

May 6, 1941.

L. J. BOBB

2,240,606

ELECTRON BEAM DEFLECTING YOKE

Filed Oct. 21, 1939

3 Sheets-Sheet 1

Fig. 1.

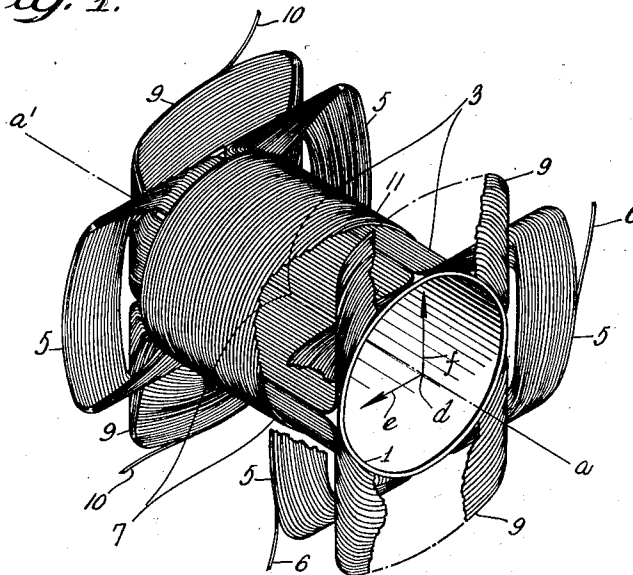
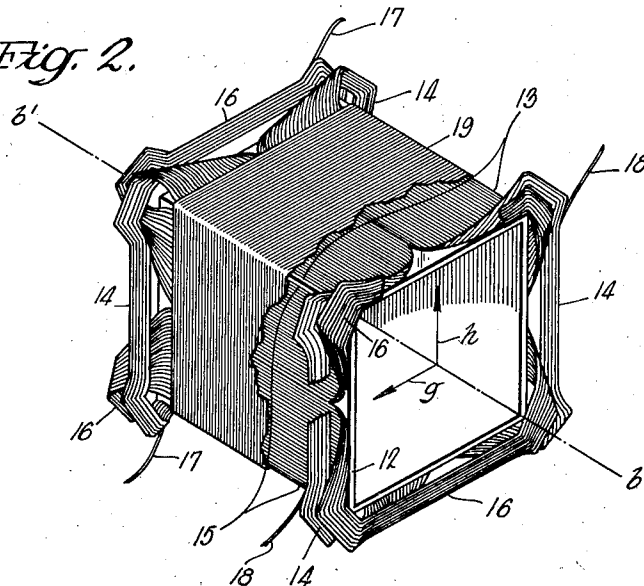


Fig. 2.



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Fig. 3.

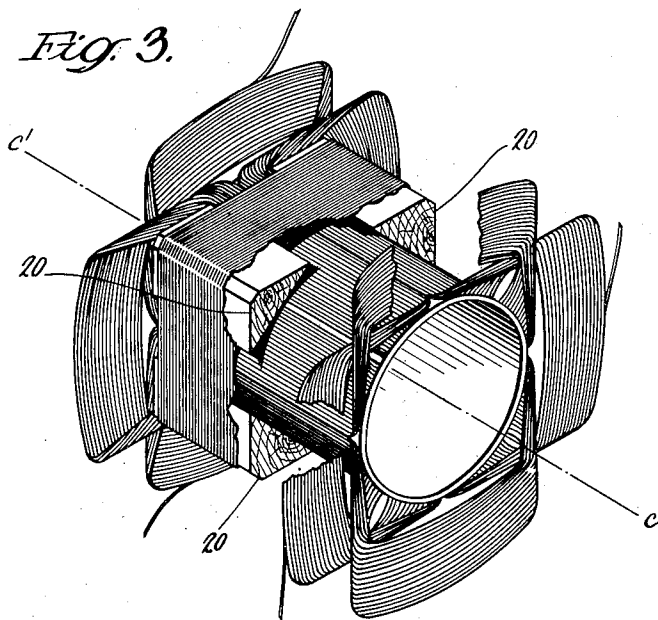
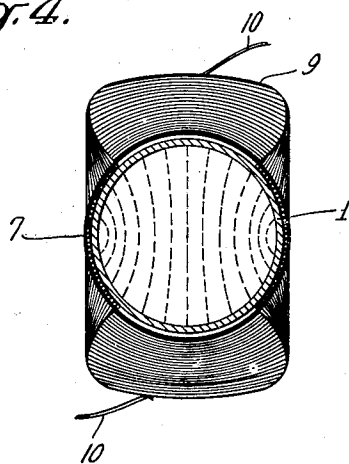


Fig. 4.



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3 Sheets-Sheet 3

Fig. 5A.

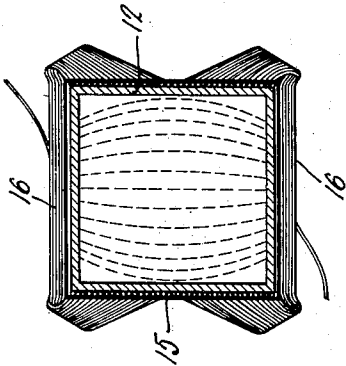


Fig. 5B.

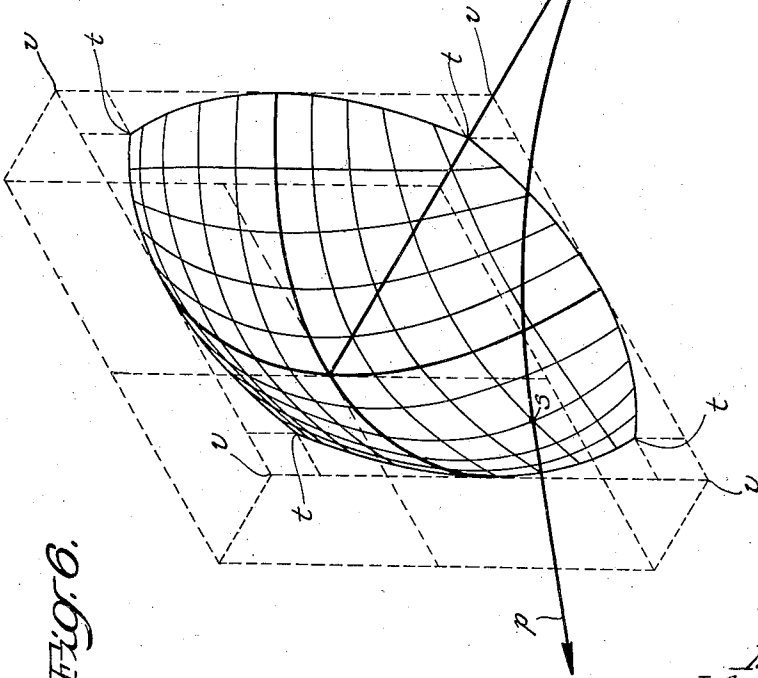
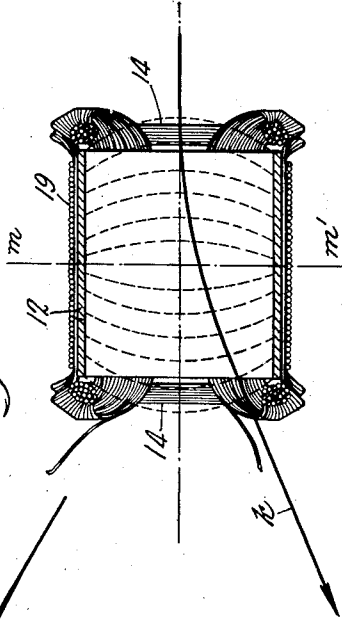


Fig. 6.

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UNITED STATES PATENT OFFICE

2,240,606

ELECTRON BEAM DEFLECTING YOKE

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mesne assignments, to Philco Radio and Tele-
vision Corporation, Philadelphia, Pa., a corpo-
ration of Delaware

Application October 21, 1939, Serial No. 360,671

6 Claims. (Cl. 250—157)

This invention relates to devices for deflecting beams of electrons or similar electrical particles, and more particularly to certain novel magnetic devices of this type. The invention is particularly adapted for use in deflecting the electron beam in cathode ray tubes of the type commonly used in television system for generating the video signal and for reconstituting a visible image from the intelligence contained in the video signal.

The fundamental principles underlying television transmission and reception, and the apparatus employed therewith, are sufficiently well known that it is unnecessary, for the purpose of this specification, to describe in detail a complete system comprising a transmitter and a receiver. It is well known in the art to employ cathode ray devices of various forms which rely mainly for the results they produce upon the deflection of a beam of electrons moving from a thermionic or other suitable cathode to a photo-electrically responsive mosaic or to a fluorescent screen responsive to electron bombardment. It is necessary for this purpose to fasciculate the electrons from the cathode into a beam of rather small cross section before they are permitted to impinge upon the mosaic or screen to which they are drawn by suitable electrostatic accelerating electrodes maintained at potentials relatively much higher than that of the cathode. This fasciculation or focusing is ordinarily accomplished by setting up non-uniform magnetic or electric fields of regular configuration in the space traversed by the electrons between the cathode and the mosaic or screen. In generating the video signal, or in reconstituting a visible image therefrom, the beam is caused to be deflected in both horizontal and vertical directions, so that the point of intersection of the beam with the plane of the mosaic or screen traces a regular pattern as is well known in the art. The desired deflection of the beam may be effected by setting up a varying electric or magnetic field in the space traversed by the electrons of the beam. This varying field is generally separated and distinct from the focusing field and is traversed by the electrons after they leave the focusing field. Although the deflecting field may be electric, it is usually more conveniently magnetic, as lower voltages are involved for a given maximum deflection.

As is well known, a beam of electrons passing through a magnetic field is deflected in a direction perpendicular both to the instantaneous direction of motion of electrons in the beam and to the lines of magnetic force cut by it. In order

to deflect the beam to varying extents in two directions which are mutually perpendicular, it is necessary to vary the intensities of the components of the field in these two directions. This is generally accomplished by using separate coils, or like configurations of conductors, with their axes mutually perpendicular to set up mutually perpendicular fields. The magnitudes of the currents in the separate coils may then be varied independently to vary the intensities of the two mutually perpendicular fields. Such a combination of means for setting up fields for deflecting a beam of electrons to varying degrees in mutually perpendicular directions is commonly referred to as a "deflecting yoke."

The design of suitable coils or conductor configurations for the production of the required magnetic deflecting fields has long been an important and difficult problem in the television art. The failure of prior attempts adequately to solve the problem has been due largely to a failure fully to appreciate the properties which the field must possess in order satisfactorily to deflect the electron beam without disturbing the focus thereof and without introducing distortion in the scanning pattern. Many early attempts to design a suitable deflecting yoke failed because designers did not recognize fundamental limitations imposed by electrical theory, nor what the configuration of the lines of force in the magnetic field should be in order to reduce defocusing and distortion to a minimum.

Accordingly, the objects of this invention are: to provide an improved deflecting yoke for deflecting an electron beam in cathode ray tubes and like devices; to provide a deflecting yoke capable of producing a magnetic field for deflecting an electron beam without appreciably defocusing the beam; to provide a deflecting yoke capable of producing a magnetic field for deflecting an electron beam in which the amount of deflection is substantially independent of the portion of the field through which the beam passes; to provide an improved deflecting yoke for deflecting an electron beam in cathode ray tubes and like devices in more than one direction; to provide a deflecting yoke capable of producing a plurality of magnetic fields for deflecting an electron beam in more than one direction, such that one of the fields produces a minimum of defocusing of the beam when it is deflected by another of said fields; to provide a deflecting yoke for use in connection with a television cathode ray device, which is capable of producing a substantially undistorted scanning pattern; and

to provide a deflecting yoke for cathode ray tubes and like devices which is economic and easy to construct, and which can readily be adjusted to give a deflecting field having the desired characteristics.

Other objects and advantages of the invention will appear from the following description and the accompanying drawings, in which:

Fig. 1 is a perspective view of one form of beam deflecting yoke used prior to the present invention;

Fig. 2 is a perspective view of one embodiment of the invention;

Fig. 3 is a perspective view of another embodiment of the invention;

Fig. 4 is a sectional view taken transversely of the longitudinal axis $a-a'$ in Fig. 1, showing the configuration of the magnetic lines of force in the field produced by one coil of the yoke shown in Fig. 1;

Fig. 5A is a sectional view taken transversely of the longitudinal axis $b-b'$ in Fig. 2, showing the configuration of the magnetic lines of force in the field produced by one coil of the yoke shown in Fig. 2;

Fig. 5B is a sectional view taken along the longitudinal axis $b-b'$ in Fig. 2, showing the configuration of the magnetic lines of force in the field produced by the yoke of Fig. 2 and their relation to the path of an electron beam passing through the yoke and deflected thereby; and

Fig. 6 is a perspective diagram showing the configuration of the magnetic lines of force in portions of the magnetic deflecting fields produced by yokes such as those shown in Figs. 2 and 3, and showing the relation between lines of force in the two fields produced by the two sections of the yoke, and showing also the relation between the lines of force in the said fields and the path of an electron beam passing there-through and deflected thereby.

In order more fully to understand the construction and appreciate the advantages of deflecting yokes constructed in accordance with the principles of the invention, it will be helpful to consider certain prior constructions and the disadvantages thereof.

Perhaps the earliest form of deflecting yoke consisted of four cylindrical multi-layer coils arranged around the cylindrical glass neck of a cathode ray tube. Opposite coils were connected in series so as to form two pairs of coils, one pair being capable of deflecting the electron beam passing through the glass neck of the tube in one direction, and the other pair serving to deflect the beam in a direction substantially perpendicular thereto. One of the disadvantages of such a simple yoke was its inability to produce a strong magnetic field inside the tube when supplied with a reasonably small current, a defect which is now referred to as "insensitivity." Another defect was the non-uniformity of the field produced by the yoke, whereby the amount of deflection was dependent upon the part of the field through which the beam passed. This gave rise to a distorted scanning pattern when the usual linearly increasing currents were supplied to the coils. Later, iron was used in this yoke to increase the intensity and uniformity of the field in the region traversed by the electron beam. This, however, added greatly to the weight and bulkiness of the yoke and made it many times more expensive.

In a later form of yoke, the coils were wound more closely to the neck of the tube to increase the field intensity within the tube. Iron was also

used, but to a lesser extent than had previously been customary. Fig. 1 shows one example of a yoke of this type. The coils are wound upon a length of tubing 1 of fibre or similar material which is adapted to slide over the cylindrical neck of the cathode ray tube. Alternatively, the coils may be wound upon a cylindrical form, removed therefrom, suitably taped so that they will retain their shape and then placed about the neck of the tube in the same positions which they occupied on the cylindrical tube or form. This method may be expedient where it is inconvenient to slide the tubular form itself over the tube neck. In Fig. 1, the coils for producing a field for deflecting the electron beam in a vertical direction comprise the group of current-carrying elements 3 disposed lengthwise of the tube between the lead lines and a corresponding group disposed opposite them on the other side of the tubular form but not visible in the drawings. It will be seen from the figure that these groups of current-carrying elements are all parts of the same winding and are connected by the end turns 5 in such a manner that, when current is supplied to the windings by means of the leads 6 the current in the conductors 3 will be opposite in direction to that in the conductors on the opposite side of the coil form. The effect of this current, if it is in the proper direction, will be to establish within the tubular form 1 a magnetic field which at the point d on the axis $a-a'$ has the direction of the arrow c . If we regard the path of an undeflected beam of electrons as corresponding to the axis $a-a'$ and being toward the lower right-hand corner of the drawing, the beam will then tend to be deflected vertically upward from the axis $a-a'$. The windings, of course, tend to set up a similarly directed magnetic field in other parts of the space surrounded by the coils, so that the deflection is cumulative as the electrons in the beam traverse the space.

In order to obtain an upward vertical deflection of the beam, the current in the windings need only be reversed. It will be noted that the end turns 5 of the coil, which serve principally to connect the useful flux producing conductors disposed parallel to the axis of the coil form and which are not themselves adapted to contribute appreciably to this useful flux, are displaced so as to lie in planes substantially perpendicular to the axis $a-a'$.

Correspondingly, the coils for producing horizontal deflection of the electron beam comprise the conductors 7 and their counterparts, not visible in the figure, on the opposite side of the tubular form. These conductors are connected as before by the end turns 9 which are disposed substantially in the planes of the end turns 5 of the first coil. With a current of proper direction supplied to the coil through leads 10, the direction of the magnetic field produced at the point d will correspond to the arrow f and will be such as to deflect the beam in the direction opposite to that of the arrow e .

In order to reduce the reluctance of the magnetic flux return path for both windings, the windings are surrounded by a return path of iron or other material of suitably low reluctance. In the yoke shown, this consists of a winding of iron wire 11 wrapped so as to embrace closely the useful flux producing turns of the windings.

The yoke above-described possesses certain disadvantages which are overcome by yokes constructed in accordance with the present invention. As pointed out in the foregoing descrip-

tion, the two coils which comprise the yoke are arranged so as to be capable of producing magnetic fields which are mutually perpendicular along the axis of the yoke, which corresponds to the path of the undeflected beam. It was also stated that the directions of the fields in other parts of the space surrounded by the coils were similar to those along the axis. This, however, is not strictly the case. In fact, the lines of force of the fields are considerably curved, as will be seen by reference to Fig. 4 which shows a cross-section of the yoke of Fig. 1 taken transversely of the axis $a-a$ and with one of the coils removed. The broken lines represent lines of force in the field set up by the remaining coil, i. e., coil 1. This curvature of the field is responsible for the defects of the yoke of Fig. 1 which will now be discussed.

One of the undesirable effects produced by the curvature of the lines of magnetic force indicated in Fig. 4 is the defocusing of the electron beam. This obtains because the electron beam fails to intercept the lines of force at right angles. There is then a component of the magnetic field in a direction parallel to the beam axis tending to increase the beam cross-section by causing the individual electron paths, which are not necessarily parallel to the beam axis, to diverge instead of to converge. The only way in which this defocusing effect can be avoided is by employing deflecting fields, the lines of force of which are everywhere perpendicular to the electron beam axis regardless of the amount the beam is deflected. Yokes constructed according to the invention are adapted to produce such a field and will now be described.

One embodiment of such a yoke is shown in Fig. 2. The coils comprising this yoke may be wound upon a square cylindrical form 12 of fibre or some similar material adapted to slide over the cylindrical glass neck of a cathode ray tube. The conductors in each coil may be disposed on opposite surfaces of the cylindrical form. Thus, the conductors 13 and a corresponding group of conductors on the opposite face of the cylinder, but not visible in the drawings, may comprise the vertical deflecting coil adapted to produce a field, the direction of which is denoted by the arrow g . These conductors in each of the two planes which are parallel to each other and to the opposing surfaces of the cylindrical form are connected by the end turns 14 so that the current in the conductors in the two different planes will be opposite in direction. The end turns may either be disposed in planes substantially perpendicular to the yoke axis, as in an embodiment later to be described and shown in Fig. 3, or they may be pressed into bundles disposed adjacent the ends of the useful flux producing conductors as in Fig. 2, or otherwise arranged so as to modify the field within the yoke. The exact effect of modifying the disposition of the end turns is difficult to explain and is best observed in the results produced. In general, it is a second order effect and the usual practice is to adjust the position of these turns until the most desirable results are obtained, as determined from the quality of the reproduced picture in the case where the yoke is used in conjunction with a television picture tube.

The horizontal deflecting coil comprises the conductors 15 and a corresponding group on the opposite face of the cylindrical form but not visible in the figure. The two groups of windings arranged in oppositely disposed planes are connected by end turns 16, as heretofore de-

scribed. The direction of the field produced by the horizontal deflecting coil is indicated by the arrow h .

Current is supplied to the vertical deflecting coil by means of the leads 17 and to the horizontal deflecting coil by means of the leads 18. About both horizontal and vertical windings is disposed a flux return path of low reluctance material which may comprise a winding of iron wire 19, as shown in the figure.

The nature of the field produced by the yoke described above will be seen by reference to Figs. 5A and 5B. Fig. 5A shows a cross-section of the yoke taken transversely of the axis $b-b'$ with one of the coils removed. The broken lines represent the lines of force in the magnetic field set up by the other coil, i. e., coil 15. It will be noted that the curvature of the lines of force is opposite in sense to that of the lines of force in the magnetic field produced by the yoke of Fig. 1. The characteristics of the magnetic field in the direction of the yoke axis is apparent from Fig. 5B which shows a longitudinal section of the yoke of Fig. 2 taken along the axis $b-b'$. The lines of force are substantially straight in the center of the yoke and become gradually more curved as its ends are approached. In this figure, the heavy line k denotes the path of an electron beam passing through this field. The deflection is due to the presence of the field produced by the other coil, not shown. It will be noted that to the left of the center line $m-m'$ of the yoke, the beam cuts the lines of magnetic force almost normally which, as heretofore pointed out, is one of the conditions necessary in order that the beam be not subject to any defocusing action. To the right of the center line $m-m'$, the beam, obviously, cannot cut the lines of force normally because of their curvature in the opposite direction. However, since the beam has not been subjected to appreciable deflection in this region, the defocusing effect is not great and can be tolerated. Of course, it will be understood that Fig. 5B shows only the field due to one of the deflecting coils, whereas in practice the beam will be under the influence of both the horizontal and the vertical deflecting fields. In order to appreciate the effects of both fields upon the beam, it is necessary to consider the interrelations between the two fields and the direction of the deflected beam.

For convenience in explaining these relations, reference may be had to Fig. 6 which is a perspective view showing some of the lines of force in both the horizontal and vertical deflecting fields with the deflected electron beam represented at p . Consider now a curved surface passing through the horizontal and vertical lines of force. This surface is intercepted by the beam p at the point s . The condition to be satisfied if the beam is to be subject to no defocusing is that the beam, regardless of the extent to which it is deflected both horizontally and vertically, should be normal to the said curved surface at its point of intersection therewith. A study of the figure, to which construction lines have been added to aid in visualization, indicates that this condition will be met if and only if the lines of force in each field considered separately are closer together at the edges of the surface than in the center. This is the condition in Fig. 6 since the corners t of the curved surface fall within the corners v of the dotted parallelepiped, the edges of which are tangent to the lines of force bounding the curved surface. Thus, in

order to fulfill the necessary condition, the lines of force in each field, considered separately and when the field is regarded as being viewed from the end of the yoke, should converge toward the sides of the yoke, as indicated in Fig. 5A, and should not diverge toward the sides of the yoke as in Fig. 4.

It will be understood that the imaginary curved surface of Fig. 6 is only one of those which may be passed through intersecting lines of force in the two deflecting fields. Other such curved surfaces may be constructed which will intercept the electron beam at various points. The condition for minimum defocusing of the beam is that the electron beam should intercept all of these imaginary curved surfaces so as to be as nearly normal to them as possible, regardless of the degree of deflection.

The reasons for the difference between the field produced by the yoke of the present invention and that produced by the prior yoke of Fig. 1 will be understood by comparing the two devices. In the yoke of Fig. 1, the windings are disposed about the circular cylindrical form or, alternatively, directly about the cylindrical glass neck of the cathode ray tube through which pass the electrons which constitute the beam to be deflected. The iron wire which forms the return magnetic path is wound directly over these deflecting coil windings. In the field produced by this yoke, the magnetic lines of force, seeking to return to the low reluctance return path by the shortest possible path, are bent outward toward the iron, as clearly illustrated in Fig. 4. This tendency is aided by the disposition of the conductors comprising the yoke. Heretofore, it was not appreciated that this outward bending of the lines of force was responsible for the defocusing of the electron beam, nor was it understood what the configuration of the field should be in order to avoid defocusing.

The present invention provides a yoke which is very simple and easy to construct and which, nevertheless, gives a deflecting field with the desired characteristics. The useful flux producing turns are disposed close to the region traversed by the electron beam so as to give as strong a field as possible in this region. The amount of iron required is small and may be applied to the coils to form the completed yoke in the form of a simple winding of iron wire which also aids in holding the coils in position on the neck of the tube. As appears from the figures, this winding forms a low reluctance flux return path in the form of a flux conducting member having minimum transverse dimensions in directions substantially perpendicular to the directions of deflection produced by the deflecting coils acting individually, these directions of deflection produced by the coils acting individually being referred to, for purposes of convenience, as the principal directions of deflection of the yoke system. With this arrangement of the iron return path, the lines of magnetic force converge towards the return path at these points of least cross-sectional dimension, which effect is aided by constructing the deflecting coils with their useful flux-producing conductors disposed substantially in planes forming the sides of a hollow rectangular prism. It appears, however, that the shaping of the lines of force into the desired pattern is due principally to the arrangement of the low reluctance return path rather than to the disposition of the conductors of the deflecting coils. Accordingly, the arrangement of the

conductors in the coils can be varied considerably, provided that the iron return path is given the correct form. This is demonstrated by the embodiment of Fig. 3 in which the deflecting coils are wound in substantially the same form as in the yoke of Fig. 1, while the low reluctance return path is given the form of that in the yoke of Fig. 2 by the insertion of triangular spacer blocks 20 placed between the deflecting coil windings and the windings of low reluctance material. These blocks may be of wood or any other suitable non-magnetic material. It will also be noted that in the embodiment of Fig. 3 the end turns of the deflecting coil windings are disposed substantially in planes perpendicular to the axis of the yoke, though it will be understood that they might be rearranged as in the embodiment of Fig. 2 to aid in shaping the field. The embodiment of Fig. 3 has been found to give results comparable to those obtained with the embodiment of Fig. 2.

A further advantage of yokes constructed in accordance with the invention is that it is relatively easy to effect slight changes in the characteristics of the magnetic fields produced by simply altering the dimensions and form of the return path winding either by changing the disposition of the coil windings or by altering the shape of the above-mentioned spacer blocks. In either case the coils function to support and shape the return path winding while the latter keeps them in their intended positions with respect to each other.

Although a yoke has been described comprising windings for producing both horizontal and vertical deflection it will be understood that a combination of magnetic and electric deflection might be found desirable. In this case the yoke in accordance with the invention would consist of but a single winding, deflection in the other direction being achieved by electric deflecting plates or other suitable means. This single winding could also be constructed in accordance with the principles of the invention to produce no appreciable defocusing of the beam when the latter is deflected by both means by simply omitting one of the windings in the embodiments hereinbefore described.

It will be understood, of course, that the invention is capable of embodiment in forms other than those shown and described, and that the scope of the invention is defined only by the appended claims.

I claim:

1. An electron beam-deflecting yoke comprising a plurality of conductors longitudinally disposed with reference to the axis of said yoke and substantially uniformly distributed so as to define an envelope bounding the space within said yoke, and a closed band of magnetic material of substantially uniform thickness defining a rectangular cylindrical envelope surrounding said first envelope and having its principal axis coincident with the axis of said yoke.

2. An electron beam-deflecting yoke comprising two deflecting elements for producing crossed deflecting fields within said yoke, each of said elements comprising groups of conductors disposed on opposite sides of said yoke, the conductors of each group being longitudinally disposed with reference to the axis of the yoke and being substantially uniformly distributed so as to define one surface of a right-rectangular cylinder bounding the space within said yoke, and a closed band of magnetic material of substantially uni-

form thickness closely embracing said conductors so as to be supported thereby and defining a second right-rectangular cylinder whose principal axis coincides with the axis of said yoke.

3. An electron beam-deflecting yoke comprising a plurality of conductors longitudinally disposed with reference to the axis of said yoke and substantially uniformly distributed so as to define an envelope bounding the space within said yoke, the ends of certain of said conductors being connected to the ends of certain others of said conductors by end connections disposed externally of the space bounded by said envelope to form at least a single deflecting element, and a closed band of magnetic material of substantially uniform thickness defining a rectangular cylindrical envelope surrounding said first envelope and having its principal axis coincident with the axis of said yoke.

4. An electron beam-deflecting yoke comprising a plurality of conductors longitudinally disposed with reference to the axis of said yoke and substantially uniformly distributed so as to define an envelope bounding the space within said yoke, and a closed band of substantially uniform thickness consisting of a winding of wire of magnetic material and defining a rec-

tangular cylindrical envelope surrounding said first envelope and having its principal axis coincident with the axis of said yoke.

5. An electron beam-deflecting yoke comprising a plurality of conductors longitudinally disposed with reference to the axis of said yoke and substantially uniformly distributed so as to define a circular cylindrical envelope bounding the space within said yoke, and a closed band of magnetic material defining a rectangular cylindrical envelope surrounding said first envelope and having its principal axis coincident with the axis of said yoke.

6. In an electron beam-deflecting yoke comprising a plurality of conductors, longitudinally disposed with reference to the axis of said yoke and substantially uniformly distributed so as to define an envelope bounding the space within said yoke, a closed band of magnetic material defining a rectangular cylindrical envelope surrounding said first envelope and having its principal axis coincident with the axis of said yoke, and non-magnetic spacer elements interposed between said envelopes and serving to support said band and to determine its rectangular configuration with reference to said first envelope.

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