June 11, 1957 D. W. EPSTEIN ET AL 2,795,720

POST-ACCELERATED COLOR-KINESCOPES

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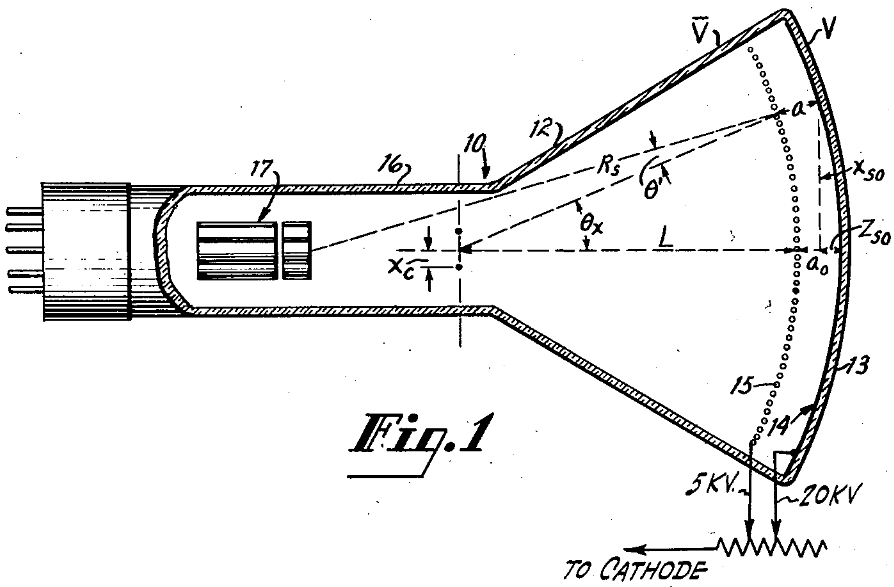

Fig. 1

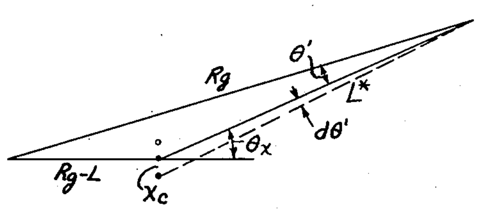

Fig. 2

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POST-ACCELERATED COLOR-KINESCOPES

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1 Claim. (Cl. 313—85)

This invention relates to cathode-ray tubes for producing television pictures in full color and, has special reference to improvements in color-kinescopes of the focused-mask line-screen variety.

An object of the invention is to construct a novel and improved focused-mask cathode-ray tube or kinescope of the line-screen type which insures improved picture quality.

Stated generally, this object is achieved in accordance with the invention by the provision of a cathode-ray tube wherein the mask wires are supported by a curved frame so that the mask surface has a cylindrical shape, and the phosphor line screen has a cylindrical curvature which is less than that of the mask and is so related to the latter as to insure more uniform separation of the color lines in a plane through the tube axis.

Various other objects and advantages will be apparent as the nature of the invention is more fully disclosed.

French Patent 866,065 to Dr. Werner Flechsig (published June 16, 1941) and its German equivalent 736,575 (published June 22, 1943) describe a color kinescope containing a bi-part screen assembly which comprises (*i*) a transparent viewing screen having a target surface made up of a multiplicity of groups of parallelly arranged strips or lines of different (e. g. red, blue and green) color-emissive areas and (*ii*) a grill formed of a large number of spaced-apart wires mounted adjacent to the target side of said screen. The beam electrons travel in substantially straight paths through the space between the grill and the screen. These straight beam-paths terminate, ideally, on respectively different ones of the (red, blue and green) line-like screen areas. The proper geometrical location of the grill wires provides a Crookes-shadow which masks those line-like screen areas which at any given instant are to remain unilluminated.

One very real limitation upon the efficient use of the above-described "Crookes-shadow tubes" is that only a small percentage of the beam electrons ever reach the viewing screen; the larger percentage being dissipated, in the form of heat, upon impact with the imperforate parts of the grill or mask. This limitation was recognized by Dr. Flechsig and his patents mention that it can be minimized (*a*) by making the mask wires of such fine gauge that the Crookes-shadow is no longer a factor in the operation of the tube, and (*b*) by substituting for the Crookes-shadow effect a beam-focusing cylindrical-lens effect which he achieved by operating the viewing screen at a relatively high potential with respect to the fine wire grill.

The present invention relates to post-accelerated cathode-ray tubes of the above-described "lenticular grill" variety and employs a cylindrically curved mask and a cylindrically curved screen which are so designed and constructed, in accordance with the invention, as to achieve uniform separation of the color lines in a plane through the tube axis which is at right angles to the mask wires; reduce defocusing at the edges and corners of the picture; and in general to achieve a more efficient utilization of the scanning beams than has heretofore been attained with tubes of this type employing either flat masks or curved masks and screens of conventional construction.

The invention is described in connection with the accompanying single sheet of drawings, in which:

Fig. 1 is a diagrammatic view, in longitudinal section, illustrating a focusing-mask kinescope of the line-screen type embodying the invention; and

Fig. 2 is a diagram which will be referred to in explaining the determination of the screen shape which, for a given grill radius, will result in the proper spacing of the phosphor lines in a plane perpendicular to the wires through the tube axis.

The color-kinescope diagrammatically illustrated in Fig. 1 is of the "line-screen" variety disclosed in the above-mentioned French and German Flechsig patents, and comprises an evacuated envelope **10** having a main chamber **12** in the form of a frustum which terminates at its large end in a cylindrically curved window **13** which constitutes the transparent foundation plate of the target or screen **14** of the kinescope.

The target surface **14** of the window **13** is provided with a multiplicity of parallelly disposed phosphor lines of different color-emissive characteristics, usually red, blue and green, arranged in a repetive pattern in groups of three. An electron-transparent light-reflecting film constituted, for example, of evaporated aluminum, coats said phosphor lines and renders the entire target surface of the screen conductive.

The cylindrically curved focusing mask or grill **15** mounted within the main chamber **12** of envelope **10** adjacent the screen **14** is formed of a large number of spaced-apart wires stretched between suitable cylindrically curved frames, in a manner well understood in the art.

The small end of the frustum **12** terminates in a tubular neck **16** which contains the usual beam source of electrons and the beam-focusing and deflecting means employed for scanning the target assembly.

A preferred embodiment of the tube employs a battery of three electron guns **17** in a plane, with a separation such that the distance between effective beam centers measured in a direction at right angles to the phosphor lines in the deflection plane is x_c. (The deflection-plane in a multi-beam C. R. tube is the plane in which the axis of each deflected beam, when extended rearwardly from the screen-unit, intersects the axis of origin of that beam.) The plane of the guns **17** is at right angles to the mask wires located on the cylindrical surface, of radius R_g, of the mask **15**. The mask wires, with a mutual separation *d*, may be electrically connected to the tube cone or conductive coating on the tube walls. As an alternative, the mask **15** may be made slightly negative with respect to the tube walls, or to a high-transparency additional grid which may be placed between the guns and the mask. Establishing such a small voltage between the mask and the tube walls reduces the number of secondary electrons drawn from the mask to the screen and thus improves picture quality.

The screen **13** is maintained at a voltage, measured with respect to the gun cathodes, which is approximately four times that of the mask **15**. It is given a cylindrical curvature which is less than that of the mask. Formulas for arriving at the preferred radius of curvature, which leads to uniform separation of the color lines in a plane through the tube axis which is at right angles to the mask wires, are given below. For example, if the radius of curvature of the mask is made 1.5 times its distance L from the plane of deflection and the separation between mask and screen is $a_0=0.073\ L$, the optimal screen curvature lies in the range from 1.8 L to 1.9 L.

The fact that the beam has a smaller angle of incidence on the curved mask than it would have on a flat mask leads to smaller defocusing with deflection. Even for a tube with a total horizontal deflection angle of 80° and a vertical deflection angle of 60°, the defocusing in the corners is less than a color line when the center is focused sharply. Furthermore, the deviation from straightness of the pattern lines is only of the order of one color line and the variation in the spacing of adjoining different-color lines is less than 8 percent. These specific numerical values refer to the foregoing example of the tube with $R_g=1.5\ L$, $a_0=0.073\ L$.

The geometrical relationships of the focusing-mask tube are indicated in Figs. 1 and 2. The tube employs the single wire grill **15** at ultor potential $\overline{V}$ with a radius of curvature R_g and the cylindrically curved screen **13** of radius R_s at a distance a (measured perpendicularly to the grill) from it. The potential V of the screen **13** is assumed to be $4\ \overline{V}$, the distance $L=13.695''$ between center grill and deflection plane being treated as very large compared to the distance a. In the numerical examples the value of a at the center, $a_0=1''$.

The objectives of the calculations given are the following:

1. The determination of the screen shape (i. e. the value of R_s or the variation of a with the deflection angle θ) which, for given grill radius R_g, will result in uniform spacing of the phosphor lines in a plane perpendicular to the wires through the tube axis.
2. A comparison of the spacing of adjoining phosphor lines in the corner of the picture and at the vertical edge center (wires vertical).
3. Determination of the deviation from straightness of the phosphor lines excited by the central gun (guns in line).
4. Determination of maximum width of the lines formed by the lens action of the grill in a horizontal and in a diagonal direction.

Basic formulas.—For the derivation of the relevant expressions it is convenient to introduce the following quantities:

$\theta_x=\text{arc sin } X_g/L^*$ deflection angle projected on plane ⊥ to phosphor lines (horizontal plane)

$\theta=\text{arc sin}\left[\frac{R-L}{R}\sin\theta_x\right]$ angle of incidence of ray from center of deflection plane on grill, projected on plane ⊥ to phosphor lines

$\theta_y=\text{arc tan } y_g/L^*$ deflection angle projected on plane ∥ to phosphor lines

$L^*=\sqrt{R_g^2-(R_g-L)^2\sin^2\theta_x}-(R_gL)\cos\theta$ distance from center of deflection plane to point of incidence on grill projected on plane perpendicular to phosphor lines

$X^*=\sqrt{V/\overline{V}+(V/\overline{V}-1)(\tan^2\theta_y+\sec^2\theta_y\tan^2\theta')}$

$X_o^*=X^*$ for $\theta_y=0$ (horizontal section through tube axis) a distance between grill and screen (measured along normal to grill)

$q=2a\tan\theta'/(1+X_o^*)$ displacement at screen of principal ray from center of deflection plane relative to normal to grill

$$\left.\begin{aligned}x_{so}&=L^*\sin\theta+q\cos(\theta-\theta')+a\sin(\theta-\theta')\\ z_{so}&=-L^*\cos\theta+q\sin(\theta-\theta')-a\cos(\theta-\theta')+a_o+L\end{aligned}\right\}$$

coordinates of horizontal section of screen relative to intersection of tube axis with screen

$R_s=(x_{so}^2+z_{so}^2)/(2Z_{so}$ effective radius of curvature of screen

In terms of these quantities the separation of the centers of two adjoining color lines (from beams separated by a distance x_c in the deflection plane) is given by

$$dx_{s'}=\frac{2ax_c}{L^*}\frac{\cos\theta_x\sec^2\theta'}{X^*(1+X^*)^2}\left(V/\overline{V}+\left(\frac{V}{\overline{V}}-1\right)\tan^2\theta_y+X^*\right)$$

measured at right angle to grill normal.

Hence, for equal separation of color lines throughout horizontal plane,

$$a=\frac{a_o}{3}\frac{L^*}{L}\frac{\cos^2\theta'}{\cos\theta_x}\frac{X_o^*(1+X_o^*)^2}{4-X_o^*}(V/\overline{V}=4)$$

Furthermore, the ratio of the spacing of the two phosphor lines in the corner of the picture (θ_x,θ_y) and on the horizontal axis (θ_x,O) is given by

$$\frac{dx_{s'}}{dx_{so'}}=\frac{X_o^*(1+X_o^*)^2(4-X^*+\tan^2\theta_y}{X^*(1+X^*)^2(4+X_o^*)}$$

The deviation from straightness of the central phosphor line of each trio is given by

$$\delta x_{s'}=2a\tan\theta'\left(\frac{1}{1+X^*}-\frac{1}{1-X_o^*}\right)$$

Finally, the line broadening at the picture edge or at the picture corners for a sharply focused center is given by $2\Delta x_s$ with

$$\Delta x_s=-\frac{d-D}{2}\{(X^*-1)(1+\tan^2\theta')-\cos^2\theta'-1\}$$

If the defocusing at the center and in the corners is balanced and Δx_s is very much smaller than $w_o=M_od/3$, Δx_s for the corners indicates also the maximum line width (for vanishing beam cross section in the deflection plane) throughout the picture.

d is the separation of the wires of the grill, D, their thickness.

Calculations were carried out in detail for $R_g/L=1$ and $R_g/L=1.5$ with $L=13.695''$ and $a_o=1''$. This corresponds to a pattern magnification $M_o=1.0489$ and a beam separation in the deflection plane $X_c=0.251''$ if $d=0.035''$. D is assumed to be 0.003''. With increasing value of a_o the screen is flattened increasingly (R_s increased) as compared with the grill. Apart from this the value of a_o, as well as those of M_o, d, and x_c have no appreciable effect on the values given below.

$R_g=L$

θ_x	θ_y	R_s	dx_s'/dx_{so}'	$\delta x_s/w_o$	$\Delta x_{so}/w_o$	$\Delta x_s/w_o$
10°	7.5°	15.78''	0.996	0	0	0.016
20°	15.0°	15.84''	0.983	0	0	0.070
30°	22.5°	15.94''	0.960	0	0	0.164
40°	30.0°	16.11''	0.927	0	0	0.310

$R_g=1.5\ L$

θ_x	θ_y	R_s	dx_s'/dx_{so}'	$\delta x_s/w_o$	$\Delta x_{so}/w_o$	$\Delta x_s/w_o$
10°	7.5°	24.71''	0.996	−0.014	0.002	0.019
20°	15.0°	24.78''	0.985	−0.096	0.004	0.074
30°	20.5°	25.11''	0.959	−0.43	0.012	0.171
40°	30.0°	25.41''	0.924	−1.14	0.015	0.321

As a matter of orientation, changing a_o from 1'' to 2'' changes R_s for $\theta_x=0$ from 15.76'' to 17.99''.

Discussion.—The angles in the first two columns are the assumed maximum deflection angles in a horizontal (lateral sides) and vertical direction (top and bottom). R_s is the radius of curvature of the screen which leads to equal spacing of color lines at the centers of the sides and in the middle of the picture. The fourth column gives the ratio of the spacing of adjoining color lines at the top and at the horizontal center line of the picture, for equal horizontal deflection. The fifth column gives the deviation from straightness of the center lines of a color line trio, measured in terms of the width w_o of a phosphor line at the center. The last two columns indicate the line broadening at the horizontal center line and in the corners measured in the same units.

It is seen that for an overall angle of 72° ($\theta_x=30°$) and $R_g=1.5\ L$, $R_s=25''$ the deviation from straightness is still less than half a color line, the defocusing of the order of ⅓ of a color line, and the variation in the spacing of adjoining color lines only about 4 percent. Electrons reflected by the screen will tend to introduce halos and decrease contrast. On the other hand, secondary electrons from the grill can be largely collected by an added high-transparency grill slightly positive with respect to the focusing mask.

Among the more important advantages of a focusing-mask kinescope of the line-screen type constructed in accordance with the present invention may be cited the following: It has the high mask transparency characteristic of a focusing-mask tube; it is possible to deposit the screen directly on a face plate of reasonable thickness, since the curvature insures high mechanical strength under pressure; ease of printing the screen, since the phosphor lines closely approximate straight lines parallel to the cylinder axis; reduced defocusing at the edges and corners of the picture; and the possibility of making line spacing uniform by giving the screen the proper curvature.

What is claimed is:

A cathode ray tube for producing pictures in full color, comprising in combination: a plurality of electron beam producing guns arranged adjacent to each other, deflecting and accelerating means common to said guns and arranged to deflect the electron beams therefrom at a common deflecting plane perpendicular to the tube axis, a cylindrically curved fluorescent screen disposed in the

paths of said beams and upon which said pictures are produced, said screen having groups of lines of color phosphors thereon extending along lines parallel to the axis of curvature of said cylindrical screen, and a focusing grill interposed between said guns and said screen, said grill being formed of laterally spaced wires extending parallel to said cylindrical axis, the longitudinal axes of said wires lying in a common cylindrical surface having a radius of curvature substantially one and one-half times the maximum distance from said grill to said deflecting plane and the radius of curvature of said screen being of the order of from 1.8 to 1.9 times said maximum distance, the cylindrical axes of said screen and said grill lying in a common plane through the tube axis and being at right angles to the tube axis, the minimum spacing between said screen and said grill being substantially 0.073 times said maximum distance from said grill to said deflecting plane.

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