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LB-830

A 45-DEGREE REFLECTION-TYPE COLOR KINESCOPE

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
INDUSTRY SERVICE LABORATORY

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Approved

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Introduction

The work at RCA on all-electronic color television has included investigation of many methods of color reproduction using cathode ray principles. Among the more important methods is the one using a direction-sensitive screen of the aperture-mask type, which is incorporated in the developmental tri-color kinescopes described in earlier bulletins. Another of the interesting methods uses electrical control of the electron beam at the phosphor screen for changing color. This bulletin describes experimental work on one variation of the latter method.

The color tube described in this bulletin is known as the 45-degree reflection-type color kinescope and uses a single electron gun; the color is changed by applying a control voltage directly to the screen assembly. The screen assembly consists of a multi-apertured metal plate coated on the front side with red, green and blue phosphor strips and mounted parallel to a glass plate coated with a transparent conductive film. An electron beam scans the back of the metal plate at an angle of incidence of approximately 45 degrees. The portion of the beam passing through the slots is reflected by the electric field between the plates causing it to fall back on one set of phosphor strips. By varying the potential of the glass "reflector" plate, the beam can be shifted from one color phosphor to another. The scanning beam is not required to follow the aperture pattern and the color purity is independent of beam focus.

A feature of this tube is the automatic registry of the three colors over all parts of the screen. The screen is not difficult to construct and the power required to switch colors at megacycle frequencies is small. Other characteristics of this tube which should be noted are: the unconventional shape of the bulb, a possible moiré pattern, and the need, in some forms of the tube, for a "keystoning" correction of the scanning.

Experimental one-gun tubes having screens seven inches in diameter have been built and operated with color pictures. Tests have shown that the basic principles of the 45-degree reflection-type color kinescope are sound, and have utility in a color reproducer. A complete evaluation of tubes of this type, in which advantages and disadvantages are weighed against those of other color kinescopes, cannot be made at this time.

Associated circuits for operating the tube with the RCA color signal are outlined. Variations of the tube including a three-gun version are also described.

General Discussion

The 45-degree reflection-type color kinescope falls into the class of tubes in which the emitted color is controlled by deflection of the beam in the immediate vicinity of the phosphor screen. A desirable feature of this class of tubes is that the color control is entirely independent of the scanning process and of the beam focus. A color picture inherently free from misregistry of the three colors may be obtained using a single gun with conventional scanning techniques. The three primary components of the color signal may be presented sequentially at any rate depending upon the color system employed.

The screen arrangement for the "beam deflection" type of color kinescope usually consists of a beam-defining structure in registry with an array of red-, green-, and blue-emitting phosphor strips or dots, plus some means of bending the beam from one strip to the next. An important advantage of tubes that have a beam-defining structure near the color screen is that the color purity is insensitive to beam focus. This is to be contrasted with the "line-screen" arrangement wherein the beam must be aimed and focused by the gun onto a thin strip of color; here, even a slight defocusing tends to dilute the colors.

Pairs of minute deflection plates mounted in front of each set of color strips have been proposed as a means of switching the beam from one color to another. Such structures are difficult to build on a fine enough scale to give a high quality color picture. Furthermore, the switching voltages required and capacitance to be driven are likely to be inconveniently high.

The 45-degree reflection-type kinescope employs a relatively simple method of controlling the beam in the neighborhood of the screen. This paper will describe some of the early experimental tubes with 7-inch screens having a line structure sufficiently fine to give about 180 black-and-white lines resolution (540 color lines). This size screen was made for convenience and was a part of a larger screen capable of 360 black-and-white lines resolution and filling a 16-inch envelope. The 7-inch experimental tubes were tested with the RCA color television signal and were found to give color pictures of pleasing quality.

Principle of Operation

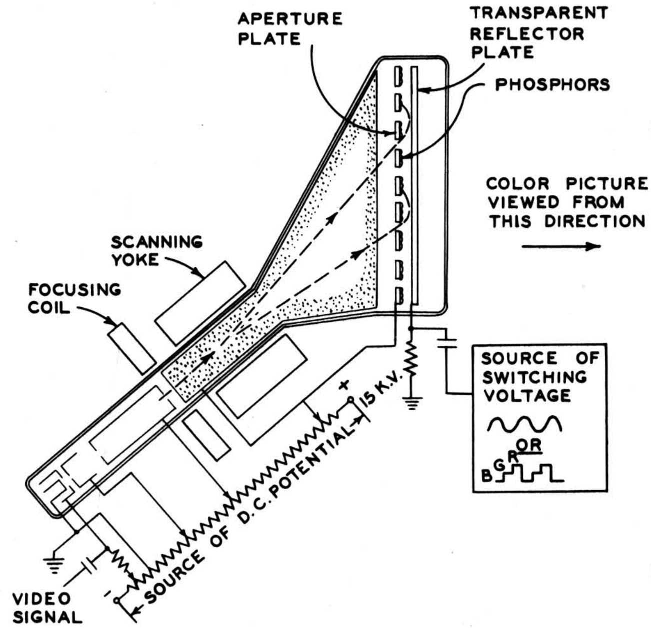

Fig. 1 - Cross sectional diagram of the 45-degree reflection type three-color kinescope. Although the beam scans the screen at approximately a 45-degree angle the picture is viewed in a normal manner.

Fig. 1 shows a cross sectional diagram of the 45-degree reflection kinescope. The screen assembly which is shown in greater detail in Fig. 2 consists of two parts: a metal aperture plate and a transparent reflecting electrode. The beam approaches the aperture plate at an angle of incidence of approximately 45 degrees and a fraction of the beam passes through the slots. An electric field between the aperture plate and the reflector electrode causes the beam to be reflected and to return in a parabolic path to the aperture plate. The reflected beam strikes one of the phosphor strips deposited on the front side of the aperture plate. The color picture is viewed directly through the transparent reflector electrode. The phosphor is deposited on the plate in the form of strips so that a group of three strips emitting red, green, and blue light respectively is laid between each pair of apertures.

The width of each of the phosphor strips within the group is approximately the same as that of the apertures so that the reflected beam can be made to fall on any one of the three colors selectively. By varying the voltage on the reflector electrode, the point of impact of the reflected beam can be shifted from one color to another. The voltage change required to switch colors is inversely proportional to the distance between the aperture through which the beam passes and the corresponding bombarded spot. In some experimental tubes, the reflected beam actually jumped across about thirty slots before returning to the plate. Under these conditions less than 100 volts change in voltage of the reflector plate shifted a 12,000 volt beam from one color to another. A still finer pattern would require less power to switch colors. The capacitance to be driven by the color control voltage need not exceed 50 to 100 μμf.

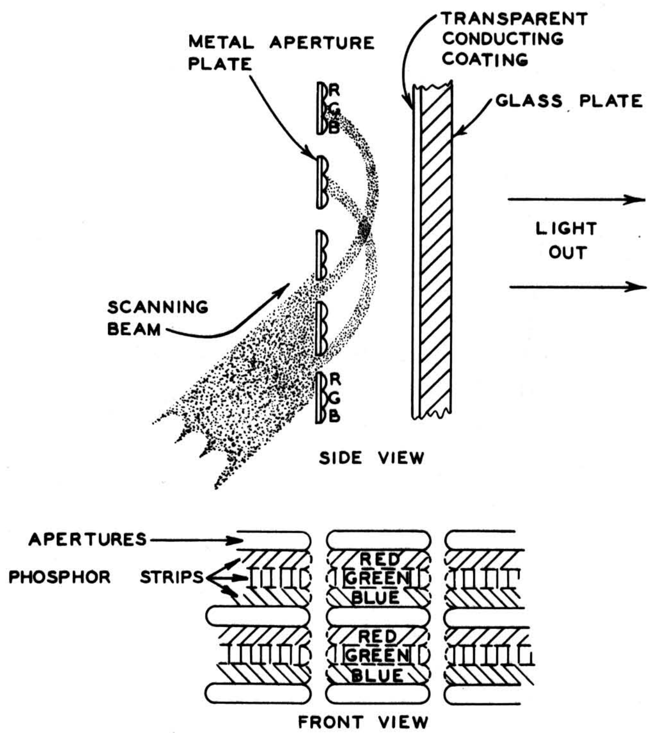

Fig. 2 - Screen assembly of the 45-degree reflection kinescope shown in greater detail. By varying the potential on the transparent reflector plate the reflected portion of the beam can be switched from one color phosphor to another.

It must be noted that the color reproduction is entirely independent of the scanning raster and of the focus of the beam. The beam is not required to follow any particular pattern of slots on the aperture plate. A conventional gun and deflection yoke are entirely adequate with no possibility of misregistry of the three colors assuming, of course, that the pattern is sufficiently fine.

The 45-degree angle of incidence of the beam requires a tube envelope of unconventional design although a compensating feature is that it permits a more compact cabinet design. In the tubes tested a keystoning correction must be added to the scanning to give a rectangular picture. Tests of the tube with the RCA color television signal are described in a later section.

Electron Optics

Basic Equations - Color Switching

In the experimental 45-degree reflection kinescopes described herein, the aperture plate and the reflector plate are accurately flat and parallel. The electron motion in such a uniform field is similar to that of a projectile in a gravitational field and is readily calculable. It is found that the distance between the point where the beam passes through an aperture and the point where it returns to the aperture plate is given by:

$$S = \frac{2V_B\ D}{V_B - V_R} \sin 2\theta \qquad (1)$$

Where: S is the range of the reflected beam (see Fig. 3),

D is the distance between the reflector plate and the aperture plate.

V_R is the potential of the reflector plate in volts,

V_B is the potential of the aperture plate in volts,

θ is the angle of incidence of the beam with respect to the aperture plate.

In order to shift the beam from one color to another the rate of change of S with respect to a change in the reflector plate potential is of interest. From Eq. (1) the differential displacement is:

$$dS = \frac{2V_B\ D\ \sin 2\theta\ dV_R}{(V_B - V_R)^2} \qquad (2)$$

Where dS is the displacement of the point of impact of the reflected beam produced by a change of reflector voltage of dV_R.

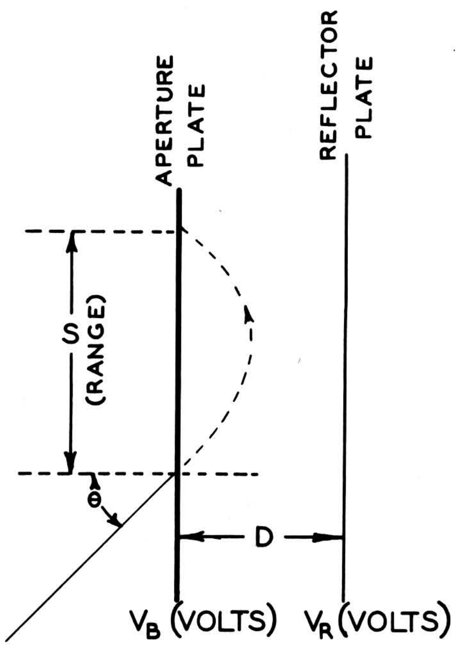

Fig. 3 - Parabolic electron trajectory in the reflecting field between the aperture plate and the reflector plate.

In the operation of these kinescopes it was found convenient to keep the mean potential of the reflector plate at ground. Setting $V_R = 0$ in Eqs. (1) and (2),

$$S = 2D \sin 2\theta \qquad (3)$$

and

$$dS = \frac{2D}{V_B} \sin 2\theta\ dV_R \qquad (4)$$

Experimental tubes were made with a spacing D = approx. 0.44 inch giving S_{max}= 0.88 inch. In the approximate center of the picture where θ = 45 degrees, the center-to-center spacing of the color strips was approximately .007 inch. Substituting these values in Eq. (4) the voltage change required to deflect a 12 kilovolt beam from one color to the next is:

$$dV_R = \frac{V_B dS_{max}}{2D} = \frac{12{,}000 \text{ volts} \times 0.007 \text{ inch}}{2 \times 0.44 \text{ inch}} = 95\text{v}.$$

The 95 volts required to switch from one color to another were readily obtainable with sine-wave color switching at 3.58 Mc, the color sequence rate in use during tests with the RCA color television system. By Eq. (2) the required switching voltage could have been reduced to approximately 50 volts for the same target structure if V_R, the average potential of the reflector plate, had been run at 3,000 volts instead of at ground. Under these conditions the beam will skim much closer to the reflector plate but not strike it because its energy at the instant of closest approach will be directed parallel to the plate.

It is noted from Eq. (4) that the shift of the reflected beam produced by a change in voltage of the reflector plate is proportional to the spacing D between the reflector and aperture plates. The spacing of 0.44 inch was chosen as a compromise giving adequate voltage sensitivity without sacrificing resolution. A very much larger spacing would allow still less power for switching but would require a beam of exceedingly narrow angle of convergence to avoid objectionable spreading in a direction parallel to the slots. (The reflecting field provides focusing of the beam but only in a direction perpendicular to the slots.) On the other hand, if extra power for switching is available, a further reduction in spacing is desirable for making the tube still less critical to misalignment and stray magnetic fields.

Color Uniformity

An electron-optical problem connected with the 45-degree kinescope is that of making the reflected beam fall on the proper color phosphor *over all parts* of the screen. Three posible approaches were considered.

(1) Curving the aperture plate and reflector plate so that the beam approaches the aperture plate at exactly 45 degrees over all parts. (Fig. 4A)

(2) Using plane electrodes but providing an electron lens between the gun and the front of the aperture plate so the 45-degree angle of incidence is preserved over the whole screen. (Fig. 4B)

(3) Using plane electrodes but arranging the position of the apertures and phosphors to compensate for the different angles of approach over the target. (Figs. 1 and 5).

The greater simplicity of constructing plane electrodes as compared to the curved

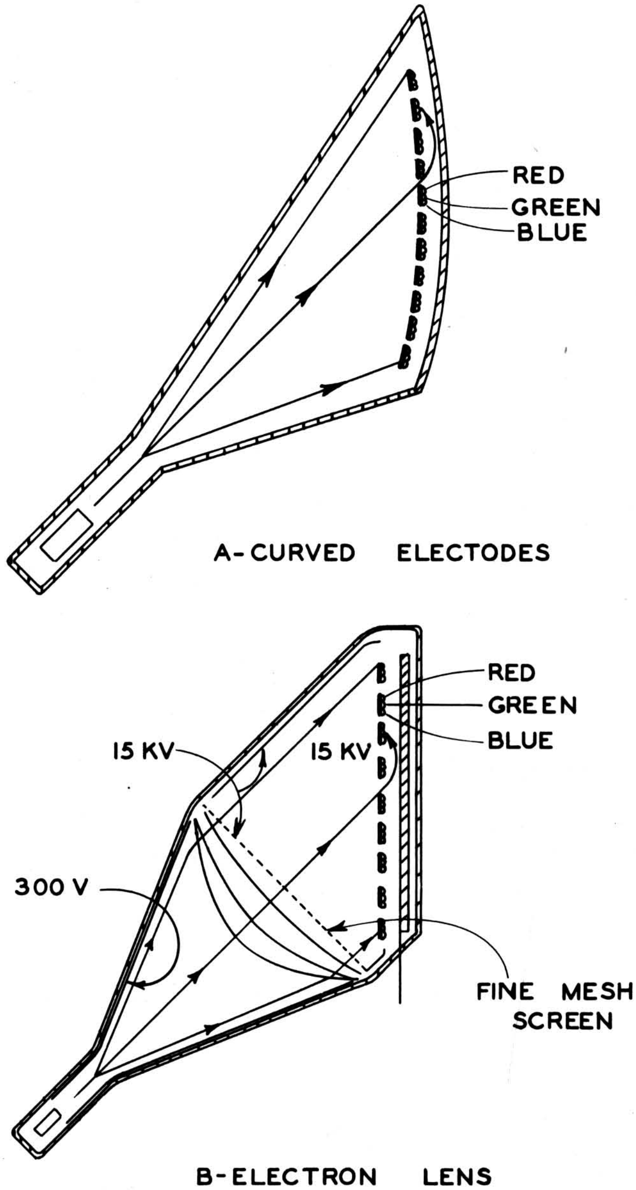

Fig. 4 – Two alternative methods of achieving color uniformity by causing the beam to strike the entire screen at 45 degrees. The electrodes in (a) are non-spherical surfaces whose vertical cross-section is a spiral and whose horizontal cross-section is a circle. The electron lens method in (b) permits plane electrodes to be used and eliminates the need for a "keystoning" correction in the scanning.

electrodes ruled out (1) for the initial experiments. The electron lens method mentioned in (2) is a promising approach but requires a longer tube with some loss in brightness due to the fine mesh screen. The third approach was used and gave very satisfactory results. Eqs. 1-4 show that the maximum values of the range S and the displacement dS occur in the center of the picture where the angle of incidence θ is exactly 45 degrees. At the top and the bottom of the picture where θ approaches 60 degrees and 30 degrees the range may decrease as much as 20 per cent. To compensate for this effect, a particular pattern of apertures has been devised for the aperture plate.

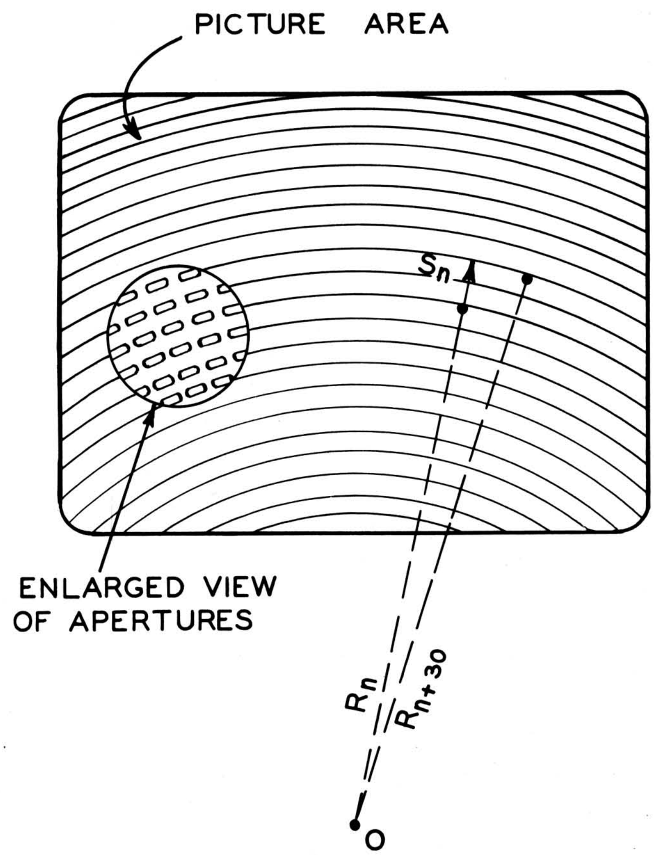

Fig. 5 – Circular pattern of apertures used in experimental 45-degree reflection kinescopes. Plane electrodes are made feasible by arranging the position of the apertures and phosphor strips to compensate for the varying angle of incidence across the screen (see Fig. 1). The insert shows an enlarged view of a small section of the aperture plate.

Fig. 5 shows the particular arrangement of apertures used in the 45-degree reflection kinescope. The insert shows an enlarged view of the slot-like apertures. These apertures are formed on concentric arcs of circles whose centers lie on a common point O obtained by dropping a perpendicular from the center of deflection to the plane of the target. The phosphors are laid on arcs about the same center with three rows of phosphor between each two rows of apertures (Fig. 2). Along each arc the beam approaches the aperture plate at the same angle. Thus, for a constant voltage on the reflector plate, the beam will excite the same color phosphor all along the arc.

The color uniformity from top to bottom was achieved by arranging the spacing between adjacent concentric arcs to take into account the fact that the range S is a maximum for a 45-degree angle of incidence. (Eqs. 1-4). For a 16-inch kinescope employing a picture 9 inches high, the spacing between rows may be approximately 20 per cent greater in the center of the picture than at the top and the bottom.

The radii of the arcs along which the apertures were to be found were calculated in a step-wise manner from Eq. (3). The plane of the target was set 8.5 inches from the center of deflection and the angle of incidence varied between 30 degrees at the bottom of the picture to 60 degrees at the top. It was decided arbitarily that the range should span thirty rows of apertures over all parts of the target and that the maximum range in the center of the picture (45 degrees incidence) should be 0.8854 inch. The radii of successive arcs were then given by:

$$R_{n+30} = R_n + 0.8854 \sin 2\theta_n$$

where

$$\theta_n = \arc \tan \left(\frac{R_n}{8.5}\right)$$

The radii were calculated for 393 arcs covering a vertical distance of $10\frac{3}{4}$ inches. This would correspond to a useful picture about $9\frac{1}{2}$ inches high having approximately 1000 color phosphor strips. The experimental tubes described herein used an aperture plate based on the central part of these calculations giving screen diameter of 7 inches.

The Focusing Action of the Reflecting Field

The preceding discussion has assumed the angle of incidence of the beam over all parts of the aperture screen is specified exactly by a line connecting the bombarded aperture with the center of the deflection coil. This is, of course, true only for the central core of the beam and then only in the absence of perturbing fields or possible misalignments of the screen. The dependence of the range S on the angle of incidence was given by Eq. (3).

Inasmuch as a variation in the range of one part in 120 in the present screen moves the beam from one color phosphor to another, the rate of variation S with a small change in θ is of interest. Differentiating Eq. (3) with respect θ, one obtains

$$\frac{dS}{d\theta} = 2S_{max} \cos 2\theta \qquad (5)$$

It is noted that $\frac{dS}{d\theta}$ is small in the neighborhood of 45 degrees. This means that the electric field between the aperture plate and the reflector plate has a focusing action in the plane of incidence of the beam. Thus the fraction of the beam passing through each aperture may actually diverge and still be brought together by the reflecting field to strike a single color strip without appreciable excitation of adjacent color strips. The relaxation of the requirements on alignment of the target and on the shielding of the beam from stray magnetic fields are further advantages of this focusing effect.

Eq. (5) shows that if the angle of incidence is greater than 60 degrees or less than 30 degrees, $\frac{dS}{d\theta} > S$ which is equivalent to defocusing. This would appear to limit the total angle of scan to 30 degrees if the benefits of the focusing action are to be obtained. Such a limitation is not a severe restriction on tube dimensions or receiver cabinet design since a 30-degree total angle centered about a 45-degree angle of incidence would permit a shorter cabinet for the same size picture than a conventional tube with a total angle of 60 degrees.

The tapering off of the focusing effect of the reflecting field at the top and the bottom of the picture makes some magnetic shielding desirable to prevent stray fields such as the earth's magnetic field from shifting the beam from the proper color. The focusing of the reflecting field in these areas does not appear to be essential for color purity since the convergence angle of a high velocity beam is a very small fraction of one degree.

It may be noted that the two alternative methods of achieving color uniformity illustrated in Fig. 4 profit by having a 45-degree angle of incidence over the *entire* screen.

Alternate Forms of the 45-degree Color Kinescope

Transmission Type Kinescope

A variation of the 45-degree reflection kinescope is the transmission type tube operating by the method illustrated in Fig. 6. The beam strikes the phosphor strips on the second plate at high velocity. The color is switched by applying an a-c voltage to the second plate.

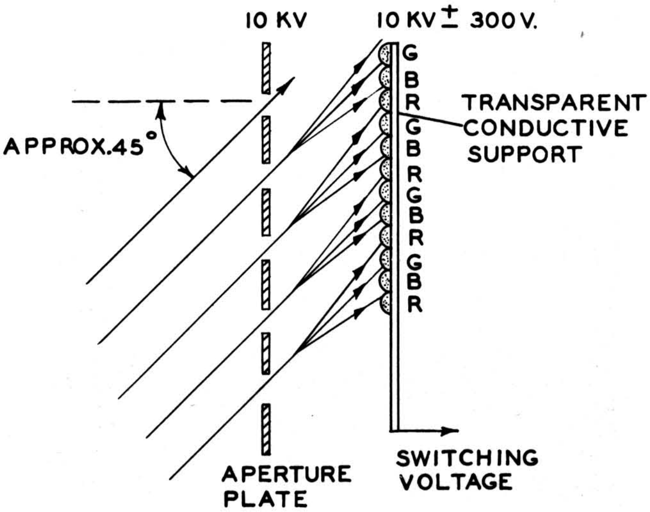

Fig. 6 - An alternate form of 45-degree color kinescope. This "transmission type" tube was considered less attractive than the reflection-type on the grounds that it was more difficult to construct, required more power to switch colors and lacked the desirable focusing features of the reflecting field.

Simple claculations show that the transmission-type tube at 45 degrees requires four to eight times as much switching voltage as the reflection tube for the same beam voltage and target spacing. There is no focusing action of the field and the target will be very sensitive to stray magnetic fields. Unlike the reflection-type tube this form requires accurate mechanical registry of the two plates. A satisfactory solution to the uniformity problem would have to be worked out before a useful tube could be built. It may be noted that the circular pattern of apertures used to achieve uniformity in the reflection type tube does not appear attractive here because of the lack of focusing.

Electron Mirrors for Compactness and Simplification of Bulb Design

The electric field between a flat plate and a fine mesh screen can be used as a plane mirror for electrons. Fig. 7 shows how such a mirror might be used to simplify or shorten the bulb design of the 45-degree tube. The target would be aligned for the apparent center of deflection instead of the actual center of deflection. The principal disadvantage is the loss in beam strength produced by the double transit through the screen S. With available high transmission screens this loss might be reduced to about 50 per cent.

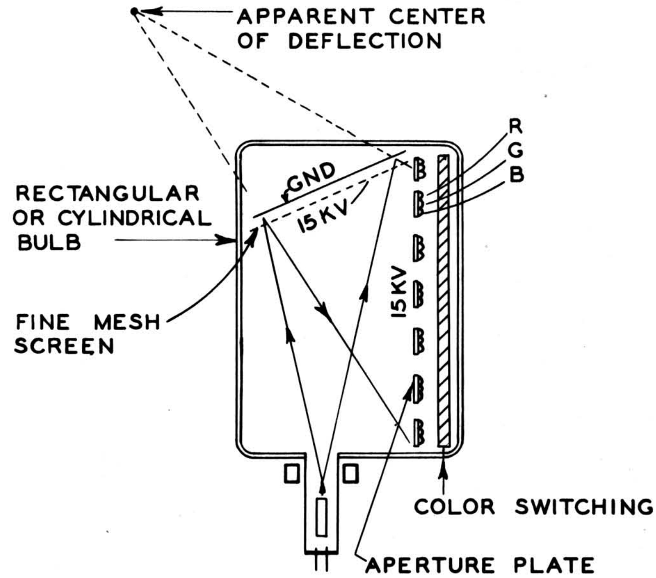

Fig. 7 - The use of an electron mirror to shorten or simplify the bulb design of the 45-degree color kinescope.

Three-Gun 45-degree Kinescope

An alternative 45-degree kinescope arrangement which does not require a color switching signal consists of three guns mounted as close together as possible with a 45-degree reflection-type target. With a 12-kv beam, color separation can be achieved by operating the cathodes of the red and blue guns approximately 95 volts above and below the potential of the green gun. This means that for each color the electrons pass through the apertures with slightly different velocities thus falling on different colors (see Eq. 4).

The beams should be as nearly superimposed as possible for best registry of the three colors. Even so, the three rasters will be slightly different in size owing to the different velocities of the beams when passing through the deflection coil. For this reason the screen should be designed to shift colors with as little change in beam voltage as practicable. With the screen assembly described above, and using a magnetic-type scanning yoke, the red and blue rasters differ in size from the green raster by about 0.4 per cent. The resulting error which is of the order of a picture element occurs only at the edge of the picture and may be neglected.

Construction of an Experimental 45-degree Color Kinescope

Aperture plates for the experimental tubes were made from copper sheets 0.002-inch thick whose openings were etched by photo-engraving techniques. A photographic master of the pattern desired was first obtained by ruling on a heavy lucite block with a stylus mounted on a vertical milling machine. The radii of the arcs were set to an accuracy of a few ten-thousandths of an inch according to the calculations outlined previously. This pattern was transferred to a photographic negative by contact printing using a point light source. A second ruling of radial lines was then combined with the curved pattern to give a negative of the slot pattern complete with radial cross bars. The cross bars are made as thin as possible consistent with adequate mechanical strength of the final aperture plate.

The copper sheet was coated with a "cold top" photosensitive enamel and exposed with ultraviolet light through the slot pattern negative. The action of the light makes possible the formation of an acid resistant coating over all parts of the copper except where the slots are to be. Immersion in an etching solution forms the holes in an accurate copy of the original pattern.

The aperture plate was then coated with the three phosphor materials emitting the primary colors. Each material was deposited in turn by settling through a mask similar but not identical to the aperture plate itself. Other methods of laying down the phosphors could have been used equally well. For a small target, a copy of the aperture plate itself could be used as a settling mask for all three colors without appreciable error by simply displacing the mask in turn for each color. For a large target with a wide angle of scan each color should have its own settling mask ruled so that the center of its arcs coincide with the center of curvature of the aperture plate. In the experimental tubes with the 7-inch screens a satisfactory compromise was made in which a settling mask was computed and ruled for the phosphor row falling midway between the slots. The error, resulting from displacing the mask ± 0.007 inch for the adjacent colors, was not objectionable for the 7-inch picture. Fig. 8 shows a photomicrograph of the three phosphors deposited on the aperture plate. The thicknesses of the coatings were adjusted for color balance to give an acceptable white.

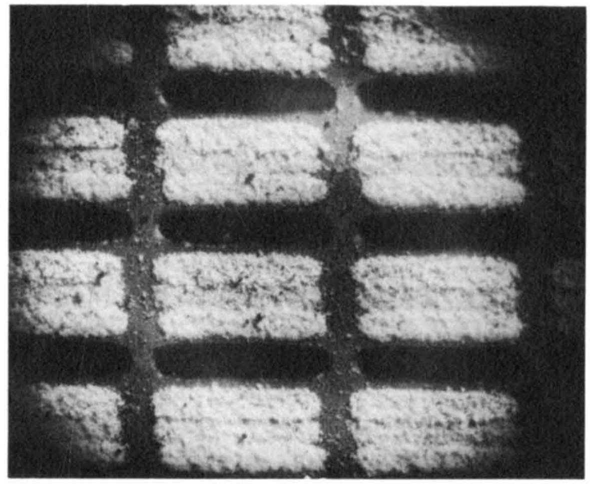

Fig. 8 - Photomicrograph of the three sets of phosphor strips deposited by settling on to the copper aperture plate.

In assembling the tube, the copper aperture plate was mounted on a rigid frame which permitted it to be stretched tight and flat. The frame also supported the glass reflector plate spaced parallel to the mask. The tolerances on parallelism and flatness of each plate are quite close. The inner surface of the glass plate was coated with a transparent conducting coating, called "Nesa", supplied by the Pittsburgh Plate Glass Company. The "Nesa" coating is highly transparent and could be formed on the glass with a surface resistance of several hundred ohms per square. The resistance was sufficiently low to give no objectionable voltage drop or power loss even when switched at megacycle frequencies. Lavite spacers were used to support the glass 0.4427 inch from the aperture plate.

Early tests of the screen assemblies were made by placing the structure in a demountable vacuum system shown in Fig. 9. Color uniformity, color stability, brightness, contrast, resolution, moiré could all be readily examined without requiring a complete color signal.

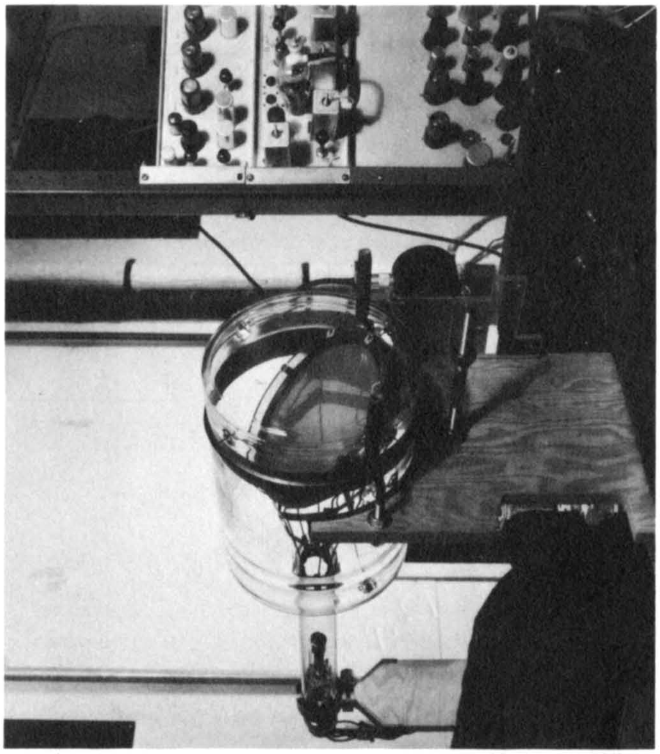

Fig. 9 - Demountable vacuum system used for testing color kinescope screens. A 7-inch diameter 45-degree reflection type screen is shown in position for test prior to being sealed in a bulb.

In parallel with the development of the screen, the associated circuitry was assembled for operating the tubes with an RCA color television signal. Sealed-off experimental tubes with 7-inch diameter screens were built and tested successfully with a full color color picture.

Operation of the 45-degree Kinescope with the RCA Color Television Signal

The 45-degree reflection-type color kinescope belongs to that class of color tubes in which the primary color emitted is determined by a control voltage applied to the screen structure. The phosphor strips were laid down on the aperture plate in groups of three having the order red, green, blue, (Fig. 2). In the absence of the color switching signal, the proper d-c bias was applied to the reflector plate to give a uniform green color. For sequential three-color reproduction, a repetitive waveform of proper magnitude was applied to the reflector plate to cause the reflected beam to oscillate from the central green phosphor to the adjacent red and blue phosphors. At the same time, the beam current was modulated in turn with each primary signal so that the total light emitted by each tri-color element carried the proper intensity, hue and saturation.

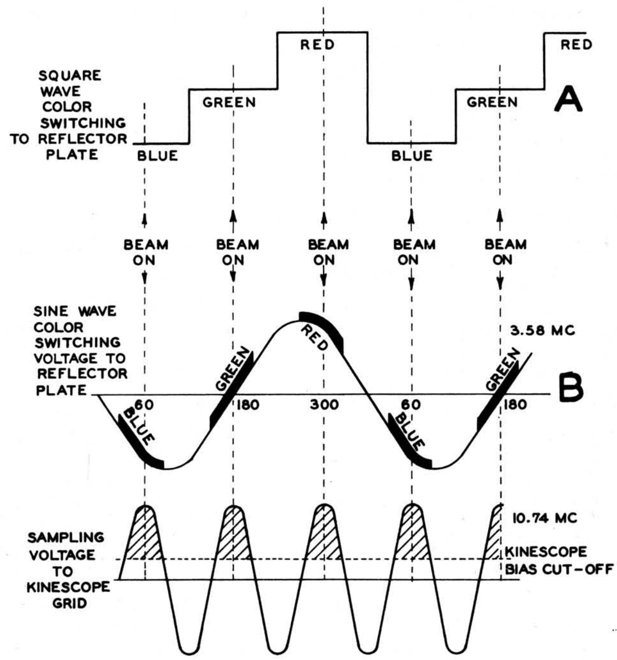

Fig. 10 - Waveforms of the color switching voltage which may be applied to the reflector plate. For low speed switching the step-wave shown in A would be preferable. For high speed switching at megacycle frequencies the sine wave shown in B was entirely suitable. Beam blanking at three times the switching frequency was used to give the required color sequence.

Fig. 10 shows two forms of switching voltage which may be applied to the reflector plate for a sequential color presentation. In A a step wave is shown. This wave shape would give the maximum light output, each color being on one-third of the time. Generating this wave form at high sequence rates presents an unusual circuit problem and an attempt was made, with some encouraging results, to do it by means of a multiresonant circuit as a plate load of a class C amplifier. For the work with the RCA color television system, however, using a 3.58-Mc color rate, it was found more convenient and, for all practical purposes, just as effective, to use the sine wave form shown in Fig. 10B.

A 3.58-Mc sine wave of approximately 75 volts rms was applied to the reflector plate. By switching the beam on at 120-degree intervals with proper timing (say at 60°, 180°, 300°, 60°, etc.) the BGRBGR (Blue, Green, Red, etc.) sequence of the dot multiplex signal was preserved. If the beam was not switched on and off, whichever color was the center color, in this case green, was repeated twice for every one of the other two to give a BGRBGR sequence. Thus the beam blanking performed the double function of eliminating the extra green line and of effecting "sampling".[1] Beam blanking was accomplished conveniently by modulating the video on the grid of the kinescope with a sine wave of three times the switching frequency, or 10.74 Mc, (as shown in Fig. 10B) synchronized with the switching voltage. This was done by linearly adding this sampling frequency to the video and then operating the grid of the kinescope Class C--much the same as in grid modulation of an amplitude-modulated radio signal.

The use of sine wave switching has the advantage of reducing the power requirements of, and of simplifying, the circuitry. Resonant circuit techniques were employed throughout.

Fig. 11 is a block diagram showing this use of sine-wave switching and the associated video and deflection circuits.

Switching and Sampling Circuits

The circuitry involved was straightforward and presented no unusual problems beyond a mechanization of Fig. 11. A possible exception was keystoning, of which more will be said later. The major difficulty encountered was that of transmitting signals over long leads and/or cables first to a demountable and then to a test rack. This is reflected in the "brute force" type of circuits which were used rather than the compact circuitry usually encountered in receiver design.

The input signals used were received via two cables connected to the master color television signal generators set up in the television studio at RCA Laboratories. One signal consisted of the 3.58-Mc color synchronizing signal and the other was the RCA color signal - i.e., standard black-and-white sync and blanking, a video signal with a 3.58-Mc color subcarrier, and a 3.58-Mc burst on the back porch of the horizontal sync pulse. The burst was not used because of the availability of the separate color synchronizing signal. The circuits were divided into two parts: the color switching and sampling circuits driven by the 3.58-Mc, and the more or less standard video and deflection circuits.

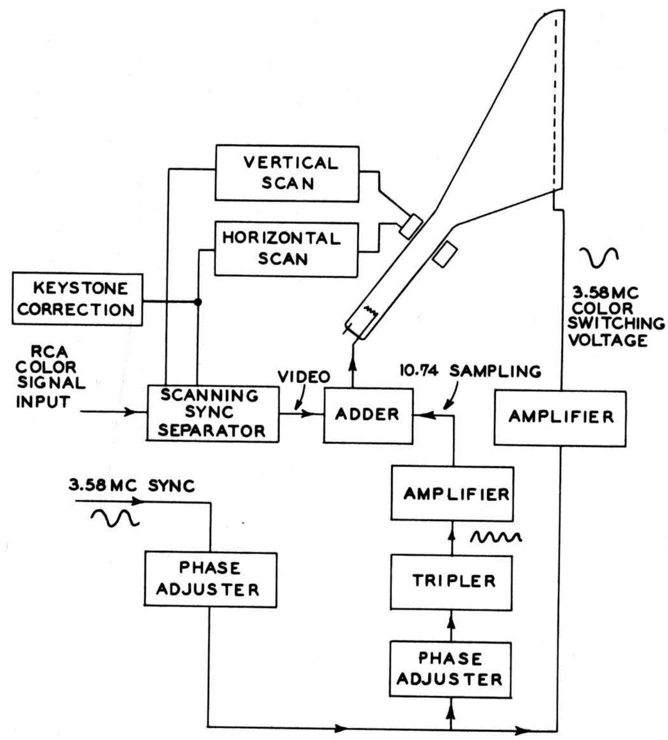

Fig. 11 - Block diagram of associated circuits for operating the 45-degree reflection kinescope with the RCA color signal. A 3.58 Mc sine wave is applied to the reflection plate and a 10.74 Mc sine wave used for sampling the signal at the gun.

The schematic diagram of the switching and sampling circuitry is shown in Fig. 12. The color sequence phase shifter adjusted the phase of the 3.58-Mc signal so that it was in phase with the transmitter sampler. This allowed a green portion of picture to appear as green, a red portion as red and so on. The phase shifter used consisted of a phase inverter in conjunction with a variable resistance-capacitance network to produce a continuously variable phase shift of 0 degrees to 140 degrees.

The output of the phase shifter was put through an isolating stage and then into a switched delay cable. The cable consisted of two lengths of 1000-ohm coaxial transmission line cut to give a fixed delay equivalent to

[1]RCA Laboratories Division, "A 6-Mc, Compatible, High Definition Color Television System", *RCA Review*, Vol. 10, pp 504-524, Dec. 1949.

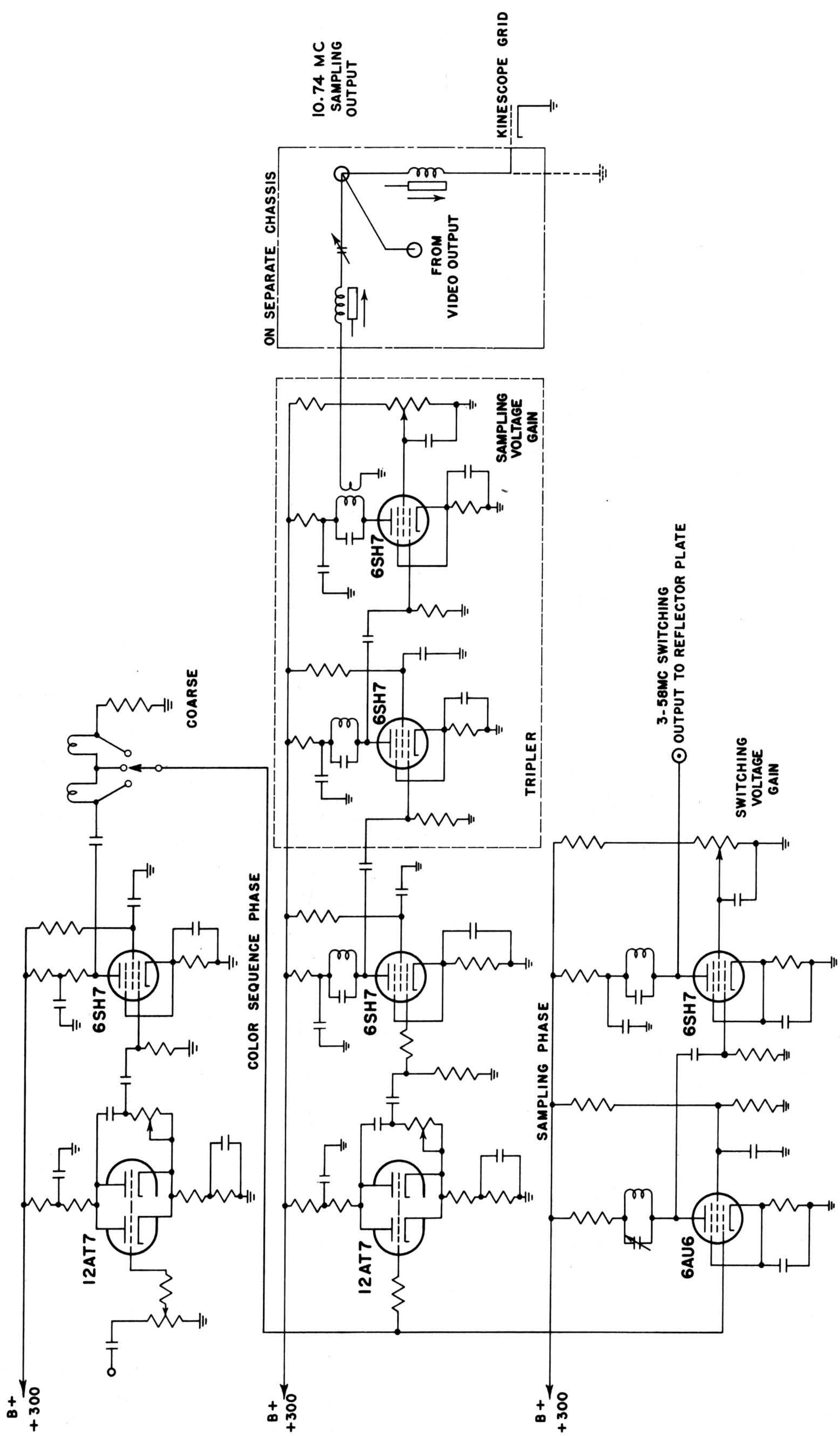

Fig. 12 - Schematic diagram of the switching and sampling circuits.

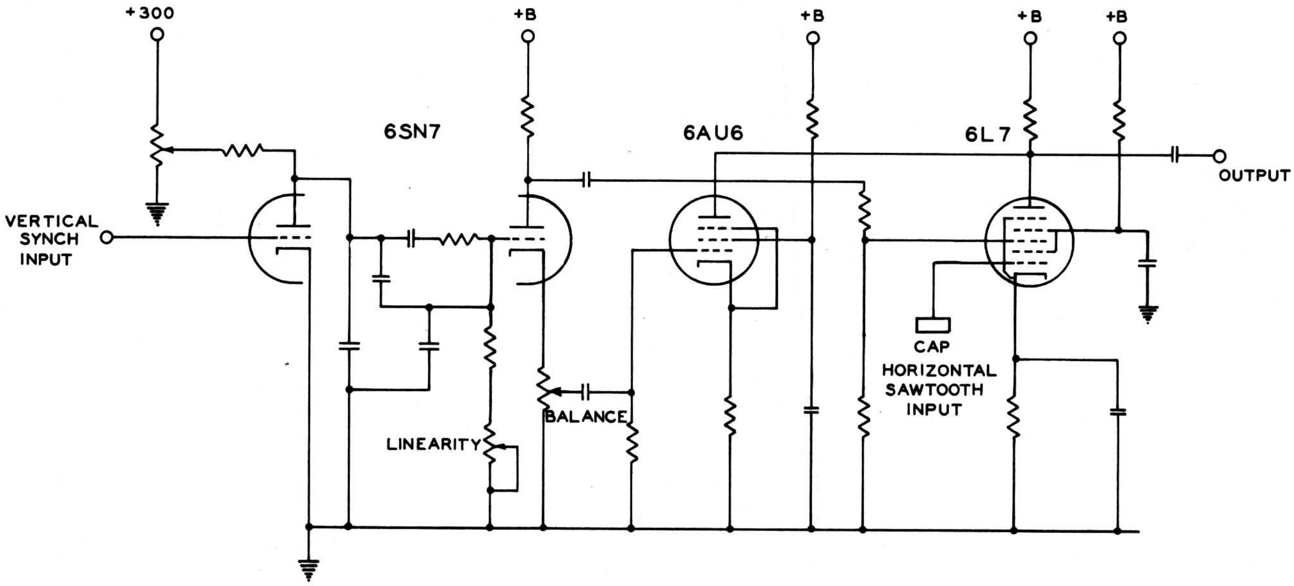

Fig. 13 - "Keystoning" circuit used in test of the 45-degree color kinescope.

120 degrees at 3.58 Mc for each section. This arrangement, in conjunction with the continuously variable unit, gave complete control over a full 360 degrees of phase shift. The output is then amplified and applied to the reflector plate of the kinescope by resonating the capacitance formed by the reflector plate and the aperture mask with a coil.

Although the "Nesa" coating of the reflector plate has resistivity, no difficulty was encountered that could be attributed to it. The output of the color-sequence phase shifter was also put through a sampling phase shifter of the continuously variable type just described. The output of this unit was then amplified, tripled, amplified again and then added to the video. The adding circuit consisted of a step-down r-f transformer, the secondary being a link coupling into the resonant circuit shown. The 10.74 Mc was then series resonated with a very small capacitor (2-5μμf). The net effect of this was to present a low impedance to the sampling frequency and a high impedance to video. The video was injected at the point shown in Fig. 12 and when put through a parallel LC arrangement which presented a low impedance to the video. The LC combination was then resonated with the kinescope grid to ground capacitance to form another series resonant circuit for the sampling frequency. In this manner an adequate sampling voltage was developed on the kinescope grid without adversely affecting the video.

The video amplifier was of the standard sort with a 4-Mc response. The final output stage provided a low output impedance to drive a long lead.

Keystoning Correction to the Deflection

The 45-degree angle of incidence of the beam in a tube of the type shown in Fig. 1 causes one side of the screen to be much closer to the gun than the other, resulting in a distortion of the scanning raster. A similar problem has been faced in television pickup tubes such as the iconoscope, although the difficulty is now accentuated because of the wider angle of scan and higher voltages. The resulting distortion appeared to be somewhat easier to correct when the screen was oriented so that the part of it closest to the gun was either at the top or the bottom of the picture. The correction to be applied to the scanning then consisted of modulating the horizontal sweep with a sawtooth component, at vertical frequency.

Relatively small attention was given to the design of the keystoning correction, but the circuit shown in Fig. 13 was found to be adequate. It was necessary to decrease the size of the power feedback capacitor in the horizontal deflection system to allow the deflection unit to follow the modulation and to minimize the effect of rectification by the damper.[2]

[2] This rectification amounts to a detection of the vertical sawtooth modulation and would cause a circulating current of this waveform in the yoke, thus skewing the picture.

Results

Color Uniformity

An exacting requirement of a color kinescope is that it give a uniform color field in each of the three primary colors. The 45-degree kinescope having a screen diameter of 7 inches gave substantially uniform colors, in some cases without the benefit of any correcting coils or magnets. In other cases, one small magnet was mounted near the deflection yoke on the target side. The purpose of such a correcting magnet was to change slightly the angle of incidence of the beam, thus correcting for target misalignment or possible effects of the earth's field. In general the tests proved the feasibility of using plane electrodes with the aperture pattern computed to compensate for varying angles of incidence.

Color Purity

Color purity was not measured quantitatively, but in general it appeared to be good. For best color purity it is desirable that the collimated fraction of the reflected beam be slightly narrower than the color strips or that an insensitive guard band be used between strips. In most of the tubes no guard band was used but the effective slot width ordinarily gave a reflected beam which was slightly narrower than the phosphor strips.

Brightness

The 7-inch color kinescope of the 45-degree reflection-type produced pictures of satisfactory brightness comparable to that of other single-gun color kinescopes. The target structure itself permits bombarding voltages of at least 15 kilovolts. However, expansion of the aperture plate owing to heat dissipated by the bombarding beam gave some trouble in experimental tubes having a two-mil-thick aperture plate. A four-mil-thick plate was found to be preferable.

An ideal color kinescope of the color switching type should allow the full beam current I_B to fall in turn on each of the three color phosphors. In the 45-degree reflection tube the maximum transmission of a plane aperture plate is 25 per cent since the phosphor strips must be laid on the aperture plate itself.[3] The vertical cross bars used in the pattern shown in Fig. 5 reduce the maximum transmission to about 20 per cent and the oblique angle of incidence further reduced the effective opening to about 15 per cent. This efficiency is comparable to the aperture-mask type of screen used in the developmental tri-color kinescopes described in previous bulletins.[4]

The direct viewing of the phosphor from the bombarded side made possible by the reflection type tube does give some increase in brightness over an aluminum-backed screen. The actual increase in brightness due to this factor has not been evaluated.

Resolution

The automatic registry of the three colors over all parts of the screen is a very significant advantage of the 45-degree tube. This characteristic showed up in improved detail when compared with other types of color kinescopes which did not have the automatic registry feature.

In addition to the registry of the three colors, the resolution is, of course, a function of the fineness of the color strips. The 7-inch experimental tube here described had color strips approximately 0.007 inch wide in the center of the target and 0.0065 inch wide at the top and bottom of the picture. Allowing for the aperture itself which is 0.007 inch wide, the total height of a white picture element was 0.028 inch or less. This allowed a vertical resolution of about 360 black-and-white lines in a picture 10 inches high, but allowed only about 180 lines in the 7-inch diameter screens tested.

The limitation on resolution in the tests made appeared to be set by the structure itself and not by electron optical limitations. This suggests the desirability of a finer pattern. In the experimental tubes, the curved slots were also broken up by vertical supporting crossbars approximately 0.006 inch wide and 0.040 inch apart in the center of the picture. These vertical black bars were visible upon close viewing of the picture and did limit resolution of a stationary picture slightly. If the test pattern were moved to minimize the

[3] A 45-degree reflection kinescope for two colors would permit a maximum efficiency of 33 per cent.

[4] Bulletins LB-808, *Characteristics and Operation of an RCA Developmental Three-Gun Tri-Color Kinescope*, LB-809, *Geometrical Considerations of an RCA Tri-Color Kinescope*, and LB-822, *Manufacture of an RCA Developmental Three-Gun Tri-Color Kinescope*.

effect of the stationary bars, the observed resolution in a picture 5 inches wide was approximately 300 lines.

It should be noted that the focusing action of the reflecting field occurs only in the vertical direction. This means that to obtain maximum horizontal resolution, the beam focus should be set for sharp focus of the reflected beam on the phosphor screen. The focusing action of the reflecting field will, however, make the vertical height of the reflected beam spot the same as the height of the defocused beam initially passing through the aperture. This is not entirely objectionable since the vertical resolution can never be better than the distance between the slots, and moire is minimized if the width of the beam covers at least two slots.

The difference in throw of the beam from top to bottom of the picture will also give some difference in focus unless a beam of very narrow angle of convergence is used. This effect was not objectionable in the 7-inch experimental tube but a larger tube may require a slight vertical sawtooth fed into the focusing electrode for best resolution.

Moiré

A moiré pattern resulting from the "beating" between the straight scanning lines and the curved slots was observed. The moiré pattern was most intense when the distance between the scanning lines was about equal to the distance between the slots and the spot size was less than this distance. Loss of vertical interlace was also noted to intensify the moiré.

In general the moiré as observed with the 7-inch tube was noticeable but not particularly objectionable. The visibility of the moiré would be expected to decrease with one of the following modifications:

(1) Closer spacing between slots so that the beam always covers two or more apertures.

(2) An elliptical spot with the largest dimension perpendicular to the slots to achieve condition (1) with the existing pattern. The 45-degree angle of approach of the beam does give a slight ellipticity to the defocused spot.

(3) Orientation of the scanning raster so that the lines make an angle of 45 degrees to 90 degrees with curved slots. Such a change in angle of approach affects the type of keystoning correction required.

Contrast

Qualitative observation of the color pictures obtained with the 45-degree reflection tube indicated good contrast. However, there is an electron optical effect which causes a loss of detail contrast in any kinescope having an electric field in front of the phosphor. A small fraction of the beam impinging on the phosphor is always reflected at high velocity. If the electric field is such as to return these electrons to the phosphor, the contrast is reduced.

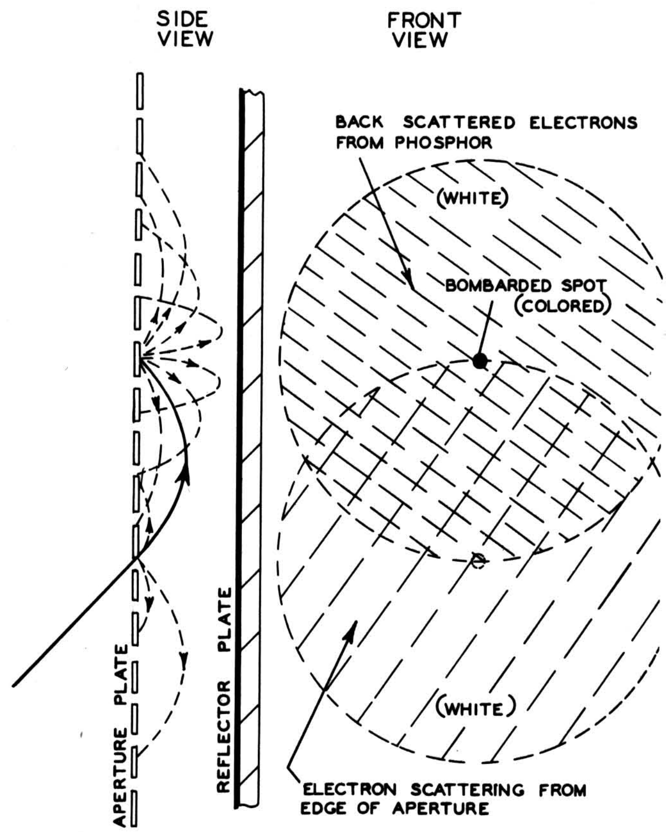

Fig. 14 - Electron paths of high velocity scattered electrons which may contribute to reduction of contrast in a reflection type kinescope.

In the 45-degree kinescope an intense stationary beam was observed to have a white halo around the bright spot on the phosphor.

The halo was white because the scattered electrons fall uniformly on all three color strips. The radius of the halo was approximately the same as the range S of the reflected beam (see Fig. 14). A still fainter disc of white light was observed around the point on the aperture plate where the incident beam passed through. This disc resulted from scattering of the primary beam on the edges of the aperture. The loss of contrast in an actual picture due to the scattering effect was barely perceptible and no effort was made to minimize it.

Color Stability

It is well known that an electron beam striking an insulator will drive the bombarded surface to some equilibrium potential whose value depends upon the secondary emission ratio of the material, the potential of surrounding electrodes, etc. Some concern was felt that the phosphor might assume a potential sufficiently different from the aperture plate to deflect the beam to the wrong color. Experimental tests showed no evidence of charging of the phosphors. The colors remained stable for all anode voltages tested ranging up to 15 kv.

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