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GEOMETRICAL CONSIDERATIONS OF AN RCA TRI-COLOR KINESCOPE

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Approved

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Introduction

This bulletin discusses the more important considerations involved in the geometry of a phosphor-dot type, directly viewed tri-color kinescope. LB-808, *Characteristics and Operation of an RCA Developmental Three-Gun Tri-Color Kinescope* describes its characteristics and structural details. An understanding of the tube geometry is essential to the tube engineer because the performance of the kinescope depends on the fact that the beam origins, the aperture mask, and the phosphor-dot plate are so related that the rays projected from a single point through the apertures in the aperture mask will strike the phosphor dots of only one color. Likewise, beams originating from two other points excite the phosphor dots of the other two colors.

In the design of the tri-color kinescope the factors to be considered include all of those involved in the design of a black-and-white tube but they are more interdependent. In addition, other factors peculiar to the tri-color kinescope are involved.

General Discussion

The tri-color kinescope consists of a tube having a metal aperture mask located between the gun and the phosphor-dot plate. The gun complement of the tube may consist of either three guns spaced 120 degrees apart about the tube axis or one gun placed on the axis of the tube. In either case, there are effectively three beams converging to a point on the aperture mask. In the three-gun tube the origin of the three beams is determined by the position of the three guns about the tube axis. In the single-gun tube, the beam is deviated from the axis, bent back again, and rotated to give virtual origins in sequence equivalent to the three-gun tube.

The geometry of the beam origins, aperture mask, and phosphor-dot plate is such that the electron beams go through the holes in the mask as the beams scan the surface and fall on phosphor dots, each beam striking dots of one color only. Thus, for each of the three colors there is a point from which it is possible to "see" only the phosphor dots of that particular color. If an electron beam passing through one of these points is deflected so that the point becomes the center of deflection, the beam will excite only the phosphor dots of one color. The three beams go through the deflection yoke off axis and each beam has its own center of deflection or color center. The three centers of deflection define a plane which shall be termed the deflection plane of the tube.

It can be seen in Fig. 1, a plane normal to the phosphor-dot plate and passing through a row of holes in the aperture mask, that for an infinitely thin aperture mask and a point source of electrons, the projection of the apertures from some point 0, or color center, onto the phosphor plane will be similar to the aperture-mask hole array, but magnified by the factor

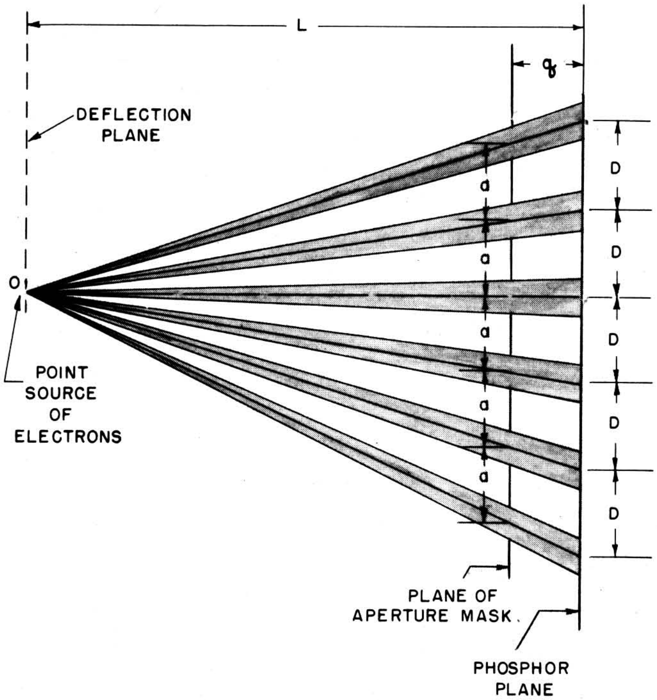


Fig. 1 – A plane through an axis normal to the plane of the phosphor array and passing through a color center O.

$\frac{L}{L-q}$. Consequently, for round holes of uniform size and spacing in an infinitely thin aperture mask, the projections of the holes are round and the size and spacing is uniform over the entire array, but dimensions of the projections are $\frac{L}{L-q}$ larger than the corresponding aperture-mask dimensions. Having chosen some point O as the first color center, two other color centers may be found lying in a plane parallel to the aperture mask through O, such that projections from the remaining two color centers through the apertures will result in the same linear distribution on the phosphor plane but intermeshed with the original projection. In order to obtain the most efficient coverage of the phosphor plane, the three projections of a single aperture should be tangent to each other. This requirement means that the centers of the three projections form an equilateral triangle. If the apertures are then arranged in equilateral triangular fashion, i.e., equally spaced from each adjacent aperture, the spacing between the apertures can be made such that the three projections of adjacent apertures intermesh to give coverage of the phosphor plane as shown in Fig. 2. The total percentage of the

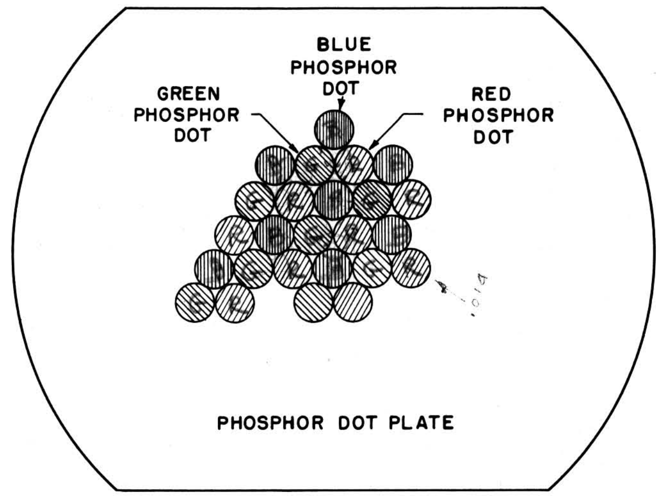


Fig. 2 – Distribution of the projections of the apertures on the phosphor plane from the three color centers.

area covered by such an array of tangent circles is independent of the size of the circles and is equal to 90.7 per cent. The color centers also must lie at the corners of an equilateral triangle, the size of which depends on L, a, and q. The orientation of this triangle with respect to the aperture-mask array is shown in Fig. 3.

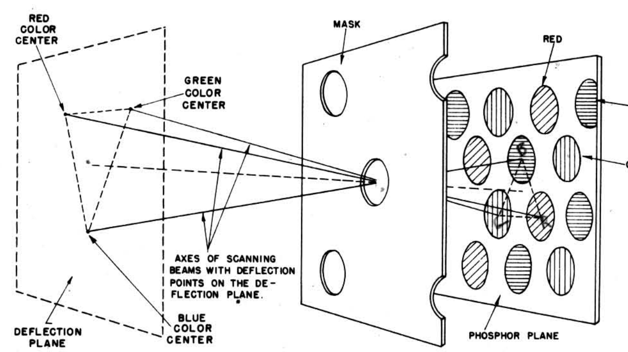


Fig. 3 – Principle of operation of a tri-color kinescope shown diagrammatically.

Therefore, the phosphor screen is made up of three identical arrays of dots intermeshed together. The implication for manufacturing is that if a stencil can be made for depositing phosphor of one color with all the dots in the right place, then the proper shift of the same stencil will result in accurate positioning of the second and third colors.

In the operation of the screen, the beams passing through the color centers in the plane of deflection are converged to a common point on the aperture mask and deflected as a unit. This mode of operation is seen diagrammatically in Fig. 3.

Mathematical Considerations

Thus far the color center has been considered to be a point. However, since an electron beam passing through the deflection plane has a finite diameter, the projection of an aperture onto the phosphor plane by such a source will be larger than that obtained from a point source. The beam diameter in the deflection plane is therefore an important factor in the design of the tri-color screen. A good approximation is to assume that the projection of an aperture is determined by the peripheral rays of the beam as it scans the aperture.

The thickness of the aperture mask influences the allowable hole size in the mask but can be neglected in this discussion since suitably thin materials are available.

Glossary of Symbols (See Figs. 4 and 5)

S – separation of the axis of the electron beam from the tube axis in deflection plane.

L – distance between deflection plane and phosphor plane.

q – distance between the plane of the aperture mask and the phosphor plane.

$M = 2m$ – diameter of the electron beam in the deflection plane.

$B = 2b$ – mask aperture diameter.

$R = 2r$ – phosphor dot diameter.

a – distance between aperture centers in the aperture mask.

D – distance between centers of phosphor dots of the same color, or between centers of picture elements.

d – radius of phosphor-dot centers within a picture element.

x – distance between the plane of the aperture mask and the crossover point of the peripheral rays of the electron beam when the beam is scanned across the center of an aperture.

The centers of adjacent phosphor dots, shown in Fig. 4 form equilateral triangles, therefore,

$$D = 2\sqrt{3}\, r = \sqrt{3}\, R$$

and $$d = \frac{2}{\sqrt{3}} r = \frac{R}{\sqrt{3}}$$

thus $D = 3d$

D not only represents the distance between centers of adjacent trios, but also the separation between centers of phosphor dots of the same color. The analysis may therefore be confined to one color at a time. Fig. 5 represents a plane determined by the axis of the tube, or

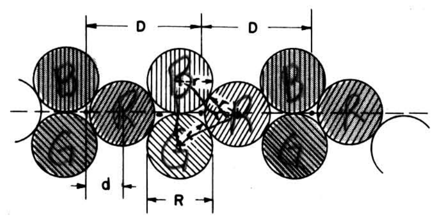


Fig. 4 – Enlarged section of phosphor-dot array.

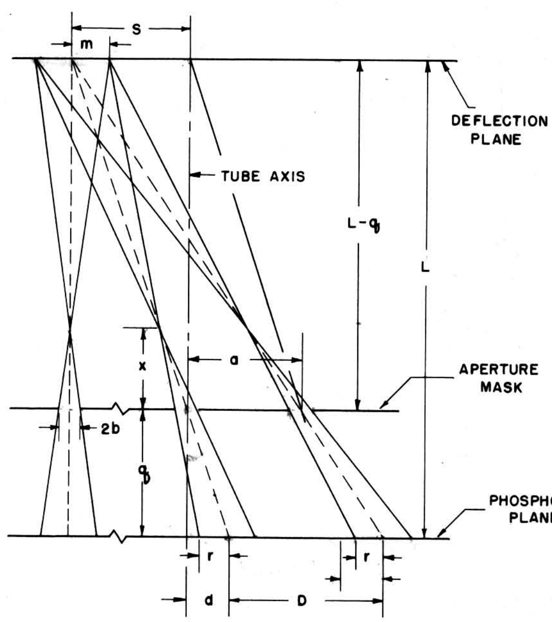


Fig. 5 – A plane determined by the axis of the tube and a color center.

normal to the center of the screen, and a color center. From similar triangles,

$$\frac{d}{q} = \frac{S}{(L-q)} \qquad \text{and} \qquad \frac{D}{L} = \frac{a}{(L-q)}$$

Eliminating $(L-q)$

$$\frac{Sq}{d} = \frac{La}{D}$$

Or

$$q = \frac{La}{3S} \qquad \text{since} \quad D = 3d$$

also from the above expressions

$$D = \frac{La}{(L-q)} = \frac{a}{1 - q/L} = \frac{a}{1 - a/3S}$$

Or

$$\frac{1}{D} = \frac{1}{a} - \frac{1}{3S}$$

also

$$\frac{1}{R} = \sqrt{3}\left(\frac{1}{a} - \frac{1}{3S}\right) \qquad \text{since} \quad D = \sqrt{3}R$$

Again from similar triangles

$$\frac{b}{x} = \frac{m}{L - (q+x)} \qquad \text{and} \qquad \frac{b}{x} = \frac{r}{q+x}$$

Eliminating x

$$\frac{L}{q} = \frac{m+r}{r-b} = \frac{M+R}{R-B} \qquad \text{since } M = 2m \text{ etc.}$$

also, since

$$\frac{L}{q} = \frac{3S}{a} \qquad \text{then} \qquad \frac{3S}{a} = \frac{M+R}{R-B}$$

The mask aperture diameter is then

$$B = \frac{a}{3}\left(\sqrt{3} - \frac{M}{S}\right) \qquad \text{since} \quad \frac{1}{R} = 3\left(\frac{1}{a} - \frac{1}{3S}\right)$$

Design Considerations

Using the limiting resolution as the starting point in designing a tri-color kinescope the maximum phosphor-dot size or separation between trios will be determined by the requirements of the system in which the tube is to be used. Having thus determined D, the relation between a and S is given by

$$\frac{1}{D} = \frac{1}{a} - \frac{1}{3S}$$

The value of S should be chosen as large as possible, consistent with the capabilities of the deflection yoke. The value of "a" may then be calculated. The ratio of L/q is given by the relation

$$L/q = \frac{3S}{a}$$

The value of L will be governed by the size of the screen and deflection angle. When L has been evaluated then q may be calculated.

The remaining unknowns are now B, the aperture diameter, and M the diameter of the electron beam in the deflection plane. B is given by the relation

$$B = \frac{a}{3}\left(\sqrt{3} - \frac{M}{S}\right)$$

Both S and "a" have been determined previously. The values of M and B must be properly chosen to yield maximum picture brightness.

Considering the effect of M alone on picture brightness, M should be as large as possible since the greater M the larger the limiting apertures in the gun and, therefore, the greater the beam current. Likewise, considering the effect of B alone on picture brightness, the larger B the greater the open area of the mask and, therefore, the greater the portion of the total beam current which strikes the phosphor to produce light (electrons which strike the mask do not contribute to picture brightness). Since both B and M have to obey the above relation there exists an optimum value for each for maximum light output. If the current density in the beam as it goes through the deflection plane is known, then the optimum values for B and M may be found mathematically.

From a further study of the mathematical relations previously given, the following relations between variables may be noted.

If a finer aperture mask is used to increase the number of phosphor dots, the brightness of the picture remains the same, provided the proper relationship is maintained between the aperture diameter and the aperture spacing.

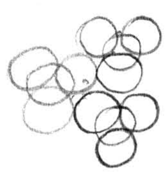
If the tube is shortened and the deflection angle correspondingly increased to keep the same size picture while S is held constant, it becomes more difficult to maintain convergence of the three beams as they are deflected because of the increased angle between the beams. However, the light output remains unchanged. On the other hand, if S is proportionately reduced to keep the angle between the beams constant, the light output goes down but convergence is not affected.

If the length of the tube is held constant and the value of S is reduced to promote easier convergence of the beams, then light output goes down. Conversely if S is increased more light output will result but convergence becomes more difficult.

Moiré Effect in Tri-Color Kinescopes

If the scanning beam in a tri-color kinescope is of uniform intensity throughout the field it does not necessarily follow that the intensity distribution on the color screen is uniform, or even as uniform as the intensity distribution in the absence of the mask; depending on the relative orientation of a particular scanning line and the array of apertures in the mask, a smaller or larger fraction of the electrons incident on the mask are transmitted and contribute to the brightness of the screen. In view of the regularity of the scanning pattern and the aperture array, relatively coarse beat phenomena may be observed between the two, resulting in intensity fluctuations across the screen which are properly described as a moiré. This moiré is least prominent if the scanning lines are placed parallel to lines bisecting the equilateral triangles formed by any three neighboring mask apertures; two successive parallel lines of this kind passing through aperture centers are then just half the distance between aperture centers apart. To render the moire unobjectionable, irrespective of small misorientations of the scanning pattern relative to the mask, it is desirable that the variation in the transmission of the mask for a scanning line be less than about 1 percent from the mean for any arbitrary position of the scanning line.

For a line width, defined for this purpose as the distance between the two points at which the line intensity has fallen to half its maximum value, equal to 0.018 inch this requirement is met for any mask with mask-aperture spacings less than 0.030 inch. If the line width is reduced to 0.013 inch, the mask-aperture spacing has to be reduced below 0.023 inch. Furthermore, even for this value, the moiré exceeds the prescribed limit slightly if the mask-aperture diameters are made much less than half the aperture spacings. Whereas these figures were calculated for an error-curve intensity distribution in the scanning line, the moiré effect may be minimized by defocusing of the spot in the plane of the mask.



Moire objection-able if $2b < \frac{a}{2}$