

Nov. 13, 1962

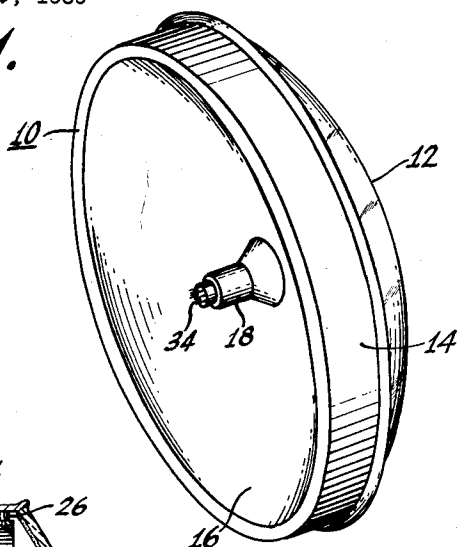
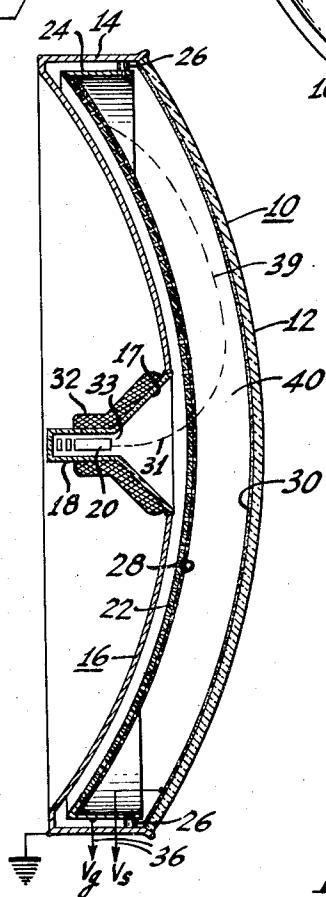
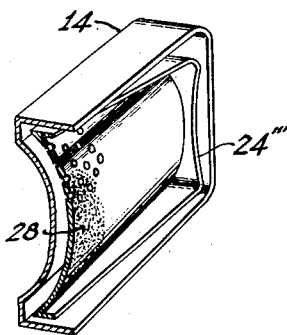
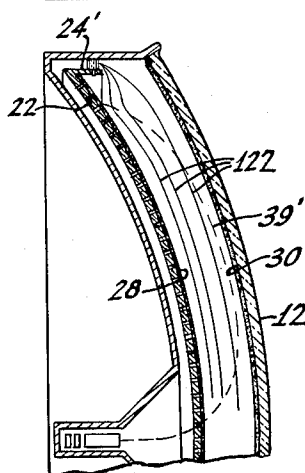
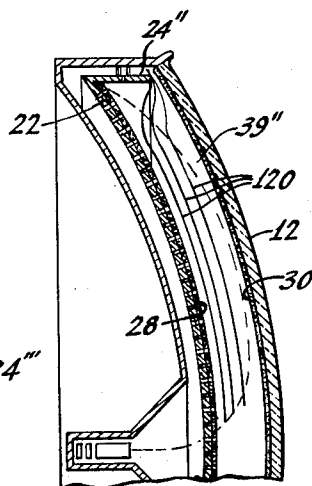
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CATHODE RAY TUBE

3,064,154

Filed Oct. 29, 1959

4 Sheets-Sheet 1

Fig. 1.*Fig. 2.**Fig. 8.**Fig. 10.**Fig. 9.*

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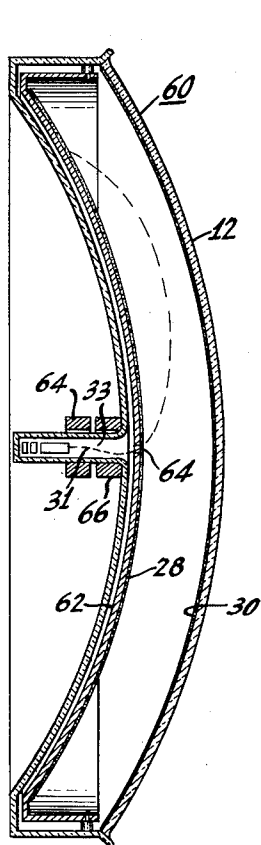


Fig. 4.

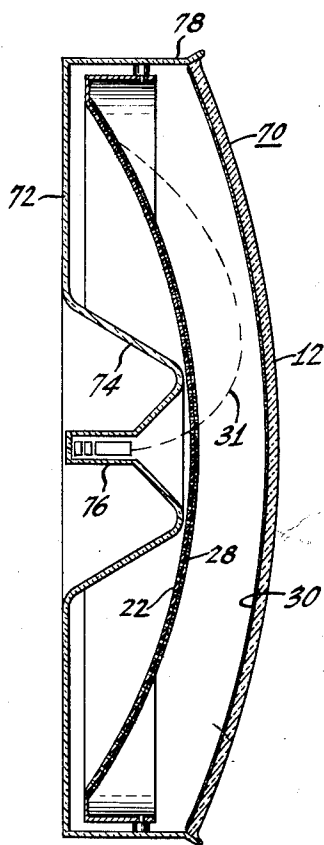


Fig. 5.

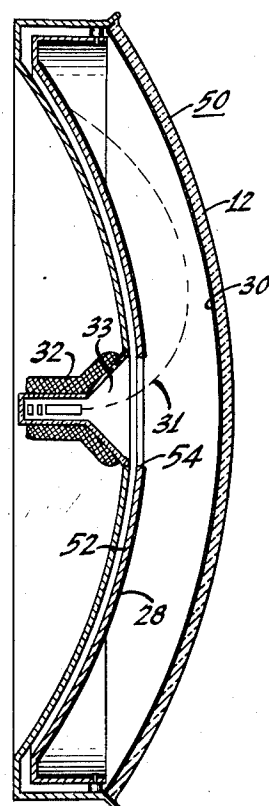


Fig. 3.

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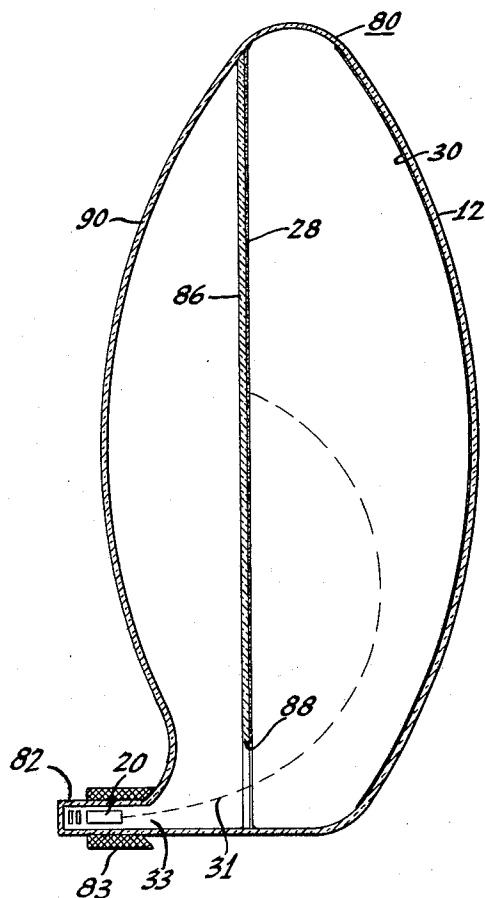


Fig. 6.

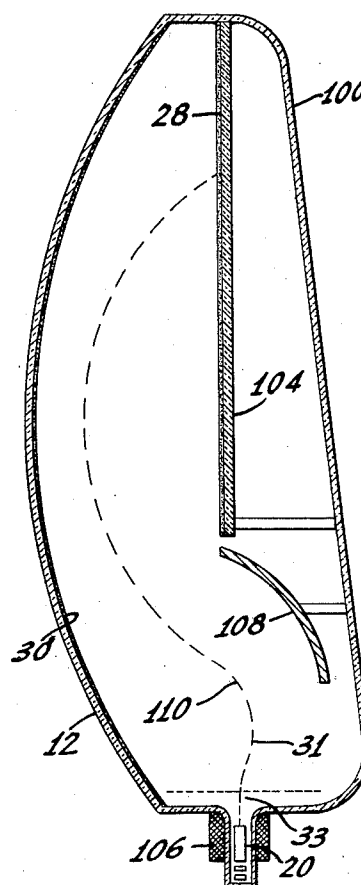


Fig. 7.

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Filed Oct. 29, 1959

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Fig. 12.

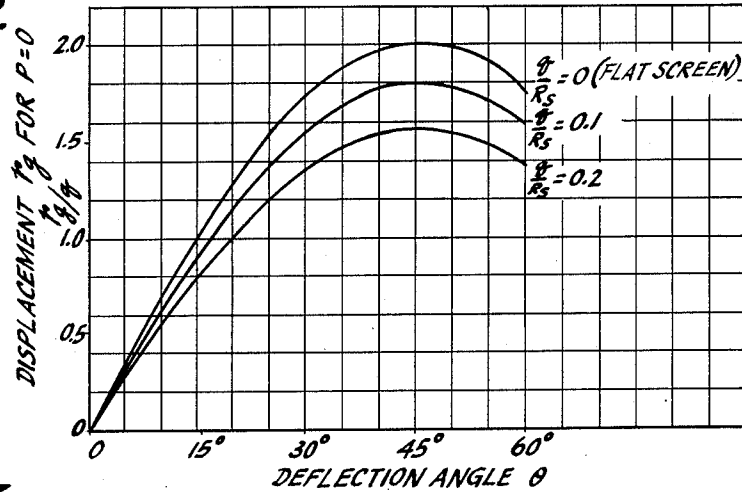


Fig. 13.

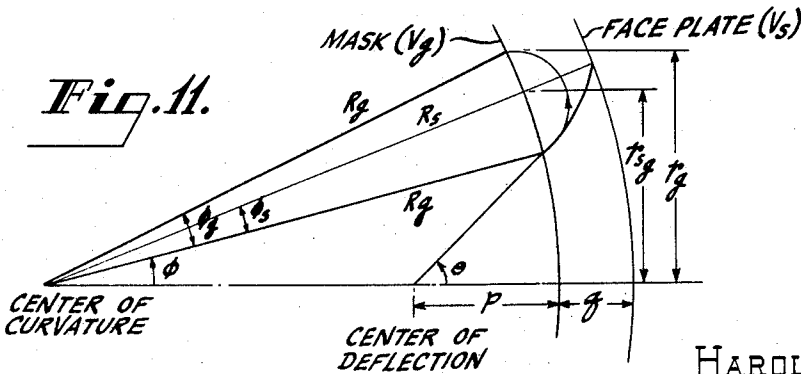
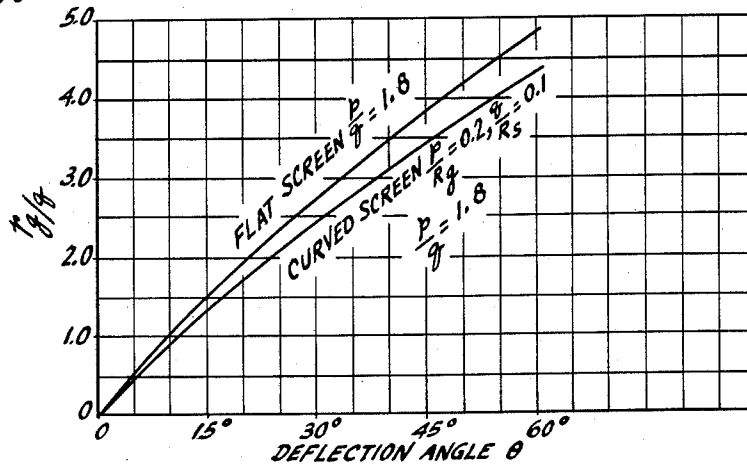


Fig. 11.

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3,064,154

CATHODE RAY TUBE

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Filed Oct. 29, 1959, Ser. No. 849,487
19 Claims. (Cl. 313—79)

This invention relates to cathode ray tubes of the image display type and particularly to such tubes having novel beam deflection arrangements.

In recent years the trend has been toward cathode ray tubes having larger image screens both in entertainment and radar type applications. In order to obtain these larger screen sizes with minimum overall tube depth, the prior art has proposed various tube structures which depart from conventional electron gun orientation and beam deflection arrangements. However, many such kinescope designs directed to this end utilize involved switching arrangements and have troublesome scanning problems.

Accordingly, it is an object of this invention to provide a new and improved cathode ray tube structure wherein a relatively large ratio of raster size to overall tube depth is obtained, and particularly to provide such a tube having a novel and simple arrangement for deflecting the electron beam to obtain a raster scan.

It is a further object of this invention to provide these features in a cathode ray tube which is void of the prior art problems present in other nonconventional scanning arrangements and in which ancillary benefits such as raster distortion correction are provided.

A cathode ray tube utilizing my invention is provided with an apertured structure mounted generally parallel to and spaced from the transparent faceplate of the tube. A phosphor screen is deposited on the apertured structure surface which faces the faceplate. An electron beam from a conventional electron gun is deflected by conventional means such as a magnetic yoke. After such deflection, the beam passes through the apertured structure from the side opposite that on which the phosphor screen is provided and is then further deflected and reflected back upon the phosphor screen by a retarding electric field. The retarding electric field is produced by a reflector electrode in the form of a transparent conductive coating on the inside of the faceplate which is operated near cathode potential.

In the drawings in which like reference numerals refer to similar parts:

FIG. 1 is a perspective view of a representative embodiment of a cathode ray tube according to the invention;

FIG. 2 is a sectional view along a diameter of the tube of FIG. 1;

FIGS. 3-5 are section views of modifications of the FIG. 2 embodiment of the invention;

FIGS. 6 and 7 are sectional views of other embodiments of the invention;

FIGS. 8 and 9 are broken away sectional views of tubes according to the invention illustrating raster-affecting electric fields;

FIG. 10 shows a broken away view of portions of a rectangular tube with an illustration of the variable depth of the skirt on the phosphor screen; and

FIGS. 11-13 are graphs used to explain various design parameters of the invention.

In FIGS. 1 and 2 an electron tube 10 is shown which includes an envelope comprising a curved transparent front wall faceplate 12, a side wall rim portion 14, and a concave, dish-shaped or annular reentrant rear wall 16 which includes a central funnel-shaped portion 17. A neck section 18 is sealed centrally in the concave rear wall 16 and houses an electron gun 20. Within the

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envelope a multiapertured plate member 22 is disposed in spaced relation to the transparent faceplate 12. The multiapertured plate member 22, which is generally co-extensive with the faceplate 12, substantially conforms in curvature to that of the faceplate 12 and is fixed to a peripheral conductive skirt cylinder 24 which is mounted on a plurality of supports 26 secured to the rim portion 14 of the envelope. While the rim portion 14 is shown as being conductive and grounded, it may comprise nonconductive material and would then not be grounded.

According to the invention a phosphor screen 28 is provided on the apertured plate member 22 on the side thereof facing the transparent faceplate 12. Such phosphor screen may comprise any one of the well-known and conventionally used materials which fluoresces in response to bombardment by an electron beam. A transparent conductive coating 30 is provided on the inside surface on the faceplate 12 and forms an electron reflector electrode as hereinafter described.

Suitable means for providing conventional deflection of an electron beam 31 produced by the electron gun 20 is provided and may comprise, for example electrostatic deflection means (not shown), as a part of the gun 20 or a magnetic deflection yoke 32 as shown. As shown in FIG. 2, the yoke 32 produces a direct or primary deflection of the beam 31 in a primary deflection region 33 of the tube. Suitable means such as the schematically shown lead-ins 34 and 36 are provided for supplying energizing potentials to the electrodes of the tube 10.

In operation of the tube 10, conventional potentials are applied to the electron gun 20, the magnetic yoke 32, and the phosphor screen 28. The reflector electrode 30 is operated at approximately cathode voltage. The electron gun 20 projects an electron beam 31 along the central axis of the tube 10 and magnetic deflection yoke 32 deflects the beam 31 in the region 33 through a conventional raster over a relatively small central portion of the multiapertured plate 22. The electron beam 31 will pass through the multiaperture plate 22 and, with a near cathode potential on the conductive coating reflector electrode 30, will follow an arcuate path 39 in the space 40 between the phosphor screen 28 and the coating reflector electrode 30. The arcuate path 39 will comprise a further deflection of the electron beam 31 away from the central axis of the tube 10 and a reflection of the beam 31 back onto the phosphor screen 28 to produce fluorescence.

It will be appreciated that the deflection of the electron beam 31 to scan a raster on the phosphor screen 28 is obtained by a combination of means which include a direct or primary deflection by the yoke 32 in the primary deflection region 33 and a reflective deflection by virtue of the retarding electric field between the phosphor screen 28 and the reflector 30. As is illustrated by the beam path 39, the deflection provided by the yoke 32 need scan the beam 31 over only a relatively small central portion of the multiapertured plate 22. Then by virtue of the electron beam 31 penetrating the multiapertured plate 22 at an angle relative to the central axis of the tube 10, the electron beam 31 will, in being reflected back upon the phosphor screen 28, be simultaneously deflected further away from the central axis of the tube. Accordingly, the reflective deflection provided in the region 40 may be considered as a magnification of the direct deflection provided by the magnetic yoke 32. This magnification may be a two-fold or greater enlargement of the primarily scanned raster. The spacing between the reflector 30 and the phosphor screen 28 must be large enough so that there will be room for the electrons to take their path between the reflector 30 and phosphor screen 28 away from the axis of the tube 10 as indicated at 39 in FIG. 2.

By virtue of this combination of beam deflection means, which requires a relatively small direct deflection prior to

penetrating the multiapertured plate 22, the electron gun 20 may be very closely spaced to the multiapertured phosphor-screen-bearing plate 22. Accordingly, a relatively short or small depth cathode ray tube is provided. Moreover, full advantage of the short tube feature resulting from the beam reflection principles is made possible by the envelope construction which includes a concave or re-entrant rear wall section. In addition, the concave rear wall construction of the envelope of tube 10 presents the advantage that the concave volume around the neck section 18 may be used to compactly house components and circuitry of equipment utilizing the tube itself.

FIG. 1 illustrates a cathode ray tube according to my invention which has been operated to reproduce an image of acceptable fidelity on the phosphor screen 28. It will be noted that in the tube 10 the phosphor screen 28 is positioned approximately midway between the electron gun 20 and the reflector 30. It is necessary that a substantial spacing of the phosphor screen 28 from the reflector electrode 30 be provided for the electron stream 39 to have room in which to take its path between the reflector 30 and the phosphor screen 28 in order to obtain the reflective magnification of the direct reflection scan produced by the yoke 32.

In the cathode ray tube 10, the percentage of the total available beam current which actually produces fluorescence is dependent upon two factors. The multiapertured plate 22 absorbs a fraction of the beam and the actual phosphor area available for reflected beam bombardment is restricted by the percentage of aperture area of the plate 22. Therefore if T is the transmission factor of the multiapertured plate 22, the percentage of the original beam penetrating the plate 22 will be T and the percentage of the reflected beam striking a phosphor area will be $(1-T)$. Accordingly, the brightness capability of the tube 10 varies as $T(1-T)$ for a beam of given intensity. The optimum condition therefore appears to be at a transmission factor for the screen of 50%. It is understood that the perforations of the screen permit electrons to penetrate the screen without hitting the phosphor. Thus, since the central portion of the screen must be perforated to permit the electron beam to penetrate it, the image of the center would not be as bright as at the outer portions of the screen if the screen were imperforate at the outer portions. The screen 28 is therefore perforated throughout for presenting a more uniform brightness of the image. As indicated below, where this feature is unimportant, or where the central hole in the screen is relatively small, the screen need not be perforated throughout.

For certain applications such as radar displays these brightness limitations may be entirely avoided by the use of an imperforate plate for supporting the phosphor screen 28 which has an open central area to let the beam through. FIGS. 3 and 4 represent such a tube.

FIG. 3 shows a cathode ray tube 50 similar to the tube 10 of FIGS. 1 and 2 except that the phosphor screen 28 is supported on a nonperforate plate 52 having a single central aperture 54 therein. The central aperture 54 is designed to be just large enough to pass the electron beam 31 at the widest angle of direct deflection provided by the yoke 32 in the primary deflection region 33. In such an embodiment no loss of beam current is occasioned either by absorption by the plate 52 as the beam 31 passes through the aperture 54, or by failure of the reflected beam 31 to strike a phosphor coated portion of the plate 52. The tube 50 is, of course, limited to applications in which a central portion is not needed for image reproduction. Such application is common in PPI type of radar displays.

FIG. 4 illustrates a modification of the tube 50 of FIG. 3 in which the central aperture of the phosphor bearing plate is reduced to a minimum. In FIG. 4 a cathode ray tube 60 includes a phosphor screen 28 provided on a plate 62 having one relatively small aperture 64 on the central axis of the tube. The

tube 60 then employs well-known double primary deflection means to doubly deflect the beam 31 in the primary deflection region 33. A first deflection yoke 64 bends the electron beam 31 off the axis of the tube and then a second deflection yoke 66 bends the electron beam 31 back in the opposite direction so that passage of the beam 31 through the aperture phosphor bearing plate 62 is confined to a relatively small central region thereof. This permits the central aperture in the phosphor bearing plate 62 to be reduced to a minimum thus providing the maximum screen size for a cathode ray tube of the type illustrated in FIGS. 3 and 4.

FIG. 5 illustrates a modification of the tubes of FIGS. 2, 3, and 4. In FIG. 5 a cathode ray tube 70 is shown in which a nonconcave rear wall 72 of the envelope is provided with a central annular reentrant portion 74 in which a central neck section 76 is disposed. The rear wall 72, unlike the concave rear wall 16 of tube 10, minimizes the bending force exerted at the peripheral seal 78 by virtue of the evacuated condition of the envelope of the tube 70. Yet, at the same time the reentrant portion 74 permits the short tube feature provided by the envelope of tube 10.

Also, in the tube 70 of FIG. 5 the faceplate 12 and phosphor screen support plate 22 are shaped so as to provide a substantial nonuniform spacing therebetween. This provides a resultant nonuniform spacing between the phosphor screen 28 and the reflector 30 which is desired for certain purposes. Such will be hereinafter more fully described.

A cathode ray tube 80 of FIG. 6 illustrates an alternative embodiment of my invention. The tube 80, insofar as operational principles are concerned, may be thought of as comprising essentially one-half of the tube 50 of FIG. 3. In this respect the tube 80 includes a neck section 82 housing the electron gun 20 which is disposed adjacent the periphery of the tube. A magnetic deflection yoke 83 is provided for deflecting the beam 31 through the primary deflection region 33. An imperforate plate 86 is provided as a support for the phosphor screen 28 and a single aperture 88 is provided therein opposite the electron gun 20. The tube 80 thus obtains the advantages of the tube 50 of FIG. 3 in that an unimpeded electron beam 31 is provided to thereby produce greater brightness output. At the same time the tube 80 avoids the disadvantage of having a central portion of the phosphor screen 28 cutaway to permit passage of the electron beam 31.

A further ancillary advantage of the cathode ray tube 80 is that since the electron gun 20 is disposed near the edge of the tube a completely transparent screen display can be provided. This can be obtained by providing as transparent elements the electron reflective electrode 30, the faceplate 12, the phosphor screen 28, the screen support plate 86, and a rear wall 90. Such transparent tube construction feature can prove highly desirable in various radar applications.

FIG. 7 illustrates a cathode ray tube 100 according to my invention which differs from the tube 80 of FIG. 6 in that the electron gun 20 is disposed generally parallel to the phosphor screen 28. In the tube 100 the phosphor screen 28 is supported on a nonperforate plate 104. The electron beam 31 provided by the electron gun 20 is given a primary deflection in the primary deflection region 33 by a magnetic yoke 106. A curved reflector plate 108 adapted to have approximately cathode potential applied thereto is disposed generally between the electron gun 20 and the phosphor screen 23 to deflect the electron beam 31 in a curved path 110. The transparent conductive coating reflector electrode 30 operated at approximately cathode potential then serves to reflect the electron beam 31 onto the phosphor screen 28 in accordance with the invention. The cathode ray tube 100 obtains the advantage of avoiding any additional thickness of the tube by virtue of an extending neck section for

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housing the electron gun such as is provided by the neck section 82 of the tube 80 of FIG. 6.

In fabricating the multiapertured support plate 22 for the phosphor screen 28 in, for example the tubes of FIGS. 2 and 5, any one of a number of well-known methods may be employed. One method which has proved to be satisfactory involves a photoengraving and etching process. A replica of a portion of the multiapertured pattern is drawn on an enlarged scale in ink on paper and then photographed. The photograph is reduced in size and duplicated to provide an entire pattern. This pattern is then transferred by photographic exposure onto an imperforate metal plate which has been previously coated with photosensitive material that hardens when exposed to light. The unhardened portions of the coating material are washed away after the exposure and the areas of the metal thus exposed are etched through. Such a method has been advantageously used to fabricate masking electrodes for the conventional present-day tricolor kinescope.

In applying the desired phosphor material to a side of the multiapertured support plate 22, care must be taken to avoid the presence of exposed phosphor material on the aperture walls. Any such phosphor would be bombarded by electrons as they penetrate the plate 22 from the back side thereof. If any phosphor material is so bombarded, a small raster will be illuminated over the small central portion of the screen scanned by the yoke 32.

One suitable method for providing the phosphor screen 28 includes covering any exposed phosphor areas on the aperture walls by an electron impervious material. A desired phosphor compound is settled according to well-known practices upon the convex surface of the multiapertured plate 22. A material such as lampblack, colloidal silver, or some high-atomic-number compound is then sprayed from the rear or concave side of the multiapertured plate 22 so as to completely coat any phosphor area subject to line of sight bombardment from the back side of the multiapertured plate. Although lampblack is desired because of its light absorption properties, higher atomic number materials provide better electron impenetrability. If turbulence occurs during spraying of the material, the material may undesirably coat front portions of phosphor of the screen. In order to prevent turbulence of the sprayed material as it passes through the apertures, a flexible sheet such as Mylar plastic is stretched over the phosphor coating on the front side of the support plate 22. This insures that the lampblack spray will not settle upon the front face of the phosphor screen 28.

In cathode ray tubes according to the invention wherein the conductive coating reflector 30 and the phosphor screen 28 are provided substantially parallel to each other, an inherent slight barrel raster distortion results. Such barrel distortion may, in fact, be beneficial in that it can compensate for normal pincushioning which is present in certain magnetic deflection yokes. It is known that the simplest and least expensive magnetic deflection yokes ordinarily produce a pincushion raster. Accordingly, such defective yokes may be used with the present invention to provide a desired straight-edge, non-distorted raster.

On the other hand, should it be so desired, such barrel distortion, or in fact other raster distortions, caused by other factors may be corrected by providing proper non-uniform spacing between the reflector electrode 30 and the phosphor screen 28. Such a construction of the invention is shown in FIG. 5. As there shown, if the spacing between the reflector electrode 30 and the phosphor screen 28 increases with increasing distances from the central axis of the tube, the raster size will be increased. This can be explained by considering the manner in which the electric field between the reflector electrode 30 and the phosphor screen 28 affects the curved beam path 39. The nearness with which the electron

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beam will approach the reflector electrode 30 depends upon the velocity of the electron beam normal to the surface of the reflector 30 and the strength of retarding electric field between the reflector 30 and the phosphor screen 28. An undeflected electron beam on the central axis of the tube will possess the greatest velocity normal to the reflector 30. When the electron beam 31 is deflected by the magnetic yoke 32 so that it approaches the reflector electrode 30 at some acute angle, it will have less velocity normal to the reflector 30. Thus, the electron beam will approach closest to the reflector electrode 30 at the central axis of the tube, and at increasing distances away from the central axis of the tube will approach less and less closely thereto. Since the size of the raster on the phosphor screen 28 depends upon the nearness to which the electron beam 31 approaches the reflector electrode 30, it follows that the raster can be increased in size by providing a closer approach of the electron beam 31 to the reflector electrode 30. One way of accomplishing this is to increase the spacing between the reflector electrode 30 and the phosphor screen 28 at increasing distances from the central axis of the tube. This amounts to establishing a decreasing strength electric field between these two electrode surfaces at increasing distances from the central axis of the tube. Accordingly, by providing such increasing spacing a pincushioning type of raster distortion can be built into the tube as an inherent characteristic thereof. Conversely, a barrel-type raster distortion can be made an inherent characteristic of the tube by providing closer spacing between the reflector 30 and the phosphor screen 28 at increasing distances from the central axis of the tube.

Another method whereby the shape of the raster may be affected in cathode ray tubes according to the invention comprises modulating the reflector 30. If the reflector potential is modulated as a function of the scan so that all beam paths approach very close to the reflector 30, a larger raster size is provided. In effect this closely parallels, in effect, a tube construction in which the spacing between reflector 30 and the phosphor screen 28 is increased with increasing distances from the central axis of the tube. In either case an electric field of decreasing strength at distances spaced from the central axis of the tube is provided. Accordingly, reflector modulation can be employed to desirably shape the raster on the phosphor screen 28 either in the direction of a pincushion-type or a barrel-type distortion.

Still another way of shaping the raster, particularly at the edges thereof, comprises varying the axial length of the conductive cylindrical skirt 24. FIGS. 8 and 9 illustrate effects on the electric field between the reflector 30 and the phosphor screen 28 for two different lengths of skirts 24' and 24'', respectively. In FIG. 8 a relatively short skirt 24' is provided while in FIG. 9 a comparatively long skirt 24'' is provided. The effect of the longer skirt 24'' is to concentrate the equipotential field lines 120 toward reflector electrode 30 near the edge thereof. On the other hand the shorter skirt 24' of FIG. 8 serves to concentrate the equipotential lines 122 near the phosphor screen 28.

The result is that in the case of an electron beam path, which extends to near the edge of the phosphor screen, such as one forming the corners of a scanned rectangular raster, the shorter skirt 24' forces the outer end of the beam path 39' to terminate on the screen at a point nearer the central tube axis than the longer skirt 24'' does the path 39''. Compare the location of the points where the electron beams of the paths 39' and 39'' impinge upon the phosphor screens 28. Thus, a long skirt 24'' can be used to pull out the corners of a raster, i.e., shape the raster toward pincushioning. Conversely a short skirt 24' can be used to pull in the corners of a raster, i.e., suppress or correct pincushioning or even give the raster a barrel shape.

It will therefore be appreciated that a suitable skirt 24

can be provided that will virtually eliminate any raster edge distortion whatever type that distortion might be. For example, a rectangular tube can be provided with a variable length skirt 24 around the periphery of the tube to produce a desired raster shaping at the edge thereof. FIG. 10 shows a portion of a rectangular tube in which the rectangular phosphor screen 23 has attached thereto a skirt 24'''. In this showing the skirt is longer at the corners to extend the path of the electron beam and therefore to extend the raster and shorter in between the corners where the raster need not be extended, so as to produce an undistorted rectangular raster on the screen. It will be understood that the showing of FIG. 10 is illustrative, and the lengths of the skirt 24''' may be made such as to overcome whatever distortion is present in the raster in which the variably length skirt is used. The lengths of the skirt need not be as described in connection with this figure. The other details of the tube are omitted from FIG. 10 since they are similar to those of FIG. 2, for example, of this disclosure.

Formulas for the Deflection of the Scanning Beam

The characteristics of the deflection of the electron beam in the tubes according to the invention have been described above. The following are mathematical approximation analyses and verifications of these stated characteristics. For reasons of mathematical simplicity, all of the formulas given below relate to tubes with concentric spherical masks and faceplates. Moderate deviations from the condition of concentricity, on the other hand, will lead to only moderate deviations of the observed results from those given by the formulas. For convenient reference, the symbols employed in the formulas are listed alphabetically below: the geometric meaning of some of them is indicated in FIG. 10.

Definition of Symbols

$A=1-V_s/V$
 $A'=(1-V_s/V)(1+q/R)$
 $-e$ charge of electron
 m mass of electron
 p distance between plane of deflection and center of mask
 q separation of mask and inner (conducting) surface of faceplate
 r_g distance of point of return to mask (scanning spot) from tube axis
 r_0 distance of point of incidence on mask from tube axis
 R radius of curvature of mask
 V voltage of mask (with respect to gun cathode)
 V_s voltage of faceplate electrode (with respect to gun cathode)
 α angle of incidence on mask ($\sin \alpha = (1-p/R) \sin \theta$)
 θ angle of deflection
 ρ distance of point between mask and faceplate from their common center of curvature
 ϕ angular coordinate of point with respect to tube axis, measured with center of curvature as origin
 ϕ_0 central angle of point of incidence on mask
 ϕ_g central angle of point of return to mask

$$\xi = 1 - \frac{A(1+q/R)}{\rho 2q \sin^2 \alpha}$$

(dot) derivative with respect to time
 (prime) derivative with respect to ϕ

Derivation of General Formulas

The path equations in the central field between mask and faceplates are

$$\ddot{\rho} - \rho \dot{\phi}^2 = -\frac{eV}{m} \frac{AR^2}{q\rho^2} \left(1 + \frac{q}{R}\right) \quad (1)$$

$$\frac{d}{dt}(\rho^2 \dot{\phi}) = 0; \rho^2 \dot{\phi} = R \sqrt{\frac{2eV}{m}} \sin \alpha \quad (2)$$

The second equation makes it possible to translate the variation with time in the first equation into a variation with central angle ϕ :

$$\rho'' - \frac{2\rho'}{\rho} - \rho + \frac{A(1+q/R)\rho^2}{2q \sin^2 \alpha} = 0 \quad (3)$$

The substitution

$$\xi = \frac{1}{\rho} - \frac{A(1+q/R)}{2q \sin^2 \alpha} \quad (4)$$

leads to

$$\xi'' + \xi = 0 \quad (5)$$

This differential equation is solved by

$$\phi - \phi_0 = \arcsin(\xi/\xi_v) - \arcsin(\xi_0/\xi_v) \quad (6)$$

with

$$\xi_0 = \frac{1}{R} - \frac{A(1+q/R)}{2q \sin^2 \alpha} \quad (6a)$$

$$\xi_v^2 = \left(\frac{1}{R} - \frac{A(1+q/R)}{2q \sin^2 \alpha}\right)^2 + \frac{\cot^2 \alpha}{R^2} \quad (6b)$$

Equation 6 can also be written in the form

$$\frac{1}{\rho} = \frac{A(1+q/R)}{2q \sin^2 \alpha} + \xi_v \sin(\phi - \phi_0 + \arcsin(\xi_0/\xi_v)) \quad (7)$$

This is the equation of a hyperbola with the focal point at the origin.

Formulas for the Spot Displacement as Function of Deflection Angle

We find directly from Equation 6:

$$\begin{aligned} \phi_g &= \theta - \alpha + 2 \arcsin \frac{q \sin^2 \alpha}{\sqrt{A'^2 R^2 - 4q(A'R - q) \sin^2 \alpha}} \\ &= \arcsin\{\sin \theta (\sqrt{1 - (1-p/R)^2 \sin^2 \theta} - (1-p/R) \cos \theta)\} \\ &\quad + 2 \arcsin \frac{2q(1-p/R) \sin \theta \sqrt{1 - (1-p/R)^2 \sin^2 \theta}}{\sqrt{A'^2 R^2 - 4q(A'R - q)(1-p/R)^2 \sin^2 \theta}} \end{aligned} \quad (8)$$

$$r_g = R \sin \phi_g \quad (9)$$

If the faceplate voltage V_s is to be held constant, the highest value of V_s for which the beam electrons do not strike the faceplate is $V_s=0$ corresponding to

$$A=1, A'=1+q/R \quad (10)$$

For this condition, which yields maximum deflection for fixed voltages, we obtain

$$\phi_g - \phi_0 = 2 \arcsin \frac{2q(1-p/R) \sin \theta \sqrt{1 - (1-p/R)^2 \sin^2 \theta}}{\sqrt{(R+q)^2 - 4qR(1-p/R)^2 \sin^2 \theta}} \quad (11)$$

If the deflection takes place at the mask, $p=0$ and $\phi_0=0$ and, simply,

$$r_g = \frac{2q \sin 2\theta (1 + (q/R) \cos 2\theta)}{1 + (2a/R) \cos 2\theta + (q/R)^2} \quad (12)$$

It can readily be shown that, for $\theta < 45^\circ$, this quantity decreases monotonically as R is decreased, i.e., as the mask and faceplate are curved more strongly. The variation of r_g with θ is shown in FIG. 11. For $p=0$ the value of r_g attains a maximum for an angle of incidence $\theta \approx 45^\circ$. For a flat mask we obtain simply

$$r_g = p \tan \theta + 2q \sin 2\theta \quad (13)$$

It is possible to increase the scanning range by modulating the faceplate voltage, making it increasingly positive as the deflection angle increases. The maximum modulation which can be used corresponds to the grazing of

the faceplate by the beam for all angles of deflection. This modulation is given by

$$A' = (1 + q/R) \left(1 - \left(\frac{R-p}{R+q} \right)^2 \sin^2 \theta \right) \quad (14)$$

With condition (14) we obtain

$$\phi_g - \phi_0 = 2 \arcsin \frac{\frac{2q}{R} \frac{R-p}{R+q} \sin \theta \sqrt{1 - \left(\frac{R-p}{R} \right)^2 \sin^2 \theta}}{\left\{ 1 - \left(\frac{R-p}{R+q} \right)^2 \left(1 + \frac{2q}{R} \right) \sin^2 \theta \right\}} \quad (15)$$

For a flat mask we obtain in this instance simply

$$r_g = (p + 4q) \tan \theta \quad (16)$$

FIG. 12 illustrates the variation of spot displacement with deflection angle for a number of different conditions. It is seen that, whereas for small values of p , barrel-shaped distortion of the scanning pattern is obtained with fixed faceplate voltage, the distortion becomes increasingly pincushioned when the faceplate voltage is increased with the deflection angle. The curves of FIG. 12 interpret into this fact in that for

$$\frac{p}{R} = 0$$

the curves curve downwardly while for

$$\frac{p}{R} = 0.2$$

the curves curve upwardly.

What is claimed is:

1. A cathode ray tube comprising a vacuum-tight envelope having a faceplate, a generally concave rear wall, a neck section extending centrally from said rear wall, and an electron gun in said neck section.

2. A cathode ray tube envelope comprising a front wall and a generally concave rear wall forming an enclosure, and a tubular neck member extending externally of said envelope from said rear wall.

3. A cathode ray tube comprising a vacuum-tight envelope having a faceplate, a rear wall, a phosphor screen having openings therethrough and position between said faceplate and said rear wall, a neck section centrally positioned in said rear wall, said rear wall having at least a portion adjacent said neck section which is concave, an electron gun in said neck section to project electrons toward said screen and through said openings, a transparent conductive coating on said faceplate substantially coextensive therewith, and terminal means for establishing an electric field between said screen and said coating to cause said electrons to impinge on said screen.

4. A cathode ray tube comprising a vacuum-tight envelope having a faceplate, a rear wall, an apertured phosphor screen positioned between said faceplate and said rear wall, a neck section positioned in said rear wall, an electron gun in said neck section to project electrons through said apertured screen, a transparent conductive coating on said faceplate substantially coextensive therewith for establishing an electric field between said screen and said coating to reflect said electrons to and upon said screen, and a primary deflection region wherein said beam can be scanned to develop a scanning raster on said screen by a deflection of said electrons before the electrons go through said apertured screen and wherein the area of said apertured screen through which said electrons go is substantially less than the area of said scanning raster.

5. An image reproducing tube comprising a multi-apertured plate having a phosphor screen coating on one side thereof, electron gun means disposed along an axis substantially perpendicular to said screen and adapted to project an electron beam through apertures thereof from the side thereof opposite said coated side, said electron beam being adapted to be scanned

through a raster pattern, and transparent electron reflective means disposed substantially coextensive with and spaced from said apertured plate on the side thereof opposite said electron gun for reflectively deflecting said beam away from said gun axis and back onto said screen.

6. A cathode ray tube comprising an envelope, an apertured phosphor screen, an electron gun disposed along an axis substantially normal to said screen and adapted to project an electron beam through said screen, said tube being adapted to utilize means to deflect said electron beam between said gun and said screen to scan said beam through a raster having a given size at the plane of said screen, and electron reflector means disposed substantially coextensive with and spaced from said screen on the side thereof remote from said electron gun to deflect said scanned beam in an arcuate path between said screen and said reflector away from said axis and back upon said screen to form a raster on the side of said screen facing said reflector substantially larger in size than said scanned raster.

7. The cathode ray tube according to claim 6 and wherein said apertured phosphor screen comprises a phosphor screen having a single aperture larger in size than said given size aligned with said axis.

8. The cathode ray tube according to claim 6 and wherein said phosphor screen is multiapertured and said gun is adapted to project said beam through apertures of said screen.

9. The cathode ray tube according to claim 6 and wherein said electron reflector means comprises a transparent conductive coating on at least a portion of said envelope and wherein the spacing between said phosphor screen and said reflector means increases with increased distances from said axis.

10. A cathode ray tube comprising an apertured phosphor screen, an electron gun disposed along an axis substantially normal to said screen and adapted to project an electron beam from one side of said screen through a deflection region and then past said screen to the other side thereof, and electron reflector means disposed substantially coextensive with and spaced from said other side of said screen, said electron reflector being spaced from said screen by a distance such that room will be provided for the electron beam to take its path away from the said axis and back to said screen upon reflection by said reflector.

11. The cathode ray tube according to claim 10 and including an envelope at least a portion of which is transparent and wherein said electron reflector means comprises a transparent conductive coating on said portion.

12. The cathode ray tube according to claim 10 and wherein said apertured phosphor screen comprises a phosphor screen having a single central aperture therein aligned with said axis.

13. A cathode ray tube comprising an envelope containing a multiapertured phosphor screen, an electron gun disposed along a central axis normal to said screen, and scan magnification means comprising an electron reflector substantially coextensive with and spaced from said phosphor screen for further deflecting the electron beam after its having been given an initial deflection away from said axis and through a curved path upon said screen.

14. The cathode ray tube according to claim 13 and wherein the spacing between said phosphor screen and said electron reflector increases with increasing distances from said central axis, said electron reflector comprising a transparent conductive coating on a portion of said envelope.

15. A cathode ray tube comprising an apertured phosphor screen, an electron gun disposed along a central axis normal to said screen and adapted to project an electron beam through said screen, a primary deflection region between said gun and said screen wherein said beam can be scanned in a raster over a relatively small central portion of said screen, and electron reflector means dis-

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posed substantially coextensive with and spaced from said screen on the side thereof remote from said gun for further deflecting said beam away from said axis in a curved path between said reflector and said screen and reflectively back upon said screen in an enlarged image of said small central portion raster, said enlarged image being at least twice as large as said small central portion raster.

16. The cathode ray tube according to claim 15 and wherein said phosphor screen and said electron reflector means are nonuniformly spaced from each other and wherein said apertured phosphor screen comprises a phosphor screen having a single aperture aligned with said axis centrally of said phosphor screen.

17. A cathode ray tube comprising a phosphor screen including a support member having a phosphor layer on one side thereof and having a single relatively small hole in the center portion thereof, an electron gun disposed along an axis extending through said hole, said gun being on the opposed side of said member from the phosphor layer, an electron reflector substantially coextensive with said screen and disposed on the opposite side of said member from said electron gun at a distance approximately equal to the distance between said gun and said screen, and double beam deflection means disposed along said axis between said gun and said screen.

18. A cathode ray tube comprising an apertured phos-

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phor screen including a support plate having a phosphor layer on one side thereof, an electron gun disposed along an axis for projecting electrons through said apertured screen, a reflector electrode facing said phosphor layer spaced from said screen and substantially coextensive with said screen, and an annular skirt surrounding said phosphor screen and extending towards said reflector electrode.

19. A cathode ray tube in accordance with claim 18 in which said screen is noncircular and in which said skirt extends varying distances towards said reflector around the periphery of said screen.

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