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IMPROVEMENT IN COLOR KINESCOPES THROUGH OPTICAL ANALOGY

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
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Improvement in Color Kinescopes Through Optical Analogy

Approved

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In color kinescopes wherein the phosphor dots are deposited by the conventional optical exposure, the movement of the deflection center with deflection angle causes a radial misregister between the phosphor dots and electron spots. This misregister has been eliminated by interposing a thin aspheric lens between the light source and the aperture mask during exposure of the phosphor screen in the manufacture of the tube.

In the elementary theory of the shadow mask tube[1] it is assumed that the electrons in the three beams move in straight lines after deflection, appearing to originate at three fixed points lying in a plane perpendicular to the axis. This plane is known as the plane of the color centers. It is possible to determine the relationship between phosphor dots on the screen and the holes in the shadow mask by using light beams emanating from small light sources located at the red, green and blue color centers. When a complete tube is operated, electron beams take the place of these light beams. To obtain color purity the yoke is so placed that its plane of deflection is located in the plane of the color centers and the electron guns are so located that the electron beams intersect the plane of deflection just where the light source was placed during exposure. This procedure is accurate for relatively small deflection angles, but the register between phosphor dots and electron dots becomes less exact for larger deflection angles[2]. This is due to the fact that the electrons do not appear to originate from a fixed point as is assumed in the elementary theory. The plane of deflection of the yoke moves closer to the shadow mask as the deflection angle is increased.

The object of this bulletin is to discuss the causes of such misregister in detail, to indicate some of the means that have been used in the past to minimize the effects, and to describe a new optical approach which eliminates misregister almost completely.

Movement of the Plane of Deflection

It is well known that in present deflection yokes, the deflection plane travels forward with the angle of deflection. To be exact, the plane of intersection of the original and the final beams moves away from the source of the electrons as the deflection is increased. The precise amount of this movement depends on the magnetic field distribution of the yoke involved. However, a first order expression may be obtained by assuming a uniform deflection field of length ℓ. If the deflection angle is given by 2u and the forward movement by Δp, the expression is:[3]

$$\Delta p = (\ell/2) \tan^2 (u/2) \qquad (1)$$

If the yoke has an effective length of 5 inches, then the forward movement will be approximately .25 inches for a 70 degree deflection angle.

Misregister Caused by Movement

The phosphor on the faceplate is deposited at those spots, where a light beam emanating from a fixed light source strikes the plate after having passed through the shadow mask. Measured along the axis (See Fig. 1), the light source is at a distance p from the shadow mask, and the shadow mask is a distance q from the faceplate along the axis. The faceplate and shadow mask have an approximately equal radius of curvature R. The inclination of the faceplate with the vertical at a distance r from the axis is given by the angle u_R. The tangent of the angle u_R is given by:

$$\tan u_R = r/\sqrt{R^2 - r^2} \qquad (2)$$

The effect of the forward movement of the deflection plane on misregister is illustrated in Fig. 1, where the effect is greatly exaggerated for explanatory purposes. Assume that the light source S is located to agree with the apparent source of the electron beam for

(1) LB-841 *A Three-Gun Shadow-Mask Color Kinescope.*

(2) H.R. Seelen, H.C. Moodey, D.D. VanOrmer and A.M. Morrell, *Development of a 21 - inch Metal Envelope Color Kinescope,* RCA Review, Vol. XVI, No. 1, pp. 122 - 137, March 1955.

(3) LB-841, *Deflection and Convergence in Color Kinescopes.*

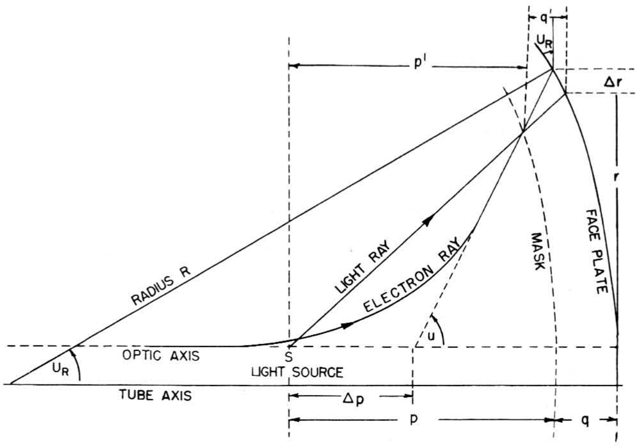

Fig. 1 - Schematic diagram of electron ray and light ray geometry.

small deflection angles. The location of the phosphor dots is determined by the light rays originating from S. Thus at the larger deflection angle shown in Fig. 1, the phosphor dot is deposited on the faceplate at a distance r from the tube axis. The electron beam passing through the same hole in the shadow mask and, thus, corresponding to this light ray, appears from a source at a distance p - Δp from the mask and strikes the faceplate at a distance r + Δr from the tube axis. The distance Δp (Eq. 1) is the amount of forward movement of the deflection centers and the distance Δr is the amount of radial misregister.

The misregister Δr is determined from the displacement Δp through the geometry of the tube. A quantitative relationship derivable from Fig. 1, which holds to a good approximation is given by:

$$\Delta r = \Delta p\ (q/p)\left[\tan u/\ (1 + \tan u_R \tan u)\right] \tag{3}$$

wherein:

Δr = radial misregister
Δp = displacement of deflection plane (Eq. 1)
p = distance from mask to light-source
q = distance from mask to faceplate
u_R = inclination of faceplate (Eq. 2)
u = half deflection angle.

This relationship takes the obliquity due to the curvature of the faceplate into consideration, but makes the approximation that $q/p = q'/p'$ (See Fig. 1).

A relatively simple explicit expression for the misregister Δr is obtained by making the reasonable approximation that

$$\tan u_R = \left[(p + q)\ /R\right] \tan u \tag{4}$$

and substituting it and (1) into Equation (3). This results in

$$\Delta r = (\ell/2)\ (q/p)\ \tan^2 u/2\ \tan u/ \left[1 + (\tan^2 u)\ (q + p)\ /R\right] \tag{5}$$

which gives Δr as a function of variable deflection angle 2u and the constant parameters of the tube R, q and p, and the length of the deflection field ℓ.

Fig. 2, shows the misregister Δr as a function of the deflection angle for various idealized yoke lengths. The radius R was assumed to be 26.4 inches, q and p were taken as .535 and 15.225 respectively. The broken line is an observed misregister curve with a practical yoke. The fact that this curve does not agree perfectly with any of the theoretical curves is not due to the approximations made in the evaluation of (5), but to the assumptions under which (5) was calculated. First, the field of the practical yoke is not uniform as was assumed in (1). Second, the mask and faceplate are not exactly spherical nor do they have exactly the same radius of curvature. Third, the forward movement

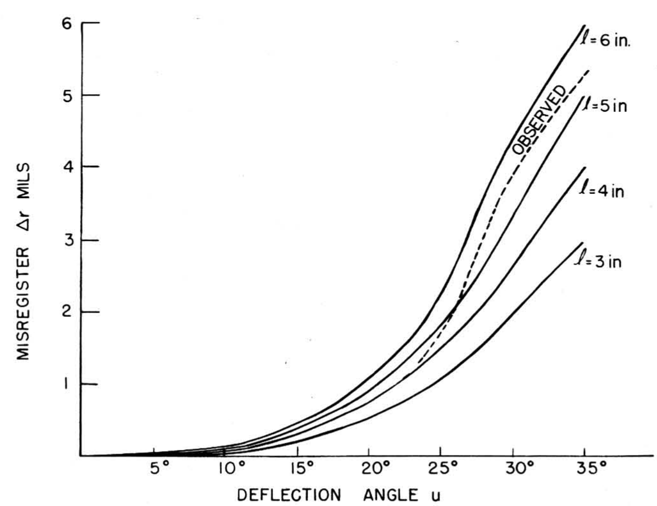

Fig. 2 - Theoretical and observed radial misregister.

of the deflection plane is not the only cause of radial misregister. There are mechanical causes which can probably account for as much as one mil of misregister. However, the observed misregister curve, which reaches about 5 mils, is always within .5 mil of the theoretical ℓ = 5 curve, which corresponds to the effective length of actual deflection yokes. Forward movement of the deflection plane, therefore, is the main factor involved in radial misregister. Fig. 2 shows that for a yoke with ℓ = 5 inches, a radial misregister of 3 mils will occur at the edge of a 55 degree tube and a misregister of 5 mils at the edge of a 70 degree tube.

Methods of Correction

There are several methods of correction for radial misregister that have been used in the past. The first is a reduction of the diameters of the apertures of the mask. This increases the tolerance with respect to misregister at the expense of some loss in brightness. Another method of correction is to move the yoke away from the mask. In that case the deflection plane starts in back of the color centers and in traveling forward as a function of deflection angle passes the color centers and ends up ahead of them, but not by as great an amount as without this corrected position. The misregister is thus split into a negative part for small deflection angles and a positive part for large deflection angles. The maximum amount can be reduced to 3 mils[2]. When the yoke position is thus compromised to improve misregister, one is no longer free to adjust yoke position to correct for other deviations from the norm such as statistical tube variations.

It will now be shown that all purely radial misregister can be entirely eliminated by interposing a lens between the light source and the shadow mask, during the exposure of the photo-resist. This lens has the property that the virtual source of light as seen from the shadow mask, moves forward in exactly the same way as the plane of deflection of the yoke does as a function of deflection angle. The beam of light after passage through the lens will therefore coincide exactly with an electron beam, and a phosphor dot will be placed on the faceplate exactly where an electron beam will strike.

A first order correction using the spherical aberration of a simple spherical lens provides a forward movement of the virtual deflection plane. However, the overall fit to the type of observed misregister curve shown in Fig. 2 is then only approximate. Since in the mass production of kinescopes the cost of a lens is a minor item, it is generally preferable to use a more exact correction lens.

To design an exact correction lens, the optical path is split into three portions forming the three angles shown as u_1, u_2, and u_3 in Fig. 3: u_1 is the inclination of the initial ray with the axis; u_2 is the inclination of the ray in the lens; and u_3 is the inclination of the final ray. The final ray inclination is determined by the fact that it must coincide with an electron beam and therefore must appear to originate from a distance $p - \Delta p$ on the optic axis. Therefore, starting with an arbitrary u_1, one can calculate the height at which this ray will emerge. An observed misregister curve, such as the dotted curve of Fig. 2, is then used with Eq. (3) to obtain the Δp appropriate for this angle. The angle u_3 is then determined. The slope

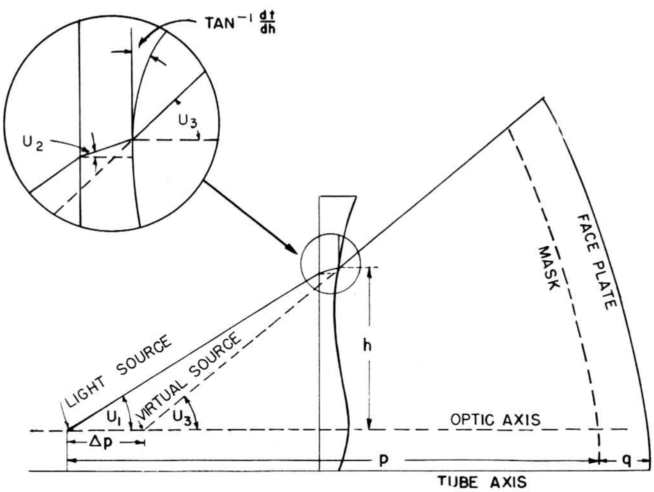

Fig. 3 - Schematic diagram of correction lens.

of the lens at this point is then determined from the formula:

$$dt/dh = (\sin u_3 - \sin u_1) \,/\, (N \cos u_2 - \cos u_3) \qquad (6)$$

where N is the index of refraction of the glass.

Such a lens has the great advantage of being easy to produce and easy to use. Once this lens is placed in the lighthouse and properly aligned, the exposure of the photo-resist is no more complicated than it was before, and in the finished tube all radial misregister is eliminated. It is interesting to note that the lens design is determined primarily by the effective length of the yoke and not by the tube dimensions.

The shape of the lens is approximately as shown in Fig. 3. It is aspheric and has a diameter of about 10 inches; the thickness first decreases, has a minimum at a radius of approximately 3 inches and then increases again quite sharply towards the end. This lens has been produced and tested. It completely eliminated systematic radial misregister. It is in use in the production of the RCA 21AXP22 color kinescope.

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