vertical coils of the yoke are such as to enable accurate positioning of the coils relative to one another in such a manner as to maintain the desired positions. By the employment of a hitherto unused expedient, the adjacent surfaces of the horizontal and vertical coils of the yoke are made to be equidistant through the region in which they coextend. This result is achieved in a manner to be described while, at the same time, the thickness of the horizontal and vertical coils is varied to effect the desired turns distribution, and there is maintained a substantially circular inner surface of the yoke which is concentric about the axis of the device.

The configuration of the flared section of the yoke is such as to effectively extend the active conductors of the coils in a manner to produce a field having lines of flux which are substantially at the required angles to the electron beam components at all times during the deflection thereof to scan a substantially rectangular raster. Such a field is of a character to compensate for an undesirable, and practically unavoidable, field in the region adjacent to the rear end of the yoke. This result is produced by properly selecting the angle which the flared section makes with the rest of the yoke, such as the straight section or the central axis of the yoke, and also by the distribution of turns in accordance with the present invention.

Another feature of the yoke in accordance with this invention by means of which there is produced a field having the high degree of precision required is the internal diameter thereof which is made somewhat greater than the outside diameter of the cathode ray tube neck about which it is mounted. This enables the yoke to be adjustably mounted in such a way as to effect the precise centering of the electron beam components relative to the field produced by the yoke. Such a facility enables compensation for any misalignment of the electron beam components relative to the central axis of the kinescope and/or to the target electrode structure. It also reduces to some extent the deleterious local field effects near the back end of the yoke previously referred to.

Still another feature of the invention is provision for the connection of the coils of at least one of the windings, such as the horizontal winding, in parallel rather than the commonly used series connection for coupling to a deflection wave source. Such an arrangement used in certain deflection circuits minimizes transient oscillations which tend to be induced in one winding by pulses in the other.

In order that the various components of the yoke be susceptible of relatively easy assembly with the high degree of precision required of a yoke of this character, the core is made of a plurality of arcuate members of ferromagnetic material and arranged to extend substantially around the windings. Since it is important to properly align the core so that it is concentric with the windings, each arcuate member is provided with a resilient pad on its concave surface. Such a provision enables clamping of the core members onto the windings to produce the desired results.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings.

In the drawings:

Figure 1 is a perspective view of a multi-beam cathode ray tube, partly broken away to show the internal construction thereof, with which the deflection yoke in accordance with the present invention may be used;

Figure 2 is a perspective view from the forward end of a deflection yoke embodying the invention;

Figure 3 is a plan view from the inside of a horizontal coil of such a deflection yoke;

Figure 4 is an end view from the front of the horizontal coil of Figure 3;

Figure 5 is a fragmentary sectional view of a horizontal coil taken on the line 5—5 of figure 4;

Figure 6 is a plan view from the inside of a vertical coil of the deflection yoke in accordance with the invention;

Figure 7 is an end view from the front of the vertical coil of Figure 6;

Figure 8 is a fragmentary sectional view of the vertical coil taken on the line 8—8 of Figure 7;

Figure 9 is a table showing the effective turns distribution in the straight and flared sections of the horizontal and vertical coils of the deflection yoke embodying the invention;

Figure 10 is a diagram of a representative flux pattern produced when any one pair of yoke coils is energized;

Figure 11 is a longitudinal cross section of the yoke showing the relationship of the horizontal and vertical coils to one another and to the associated core in accordance with the invention;

Figure 12 is a transverse cross-sectional view of the yoke embodying the invention taken through the straight section thereof and showing the general cross-sectional coil and core configuration and mutual relationship in a completely assembled yoke;

Figure 13 is a graphical layout of the horizontal and vertical coils showing the manner in which the parallelism of adjacent surfaces of the coils is effected; and,

Figure 14 is a fragmentary circuit diagram of one of the possible coil connections of the yoke made in accordance with this invention to obviate transient oscillatory effects in the vertical deflection yoke winding.

Reference first will be made to Figure 1 of the drawings for a description of the general relationship of a yoke embodying the invention to a multi-beam cathode ray tube such as a tri-color kinescope employed for image reproduction in a color television receiver. The kinescope **21** may be of the same general type as that disclosed in the I. R. E. paper by H. B. Law previously referred to. It will be understood, however, that the kinescope alternatively may be of other types, such as that disclosed in the R. R. Law I. R. E. paper. In either case, the kinescope **21** preferably has a substantially flat luminescent screen **22** which is provided with a multiplicity of small phosphor areas arranged in groups and capable respectively of producing light of the different component colors in which the image is to be reproduced when excited by electron beams or components thereof. Preferably, the luminescent screen is metalized so that a suitable electrical connection may be made thereto for the impression thereon of a desired potential. Metalization of a luminescent screen of the character referred to may be effected in the manner disclosed in a paper by D. W. Epstein and L. Pensak titled "Improved cathode ray tubes with metal-backed luminescent screens," published in the RCA Review, vol. VII, March 1946, at pages 5–10. In back of and spaced from the screen **22** there is a beam-masking device, such as an apertured electrode **23**. In the case of an apertured mask, there is provided an aperture for and in alignment with each group of phosphor areas of the screen **22**. It is to be understood that the deflection yoke in accordance with the present invention is not necessarily limited for use with multi-beam cathode ray tubes having the particular type of target electrode structure shown and described herein for illustrative purposes. The character of the beam-making device, such as an electrode, and/or electron optical apparatus, by means of which the different electron beam components are caused to impinge at different angles upon the luminescent screen is immaterial to the practice of the present invention. Other devices for this purpose may be used without necessitating any modification or alteration of the deflection yoke embodying the principles of this invention.

In the particular cathode ray tube illustrated, there is provided a plurality of electron guns equal in number to the number of component colors in which the image is to be reproduced. These electron guns **24**, **25** and **26** may be identical and entirely conventional. As illustrated, they are mounted in the rear section of the neck portion **27** of the color kinescope and are grouped symmetrically in a triangular configuration about the central axis of the kinescope. The three electron guns **24**, **25** and **26** produce respectively schematically represented electron beams **28**, **29** and **30**. These beams are adjusted either by the mechanical positioning of the respective electron guns from which they emanate relative to the longitudinal axis of the kinescope, or by electron-optical means, or both, to converge substantially in the plane of the aperture mask electrode **23**, as indicated in the drawing. When they are converged in this manner, they pass through one or more of the apertures of the mask from different directions and impinge upon different phosphor areas of the various groups so as to produce red, green and blue light, for example. It is to be noted that the size of the phosphor areas and of the mask apertures, the angles between the beams, and the spacing of the mask **23** from the screen **22** as compared with the length of the tube are somewhat exaggerated for the purpose of better illustrating the operation of this type of kinescope.

In order to deflect the array of electron beams **28**, **29** and **30** both horizontally and vertically to scan a substantially rectangular raster at the target electrode including the screen 22, the kinescope is provided with an electromagnetic deflection yoke **31** embodying the present invention. The yoke in general surrounds the neck **27** of the kinescope by means of the substantially straight section **32** thereof to be more fully described subsequently. It also is to be understood that the forwardly disposed flared section **33** of the yoke extends somewhat beyond the junction between the neck **27** and the conical section **34** of the kinescope **21**. It is to be further understood that the angle at which the flared section of the yoke deviates from the central axis of the kinescope and of the yoke does not necessarily have any relation to the angle of the conical section **34** of the kinescope, nor of the maximum deflection angle of the multiple beam array. As further described in a subsequent portion of this specification, the flare angle is chosen primarily for the purpose of producing the proper flux pattern in the forward end of the yoke region.

In order to more clearly disclose the novel configuration and construction of a multi-beam deflection yoke embodying the present invention, further reference will be made to Figure 2. The perspective view of the forward end of the deflection yoke 31 in accordance with the invention shows generally the essential portions of the horizontal deflection winding coils **35** and **36**. Since both of these coils are substantially identical, the details of only one of them will be described. The lower coil **36** includes side conductors having main portions **37***a* extending for a relatively large distance along and lying substantially parallel to the central axis of the yoke. The side conductors also have extended portions **37***b* extending for a smaller distance along and deviating from the central axis. The two parallel side conductor portions **37***a* of one horizontal coil, together with corresponding side conductor portions of the other horizontal coil and with similar portions of the two coils **38** and **39** comprising the vertical winding, form the straight section of the yoke. The two extended side conductor portions **37***b* of one horizontal coil **36**, together with corresponding extended side conductor portions of the other horizontal coil **35** and with similar portions of the two vertical coils **38** and **39**, form the flared section of the yoke. The particular deviation of the extended side conductors such as conductors **37***b* from the central axis of the yoke in order to effect the desired flux distribution will be described subsequently in greater detail.

Each of the groups of side conductors **37** of each of the horizontal coils **35** and **36** and of each of the vertical coils **38** and **39** extend circumferentially around the central axis of the coil through respective predetermined angles. These angles are the same for each of the horizontal coils and also for each of the vertical coils which, in the particular illustrative embodiment of the invention, also are substantially the same for the horizontal and vertical coils. In any case, the circumferential angle for each group of side conductors is less than 90° so that for any two groups of corresponding side conductors the total angle is less than 180°. Accordingly, there is an opening or window formed substantially at the center of each of the coils. In the case of the horizontal coil **36**, the opening or window **40** is formed in this manner. A similar opening or window **41** is formed in the vertical coil **39** and is shown by the dotted lines because the vertical coils lie outside of the horizontal coils in the assembled yoke.

One of the constructional features of a deflection yoke in accordance with the invention also is illustrated in Figure 2. There is provided an insulating spacer **42** between the adjacent outer edges of the straight portions of the respective side conductor groups of the pair of horizontal coils **35** and **36**. As will be more clearly illustrated in connection with a subsequent portion of the description, these spacers, such as the spacer **42**, maintain gaps between those portions of the horizontal coils which have the greater number of conductors. Such spacers are useful in manufacturing yokes embodying this invention in large quantities by providing a facility with which to make small modifications in the conductor distribution in the coils after they have been formed by appropriate tools. Yoke winding tools are relatively expensive and it is impractical to provide suitable tools with the high degree of precision required to effect the exact winding distribution. Within limits, it is much more practical and less costly to provide the desired modification of the winding distribution merely by changing the thickness of the spacers between the horizontal coils.

It will be appreciated that some means is desirable for effecting small modifications in the winding distribution of a yoke which is to be employed in connection with a tri-color kinescope where the convergence of the electron beams is necessary. A practical example of the manner in which the dimensions of the spacers between the horizontal coils of the yoke winding may be employed to advantage is a situation where two of the beams are found to converge but the third one is somewhat lower at the target electrode. Specifically, it customarily is the practice to arrange the electron guns **24**, **25** and **26**, as shown in Figure 1, so that the guns **24** and **26** are in a horizontal plane and are effective to produce electron beams for the development of red and green light, respectively. The gun **25**, which is located at the other apex of an equilateral triangle, produces a beam which develops blue light when the phosphor screen is impinged. In such a situation, if it is found that the red and green beams from the guns **24** and **26** converge as desired, but the beam from the blue gun **25** is lower, it is an indication that the flux field produced by the yoke **31** has either too much of a pin-cushion shape or not enough of a barrel shape. In order to correct this, the width of the spacers **42** may be increased, thereby increasing the gaps between the horizontal coils. Such a modification of the winding distribution produces a flux field which is more barrel-shaped than previously. Such a flux field is effective to deflect the beam from the blue gun **25** so that it impinges upon the phosphor screen **22** at a higher point, thereby effecting the desired convergence of it with the red and green beams. In order to provide for the use of the spacers, such as the spacer **42**, a suitable allowance must be made in the construction of the horizontal coils. This feature will be shown and described in greater detail subsequently.

In this general connection, it has been found desirable to mount the vertical coils of the yoke in such a manner that the adjacent portions of the respective coils are substantially in contact with one another, thereby leaving little or no gaps between the coils.

Another feature of the deflection yoke in accordance with this invention which, in conjunction with some of those already described, provides a more efficient yoke by which to produce a beam deflection field of a high order of precision and which minimizes any adverse angular displacement of the beams is the spacing of the end conductors at greater than a minimum distance from the central axis of the yoke. In the horizontal coils **35** and **36**, for example, the forward end conductors **43** and **44** are grouped substantially as illustrated so that they are somewhat farther removed from the central axis than would be necessary merely to effect the connection between the two groups of conductors in the respective coils. Similarly, the end conductors **45** and **46** at the front or flared end of the yoke of the vertical coils **38** and **39** respectively are so treated. By such a treatment, it is seen that there is produced a field of minimum intensity in a longitudinal or axial direction. Consequently, any tendency for such an extraneous field to cause a rotational or twisting movement of the beams about the center of the array is minimized.

At the rear end of the yoke, the ends of the horizontal and vertical coils may be similarly treated, if desired. As indicated in Figure 2, a somewhat similar treatment is provided for the rear end conductors **47** of the vertical coil **38**. A more detailed showing of this feature of the yoke may be obtained from other figures of the drawings to be described subsequently.

For the achievement of maximum performance of a deflection yoke in accordance with this invention, it is desired that there be a minimum of crossing of the side conductors of the respective coils. It is desired that the side conductors lie substantially parallel to one another in the straight section, and in a uniform radial pattern in the flared section of the yoke. Such a constructional feature is particularly important in order to produce the desired flux patterns at all points in the resultant field so as to deflect the beams properly at all angles of deflection. Also, in the flared section it is desirable that all of the side conductors extend axially for substantially the same distances before they are bent into the end conductors. In this way, a more precise field in the critical forward end region of the yoke is produced and, consequently, a more uniform performance is achieved for all angles of deflection, particularly the larger ones for the scansion for the corners of the rectangular raster.

Reference now will be made to Figures 3, 4 and 5 of the drawings for a more detailed description of the configuration of one of the horizontal coils of the yoke embodying this invention. In Figure 3, which is a plan view of the coil **35** as viewed from the inside, the general configuration of the straight and flared sections, together with the treatment of the forward and rear end turns, is shown. It may be seen that the rear end conductors **48** are treated in much the same manner as the forward end conductors **44** substantially as described. Also, from Figure 4, it is to be noted that the horizontal coil **35**, including the window **40**, extends for a few degrees less than 180° around the neck of the kinescope. Inasmuch as the other horizontal coil **36** as shown in Figure 2 is a substantial duplicate of the coil **35**, it is seen that when assembled, the pair of horizontal coils almost completely surround the neck of the kinescope except for approximately 8° at the respective adjacent portions. This arrangement allows for the insertion of the spacers **42** previously referred to in the description of Figure 2.

Figure 5 indicates a representative cross section of the horizontal coil **35** taken on a radial line extending from the central axis of the yoke. In this figure, the thickness of the side conductors in the straight section of the yoke is indicated by the letter "A." Also, the letter "B" represents the thickness of the extreme portion of the flared section of the yoke. These dimensions are representative of the turns distribution in the horizontal yoke coil. At different radial angles, these dimensions vary in accordance wtih the variation in the turns distribution of the coil. As may be seen from Figure 4, the side conductors of either half of the horizontal coil **35** extend peripherally for approximately 71°. The table of Figure 9 indicates the different coil thicknesses "A" and "B" in steps of 15° of angle. It is seen that the thickness "A" and, therefore, the turns distribution of the straight section of the yoke varies from a maximum of approximately .125 inch at one end of the coil to approximately .057 inch at the window end of this one-half of the coil. Likewise, it is seen that the thickness "B" and, consequently, the turns distribution in the extremity of the flared section of the yoke varies from approximately .075 inch to a minimum of .034 inch at the window **40**. The transition from one coil thickness to another in each of the straight and

flared sections of the yoke is made as gradual as practicable.

By referring now to Figures 6, 7 and 8 of the drawings, a similar showing of the details of one of the vertical coils **38** is made. Figure 7 indicates the same angles as are indicated in Figure 4 so as to properly illustrate the relationship between the horizontal coil **35** and the vertical coil **38**. In the case of the vertical coil, the thickness corresponding to the turns distribution of the straight section thereof is represented by the letter "C" and the thickness of the extremity of the flared section is represented by the letter "D." The variations in the straight and flared section thicknesses also are indicated in Figure 9. From this it may be seen that the thickness of one of the vertical coils varies from a maximum of approximately .125 inch to a minimum of approximately .056 inch at the window **41***a* corresponding to the window **41** in the vertical coil **39**, as shown in Figure 2. Similarly, the flared section thickness varies from a maximum of .092 inch to a minimum of .043 inch at the window **41***a*. It is also to be understood that the transition from one thickness to another is in a smooth gradual manner as in the case of the horizontal coils previously described.

It should be noted that the turns distribution in either the straight or flared sections of any of the horizontal or vertical coils in the yoke in accordance with the present invention is materially different from the turns distribution which would be obtained if either a cosine or a cosine squared distribution were to be followed. On the contrary, one of the noteworthy features of this aspect of the invention is that the actual turns distribution does not vary in accordance with any fixed power of the cosine or any other function of the angle. The turns distribution in the straight section of the yoke, including the horizontal and vertical coils, is made in accordance with the data given in the table of Figure 9 so as to produce the required flux field in the region enclosed by this section of the yoke. The indicated turns distribution in the flared section of the yoke is chosen in accordance with this invention to produce such a non-uniform field in the forward region of the yoke so that all the beams, in the deflection angle of kinescope operation, approach the lines of flux at the proper angles to compensate for the angles of approach to the flux lines at the rear end of the yoke. In the achievement of this latter result, the angle which the flared section of the yoke makes with the longitudinal axis thereof or with a plane perpendicular thereto is suitably chosen. As indicated in Figure 5, the angle which the flared section of the horizontal coils makes with a plane perpendicular to the axis of the yoke is approximately 30°. As indicated in Figure 8, the vertical flared section of the yoke makes an angle of approximately 34° with a plane normal to the axis of the device.

The desired flux patterns produced by the deflection yoke in accordance with the present invention in the straight and flared sections are indicated generally in Figure 10, to which reference now will be made. This representative field pattern is, for example, that produced by the horizontal winding, including the coils **35** and **36**. The broken lines indicate the lines of flux produced by this winding and were obtained by means of iron filings placed effectively at the center axis of the yoke and extending generally in the direction of the vertical deflection of the electron beams. The solid lines **49** represent the limits of the electron beam deflection under the influence of the vertical winding of the yoke. It is to be understood that such a field pattern is produced in all planes running through the central axis of the kinescope.

It may be seen from this field pattern that the electron beams pass through the yoke and are confined generally to the central axial portions thereof. In this way, they are removed from the adverse effects of the local fields produced in proximity to the windings, particularly at the rear and forward ends of the yoke. In general, it may be seen that the field pattern has a pronounced barrel-shape about a central portion occurring in the region of the straight section where the lines of flux are practically normal to the axis. The curvature of the flux lines at the rear end of the yoke is a result of the end turns and also by reason of the discontinuity or change of direction of the active conductors in the straight section of the yoke into the end turns. It also can be seen that the adverse field effects are more pronounced in those regions adjacent to the yoke windings. Even by confining the electron beam paths to the central portions of the yoke, it may be seen that the fields which are traversed by these beams at the rear end of the yoke are different for different angles of beam deflection. Hence, since all of the beams do not pass through the same parts of the field produced by the yoke, they are differently effected. By suitable treatment of the end turns at the rear end of the yoke, these adverse field effects may be minimized, but as a practical matter, may not be entirely eliminated.

However, in accordance with the present invention, the forward end of the yoke is so constructed as to compensate for any adverse field effects produced at the rear end of the yoke. This compensation is effected by suitably choosing the angle which the flared section makes with the axis of the tube, together with the particular distribution of conductors in this flared section. It is evident that the forward end of the yoke cannot be made identical to the rear end of it for the purpose of effecting the desired compensation because of the fact that the electron beams are already deflected from the central axis of the tube by the time they reach the forward end of the yoke. Hence, by constructing the flared section of the yoke in the manner described, the field produced thereby, as indicated in Figure 10, is of a suitable character to compensate for the adverse non-uniform deflection of the electron beams produced by the local field at the rear end of the yoke, taking into account the fact that the beams have been deflected from the central axis by the time they are subjected to the influence of the field produced by the flared forward section of the yoke.

By referring now to Figure 11 of the drawings, the general illustration of a complete deflection yoke is given showing the particular relationship of the horizontal and vertical coils and the core associated therewith. As is the usual practice, the horizontal coils, such as the coil **35**, are mounted in the innermost portion of the yoke and the vertical winding, including the coil **38**, is mounted externally thereof such as in the nested fashion shown. The horizontal and vertical coils are separated by insulating material fashioned somewhat in the form of a spool **51**. Inasmuch as the insulation between the horizontal and vertical windings of the yoke must stand relatively high operating potentials and voltages and must also be resistant to the harmful effects of corona, in one practical embodiment of the present invention it is made of a high temperature neoprene rubber. The insulating spool **51** also is somewhat elastic so as to accommodate small variations in the adjacent coil surfaces of the horizontal and vertical windings. Also, it has a relatively constant thickness which, together with its elastic characteristic, enables the assembly of the horizontal and vertical coils of the yoke windings, in a substantially concentric manner. As previously indicated and as described in greater detail subsequently, the adjacent surfaces of these coils are given such configurations as to be susceptible of assembly in the manner described.

Also, resilient pads **52**, such as of soft rubber, are placed between the vertical coils and the core so as to permit a snug fitting concentric assembly of the ferrite core with respect to the coil assembly despite slight differences caused by production tolerances on the inside diameter of the core assembly and the outside diameter of the coils. The configuration of the core in the present instance comprises a plurality of components. These components are arcuate members of a suitable ferro-

magnetic material, such as a ferrite referred to and arranged in two adjacent rings longitudinally of the yoke. Each of the core rings comprises four arcuate members extending circumferentially for approximately 90° each. One of the arcuate core members **53** which make up the rearwardly positioned ring of the core has a substantially rectangular cross section as indicated. Each of the core members **54** of the forwardly positioned core ring has a cross section such as that shown. With respect to the core member **54**, it is to be noted that one of the circular edges is effectively beveled so as to conform generally to the flared portion of the yoke. Also the resilient pads **52** may conveniently be flat strips of rubber cemented to the core members on the concave surfaces thereof.

The foregoing description of Figure 11 covers the operating or functioning portions of the deflection yoke embodying the invention. There also is provided a terminal washer **55** of insulating material located between the rear end of the core and the outer surface of the insulating spool **49**. The washer **55** serves to insulate and support a plurality of terminals such as the terminal **56**. The coils of the horizontal and vertical windings of the yoke are connected respectively to such terminals for the further connection thereto of conductors leading to suitable sources of deflection wave energy.

The four coils of the yoke, together with the insulating spools associated therewith, and the eight members of the core are held together by a plurality of metallic bands **57** surrounding a suitable layer of insulating tape **58**, the bands being securely fastened by means such as respective seals **59**.

Another aspect of the general relationship of the coils and associated core, together with the insulating members, is shown in Figure 12 to which reference now will be made. In general, this cross-sectional view through the straight section of the yoke shows the relationship in which the horizontal coils **35** and **36** are mounted relative to the vertical coils **38** and **39**. It may be seen from this view of the yoke that the two coils of the horizontal winding are separated by the spacers **42** and the two coils of the vertical winding are mounted in a mutually abutting relationship, as previously described. By reason of such an arrangement, a more uniform and more precise field may be produced. Also, from this figure, there may be seen the substantially 90° arcuate form of the core members, such as the member **54**. In order that a yoke embodying the present invention have a maximum of efficiency, it is desirable to have the core pieces fit snugly around the periphery of the yoke windings and, at the same time, to have a substantially abutting relationship at the ends thereof to one another. By such means, the core is located as closely to the windings and to the magnetic field produced thereby as possible and the abutting of the core ends minimizes any air gaps in the magnetic circuit through the core. Also, it is to be appreciated that the two core rings should be in as intimate contact with one another as possible. Further in this connection, the abutments between the adjacent core members in one of the rings should coincide substantially with the abutments of the core members in the other ring for the purpose of providing a magnetic circuit having a minimum of reluctance. Also, they should coincide closely with the horizontal and vertical lines of the yoke.

Reference now will be made to Figure 13 of the drawings for a more detailed description of the manner in which another feature of the invention is provided. As previously stated, in order to achieve the high degree of precision which is required in a yoke of the character embodying the invention, it is desirable to maintain a uniform spacing between the adjacent surfaces of the yoke coils which overlie one another. The geometrical relationship by means of which this feature is attained is shown in this figure with reference to overlying portions of a horizontal coil **35** and a vertical coil **38**. Only one-half of each of these coils is shown for the reason that the other halves are identical and it will be understood that the entire yoke is symmetrical about the vertical and horizontal diametral planes, for example. The point **61** represents the central axis of the yoke. This point therefore, will be understood to lie on the longitudinal axis through the yoke. For the first portion of each of the horizontal and vertical coils **38**, the outer surface of the horizontal coil **35** and the inner surface of the vertical coil **38** lie on respective arcs of a circle having a center **62** lying on a longitudinal axis displaced by distance "X" from the yoke central axis on which lies the point **61**. The radius VI_1 of the inner surface of the vertical coil **38** and the radius HO_1 of the outer surface of the horizontal coil **35** differ by a predetermined amount. For the second portions of these coils, the outer surface of the horizontal coil **35** and the inner surface of the vertical coil **38** lie on respective arcs of a circle having a center **63** lying on a longitudinal axis displaced from the yoke central axis including the point **61** by distance "Y." Again, the radius VI_2 of this portion of the inner surface of the vertical coil **38** and the radius HO_2 of the outer surface of the second portion of the horizontal coil **35** differ from one another by the same predetermined amount as the difference between the radii VI_1 and HO_2. It thus is seen that the spacing between the two adjacent surfaces of the horizontal and vertical coils is maintained constant throughout the region in which they coextend.

The first and second portions of the horizontal and vertical coils **35** and **38** respectively lie generally below and above a tangent line **64** running through the centers **62** and **63**. In one practical form of the invention, the eccentric distances "X" and "Y" are equal. Accordingly, the tangent line **64** makes a substantially 45° angle with either the horizontal or vertical diametral plane of the yoke. Also, the specified turns distribution in the respective horizontal and vertical coils **35** and **38** is obtained by making the inner and outer surfaces respectively of the horizontal and vertical coils **35** and **38** concentric about the yoke central axis through the point **61**. As indicated, the inner surface of the horizontal coil **35** lies on an arc of a circle having a radius HI. Similarly, the outer surface of the vertical coil **38** lies on an arc of a circle having a radius of VO.

Still another feature of the invention is illustrated in Figure 14, to which reference now will be made. The horizontal coils "H" may be connected in parallel with one another and to a source of a horizontal deflection wave. The vertical coils "V" are conventionally connected in series with one another and to a suitable source of a deflection wave at the vertical scanning frequency. It has been found that a parallel connection of the horizontal coils is effective in materially reducing the effect in the reproduced image of vertically displacing the horizontal scanning lines which is a result of an oscillatory condition commonly termed "ringing" produced in portions of the horizontal and vertical coils triggered to the horizontal retrace pulses. By connecting the horizontal coils in parallel, the retrace pulse effectively is balanced so far as its effect upon the vertical coils is concerned. As a result, very little capacitively coupled current flows through the vertical coils. Also, ringing in the horizontal coils can cause such a vertical line displacement. The parallel connection of the horizontal coils reduces both of these ringing effects. Inasmuch as there is an insulating spacer provided between the two coils of horizontal winding, it is not necessary to wind the coils in opposite directions in order to permit the parallel connection thereof as described. It also has been found that another beneficial result of connecting the horizontal coils in parallel is the elimination of the

need for a damping network which ordinarily is connected across the high potential horizontal coil of this yoke winding.

From the foregoing description of an illustrative embodiment of the invention which has operated satisfactorily in practice, it is seen that there is provided a high precision deflection yoke which is capable of producing a field of a desired flux distribution to scan a substantially rectangular raster in the plane of a relatively flat target electrode and with a minimum of electron beam distortion. When used in deflecting a plurality of beams in a cathode ray tube, such as a tri-color kinescope, a yoke in accordance with the present invention has a circumferential distribution of the conductors having such a variation as to provide an optimum convergence of the electron beams at substantially all points of the scanned raster. Such a result is obtained by the provision in the yoke of straight and flared sections. The turns or conductor distribution in the straight section is of a character to produce a field having a predetermined flux distribution. The turns or conductor distribution, together with the angle of divergence of the flared section of the yoke, produces a field of a character such that when the field at the rear end of the yoke is taken into account, there is substantially no resultant component to effect the deflection of the beams in an undesired direction.

A field of such a character is made symmetrical about the axis of the yoke by maintaining a substantially constant spacing between the adjacent surfaces of the horizontal and vertical coils in accordance with the invention. In such a case, it is possible to use insulation between the horizontal and vertical coils having a uniform thickness and to maintain substantial concentricity of these coils. The provision of insulation of uniform thickness between the vertical coils and the core also enables the maintenance of a concentricity of the core relative to the coils. Such an overall concentricity of coils and core is effective in producing the desired axial symmetry of the field developed by such a yoke in accordance with the invention.

Also, the further feature of the invention of connecting the horizontal coils in parallel not only eliminates the necessity for a damping network, but also minimizes the transient oscillations in the vertical winding which tend to be produced by the horizontal flyback pulses.

Having described an illustrative embodiment of the invention, the following claims set forth the scope of the invention.

What is claimed is:

1. A deflection yoke for a cathode ray tube comprising, horizontal and vertical beam deflection windings having respective pairs of coils, the coils of each winding being oppositely disposed to one another about a central axis and the coils of one winding having a substantially 90° angular position about said central axis relative to the corresponding coils of the other winding, each of the coils of said windings having side conductors extending substantially parallel to said central axis, said side conductors being grouped circumferentially around said central axis with a conductor distribution varying from a relatively small percentage of the total side conductors at one circumferential coil extremity to a larger percentage of the total side conductors at the other circumferential coil extremity, one of said windings overlying the other so that at least portions of the adjacent inner and outer surfaces of the respective windings are coextensive, first corresponding angular portions of said respective adjacent surfaces lying on first respective circular arcs about a first longitudinal axis at respective radial distances having a predetermined difference, and second corresponding angular portions of said respective adjacent surfaces lying on second respective arcs about a second longitudinal axis at respective radial distances having said predetermined difference, whereby said adjacent coextensive surfaces are substantially parallel.

2. A deflection yoke as defined in claim 1 wherein, said first and second longitudinal axes are parallel to said central axis and are so positioned relative to one another that the different angular portions of each of said adjacent surfaces are tangent cylindrical sections having a line of tangency bounding said angular portions.

3. A deflection yoke as defined in claim 2 wherein, said first and second longitudinal axes respectively together with said central axis define mutually perpendicular planes respectively bounding at least one circumferential extremity of said coils.

4. A deflection yoke as defined in claim 1 wherein, the non-adjacent surfaces of said windings are cylindrical about said central axis.

5. A deflection yoke for a cathode ray tube comprising, horizontal and vertical beam deflection windings having respective pairs of coils, the coils of each winding being oppositely disposed to one another about a central axis and the coils of one winding having a substantially 90° angular position about said central axis relative to the corresponding coils of the other winding, each of the coils of said windings having side conductors extending substantially parallel to said central axis, said side conductors being grouped circumferentially around said central axis with a conductor distribution varying from a relatively small percentage of the total side conductors at one circumferential coil extremity to a larger percentage of the total side conductors at the other circumferential coil extremity, one of said windings overlying the other so that at least portions of the adjacent inner and outer surfaces of the respective windings are coextensive, first corresponding angular portions of said respective adjacent surfaces lying on first respective circular arcs about a first longitudinal axis at respective radial distances having a predetermined difference, and second corresponding angular portions of said respective adjacent surfaces lying on second respective arcs about a second longitudinal axis at respective radial distances having said predetermined difference, whereby said adjacent coextensive surfaces are substantially parallel, and insulating material between said horizontal and vertical deflection windings, said insulating material being of substantially constant thickness at least in the region of co-extensiveness between the respective windings.

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