May 15, 1956 D. D. VAN ORMER 2,745,978

CATHODE RAY TUBE

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Fig. 1.

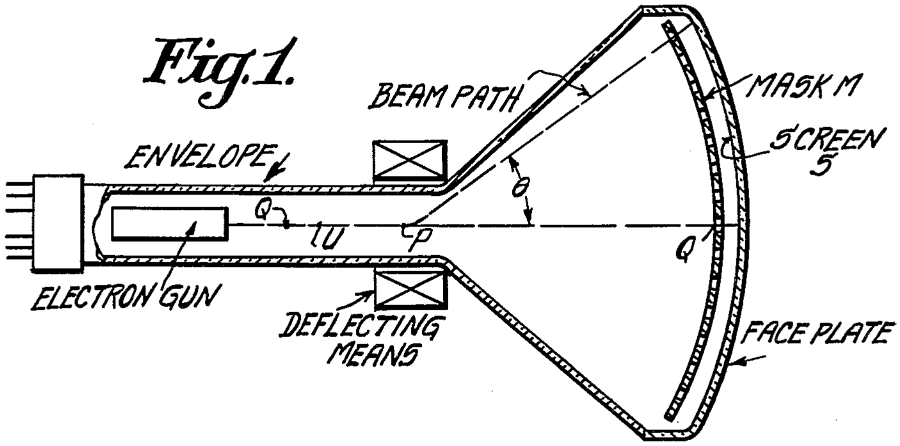
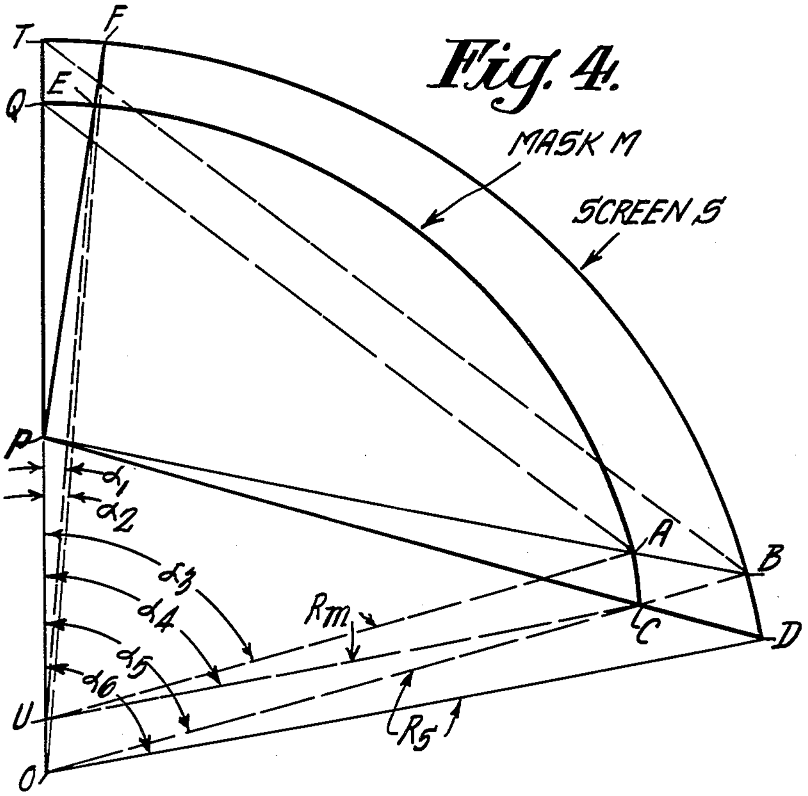


Fig. 4.



INVENTOR.
David D. Van Ormer
BY
William A. Zalesak
ATTORNEY

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Fig. 5.

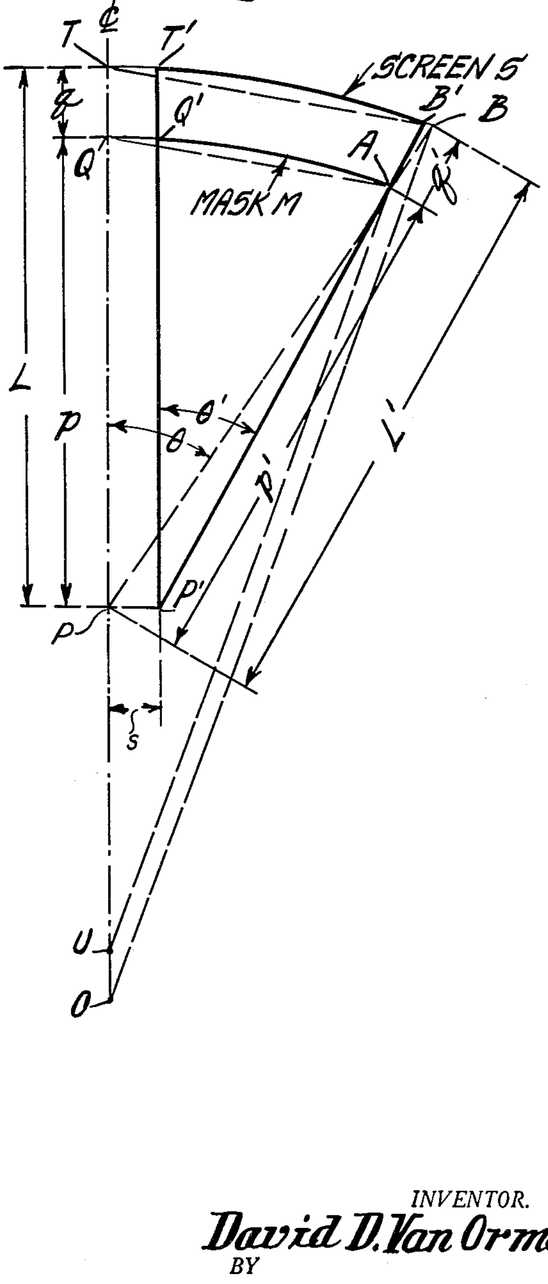
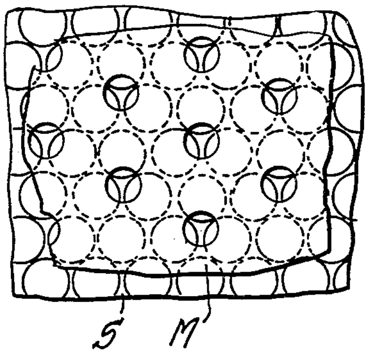


Fig. 2.



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David D. Van Ormer

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William A. Zalesak

ATTORNEY

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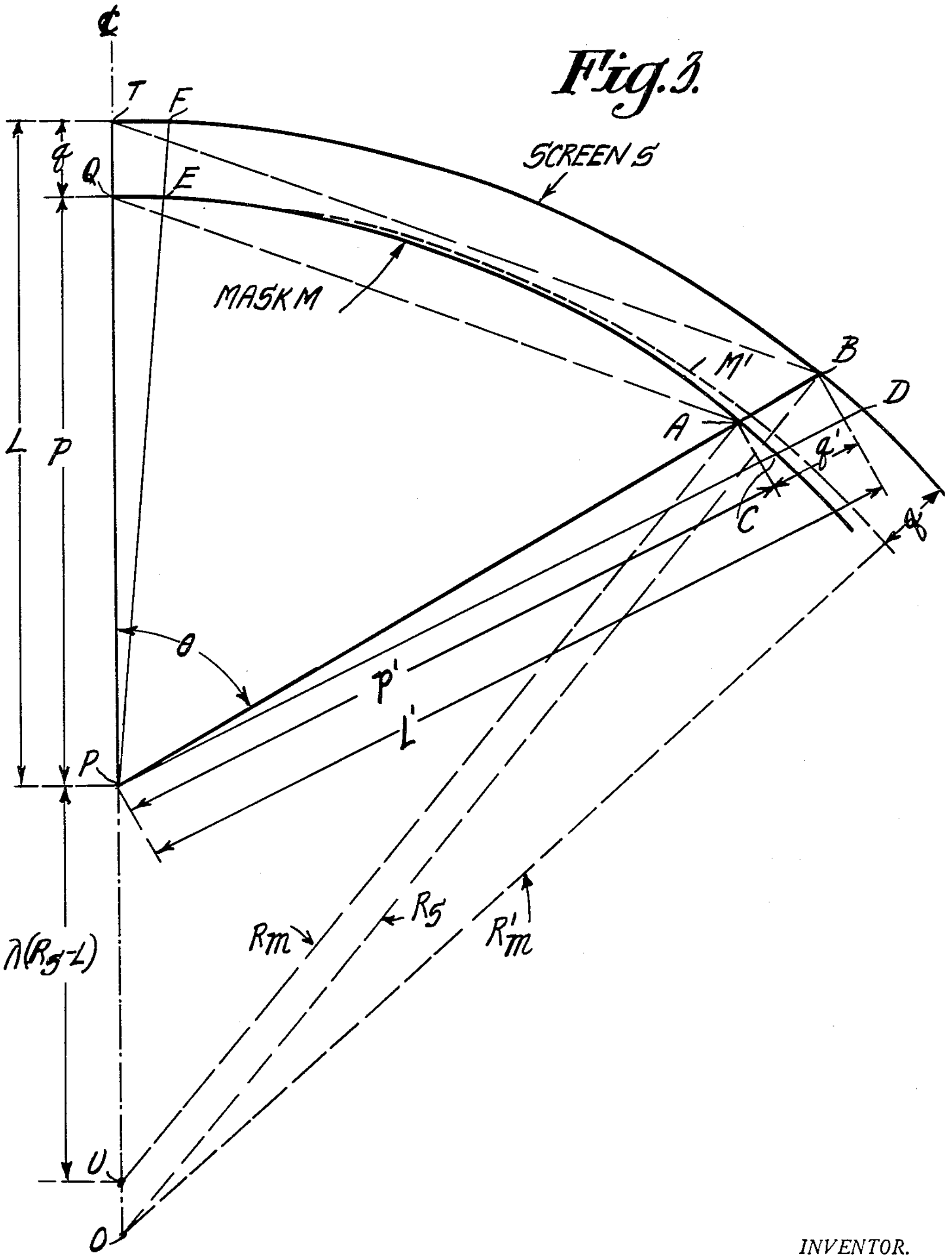
Fig. 3.



INVENTOR.

David D. Van Ormer

BY

William A. Zalesak

ATTORNEY

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CATHODE RAY TUBE

David D. Van Ormer, Lancaster, Pa., assignor to Radio Corporation of America, a corporation of Delaware

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4 Claims. (Cl. 313—69)

This invention relates to improvements in color-kinescopes and other cathode ray tubes of the kind having a center-of-scan and a target assembly comprising an electrode containing a multiplicity of systematically arranged apertures through which beam-electrons pass along different angularly related paths in their transit from said center-of-scan to selected ones of the metallized elemental color-phosphor areas on a nearby "screen-plate." In such a color kinescope, color selection is obtained in a three-color arrangement involving red, green, and blue colors, for example, by causing electrons to pass through the apertures along three convergent directions, as from three laterally spaced electron guns, one for each color, and impinge upon red, green, and blue elemental phosphor areas on the screen-plate. The response to each color at the screen-plate is controlled by controlling the beam current of the beam impinging on phosphor areas of that color in accordance with the color signal used.

The present invention is concerned with tubes in which the screen plate and apertured electrode are curved surfaces. The preferred methods of laying down the elemental red, green and blue color phosphors on the screen plate involve the use of the apertured electrode as a stencil, or as a photographic negative, to determine the positions of the phosphor deposits on the screen plate. Each aperture determines the positions of the three areas of a group of red, green and blue phosphors. Preferably, the size of the apertures is such that the three areas of each group are close together, and the spacing between adjacent apertures is such that the areas in adjacent groups are also close together. The apertured electrode is made with apertures of uniform diameter and uniform spacing. In order to maintain the desired spacing between adjacent groups it is necessary that the pattern of the apertures be reproduced with constant magnification on the screen plate. In other words, the spacing between the groups must be uniform over the screen plate area. In a tube having a planar screen plate and a planar apertured electrode constant magnification is obtained by providing uniform spacing between the apertured electrode and screen plate. Where the screen plate and apertured electrode are curved, instead of planar, constant magnification is not obtained with uniform spacing therebetween.

Therefore, the object of the present invention is to provide a cathode ray tube of the kind described having a curved screen plate and a curved apertured electrode constructed and arranged to produce substantially constant magnification of the aperture pattern on the screen plate.

In accordance with the invention, the spacing between the apertured electrode and the screen plate, as measured along the beam path from the center-of-scan, is greater at the outer margin of the electrode than at the central axis. Specifically, the spacing between the parts is such that the ratio of the distance between the center-of-scan and the apertured electrode to the distance between the center-of-scan and the screen plate is constant for any angle of deflection of the beam from the central axis.

In the accompanying drawing:

Fig. 1 is a longitudinal sectional view of a cathode ray tube embodying the invention;

Fig. 2 is an enlarged detail view of a portion of the target assembly in Fig. 1; and

Figs. 3–5 are diagrams that will be referred to in the description of the invention.

Fig. 1 shows a cathode ray tube designed for visual reproduction of color television signals. The tube comprises an envelope containing a tri-color fluorescent screen S at one end, an electron gun G at the other end for projecting three beams of electrons toward said screen, and an apertured mask electrode M between the electron gun G and the screen S. The tube is designed for use with suitable magnetic deflecting means for deflecting the electron beams away from the central axis to scan the mask and screen. The beams are deflected along a curved path but will be considered as originating at a point P, usually called the "center-of-scan," obtained by projecting the centroid of the beams back to the central axis. The transverse plane through the point P is called the "plane-of-deflection." For simplicity, only one beam path has been shown in Fig. 1, originating along the central axis and corresponding to the centroid of the three beams. The three beams, one for each of the colors red, green and blue, pass through the plane of deflection in a triangular array with each beam spaced a short distance outwardly from the central axis, as will be discussed in connection with Fig. 5.

The mask M contains a multiplicity of circular apertures in a hexagonal array, and the screen S comprises a multiplicity of circular color phosphor areas arranged in triangular groups of red, green and blue areas with the center of each group registering with one of the mask apertures, as shown in Fig. 2. The mask is made with uniformly spaced apertures. When the mask is mounted adjacent the screen and used as a stencil for laying down the phosphor areas or dots on the screen the pattern of the phosphor areas is determined by the projection of the apertures in directions from the point P. The divergent projection angles cause a slight magnification of the aperture pattern on the screen. If the mask and screen were planar, the magnification would be constant over the total area of the electrodes. However, it is also preferable that the screen be provided on the inner surface of the face plate, which must be curved to withstand atmospheric pressure without imploding. The screen S is shown in Fig. 1 on a spherical face plate having a center of curvature at O. It will be shown that in this case the mask M must also be a sphere of smaller radius than the screen and having a center of curvature at a point U, between O and P. Due to the smaller radius of the mask, the mask and screen are spaced farther apart at the outer edge than at the central axis.

Fig. 3 shows a portion of the phosphor screen S and apertured mask M of Fig. 1 in axial section. For the purpose of illustration, the screen S is shown as having a circular cross-section with radius R_s and center of curvature O on the central axis OT, of the tube. A center-of-scan for a single beam is shown at P on the axis OT. PB is a beam path for an arbitrary deflection angle θ from the central axis OT. PT is the beam path through an aperture Q at the center of the mask.

Since the object of the invention is to produce constant magnification of the aperture pattern on the screen it is necessary to determine the correct mask shape and spacing to produce this result. For this purpose, it is assumed that the mask has nearly the same curvature as the screen. PF and PD are drawn such that $QE=AC$ (for example, through adjacent equally-spaced apertures). Let

$$
\begin{gathered}
p=\overline{PO}\\
q=\overline{QT}\\
L=p+q\\
p'=\overline{PA}\\
q'=\overline{AB}\\
L'=\overline{PB}=p'+q'
\end{gathered}
$$

If QE is very small (to a close approximation), QE is parallel to TF, and AC is parallel to BD, and hence,

$$\frac{\overline{TF}}{\overline{QE}}=\frac{L}{p},\text{ or }\overline{TF}=\overline{QE}\frac{L}{p}$$

and

$$\frac{\overline{BD}}{\overline{AC}}=\frac{L'}{p'},\text{ or }\overline{BD}=\overline{AC}\frac{L'}{p'}$$

$$\therefore\frac{\overline{BD}}{\overline{TF}}=\frac{\overline{AC}}{\overline{QE}}\,\frac{L'}{p'}\,\frac{p}{L}=\frac{pL'}{p'L}\qquad(1)$$

To make $\overline{BD}=\overline{TF}$, for constant magnification,

$$\frac{pL'}{p'L}=1$$

$$\frac{p}{L}=\frac{p'}{L'}\equiv\lambda(\text{a constant})\qquad(2)$$

or

$$\frac{p}{p+q}=\frac{p'}{p'+q'}\equiv\lambda\qquad(2')$$

The magnification ratio is equal to 1/λ. Equation 2 shows that in order to obtain constant magnification the mask cannot be uniformly spaced from the screen. Therefore, the mask cannot have the same center of curvature as the screen. The shape and location of the mask can be determined geometrically as follows. Assume the mask passes through Q at a distance q from the screen at the central axis. Draw TB, and then from Q draw QA parallel to TB. ΔPQA and ΔPTB are similar, hence,

$$\frac{p'}{L'}=\frac{p}{L}\equiv\lambda$$

which is the requirement for constant magnification. Then, from A draw AU parallel to BO. The point U is the center of curvature of the mask M, and R_m is the radius thereof. Since ΔPAU and ΔPBO are similar,

$$\frac{R_m}{R_s}=\frac{p'}{L'}=\lambda$$

$$\therefore R_m=\lambda R\qquad(3)$$

and

$$\frac{\overline{PU}}{\overline{PO}}=\frac{p'}{L'}=\lambda$$

$$\overline{PU}=\lambda\overline{PO}=\lambda(R_s-L)\qquad(4)$$

$$L'=-(R-L)\cos\theta\pm\sqrt{(R-L)^2\cos^2\theta+2RL-L^2}\qquad(5)$$

Since the angle θ in Fig. 3 was arbitrarily chosen, the analysis given above applies to any portion of the mask and screen in the plane of Fig. 3. Moreover, Fig. 3 applies to any plane through the central axis of the tube. Therefore, if the screen is a sphere of radius R_s, the mask will be a sphere of radius $R_m=\lambda R_s$, where $\lambda=p/q$.

A spherical mask M′ of radius R'_m with its center at O, concentric with the screen and therefore, uniformly spaced therefrom, is shown dotted in Fig. 3 for comparison with the desired mask M. No attempt has been made to show (on the scale of Fig. 3) the departure of the mask M′ from constant magnification.

In Fig. 4, $R_m=\lambda R_s$ as in Fig. 3. Lines EU, FO, AU, CU, BO and DO have been constructed, forming angles α_1, α_2, α_3, α_4, α_5 and α_6 with the central axis OT. For small angles the arcs $\overset{\frown}{QE}$, $\overset{\frown}{TF}$, $\overset{\frown}{AC}$ and $\overset{\frown}{BD}$ are approximately equal to the corresponding chords. Therefore,

$$\overline{QE}=R_m\alpha_1=\lambda R_s\alpha_1$$
$$\overline{TF}=R_s\alpha_2$$
$$\overline{AC}=R_m(\alpha_4-\alpha_3)=\lambda R_s(\alpha_4-\alpha_3)$$
$$\overline{BD}=R_s(\alpha_6-\alpha_5)$$

but

$$\overline{QE}=\overline{AC}$$
$$\alpha_1=\alpha_2$$
$$(\alpha_6-\alpha_5)=(\alpha_4-\alpha_3)$$
$$\alpha_1=\alpha_4-\alpha_3=\alpha_6-\alpha_5$$
$$\therefore\overline{BD}=\overline{TF}.\ (\text{constant magnification})$$

It can also be shown that if the screen is a cylinder, or any other quadratic surface, the mask should be a similar quadratic surface reduced by $\lambda=p/L$, with the distance between the curvature center and the deflection center equal to $\lambda(R-L)$. If the condition for constant magnification, p'/L'=a constant, is satisfied the phosphor screen may have any shape.

In Figs. 3 and 4 the beam was assumed to be projected through the deflection plane on the central axis OT of the tube, and it has been shown that if the screen and mask are spaced so that p'/q' is a constant, constant magnification is obtained for such a beam. It is obvious that if three beams are projected through the deflection plane at points around the central axis and equally spaced therefrom, constant magnification will be produced with respect to the centers of the groups or trios of phosphor areas on the screen.

It can be shown that for constant magnification with a single beam spaced laterally a distance s from the central axis the mask should have a radius $R_m=\lambda R_s$ with a center of curvature spaced laterally from the central axis a distance $(1-\lambda)s$. Three beams having three different deflection centers spaced from the central axis would require a mask having the same radius but three different centers of curvature. Since this is impossible, an approximation is made in which the center of curvature of the mask is located on the central axis, as in Fig. 3, to produce constant magnification of the group centers on the screen.

In Fig. 5, all of the letters except P′, B′, Q′, T′, O′ and s correspond to the same letters in Fig. 3, for a beam along the central axis. The point P′ represents the deflection center (or center-of-scan) of a beam spaced laterally a distance s from the point p on the central axis OT. The distance s is greatly magnified relative to the other dimensions in the figure in order to show clearly the effect of the spacing s. In an actual tube the distance s would be only a small fraction of the relative distance shown. The mask M is shaped and spaced relative to the screen as in Fig. 3 so that an electron from P through point A would land at B on the screen. An electron from P′ through A would land at B′. The distance $\overline{BB'}$, which is the radius of a group or trio of phosphor areas on the screen, will differ from the corresponding distance required for constant magnification by a small amount due to the fact that the line BB′ is not exactly parallel to the line PP′. Since the maximum value of the deflection angle (θ) is usually not greater than 30° to 35°, the departure from constant magnification at the outer edge of the screen will be very small. In a 19 inch tube with three convergent beams the change in magnification from the center to the outer edge of the screen is only about one-tenth of one per cent.

What is claimed is:

1. A cathode ray tube having a central axis, a curved fluorescent screen, electron gun means for projecting at least one beam of electrons toward the concave side of said screen, a center-of-scan intermediate said gun means and said screen whereat said beam is deflected relative to said axis to scan said screen, and a curved electrode having a multiplicity of systematically-arranged uniformly-spaced apertures mounted adjacent to said curved screen between said screen and said gun means, the spacing between said apertured electrode and said screen, as measured along the beam path from the center-of-scan, being greater at the outer margin of the electrode than at the central axis of the tube.

2. A cathode ray tube as in claim 1, wherein center-of-scan is located on said central axis and the ratio of the

distance between the center-of-scan and the apertured electrode to the distance between the center-of-scan and the screen is substantially the same for any angle of deflection of the beam from the central axis, to produce substantially constant magnification of the pattern of said apertures on said screen at any deflection angle.

3. A cathode ray tube as in claim 2, wherein said screen is a portion of a sphere of radius R_s and said apertured electrode is a portion of a sphere of radius $R_m=\lambda R_s$, were λ is said ratio of distances, and the center of curvature of said apertured electrode is located on the central axis at a distance $\lambda(R_s-L)$ from the center-of-scan, where L is the distance along the central axis between the center-of-scan and the screen.

4. A cathode ray tube having a central axis, a curved fluorescent screen, electron gun means for projecting three electron beams toward the concave side of said screen, said beams having centers-of-scan in a common plane of deflection intermediate said gun means and said screen whereat the beams are deflected relative to said axis to scan said screen, and a curved electrode having a multiplicity of systematically-arranged uniformly-spaced apertures mounted adjacent to said curved screen between said screen and said gun means, the spacing between said apertured electrode and said screen, as measured in the direction from the intersection of the plane of deflection with the central axis, being greater at the outer margin of the electrode than at the central axis of the tube.

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