

Dec. 20, 1955

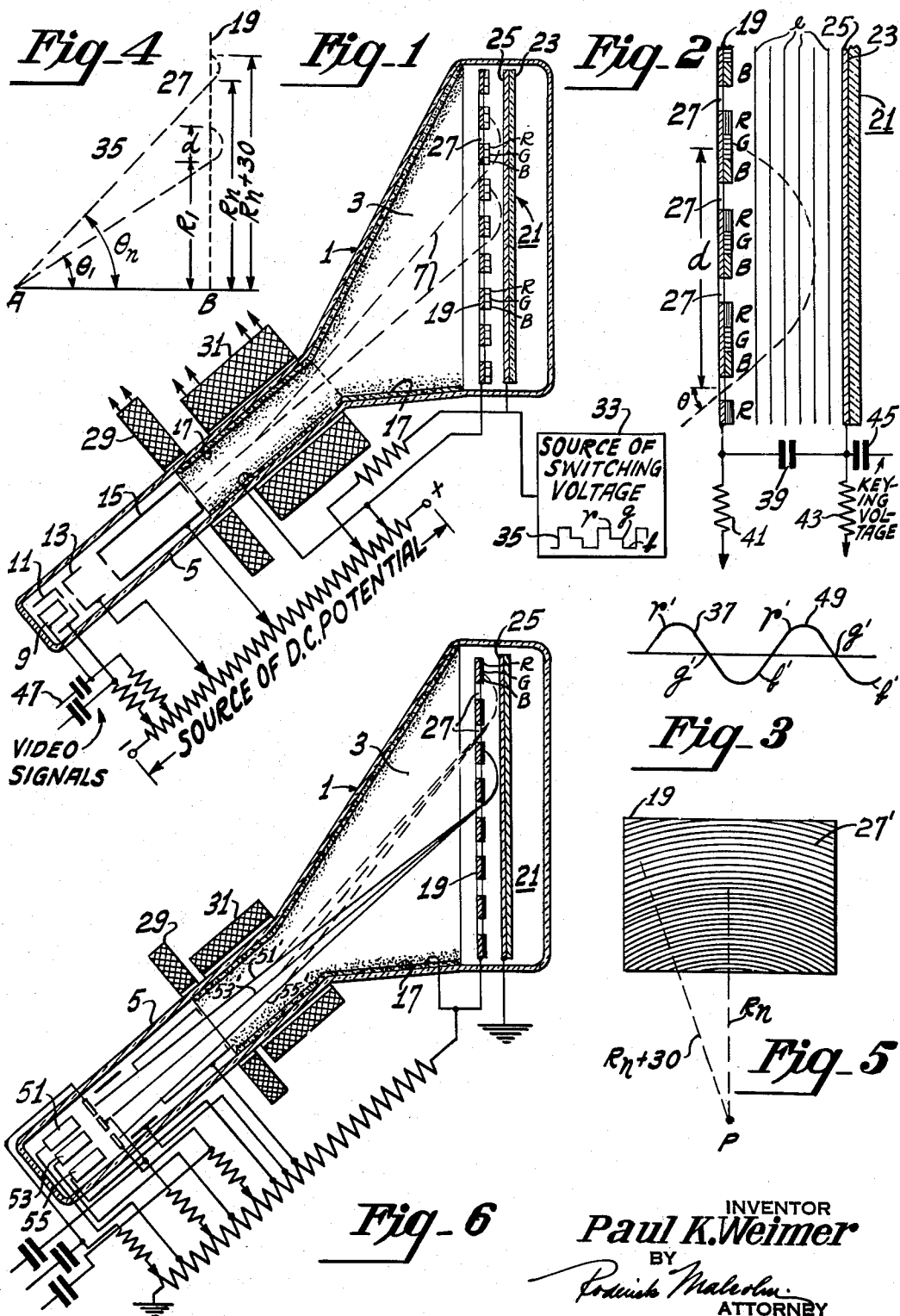
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2,728,025

POST-DEFLECTED CATHODE-RAY TUBES

Filed May 17, 1951

3 Sheets-Sheet 1



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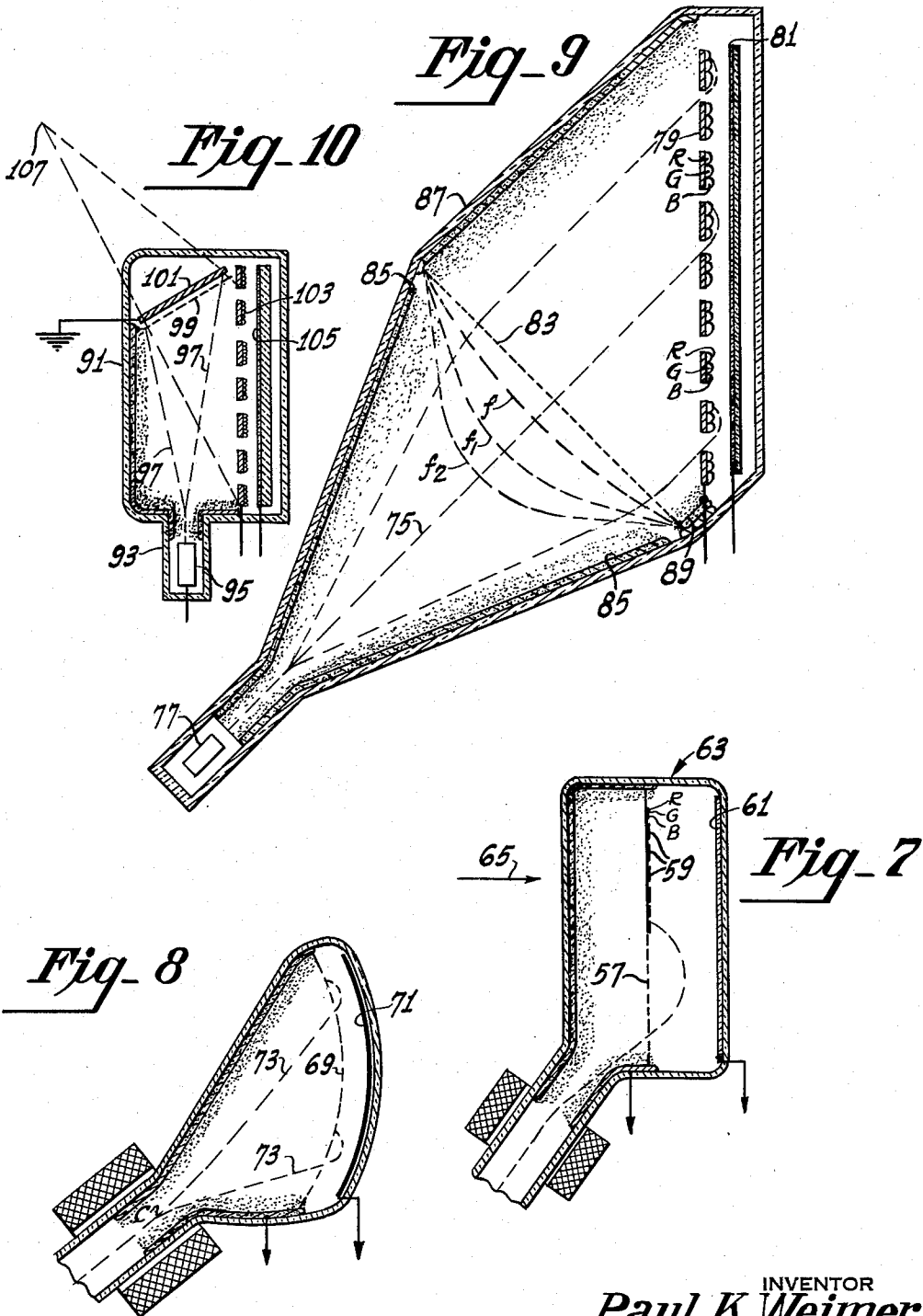
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POST-DEFLECTED CATHODE-RAY TUBES

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3 Sheets-Sheet 2



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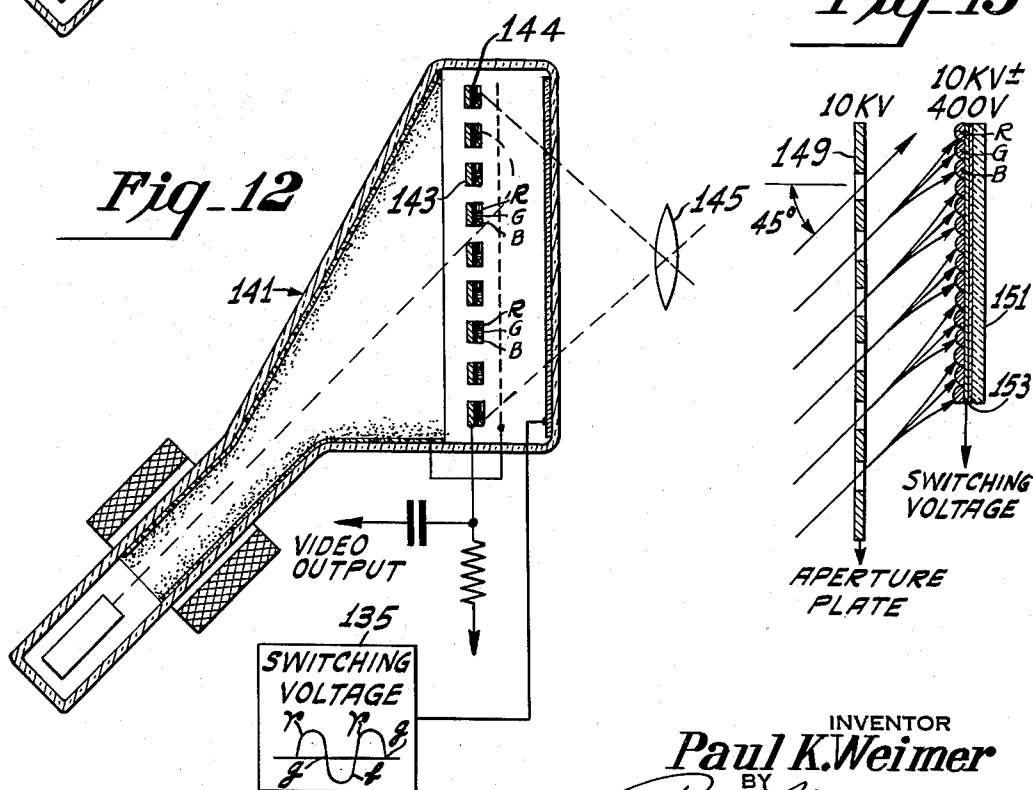
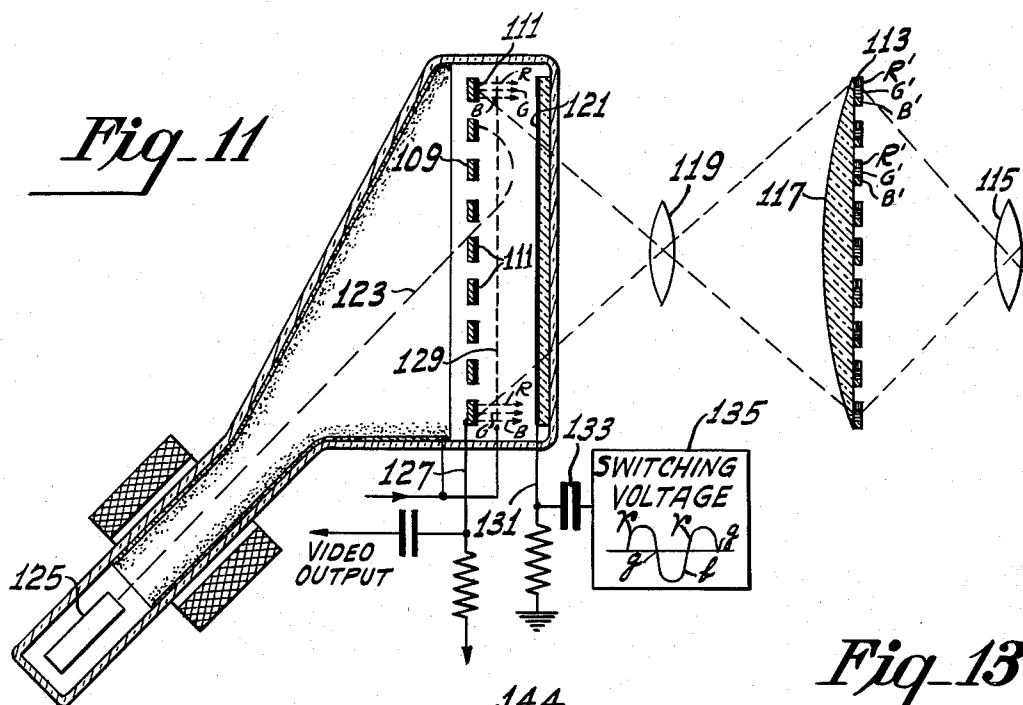
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POST-DEFLECTED CATHODE-RAY TUBES

Filed May 17, 1951

3 Sheets-Sheet 3



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POST-DEFLECTED CATHODE-RAY TUBES

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Application May 17, 1951, Serial No. 226,837

29 Claims. (Cl. 315—21)

This case is a continuation-in-part, and is substituted for, the co-pending application of Paul K. Weimer, Serial No. 146,199, filed February 25, 1950, now abandoned.

This invention relates to cathode-ray tubes and particularly to improvements in color-television tubes of the so-called "post-deflected" variety.

A "post-deflected" cathode-ray tube is one wherein the electron-beam (or beams) in addition to being subjected to a conventional ("horizontal and vertical") scanning movement is also subjected, in the vicinity of the screen, to an auxiliary or "vernier" deflecting force for the purpose of directing it, with the required degree of accuracy, from one sub-elemental screen-area to another.

The prior art recognizes several varieties of post-deflected color-television tubes. Irrespective of the advantages claimed for a particular post-deflected tube its performance is necessarily limited by certain characteristics inherent to its class. By way of example, if the tube comprises a color-kinescope of the conductive "plate" (see copending application of R. L. Snyder, Serial No. 141,611, now U. S. Patent 2,571,991, issued October 16, 1951) or "line-screen" (see Bedford 2,307,188) variety (wherein the beam is directed from one color-line to another "at the screen" by the application of different switching voltages to the screen's conductive elements) the capacitance occasioned by the very presence of the closely spaced conductive elements on the screen imposes a definite limit upon the switching speed. Furthermore, such tubes are difficult to manufacture because of the large number (e. g. 1000 or more) of conductive connections between the conductive color-elements and the switch.

While the use of an auxiliary magnetic deflecting coil for supplying the vernier color-selecting force to the beam dispenses with the necessity for individual connections to the color-areas on the "line-screen," such coils cannot ordinarily operate at the high switching speed (say, 3.8 megacycles per second) required in "dot" or "element-sequential" television systems. Hence, color-television tubes employing auxiliary deflecting coils, like the ones employing a conductive plate or line-screen, are limited in their useful application to color television systems of relatively low switching speeds (e. g. "frame" or "field" sequential systems).

In another variety of post-deflected color-television tube (see co-pending applications of Paul K. Weimer, Serial Nos. 33,721 filed June 18, 1948, now U. S. Patent 2,618,700, and 134,453 filed December 22, 1949, now U. S. Patent 2,650,264) the vernier deflecting force required for directing the beam to the selected color-area comprises an asymmetric electrostatic field established adjacent to the target side of the screen. Such tubes operate at any desired switching speed without the use of an auxiliary magnet or numerous switch contacts. However, the desired asymmetry in the auxiliary deflecting field is not easily achieved since it involves the use of a screen-assembly of somewhat intricate construction, comprising either (a) at least three beam directing plates containing offset apertures, (b) a corrugated or "hill-and-

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dale" screen having different color-phosphors on its angular faces or (c) permanently biased metal strips interposed between discrete tri-color phosphor bands.

Accordingly, the principal object of the present invention is to provide an improved cathode-ray tube of the "post-deflected" variety and one wherein the "post-deflection" of the beam is achieved without the use (a) of auxiliary magnets (b) numerous switching elements or (c) excessively high switching voltages.

Other and related objects of the invention are to provide an improved screen-assembly for color-television tubes and one characterized (a) by the simplicity and economy of its parts (b) its low inter-electrode capacitance (c) its high optical resolution and (d) one wherein color-reproduction is entirely independent of the scanning raster and of the focus of the beam.

The achievement of the foregoing and related objects, in accordance with the present invention, may be said to be predicated upon an appreciation of the fact (and its application to the television-tube art) that an electron-beam in passing through an apertured field electrode or "plate" at an angle other than a right-angle can be deflected to a limited but useful extent by varying the intensity of a substantially uniform or "symmetrical" electric field established between said apertured plate and a second parallel "plate."

In applying the above described inventive concept to the construction of post-deflected television (camera and receiving) tubes, the non-apertured "second plate" must be made of translucent or transparent materials in order to permit the passage of light moving to or from the target surface of whichever one of the field electrodes or "plates" has been selected as the electron-sensitive "screen" of the tube.

Either the rear surface of the transparent plate or the obverse surface of the apertured plate may be the one to which the ray-sensitive "screen" material or materials are applied. In the "reflecting type" tube (i. e. wherein the ray-sensitive coating is applied to the apertured plate) the "screen plate" is maintained at a positive potential with respect to the other. In the transmission type (wherein the ray-sensitive coating is supported on the transparent electrode) the screen plate may swing either positive or negative with respect to the apertured plate.

Thus, if the obverse surface of the apertured plate comprises the screen, the electrons which pass through its apertures into the uniform electric field between the plates are repelled by the negative potential on the transparent plate and are drawn rearwardly toward the screen by the positive potential thereon. On the other hand, if the rear surface of the transparent plate comprises the "screen," the entering electrons continue to move forwardly under the influence of the positive potential applied to that plate. In either event, the "switching potentials" required to direct the entering electrons to a particular elemental or sub-elemental area on the surface of the screen are preferably, but not necessarily applied to the transparent plate.

As a practical matter, it is usually preferable to use the apertured plate instead of the transparent plate as the screen of the tube. Why this is so will become apparent when it is appreciated that in tubes wherein the screen materials are applied to the apertured plate, the vernier deflecting potentials are applied to the electrons during a period when they are reversing their direction of movement. As a consequence, very little power is required to effect said vernier movement.

As previously indicated, the invention is applicable both to color receiving-tubes (i. e. "color-kinescopes") and to color-cameras (i. e. "pick-up" tubes). In both types of tube, the color-response characteristics of the numerous sub-elemental screen-areas are preferably fixed

during the manufacture of the tube by a judicious selection of the electron-sensitive materials of which the screen is comprised. Alternatively, a multi-color optical filter may be used in conjunction with a screen of a single color-emissive or color-response characteristic. An optical color-filter can be used in conjunction with either a photoconductive or photoemissive type screen, especially the former, since, at present, photo-conductive materials of all desired color-response characteristics are not readily available.

The invention is described in greater detail in connection with the accompanying three sheets of drawings, wherein:

Fig. 1 is a longitudinal-sectional view of a color-kinescope constructed in accordance with the invention, certain circuit connections being shown schematically;

Fig. 2 is an enlarged view of a portion of the target and screen structure of the tube of Fig. 1;

Fig. 3 shows one type of wave-form which may be employed as the screen "switching voltage" in the tubes of the invention;

Figs. 4 and 5 are schematic showings of the factors involved in forming the target structure of the tube of Fig. 1;

Fig. 6 is a view, similar to Fig. 1, but showing the invention embodied in a color-kinescope having a battery of three electron-guns, instead of a single gun;

Figs. 7, 8, 9 and 10 are longitudinal sectional views showing alternative embodiments of color-tubes within the invention;

Fig. 11 is a longitudinal sectional view of a television camera tube having a photo-conductive screen and including a lens system containing a tri-color filter, all constructed and arranged in accordance with the principle of the invention;

Fig. 12 is a view, similar to Fig. 11, of a color-camera tube, but having a screen made up of photoemissive materials of different light-color characteristics and utilizing a simplified optical system, and

Fig. 13 is a sectional view of a color-target or screen assembly for a color television tube wherein the ray-sensitive materials are supported upon the translucent front plate of the assembly, instead of upon the apertured rear-plate.

The color-kinescope shown in Figure 1 comprises an evacuated envelope 1 having a viewing chamber 3 and a dependent tubular neck portion 5. An electron gun in the neck 5 projects a beam of electrons 7 along the axis of the neck into the viewing chamber. The conventional electron-gun here shown comprises an indirectly heated cathode 9, a control grid 11, an accelerating electrode 13 and a first anode 15. As is also conventional, the kinescope is provided with a second anode in the form of a conducting coating 17 on its inner surface. The tubular portion of this funnel-like coating 17 terminates adjacent to the first anode 15 and the rim of its cone is presented across an intervening space to the rear surface of an apertured field-electrode or "target-plate" 19 in the viewing chamber 3.

In the embodiment of the invention shown in Figs. 1 and 2, the target 19 is disposed transversely with respect to the axis of the electron-gun. The beam in traveling along said axis approaches the center of the target at an angle of about 45°. The other field-electrode 21 in the viewing chamber 3 is an optically transparent electron-mirror. The target 19 and the electron mirror 21 are coextensive in area. The spacing between them is not critical. In one embodiment of the invention the spacing was about one-half inch.

The plate-like transparent foundation 23 of the electron-mirror 21 is provided with an optically transparent conductive coating 25 on the side facing the obverse surface of the apertured target 19. Alternatively, the conductive material may be incorporated in the body of the transparent plate or sheet 23.

As above indicated, the metal target 19 is of apertured construction. The apertures 27 in the target 19 may assume various patterns and shapes. Thus, as shown in Figs. 1 and 2 they take the form of parallel slits which extend horizontally across the target from one edge to the other. As shown at 27', Fig. 5, they are of arcuate contour, drawn about a common center P. In any event, the obverse or "front" surface of the target 19 is provided, on the metal surfaces which lie between adjacent apertures, with a number (in this case, three) of parallel phosphor lines R, B and G, respectively. Each of these phosphor lines emits light of a particular color component when struck by the electron beam from the gun. When the color components of the phosphor lines comprise red (R), blue (B) and green (G), the particular phosphor compounds of which the lines are formed may be the ones set forth in Leverenz U. S. Patent 2,310,863.

The function of the mirror electrode 21 is to reflect the electrons, which enter its field through the apertures or slits 27 in the target 19, rearwardly, in paths of curvatures calculated to cause the electrons to impinge upon selected ones of the red (R), blue (B) or green (G) phosphor lines. The manner in which the mirror 21 and other parts of the color-kinescope of Figs. 1 and 2 operate to fulfill their intended functions will be apparent from the following.

As shown in Fig. 1, there are two magnetic field-producing members 29, 31 on the neck 5 of the envelope 1. The magnetic field of the first member 29 serves to concentrate the electrons into a beam as they emerge from the first anode 15. The concentration of the electrons is aided by an electrostatic lens-field between the adjacent ends of the first anode 15 and the second anode 17. This lens effect is achieved by maintaining the separate lens elements 15 and 17 at different potentials. Thus in one case, where the control grid 11 was maintained at a direct current potential of about 20 volts negative with respect to the cathode 9, and the accelerating electrode 13 at a positive voltage of 100 volts, the first anode 15 and the second anode 17 were operated at about 2,000 and 10,000 volts, respectively.

The reflecting action of the electron-mirror 21 is achieved by operating it at a D. C. potential which is negative with respect to the target 19. The resulting uniform field between the mirror 21 and the other "field-electrode" 19 is indicated by the straight uniformly spaced equipotential lines between said electrodes 19 and 21 in Fig. 2. The average potential applied to the conductive surface 25 of the mirror 21 determines the distance between the point of impact of the reflected beam on the aperture-plate 19 and the corresponding aperture through which the beam passed. This potential may range from an arbitrary negative value (with respect to the cathode) to about one-third of second-anode potential. The change in potential of the mirror required to direct the reflected electrons from one color-line to another is small; say 100 volts, more or less.

The second magnetic member or yoke 31 comprises two pairs of coils (as indicated by the two pairs of leads) disposed at right angles to each other adjacent to the outlet of the neck 5 of the envelope 1. In operation, the deflecting coils of each pair are connected in series to an appropriate saw-tooth oscillator (not shown). The resulting magnetic field directs the beam 7 across the surface of the target 19 in a desired scanning pattern. Since, in the instant case, the beam approaches the target at an angle, appropriate "keystone" correcting voltages may be applied to the yoke 31. The resulting magnetic fields operate in a known manner to direct the beam across the rear surface of the apertured target 19 in a rectangular pattern. The scanning movement of the beam need not follow the pattern of the apertures in the target. Thus if the apertures are arranged in arcuate array (as they are in Fig. 5) the beam need not trace an arcuate path

but may be endowed with a conventional straight-line scanning movement.

The color-kinescope of Figs. 1 and 2 is capable of reproducing a color-image transmitted by any system wherein the "video" signals representing one color component of the televised scene follow those of another color, in sequence. Present day color-television systems are commonly identified by the time-sequence of their color-signals, thus, "frame," "line" or "dot." The color-kinescope of the present invention can handle the video signals of any such system or of any system that utilizes a multiple of such time-sequences. In translating the video signals into an optical image the electron-mirror 21 is connected by an appropriate "keying" circuit to the control grid 11 so that the electron-beam in striking a particular one of the phosphor-line (R, B or G) on the obverse surface of the target 19 will be modulated with the video signals corresponding to the luminescent color of that particular phosphor line.

When the incoming signals applied to the control grid 11 are of the "dot (or 'element')-sequential" variety, a switching voltage, from a source 33 is applied to the mirror 21. The switching voltage may have the waveform shown at 35 in Fig. 1. When a "red" video signal is applied to the grid 11, the r portion of the switching voltage is applied to the mirror 21. The mirror is thus driven to a maximum voltage and reflects the beam 7 to a red-phosphor line R. Similarly, when green (g) and blue (b) signals are applied, in sequence, to the grid 11, the mirror 21 is simultaneously driven to the intermediate and minimum potentials by the g and b portions of the stepped switching voltage 33.

Another switching system which has been used successfully with a tube of the type of Figure 1, is disclosed by the same inventor in Patent No. 2,650,264. In applying that system to the tube of the present invention, a switching voltage having a sinewave form is applied to mirror 21, and, simultaneously, a cut-off voltage is applied to control grid 11 of the gun, to cut-off the beam between points 120 electrical degrees apart relative to the sinusoidal voltage applied to the mirror 21. The switching voltage applied to the mirror 21 has a wave form similar to that shown at 37 (Fig. 3). The grid 11 is pulsed "on" at points r' , g' and b' of the switching voltage, which are 120 electrical degrees apart. When grid 11 is pulsed "on" at potential r' of the mirror 21 a "red" video signal is simultaneously applied to the grid 11 to modulate the beam 7, appropriately. At this time the mirror 21 is pulsed, positive to its mean value to reflect the beam 7 to a red color line. In a similar manner, when the mirror 21 assumes the voltage values represented by points g' and b' of the wave 37, the mirror 21 will have a mean value at g' and a voltage negative to this mean value at b' , respectively. At these times, the beam 7 is pulsed "on" and is reflected to the green (G) and blue (B) lines, respectively. Simultaneously the appropriate green and blue video signals are respectively applied to grid 11 to modulate the beam 7.

The application of the beam pulsing and reflecting system described above, and claimed in the above cited co-pending application, is not limited to the tube structure here described. It is mentioned merely by way of explanation and as illustrative of systems which may be used with the color-kinescope of the present invention.

The keying voltages may be applied to the cathode 9 as indicated at 47 (Fig. 1), instead of to the mirror 21. In this case a fixed potential difference is maintained between the target 19 and mirror 21 in order to provide a constant repelling field for the electron beam. In this arrangement the keying voltages modulate the velocity of the electron beam in accordance with the color signals. The beam when modulated with a particular color signal passes into the repelling or deflecting field of the mirror 21 at a velocity, or with energy, different from that of the beam when modulated by the other color signals. Thus,

beam portions having different velocities will be differentially deflected and land on different ones of the color lines R, B and G in accordance with the velocity or "color" modulation of said beam portions.

Instead of applying keying voltages to the cathode 9 as described above, the electron beam 7 may be velocity-modulated in accordance with sequential color signals applied to the control grid 11, by applying the keying voltages to the target 19. As shown in Figure 1, the metal target or screen 19 is connected to the second anode 17 and is at the highest positive potential in the tube. Changing the voltage of the target 19 changes the final velocity of the electron-beam before it enters into the retarding field between the target 19 and mirror 21. The velocity of the entering beam thus determines the particular phosphor-line to be illuminated. To maintain the retarding field of the mirror 21 constant at all times in spite of the voltage fluctuations of the apertured target 19, a circuit arrangement, shown in Figure 2, may be used. Here the target 19 and mirror 21 are connected through a condenser 39, and each is connected to its respective energy source through resistors 41 and 43, respectively. The keying signals are here capacitively coupled to both the target 19 and the mirror 21. A blocking capacitor 45 isolates the D. C. potentials from the keying source.

Thus far in the description of the invention reference has been made only to tubes wherein the source of the electrons comprises a single gun. The disclosure in this respect is illustrative, only. In the three-color kinescope shown in Fig. 6, a battery of three guns 51, 53, 55, each individual to one color-component, is employed. In this embodiment of the invention the three beams may be pulsed "on" and "off" in sequence, if the video signals are multiplexed. The "on" beam is modulated with the part of the multiplexed signal which is allotted to that beam. The three beams are focused at substantially the same spot on the apertured target surface 19 by means of the coil 29 and scanned over said surface to produce substantially the same effect as that produced by a single beam. Alternatively, for a simultaneous 3-color system all three beams can be on at once, each beam being modulated with its own "video" signal. In either case each beam can strike only its own color-area because color selection is accomplished by individually adjusting the velocity of the respective electron beams 51', 53', 55' as they leave the separate guns 51, 53, 55. However, as in the other embodiments of the invention the beam is "post-deflected" (i. e. "at the screen"), but here the selective effect of post-deflection obtains by reason of the difference in the field penetrating power of the different-velocity beams. Thus, in one embodiment of the invention employing a 12 kilovolt beam, color separation was achieved by operating the "red" and "blue" guns approximately 95 volts above and below, respectively, the potential of the "green" gun. In practice, the guns 51, 53, 55 should be mounted as close together as possible to simplify the problem of beam convergence.

As previously set forth the distance between the apertured target 19 and the mirror 21 is not critical. A spacing of about one-half inch has proven satisfactory. If the spacing is made too large, difficulties may be encountered in focusing the beam, or beams. If the spacing is made progressively smaller a point is reached where the capacitance between the target and mirror is so large that it becomes difficult to apply switching voltages of the desired very high frequency.

The spacing between adjacent ones of the apertures 27 in the target or screen 19, is preferably but not necessarily less than the diameter of a picture element area. A "picture element area" may be defined as a target surface area the dimensions of which are determined by the number of scanning-lines used and the height of the raster area. Thus, if the raster scanned by the beam 7

of Fig. 1 is, say, 8 inches high, and the normal 525 lines are used to scan this raster, then each scanning line is approximately 16 mils of an inch in width. The diameter of the "picture element area" in this case, therefore, should preferably be somewhat less than 16 mils. For purposes of illustration, however, the distance between adjacent apertures in the target may be taken to be equal to the diameter of a "picture element area." Thus, if the distance between adjacent apertures in this target 19 is divided into four equal parts, the width of the apertures 27 would be 4 mils of an inch, and each of the phosphor lines would have the same width, for this size target.

During the operation of a tube of the type shown in Figs. 1, 2 and 6, the electron beam 7 (or beams, 51', 53', 55', Fig. 6) need not strike all portions of the target or "mask" 19 at the same angle of incidence. However, the tube structure is such, that when the beam strikes the center of the target, its angle of incidence is substantially 45°. The beam in passing through an aperture 27, at this angle, traverses the maximum distance (measured along the target), between the point at which the beam passes through the target and the point at which it lands on the back of the target. In Figure 2, this distance is represented by d . The path of the electron beam in the space between the target 19 and the electron mirror 21 is a parabola and is analogous to the path of a projectile fired at the same angle of elevation. The electrical equation for this path is also analogous to that of the path of a projectile and can be represented by:

$$d = 2 \frac{V_B D}{\Delta V_P} \sin 2\theta \quad (1)$$

in which d represents the distance, as described above, between the point at which the beam 7 passes through an aperture 27 and the point on which the beam lands, as shown in Figure 2. V_B is the energy of the electron beam 7, represented in volts. D is the distance between the target 19 and the mirror 21, while ΔV_P is the potential difference between the target and mirror. θ is the angle of incidence of the beam in passing through the aperture 27 of the target 19.

It will be apparent, from an inspection of Figures 1 and 2, that due to the changes in the angle of incidence of the beam 7, from point to point on the surface of the target 19, the range or value of d goes from the maximum distance at the center to something less than maximum at other points on the target, in accordance with the Equation 1. For example, the electron beam in moving vertically with respect to the center of the target may strike the target at an angle of say, 60° at the top, and close to 30° at the bottom. The angle of incidence also changes as the beam is scanned horizontally from side to side. Such a variation in range may give non-uniform color-fields. One method of ensuring uniform color-fields is to use a particular pattern of apertures in which the spacing varies from the center to the edge. That is, as the distance d changes from point to point with the value of θ , the spacing between the apertures 27 in the target 19 should also change, so that the beam is sure to strike the proper phosphor line between said apertures. The above Equation 1 may be used to find the range d at any point on the surface of the target.

The Equation 1 gives the distance between the target openings 27 for all points of contact of the beam on the target surface. The angle θ can be computed knowing the position of the point of deflection of the beam and the dimensions of the tube and target.

In making a target or screen similar to the structure 19 of Figure 1, the values of d were found for all points along the vertical line passing through the center point of the target. Then to avoid making additional calculations for the value of d at all points on horizontal lines on either side of the vertical line, it was decided to form

the apertures 27 as concentric curves passing through the center vertical line. Each curve included all points at which the beam struck the target at the same angle of incidence, θ . Thus, the concentric curves had a common center at the intersection of the plane of the target 19 and the perpendicular to the plane from the point at which the electron beam is deflected by the deflecting or scanning fields of the magnetic yoke 31. In Fig. 4, this deflection point is represented by A. By making the apertured slits in this manner, the electron beam passing through any one aperture 27 on the center line is reflected to the same color strip whenever the beam passes through the same slit on either side of the target.

To construct a target or screen of the type described, the above Equation 1 was used and the values of the several factors were arbitrarily selected. For example, it was decided that the spacing between apertured slits 27 in the target 19 should be substantially 30 mils since, with the techniques available at the time, such a degree of fineness could more easily be obtained. With this aperture-spacing, it was next decided that an optimum range, or value for d , in Equation 1, should be equal to the distance between thirty apertures 27. Thus, at the center of the target, where θ was equal to 45°, the value of d was approximately 0.9 inch. For such a target, the spacing of the apertures was chosen so that at any other point of incidence of the beam on the target surface the value of d was equal to $0.9 \sin 2\theta$.

In constructing the target or screen 19, described above, the distance between the point of deflection A (Figure 4) and the projection of that point on the plane of target 19, or B was made substantially 8.5 inches.

The first arcuate aperture 27 was formed at the bottom of the target 19. This aperture was found on a radius R_1 determined from the known distance AB and the target dimensions. The radius of the 31st aperture was calculated as follows. The angle θ , between AB and the beam path from A to this first aperture, was found from the relationship

$$\tan \theta_1 = \frac{R_1}{8.5}$$

Using this value of θ_1 , d_1 was calculated from the above formula $d_1 = 0.9 \sin 2\theta_1$. The radius of the 31st line was obtained by adding d_1 to R_1 . To find $R_2, R_3 \dots R_{30}$, the radii respectively, of the 2nd, 3rd ... and 30th apertures, the distance on the center vertical line between the 1st aperture and the 31st was divided into thirty parts, with the parts at the bottom of the screen slightly narrower than those near the 31st aperture. The radii of all the apertures greater than R_{31} were then calculated as was done for R_{31} using the general formulas:

$$R_{n+30} = R_n + d_n$$

where

$$d_n = 0.9 \sin 2\theta_n$$

$$\tan \theta_n = \frac{R_n}{8.5}$$

For convenience in computation it was assumed that the beam passing through a given aperture, instead of being reflected to strike the phosphor, actually passed back through the aperture thirty lines up. In actual operation, of course, the potential of the mirror is so adjusted that the beam from aperture R_1 , say, strikes the phosphor strips near the aperture having a radius R_{31} , instead of passing back through this aperture. The error due to this approximation in computing radii is very small and, if desired, may be completely eliminated by changing the target angle a small fraction of a degree.

The above described method of making the masking screen or target 19 is one which has been successfully demonstrated. However, other methods may be used in the design and construction of the target. Also, with the arcuate type of apertures disclosed in Fig. 5, for example, any form or pattern of beam-scanning may be used.

That is, it is not necessary to scan the beam along the arcuate slots. For example, conventional parallel line scanning has been used successfully with the arcuate slotted target 19 of Fig. 5.

Also, the apertures in the target 19 need not be slots, as described above. They may be an array of small round holes arranged in any arbitrary pattern provided that the phosphor coated portions are so positioned that the varying angle of approach of the beam is taken into account in the manner described. The invention is not limited to the form of kinescope shown in Figs. 1 through 6. As shown in Fig. 7, for example, the electron beam is caused to pass through a target electrode 57 having apertures in its lower half, only. The range of the beam between the point at which it passes through the apertured electrode 57 and the point at which it lands on the obverse surface of the electrode is made considerably larger than disclosed in the tube of Figs. 1 to 6, so that the electrode 57 may be constructed with a top solid upon which parallel or concentric phosphor lines 59 are arranged in the R, G, B sequence previously described. Furthermore, the reflecting electrode may comprise a transparent conductive coating 61 deposited on the face plate of the tube envelope 63 of Fig. 7 or, if desired, the reflecting electrode 61 may be opaque and the solid, phosphor-supporting, portion of electrode 57 may be transparent, so that the picture may be viewed from the direction of the arrow 65.

In operating post-deflected color tubes of the present invention it has been observed that color-dilution occasioned by the presence of stray magnetic fields (in the ambient) is minimized when the beam's angle-of-approach to the uniform electric field (e , Fig. 1) in the space between the target plates (19 and 25, Figs. 1-6; 57, 61, Fig. 7) is substantially 45° . Figs. 8 and 9 show tubes wherein the beam approaches the target assembly at this optimum (45°) angle over all parts of the target, i. e. irrespective of the instantaneous scanning position of the beam.

Figure 8 shows a kinescope in which the reflecting electrode and the apertured masking electrode comprise curved plates 69 and 71, respectively. The curvature of these electrodes 69 and 71 is such that their surfaces are generated by a spiral of a type in which the electron beam 73 will always approach the rear surface of the apertured plate 69 at an angle of incidence of 45° . In such a device, the distances between the apertures in the masking electrode 69 may be uniform. In this case the distance between the point of penetration of the beam through electrode 69 and its point of impact on said electrode is constant. If the spiral curve is positioned at the vertical center line of electrodes 69 and 71 in a position such that the beam, in scanning the center line, strikes along the line at a constant angle of incidence of 45° , then the surface, of electrodes 69 and 71 may be obtained by rotating the spiral curve around the point of deflection of the electron beam indicated by C in Fig. 8.

The optimum (45°) angle-of-approach can also be achieved in a tube employing plane (instead of curved) target electrodes. This is demonstrated in the embodiment of the invention shown in Fig. 9. Here the electron beam 75 from the gun 77 passes through an electron-lens in its transit to a target-assembly made up of plane plates 79 and 81 similar to the ones (19 and 25) described in connection with Figs. 1, 2 and 6. The curved equipotential lines (indicated by the broken lines f , f_1 , f_2) of the lens are present by reason of the potential difference between an auxiliary electrode 83, of meshed construction, and the conductive coating or "second anode" 85 on the inner surface of the envelope 87. The auxiliary electrode or lens element 83 spans the path of the beam 75 in the space between the gun 77 and the apertured plate 79. This lens element 83 may operate at the same potential as the plane apertured plate 81 and, to this end, may be connected to said plate by a lead 89

within the envelope of the device. In any event, when the field f , f_1 , etc. of the electron lens 83, 85 is of the proper curvature it causes the beam 75 to approach the target surface of the plate 79 at an angle of 45° irrespective of the instantaneous position of the beam upon entering said field.

By the use of an electron-mirror of suitable design the invention can be embodied in a cathode-ray tube of smaller overall dimensions than those thus far described. Fig. 10 shows one such embodiment. Here the tube envelope comprises a cylindrical glass main chamber 91 having a short dependent neck 93 which accommodates the gun 95 of the tube. The beam 97 from the gun is directed by conventional scanning means (not shown) upon a bi-part electron mirror 99-101 disposed at the far side of the main chamber 91 at a suitable angle with respect to the target assembly 103, 105. The target assembly (which may be similar to the ones described in connection with Figs. 1, 2 and 6) is mounted adjacent to the front of the cylindrical main chamber 91. The electron-mirror thus comprises the "virtual source" of the scanning beam. As indicated by the point 107, the apparent center-of-deflection of the electrons from this "virtual source" is exterior of the tube. It will be understood that wherever "source-of-electrons," or similar term, is used in the accompanying claims it should be interpreted broadly enough to embrace a "virtual" source-of-electrons.

In Fig. 11 the invention is shown as embodied in a camera or "pick-up" tube. Here, as in the kinescopes of the earlier described embodiments of the invention, the "screen" of the tube comprises the front surface of the apertured target electrode or "plate," which is here designated 109. However, this surface instead of being divided into lines constituted of different color-phosphors, comprises but a single photo-conductive material 111, such for example as antimony sulfide. In this case, different sub-elemental areas of the unitary screen-surface 111 are allotted to the different colors (red, blue and green) by means of a color-filter 113 and lens system 115, 117, 119 mounted in front of the electrically conductive transparent plate 121. The first lens 115 projects a color image of the scene to be televised upon the optical color-filter 113 and through the field lens 117. The filter converts the natural color image from the lens 115 into a divided image made up of narrow bands of red, blue and green lights. These colored bands (or "dots") of light are projected by the field lens 117 and the projection lens 119 onto the photoconductive coating 111 on the apertured plate 109. Each photoconductive particle or elemental area of this coating 111 is thus rendered more or less conductive as determined by the intensity of the colored light which impinges thereon. As a consequence, the electrically positive charges which are applied to said elementary areas by the impact of the scanning beam 123 from the gun 125 are permitted to leak off through the metal plate 109 and its external lead 127. The video or output signals, representative of the scene being televised, may be taken off either from the lead 127 or from a (secondary-electron) collector-electrode 129 of open-work construction which is mounted in the space between the plate 109 and the translucent conductive coating on the transparent plate 121.

The reflecting scanning-action of the beam is the same as that which takes place in the previously described "receiving" tubes. In the instant case the "switching voltage" is applied to the mirror through the lead 131 (of the "mirror" 121) and a capacitor 133 from a sine-wave source 135 similar to the one shown in Fig. 3. At the proper phase indicated by r this voltage operates to repel the electron-beam 123 in the proper arc to impinge upon one of the screen areas R upon which the red bands of light are focused by the color filter 113. During the negative cycle of the switching voltage at the time b the beam is reflected to one of the screen-areas B upon which

the blue light is focused and at the intermediate time *g* the beam strikes one of the green illuminated screen areas *G*.

The camera tube 141 of Fig. 12 relies for its color response-characteristic upon a tri-color photo-emissive screen 143 of the mosaic type instead of upon the photoconductive screen and optical-color filter of Fig. 11. This simplifies the optical-lens system, which is here exemplified by a single lens 145. The pattern of the different light sensitive areas (*R*, *B* and *G*) on the screen 143 is the same as that described in connection with the tri-color phosphor screens of the "kinescope" embodiments of the invention. Appropriate photo-sensitive screen materials are: for the "red," the cesium-oxygen-silver compounds of an S-1 photo screen, for "blue," the antimony-cesium compounds of an S-4 screen, for "green," the bismuth-silver cesium oxide used for the photocathode in the "5820" image-orthicon all as described by Zworykin and Ramberg in "Photo-Electricity" published by John Wiley and Sons. These or similar photo-emissive materials are deposited on an insulating layer 144 which in turn is coated on the front side of the aperture plate. The photoemissive surfaces must be broken up into microscopic globules insulated from each other as is done in the iconoscope or orthicon pick-up tubes.

In the embodiment of the invention shown in Fig. 13, the electrons enter the uniform electric field between the apertured plate 149 and the conductive glass plate 151 at the same (45°) acute angle as in the other embodiments of the invention. Here, however, the color-phosphors or other ray-sensitive materials *r*, *b* and *g* are applied to the conductive surface 153 of the transparent plate 151 and the electron-beam or beams continue to move forwardly under the influence of a high positive biasing potential applied to said conductive surface 153. As indicated by the legend on the drawing the beam is "switched" from one ray-sensitive band to another, in the same *r*, *b*, *g* group, by applying the "switching voltage" to the conductive coating 153. The "transmission" type of tube shown in Fig. 13 may also be made in either the kinescope or pick-up tube form. In the latter case, no meshed electrode like 129 in Figs. 11 and 12 is required to collect the secondary electrons.

Simple calculations show that the "transmission type" 45° target assembly of Fig. 13 requires four to eight times as much switching voltage as the "reflection type" tubes of the earlier described embodiments of the invention. The electric field between the apertured plate 149 and the conductive coating 153 on the glass plate 151 has no focusing effect upon the beam, hence the beam is quite sensitive to stray magnetic fields. Furthermore, unlike the "reflection type" tubes of the earlier described embodiments, this "transmission type" tube requires accurate mechanical registry of the two "plates" 149 and 153. However, these disadvantages are at least partly offset by the relatively higher definition which can be achieved when the ray-sensitive materials do not have to be laid down upon an apertured foundation surface.

From the foregoing it is apparent that the present invention provides an improved post-deflected cathode-ray tube and one where post-deflection is achieved without the use (a) of auxiliary magnets, (b) numerous switching elements or (c) excessively high switching voltages. Attention is called to the fact that in the accompanying claims the term "ray-sensitive" has been selected as generic to all of the various kinds (e. g. electron-sensitive light emitters, light sensitive electron emitters and light-sensitive semi-conductors) of screen-coating materials employed in television image-reproducing ("kinescopes") and image-camera ("pick-up") tubes.

What is claimed is:

1. A cathode-ray tube of the "post-deflected" variety comprising a beam-source of electrons; a first field-electrode disposed at an acute angle with respect to said source

in a position to be scanned by the beam from said source and containing a multiplicity of apertures through which beam electrons pass during said scanning movement, a transparent field-electrode mounted in uniformly spaced parallel relation with respect to said apertured field-electrode, a ray-sensitive coating on a single one only of the uniformly spaced facing surfaces of said field-electrodes, and terminal means connected to said field-electrodes for establishing a substantially symmetrical electric field therebetween of a direction an intensity adapted to direct said passed electrons to a selected area of said ray-sensitive coating.

2. A cathode-ray tube in accordance with claim 1 and wherein said ray-sensitive coating is supported upon said apertured field electrode.

3. A cathode-ray tube in accordance with claim 1 and wherein said ray-sensitive coating is supported upon said transparent field electrode.

4. The invention as set forth in claim 1 and wherein said ray-sensitive coating comprises a phosphor material.

5. The invention as set forth in claim 1 wherein said ray-sensitive coating is comprised of discrete areas constituted of different phosphor materials each capable of emitting light of a color peculiar to a particular area.

6. The invention as set forth in claim 1 and wherein said ray-sensitive coating comprises a photoemissive material.

7. The invention as set forth in claim 1 and wherein said ray-sensitive coating comprises a photoconductive material.

8. The invention as set forth in claim 1 and wherein said ray-sensitive coating comprises a photosensitive material, and a light-transparent output electrode is mounted in the space between said field electrodes.

9. The invention as set forth in claim 1 and wherein said source of electrons comprises an electron-gun and an electron-mirror mounted in a position to reflect electrons from said gun toward said apertured field electrode at said acute angle.

10. The invention as set forth in claim 1 and wherein said source of electrons comprises a battery of electron-guns trained to converge adjacent to said apertured field-electrode and having individually controllable muzzle velocities.

11. The invention as set forth in claim 1 and wherein said field electrodes are concave on the side facing said source of electrons.

12. The invention as set forth in claim 1 and wherein said acute angle as measured at the center of said apertured field-electrode is of the order of 45°.

13. A cathode-ray tube of the "post-deflected" variety comprising, an evacuated envelope containing a transparent foundation plate having an electrically conductive transparent surface, a multi-apertured metal plate having an obverse surface presented in substantially uniformly spaced parallel relation across an intervening space to said electrically conductive surface of said foundation plate, a ray-sensitive coating on one only of said uniformly spaced parallel surfaces, a source of electrons disposed in a position to scan the rear surface of said multi-aperture plate at an acute angle, terminal leads for applying to said plates a potential for establishing in the space therebetween a substantially uniform electric field of a direction adapted to direct the electrons, which enter said space at an acute angle through the apertures in said multi-aperture plate, to said ray-sensitive coating, and terminal means effectively coupled to one of said plates for applying a variable potential thereto, whereby to vary the effective intensity of said uniform electric field and thereby to vary the acute trajectories of said entering electrons and thus to direct said electrons selectively to different surface-areas of said ray-sensitive coating.

14. An electron discharge device comprising, an electron gun means for forming an electron beam along a beam path, a target electrode positioned transverse to said beam path, said target electrode having apertures

therethrough for the passage of the electrons of said beam, a reflector electrode positioned transverse of and at an angle to said beam path on the other side of said target electrode from said electron gun means, and a ray-sensitive coating on said other side of said target electrode.

15. An electron discharge device comprising, an electron gun means including an electron source for forming an electron beam along a beam path, a target electrode positioned transversely to said beam path, said target electrode including a plate of material having a plurality of apertures therethrough from one face to the other, means between said electron gun and said target electrode for scanning said electron beam over said one face of said target electrode, a conductive reflector electrode positioned at an angle and transversely to said beam path opposite to said other side of said target plate, a ray-sensitive coating on said other side of said target electrode, and lead means connected to said reflector electrode and adapted to provide said reflector electrode with a potential negative relative to said target electrode for reflecting the electrons of said beam to said ray-sensitive coating.

16. An electron discharge device comprising, an electron gun means including a source of electrons for forming an electron beam along a beam path, a target plate electrode positioned transversely to said beam path and having apertures therethrough from one face thereof to the other, means between said electron gun and said target electrode for scanning said electron beam over said one face of said target plate, a reflector electrode positioned transversely to said beam path, said reflector electrode having a conductive surface facing said other side of said target plate and positioned at an angle to said normal beam path, a ray-sensitive coating on said other side of said target electrode, and lead means connected to said conductive surface and adapted to provide a potential negative relative to said target plate for reflecting beam electrons back to said ray-sensitive coating.

17. An electron discharge device comprising, an electron gun means including a source of electrons for forming an electron beam along a beam path, a target plate electrode positioned transversely to said beam path, said target electrode having a plurality of apertures from one face to the other for the passage therethrough of beam electrons, a conductive reflector electrode positioned transversely to said beam path, and having a surface opposite to said other face of said target electrode, said reflector electrode surface being positioned at an angle to said normal beam path, means between said electron gun and said target electrode for scanning said electron beam over said one face of said target electrode, a plurality of different ray-sensitive coatings on said other surface of said target electrode, lead means connected to said reflector electrode for providing said reflector electrode with a potential negative relative to said target plate for reflecting the electrons of said beam to one of said ray-sensitive coatings, and means connected to said lead for varying the negative potential applied to said reflector electrode for reflecting said electrons to another of said ray-sensitive coatings.

18. An electron discharge device comprising, an electron gun means including an electron source for forming an electron beam along a beam path, a target electrode positioned transversely to said beam path, said target electrode including a plate having apertures extending as concentric slits between opposite sides of said plate, means between said electron gun and said target electrode for scanning said electron beam over one surface of said target plate, a conductive reflector electrode positioned opposite to the one surface of said target plate and at an angle to said beam path, a plurality of ray-sensitive coatings on said one target surface, each of said ray-sensitive coatings formed as a strip concentric to said target apertures and positioned on said other target sur-

face, lead means connected to said reflector electrode to provide said reflector electrode with a potential negative to said target plate for reflecting beam electrons passing through said apertured target back to one of said ray-sensitive coatings, and circuit means connected to said lead for varying the negative potential applied to said reflector electrode to direct said reflected electrons to another of said ray-sensitive coatings.

19. An electron discharge device comprising, an electron gun including an electron source for providing a beam of electrons along a beam path, a target electrode positioned transversely to said beam path and inclined at an angle thereto, a portion of said target electrode having apertures therethrough for the passage of said electron beam, ray-sensitive material on the surface of said target electrode facing away from said electron gun, an electron reflecting electrode having a surface spaced from and facing said coated target surface, said reflecting electrode surface being substantially equidistant at all points from said coated target surface.

20. An electron discharge device comprising, an electron gun including an electron source for providing a beam of electrons along a beam path, a target electrode positioned transversely to said beam path and inclined at an angle thereto, a portion of said target electrode having apertures therethrough for the passage of said electron beam, a ray-sensitive material on the surface of said target electrode facing away from said electron gun, an electron reflecting electrode having a surface spaced from and facing said coated target surface, said reflecting electrode surface being substantially equidistant at all points from said coated target surface, said apertures comprising concentric arcuate openings through said target electrode portion.

21. An electron discharge device comprising, an electron gun including an electron source for providing a beam of electrons along a beam path, a target electrode positioned transversely to said beam path and inclined at an angle thereto, a portion of said target electrode having apertures therethrough for the passage of said electron beam, said target apertures comprising substantially concentric arcuate openings, a ray-sensitive material on the surface of said target electrode facing away from said electron gun, an electron reflecting electrode having a surface spaced from and facing said coated target surface, means for deflecting said beam from said normal beam path at a common point of deflection between said electron source and said target electrode, said deflecting means including field generating means for scanning said beam over said target portion.

22. An electron discharge device comprising, an electron gun including an electron source for providing a beam of electrons along a beam path, a target electrode positioned transversely to said beam path and inclined at an angle thereto, a plane portion of said target electrode having apertures therethrough for the passage of said electron beam, a ray-sensitive material on the surface of said target electrode facing away from said electron gun, an electron reflecting electrode having a conductive spaced from and facing said coated target surface, said reflecting electrode surface being substantially equidistant at all points from said coated target surface, means for deflecting said beam from said normal beam path at a common point of deflection between said electron source and said target electrode, said deflecting means including field generating means for scanning said beam over said target portion, said target apertures comprising substantially concentric arcuate openings having a common center at the projection of said deflection point on the plane of said target electrode portion.

23. An electron discharge device comprising, an electron gun including an electron source for providing a beam of electrons along a beam path, a target electrode positioned transversely to said beam path and inclined at an angle thereto, a portion of said target electrode

having apertures therethrough for the passage of said electron beam, a ray-sensitive material on the surface of said target electrode facing away from said electron gun, an electron reflecting electrode having a surface spaced from and facing said coated target surface, the apertured portion of said target being separated from said coated portion.

24. In a color television receiver, a cathode-ray tube having a transparent end wall, an electron gun supported within said tube for directing an electron beam toward said wall, an electrode having closely spaced perforations positioned between said gun and said wall, said electrode having different color-producing phosphors supported on the side thereof adjacent said wall, and arranged in recurring patterns symmetric relative to said perforations, said electrode being positioned with respect to said electron gun in a manner such that the electron beam produced by said electron gun impinges upon or passes through the perforations in said electrode at some acute angle of incidence, means for maintaining said electrode at a positive potential relative to said wall whereby electrons after passing through said electrode may be deflected in direction to strike said side and means for controlling the path of electrons between said wall and electrode selectively to excite said different color-producing phosphors.

25. In a color television receiver, a cathode-ray tube having a conductive transparent end wall, an electron gun supported within said tube for directing an electron beam toward said wall, a perforated electrode positioned between said gun and said wall, said electrode having different color producing phosphors supported on the side thereof adjacent said wall, and arranged in recurring patterns symmetric relative to said perforations, said electrode being positioned with respect to said electron gun in a manner such that the electron beam produced by said electron gun impinges upon or passes through the perforations in said electrode at some acute angle of incidence, measured with respect to the plane of said electrode, said electrode being maintained at a positive potential relative to said wall whereby electrons after passing through said electrode may be reversed in direction to strike said side, and means for varying the potential between said wall and said electrode to vary the path of electrons therebetween selectively to excite said color-producing phosphors.

26. The method of producing a color television picture in a cathode-ray tube which comprises passing a stream of electrons through a layer of different color-producing phosphors at some acute angle of incidence, reversing the path of the electrons, and correlating the travel of the reversed electrons with a received signal selectively to excite desired of the different phosphors.

27. In a color television receiver, a cathode-ray tube having a transparent end wall, an electron gun supported within said tube for directing a beam of electrons toward said wall, a first electrode positioned between said gun and said wall, said first electrode having closely spaced perforations therein and having different color-producing phosphors supported on the side thereof adjacent said wall, said first electrode being positioned with respect to said electron gun in a manner such that the electron beam produced by said electron gun impinges upon or passes through the perforations in said first electrode at some acute angle of incidence, a second transparent reflecting electrode positioned between said first electrode and said wall, said first electrode being maintained at a

positive potential relative to said reflector electrode whereby electrons passing through said first electrode are deflected in direction to strike said side and means for varying the voltage between said electrodes to control the path of electrons therebetween selectively to excite said color-producing phosphors.

28. In a color television receiver, a cathode-ray tube having a transparent end wall, a first perforated electrode positioned in front of said end wall and having different color-producing phosphors supported on its side adjacent said wall, an electron gun positioned within said tube and arranged to direct a beam of electrons toward said electrode, said first electrode being positioned with respect to said electron gun in a manner such that the electron beam produced by said electron gun impinges upon or passes through the perforations in said first electrode at some acute angle of incidence with respect to all points on the surface of said first electrode, means for deflecting said beam of electrons repeatedly across said first electrode, a reflecting electrode positioned between said first electrode and said end wall, said first electrode being maintained at a potential positive relative to said reflecting electrode, means for varying the intensity of said beam in accordance with a received television signal, and means for varying the potential difference between said first and reflecting electrodes in accordance with received color synchronizing signals to control the path of electrons between said two electrodes selectively to excite the different color-producing phosphors in accordance with a received color television signal.

29. A cathode ray tube having a transparent end wall, an electron gun supported within said tube for directing a beam of electrons toward said end wall, a first perforated planar electrode positioned in front of said end wall and having different color producing phosphors symmetrically arranged intermediate the perforations therein on its side adjacent said end wall, said first electrode being positioned with respect to said electron gun in a manner such that the electron beam produced by said electron gun impinges upon or passes through the perforations in said first electrode at some acute angle of incidence measured with respect to the plane of said first electrode, a second planar transparent electrically conductive electrode positioned parallel to said first electrode between said end wall and said first electrode, said first electrode being maintained at a positive potential relative to said second electrode whereby electrons passing through said first electrode are deflected in a direction to strike the different color producing phosphors on said first electrode, and means for varying the voltage between said electrodes to control the path of the deflected electrons between the two electrodes to excite selectively the different color producing phosphors.

References Cited in the file of this patent

UNITED STATES PATENTS

2,296,908	Crosby	Sept. 29, 1942
2,343,825	Wilson	Mar. 7, 1944
2,446,440	Swedlund	Aug. 3, 1948
2,461,515	Bronwell	Feb. 15, 1949
2,529,485	Chew	Nov. 14, 1950
2,532,511	Okolicsanyi	Dec. 5, 1950
2,568,448	Hansen	Sept. 18, 1951
2,577,038	Rose	Dec. 4, 1951
2,580,073	Burton	Dec. 25, 1951