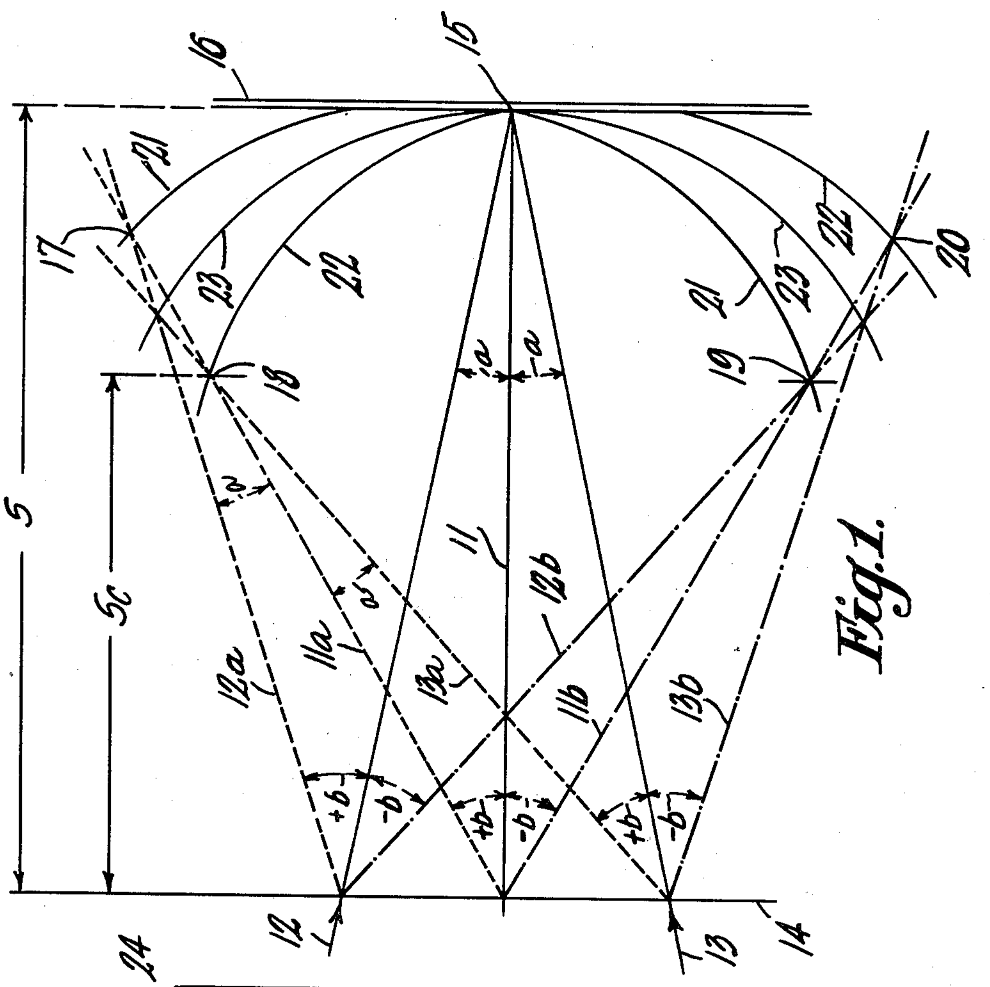
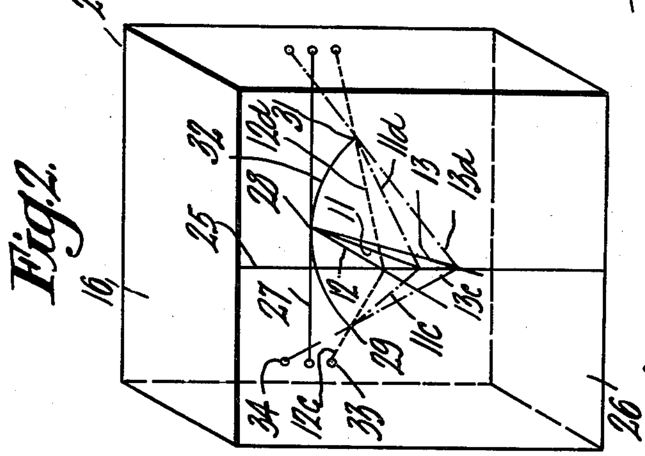
June 19, 1956 A. W. FRIEND 2,751,519

ELECTRON BEAM CONTROLLING SYSTEM

Filed May 26, 1950 3 Sheets-Sheet 1





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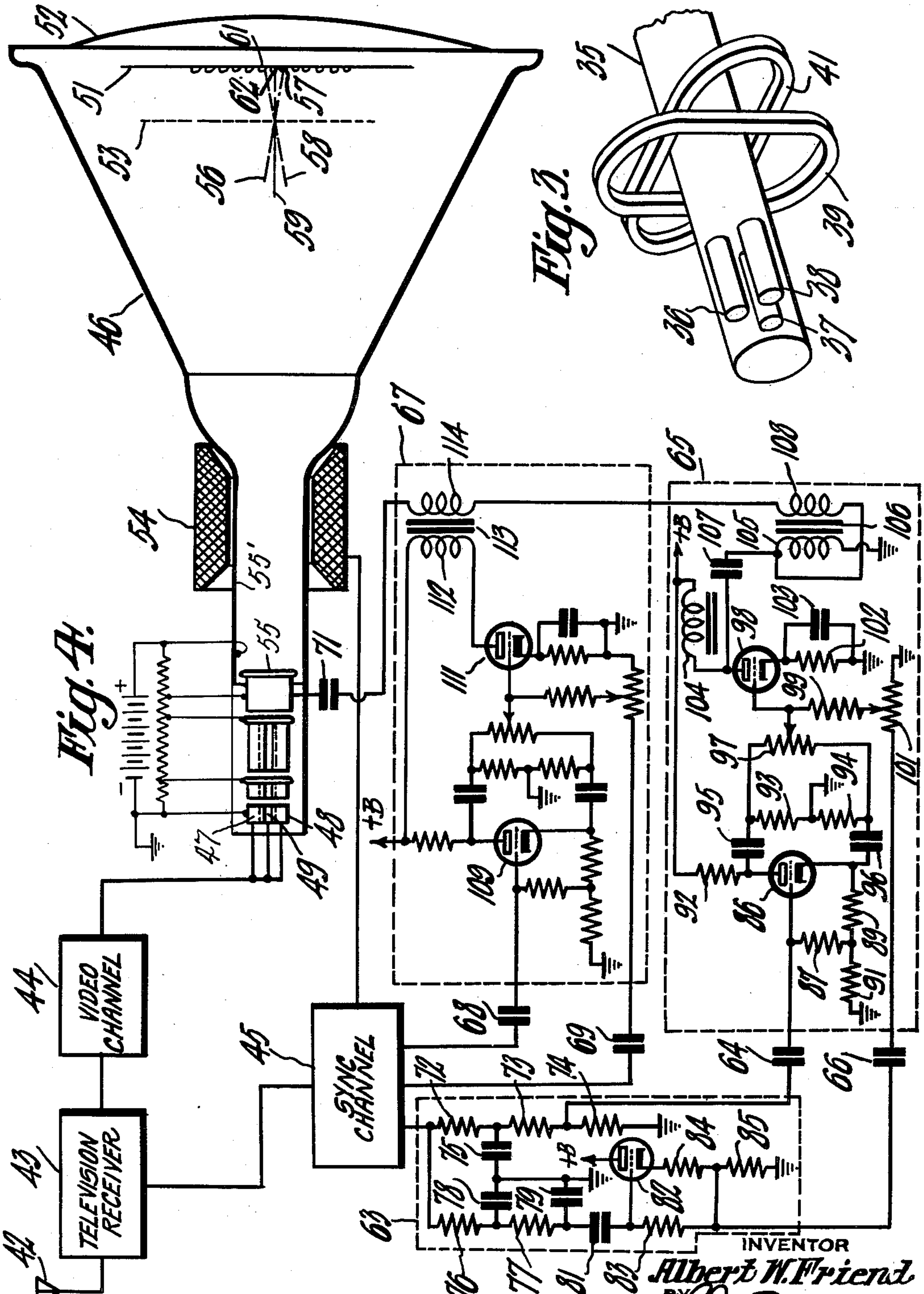
ELECTRON BEAM CONTROLLING SYSTEM

Filed May 26, 1950 3 Sheets-Sheet 2



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Filed May 26, 1950 3 Sheets-Sheet 3

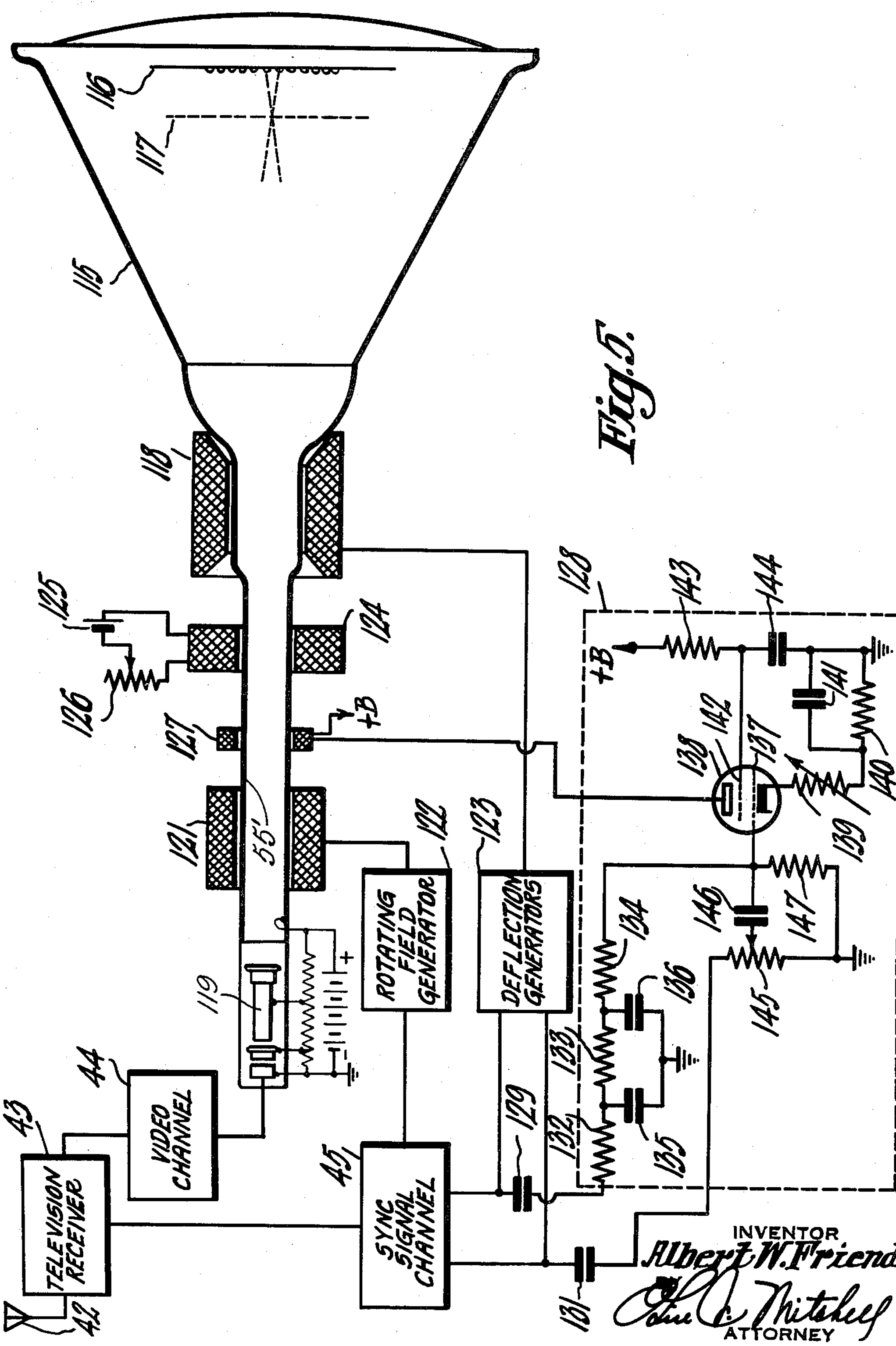

Fig. 5.

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ELECTRON BEAM CONTROLLING SYSTEM

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Application May 26, 1950, Serial No. 164,444

24 Claims. (Cl. 315—13)

This invention relates to systems for controlling the electron beams of cathode ray tubes. Although not necessarily limited thereto, the invention relates to systems for effecting convergence of a plurality of electron beam components at all points in a predetermined plane.

One of the common uses of cathode ray tubes is for the reproduction of television images. More particularly, in color television systems, there have been devised cathode ray tubes capable of reproducing images substantially in a plurality of their natural component colors. A typical tube of this character, which has been successfully used, forms a subject matter of a copending U. S. application of Alfred C. Schroeder, Serial No. 730,637, filed February 24, 1947, now Patent No. 2,595,548 issued May 6, 1952, and titled "Picture Reproducing Apparatus." In general, such a tube is provided with a luminescent screen made up of a multiplicity of phosphor areas of sub-elemental dimensions arranged in groups substantially of elemental size. Each of the different phosphors of these groups is capable of emitting light of a different one of the component image colors when excited by an electron beam. Such a tube is provided with an apertured masking electrode mounted between the screen and a plurality of electron guns. These guns are arranged with respect to one another so that they direct beams of electrons through the apertures of the masking electrode from different angles so that predetermined ones of the sub-elemental phosphor areas may be selectively excited.

Another tube of the same general character as that disclosed in the Schroeder application referred to, forms the subject matter of a copending U. S. application of Russell R. Law, Serial No. 165,552, filed June 1, 1950 and titled "Color Television." The chief difference between the Law and Schroeder tubes is in the use of a single electron gun in the Law tube. This preferably is mounted along the central axis of the tube. The single electron beam which is produced by the gun is subjected to a particular type of deflection by means of which it is rotated about the central tube axis. It is seen, therefore, that, by suitably controlling an electron beam of the character described, the apertured masking electrode and the luminescent screen may be approached from different angles by electron beam components substantially in the same manner as effected in the Schroeder tube.

The expression "electron beam components" as used in this specification is intended to cover the type of phosphor-exciting electronic energy produced by a single or a plurality of electron guns. This energy may be continuous or pulsating as required without departing from the scope of this invention.

In either the single or multiple electron gun type of color television kinescope it is necessary to deflect all of the electron beam components over the target electrode in a manner to form a conventional television raster. Furthermore, it is desirable that this deflection of the different electron beam components be effected by a single deflection system. This, however, presents the

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problem of producing convergence of all of the electron beam components at all points of the target electrode. This necessary result may be accomplished only by the provision of additional means in a new system which forms the subject matter of the present invention.

As used in this specification, the term "convergence" is intended to denote a desired positional relationship of a plurality of electron beam components. This positional relationship may be effective superimposition, substantial contiguity or predetermined mutual spacing of the beam components depending upon such factors as the type of target electrode with which the beam components are employed.

It is an object of this invention to effect substantial convergence at all points in a predetermined plane of a plurality of electron beam components emanating from different points spaced from a longitudinal axis of a cathode ray tube.

Another object of the invention is to effect substantial convergence at all points in a predetermined plane of a plurality of electron beams emanating respectively from a plurality of electron guns mounted in spaced relationship to the central axis of a cathode ray tube.

Still another object of the invention is to effect substantial convergence at all points of a predetermined plane of a plurality of electron beam components having paths spaced from the central axis of a cathode ray tube and all emanating from a single electron gun located substantially on said central tube axis.

A further object of the invention is to effect electrostatically substantial convergence of a plurality of electron beams which have paths spaced from the central axis of a cathode ray tube and which are electromagnetically deflected over a target electrode.

A still further object of the invention is to effect electromagnetically substantial convergence of a plurality of electron beam components which have paths spaced from the central axis of a cathode ray tube and which are electromagnetically deflected over the target electrode.

In accordance with the invention, the cathode ray tube is provided with an electron-optical system adjacent to the paths of a plurality of electron beam components ahead of the point at which they are subjected to the influence of the deflection system by which the target electrode is scanned. The electron-optical system is variably energized to effect convergence of the electron beam components at all points in the plane of the target electrode. The energization of the electron-optical system is varied as a function of the variable energization of the deflecting system. Specifically, in order to control convergence of the electron beam components in a vertical sense, and to a lesser extent in a horizontal sense, the energization of the electron-optical system is varied as a function of the vertical deflection. Similarly, the energization of the electron-optical system is varied as a function of the horizontal electron beam deflection in order to control beam convergence in a horizontal sense, and to a lesser extent in the vertical sense.

The electron beam deflection and the dynamic electron-optical convergence systems may be either electromagnetic or electrostatic. For example, in one of the illustrated embodiments of the invention, the beam deflection system is electromagnetic and the electron-optical system is electrostatic. In another illustrated embodiment of the invention both deflection and convergence systems are electromagnetic.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation as well as additional objects and features thereof will best be understood from the following description, taken in conjunction with the accompanying drawings.

In the drawings:

Figure 1 is a graphical representation of one phase of the problem of effecting convergence of a plurality of electron beam components at all points in the plane of a target electrode;

Figure 2 is a graphical representation of another phase of the electron beam convergence problem;

Figure 3 is an illustration of one form of electron-optical system which may be embodied in a system according to this invention;

Figure 4 is a circuit diagram of a television receiver embodying a form of the invention employed in conjunction with a cathode ray tube having a plurality of electron guns and an electrostatic dynamic electron-optical beam convergence system; and

Figure 5 is a circuit diagram of a television receiver embodying the invention in another form which uses a cathode ray tube having a single electron gun and an electromagnetic electron-optical system for effecting convergence of a spinning type of electron beam at all points in a plane of a target electrode.

Before this invention can be fully appreciated, the problem which is to be solved by it must be understood. For this purpose, reference will be made first to Figure 1 of the drawings. The geometrical relationships between a pair of electron beam components are illustrated in this figure. The angular disposition of the beam components relative to one another and to the axis and target electrode of a cathode ray tube are greatly exaggerated in this figure. By such means, the critical relationship between the electron beam components may be more clearly shown. It is assumed that the electron beam components considered here originate at points disposed at equal distances above and below a longitudinal axis of the tube. The representations in this figure are in effect projections of the paths of the electron beam components into a vertical plane. However, for ease of reference in the following portions of this description, the lines representing the path projections of the beam components will be referred to as the electron beams themselves.

The central longitudinal axis of the cathode ray tube is represented by the line **11**. The upper and lower electron beam components **12** and **13** respectively approach the axis **11** from substantially equal angles "*a*." The angles "*a*" will be referred to herein as the convergence angles of the electron beam components. The line **14** represents the plane in which deflection of the electron beam components is assumed to be effected. In the absence of any deflection of the electron beam components **12** and **13** they converge at a point **15** on the axis **11** of the tube in the plane of a target electrode **16**. It will be noted that the convergence point **15** is located substantially centrally in a vertical sense on the target electrode.

It will be considered that, for color television purposes, the target electrode **16** is provided with a plurality of apertures, one of which is located at the point **15**. Both of the undeflected electron beam components **12** and **13** will pass through the aperture at an angle "*a*" with the axis **11**. As a consequence, the beam components approach a luminescent screen (not shown in this figure) from different angles in order to excite selectively the phosphor areas thereof. It is necessary, however, for the successful operation of a device of this character that the electron beam components be made to converge at all other points in the plane of the target electrode **16**. It will be demonstrated presently that, in order to effect such convergence, facilities in addition to the usual electron beam-deflecting system are required.

In considering this phase of the problem of effecting convergence of a plurality of electron beam components, it will be considered that deflection of the electron beams **12** and **13** is to be made vertically substantially in the plane of the drawing. Assume that, under the influence of a suitable deflecting system effective substantially in the plane indicated by the line **14**, each of the electron beam components **12** and **13** is deflected upwardly through an angle "$+b$." The deflected beams then follow the broken lines **12*a*** and **13*a***. It also may be considered that the axis **11** is deflected through the angle "$+b$" and therefore takes the position indicated by the broken line **11*a***. It will be seen that the convergence angle "*a*" between the deflected beam components **12*a*** and **13*a***, respectively, and the deflected axis **11*a*** remains unchanged. However, the point **17** at which the deflected beam component **12*a*** intersects the deflected axis **11*a*** is considerably short of the plane of the target electrode **16**. It also does not coincide with the point **18** at which the deflected beam component **13*a*** intersects the deflected axis **11*a***. As a result, the deflected beams **12*a*** and **13*a*** will not pass through the same aperture in the target electrode **16**. Consequently, two different elemental areas of the luminescent screen will be excited by the beams **12*a*** and **13*a***.

When the electron beam components **12** and **13** are deflected downwardly through an angle "$-b$" along the dot-dash lines **12*b*** and **13*b*** they intersect a deflected axis **11*b*** at different points, neither of which is in the plane of the target electrode **16**. In this case, the deflected beam component **12*b*** intersects the deflected axis **11*b*** at the point **19** which is spaced from a plane of the target electrode **16** a distance substantially equal to the spacing of the intersection of point **18** of the upwardly deflected beam component **13*a*** and the axis **11*a***. Similarly, the downwardly deflected beam component **13*b*** intersects the axis **11*b*** at a point **20**. This point is located substantially at the same distance short of the target electrode as the point **17** representing the intersection of the upwardly deflected beam component **12*a*** and the axis **11*a***.

The arc or curve **21** represents the locus of the intersections of the electron beam component **12** and the effective axis **11** of the tube. Similarly, the arc or curve **22** is the locus of the intersections of the beam component **13** and the effective tube axis. These curves graphically represent the dynamic control required by an electron-optical system to effect substantial convergence of the electron beam components at all points in the plane of a target electrode. For small values of the convergence angle "*a*," the curve **22** may be expressed by the equation

$$\frac{Sc}{S}=1/2[1+\cos(a+2b)]$$

S is the distance between the plane of deflection **14** and target electrode **16**. *Sc* is the distance between the plane of deflection **14** and the intersection of the deflected beam component **13*a*** and the tube axis **11*a*** in the absence of any dynamic beam convergence control. The same equation, with the sign of angle "*a*" reversed, represents the curve **21**.

It may be readily determined, by inspection of Figure 1, that the solution to the problem of effecting convergence of a plurality of electron beam components at all points in a television or other raster may not be completely solved by providing a target electrode of a particular curvature. In the present case, a compromise target electrode configuration would be in the form of a curve **23** lying substantially midway between the arcs **21** and **22**. The curve **23** represents the locus of the convergence points of the electron beams **12** and **13**. In practice, the curves **21** and **22** may be made to approach closely the shape of curve **23** by minimizing the convergence angles "*a*." Nevertheless, such a target electrode configuration is not particularly adapted for use in a television image reproducing device. In devices of such character it is desirable to provide the target electrodes with shapes which are as flat as possible.

Reference will now be made to Figure 2 of the drawings which illustrates graphically another phase of the problem of effecting electron beam convergence at all points in the plane of a target electrode. In this case the horizontal deflection of the electron beam components 12 and 13 is considered without taking into account any vertical deflection of these beams. The figure is a perspective view from the electron gun side of the target electrode, taken from a point above and slightly to one side of the central axis of the tube. In order to enhance the perspective effect, the figure is in a form of a transparent block 24. As viewed in this figure the target electrode 16 forms the back wall of the block. The vertical line 25 located substantially at the center of the front wall 26 of the block indicates the axis about which the electron beam components 12 and 13 are deflected horizontally. The horizontal line 27 across the target electrode 16 indicates the desired locus of electron beam convergence. As shown, the electron beam components 12 and 13 are equiangularly located relative to the longitudinal axis 11. In the absence of any deflection of the beam components, they converge at a point 28 substantially at the center of the target electrode 16 on the horizontal line 27.

Assume now that the beam components 12 and 13 are deflected to the left along the broken lines 12*c* and 13*c* respectively. Since it is assumed that no vertical deflection of the beam components is effected at this time, the beams converge on the deflected axis 11*c* at the point 29. It will be noted, however, that the point 29 is located in space considerably short of the plane of the target electrode 16. Likewise, when the beam components 12 and 13 are deflected horizontally to the right along the dot-dash lines 12*d* and 13*d* respectively, they intersect the deflected axis 11*d* at the point 31. This point also is much short of the plane of the target electrode 16.

It will be noted that, irrespective of the horizontal deflection of the beam components 12 and 13 they always converge on the axis 11 at the same radial distance from the horizontal deflection axis 25. The convergence point has a locus represented by the arc 32. As projected in a horizontal plane the arc 32 is circular with its center on the line 25.

In order to more fully appreciate the adverse effect that this type of deflection has upon the operation of a cathode ray tube, the deflected electron beams have been extended to the points at which they intersect the target electrode 16. The deflected beam component 12*c* intersects the target electrode at a point 33 considerably below the horizontal line 27. Likewise, the beam component 13*c* intersects the target electrode 16 at a point 34 which is considerably above the horizontal line 27. A similar condition exists at the other extreme of the horizontal deflection of the electron beam components. The deviation from the desired horizontal line 27 varies directly as the deflection angle of the beam components varies from the central position of the beams. Since the locus of the convergence points of the electron beam components is a circular arc in this case, a curve of this character represents the convergence control required.

The dynamic convergence control of the electron beam components which is necessary to effect convergence of the plurality of electron beams substantially at all points in the plane of a target electrode is at best a compromise between the two different types of control required for the two different phases of the deflection problem. These were indicated as horizontal and vertical deflection, respectively, in the illustration for the particularly assumed beam projections, only. In view of the foregoing analysis of the problem, it will be understood that the required beam convergence which may be produced by any equivalent axially symmetric electron-optical system necessarily is a compromise between the correction indicated by the circular arc locus 32 of Figure 2 and the centrally disposed arc 23 of Figure 1.

One way in which to effect the desired convergence of a plurality of electron beams as they are deflected horizontally and vertically is by the use of two separate asymmetric electron-optical systems, or equivalent lenses. These systems may be made with the precise astigmatic asymmetry required in order to produce the two types of deflection beam convergence indicated by the curves 22—23 and 32 of Figures 1 and 2, respectively. The dynamic convergence control which may be effected by systems of this character is applied in two directions at right angles to one another, such as horizontally and vertically.

Such an asymmetric electron-optical system is shown schematically in Figure 3 of the drawings to which reference now will be made. The cathode ray tube 35 is provided with three electron guns 36, 37 and 38 located at one end of the tube neck. Preferably, the electron guns are symmetrically located with respect to the longitudinal axis of the tube. The dynamic convergence of the electron beams produced by these guns may be effected by a pair of crossed elliptical lenses. These lenses or electron-optical systems are provided by a pair of substantially elliptical coils 39 and 41. The coil 39, when suitably energized, produces an elliptical lens which is effective to produce convergence of the electron beams as they are deflected horizontally. Likewise, the coil 41 produces an elliptical lens by which to effect convergence of the beams for all vertical deflections thereof.

Dynamic electron beam convergence is achieved by the use of magnetic lenses of the character described and shown in Figure 3 when the coils 39 and 41 are suitably energized. The energization of the horizontal convergence coil 39 should vary as a function of the arc 23 of Figure 1 at the horizontal scanning recurrence rate. Similarly, the energization of the vertical coil 41 should be varied as a function of the curve 23 of Figure 1, at the vertical scanning recurrence rate. The astigmatic function of each lens is arranged to provide correct convergence at right angles to the deflection direction, in accordance with the circular arc locus 32, of Figure 2.

With the foregoing description of the problems involved in effecting convergence of a plurality of electron beam components in scanning a raster in a plane in a target electrode, reference will now be made to Figure 4 of the drawings. This figure shows an embodiment of this invention used in conjunction with a tri-color kinescope having three electron guns to provide the electron beam components. Also in this form of the invention, the kinescope is provided with an electrostatic dynamic electron-optical system for effecting a compromise convergence of all of the beam components. In general, the dynamic beam convergence system employed as part of this invention is somewhat similar to that used to vary the beam focus in U. S. Patent No. 2,123,011 issued July 5, 1938 to J. E. Keyston et al. for "Electron Discharge Apparatus."

The color television receiver includes an antenna 42 coupled to a conventional composite television signal receiver 43. It will be understood that this receiver may include the usual carrier wave amplifiers, frequency converter, signal detector and other necessary facilities. The output of the receiver 43 is coupled to a video signal channel 44 and also to a synchronizing signal channel 45. The circuit details of these channels have not been shown for the reason that they may be entirely conventional and form no part of the present invention and are not necessary to an understanding of the invention.

The receiving system also includes a cathode ray image-reproducing tube of the type commonly referred to as a multi-color kinescope. In the present case, it will be assumed that the cathode ray tube 46 is a tri-color kinescope capable of reproducing an image in three of its component colors. One representative example of a tri-color kinescope of the kind suitable for use in conjunction with the present invention is shown in the previously mentioned Schroeder Patent No. 2,595,548. The Schroeder tube, and also the tube **46**, is provided with three electron guns and a luminescent screen. The screen is selectively excited to produce differently colored light by electron beam components approaching it from different directions.

The tube **46** is provided with electron guns **47**, **48** and **49**. It will be understood that the electron guns preferably are symmetrically disposed with respect to one another and also relative to the central axis of the tube, such as in the case of the electron guns **36**, **37**, and **38** of Figure 3. Also the tube **46** is provided with a luminescent screen **51** which is substantially flat as shown.

In the particular tube illustrated, the screen **51** is mounted on a transparent plate which is supported in back of, and somewhat spaced from, the end wall **52** of the tube. It is to be understood that such a structural arrangement is not intended to be limiting. Alternatively, it may be desirable in some instances to provide the luminescent screen directly upon the inner surface of the end wall of the tube. In any case, the luminescent screen consists of a multiplicity of groups of phosphor areas or dots, each of sub-elemental dimensions capable respectively of emitting light of different colors when excited by impinging electrons. The groups of phosphor areas may be arranged in any desired pattern such as clusters of small areas of circular, triangular, hexangular, or other configurations or the linear strips extending from one side of the screen to the other.

The tube **46** also is provided with an apertured masking electrode **53** mounted in back of, and in spaced relation to, the luminescent screen **51**. This electrode is provided with apertures conforming in shape substantially to the configuration of the phosphor groups. For example, in the case of substantially circular groups of phosphor areas, the apertures in the electrode **53** will be substantially circular. One aperture for each group of phosphors preferably is provided.

The color kinescope **46** also is provided with a deflecting system which, in the present case, is an electromagnetic yoke **54**. The deflecting yoke is mounted in the usual manner about the outside of the neck portion of the kinescope.

The color kinescope also is provided, in accordance with this invention, with a dynamic electron-optical system located in the region between the electron guns and the deflecting yoke. In the present form of the invention, this electron-optical system is electrostatic and includes a cylindrical anode member **55** surrounding the paths of the electron beam components emanating from the three electron guns. In order for this electrode to perform the function of effecting convergence of the electron beam components at substantially all points in a raster scanned at the masking electrode **53**, it is necessary that the field produced by it and the final anode wall coating **55**, be varied suitably as a function of both the horizontal and vertical deflections of the beam components to form the raster.

Before describing the control circuits for the different electrodes of the color kinescope **46**, a brief reference will be made to the manner in which the electron beam components cooperate with the apertured electrode **53** to excite selectively the sub-elemental phosphor areas of the luminescent screen **51**. Consider, for example, the excitation of the substantially central point of the screen **51**. The electron gun **47** is actuated concurrently with the reception of the video signal representing the red component of this area of the image. The electron beam component emanating from this gun follows a path which is indicated at **56** as it approaches the masking electrode **53**. It is seen that the angle of approach is from above the central axis of the tube. Consequently, this beam component, after traversing the aperture of the electrode **53**, impinges upon a red light-emitting phosphor area **57**. Similarly, in concurrence with the reception of green and blue video signals the electron guns **48** and **49**, respectively, are actuated to produce electron beam components which approach the electrode **53** from angles represented by the lines **58** and **59**, respectively. As a consequence, the green and blue sub-elemental phosphor areas **61** and **62**, respectively, are selectively excited.

The synchronizing signal channel **45** of the color television signal-receiving system may be considered to include the usual apparatus including synchronizing signal separators and deflection generators. The horizontal and vertical deflection generators are coupled conventionally to the deflecting yoke **54** for suitably varying its excitation to deflect the beam components to form a television raster.

The apparatus included in the synchronizing signal channel **45** also is employed to control the development of suitable voltages for impression upon the dynamic electron-optical system including the anode **55**. For example, short voltage pulses at the vertical deflection frequency may be derived from the vertical deflection generator. These vertical frequency pulses are impressed upon wave shaping apparatus **63**. This apparatus serves to develop a sawtooth wave and a wave having a substantially parabolic form, both having the vertical deflection frequency. The vertical frequency sawtooth wave is coupled by a capacitor **64** to a vertical convergence control voltage generator **65**. Also the vertical frequency parabolic wave is coupled by a capacitor **66** to the vertical convergence control voltage generator **65**. This apparatus functions to combine the waves to produce a composite vertical frequency wave for impression upon the anode **55**.

In a similar manner, a horizontal frequency sawtooth wave is derived from the synchronizing signal channel **45** and is impressed upon a horizontal convergence control voltage generator **67** by means of a coupling capacitor **68**. Also, a horizontal frequency parabolic wave is impressed upon the generator **67** by a coupling capacitor **69**. A composite horizontal frequency wave is produced by the generator **67** for impression upon the anode **55**.

The vertical frequency pulses may be derived from the output circuit of the vertical deflection generator. The horizontal frequency sawtooth voltage may be obtained at the output circuit of the horizontal sawtooth oscillator. The horizontal frequency parabolic wave conveniently may be derived from the storage capacitor of the damper-booster forming part of the horizontal deflection system. A typical damper-booster of the type referred to is disclosed in an article by A. W. Friend titled "Television Deflection Circuits," published at page 98 of the March 1947 RCA Review, vol. VIII, No. 1. Figure 19 is representative.

The outputs of the vertical and horizontal convergence control voltage generators **65** and **67** respectively, are combined to produce a composite convergence control voltage which is impressed by means of a coupling capacitor **71** upon the anode **55**. The electric field produced by this anode varies, therefore, in accordance with both horizontal and vertical deflections of the electron beam components. Consequently, the beam components may be made to converge substantially at all points of the raster scanned in the plane of the masking electrode **53**.

Details of an illustrative embodiment of apparatus for developing the electron beam convergence control voltages also are shown in Figure 4. The wave-shaping apparatus **63** includes a resistive-capacitive network consisting of a series connection of resistors **72**, **73** and **74** and a shunt capacitor **75** to ground from the junction point between resistors **72** and **73**. This network is connected to the synchronizing signal channel **45** for the impression thereon of voltage pulses by which there is developed at the junction point between the resistors 73 and 74 a substantially saw-toothed voltage having the frequency of the vertical deflection of the electron beam components.

The wave-shaping apparatus 63 also includes a resistive-capacitive network consisting of a series connection of resistors 76 and 77 and shunt capacitors 78 and 79 connected to ground substantially as shown. The input terminal of this network is coupled to the synchronizing signal channel 45. The output terminal of the network is coupled by a capacitor 81 to the control grid of an electron amplifier tube 82. A grid-leak resistor 83 is coupled from the control grid to the junction point between resistors 84 and 85 connected in series between the cathode of the tube and ground. The apparatus functions to produce a substantially parabolic wave form at the junction point between resistors 84 and 85 at the vertical deflection frequency.

The vertical convergence control voltage generator 65 includes an input electron tube 86, to the control grid of which the coupling capacitor 64 is connected. Also, this circuit is provided with a grid-leak resistor 87 connected between the control grid and the junction point between a pair of resistors 89 and 91 connected in series between the cathode of the tube 86 and ground. Space current for the input tube is provided from a source indicated at +B, through a load resistor 92 connected to the anode of the tube.

A balanced output circuit is provided for the tube 86. It comprises a series connection of substantially equal resistors 93 and 94 which are coupled respectively by a capacitor 95 to the anode of the tube and a capacitor 96 to the cathode of the tube. The junction point between the output circuit resistors is grounded. The terminals of the output circuit resistors 93 and 94 are connected together by a potentiometer 97. By suitably adjusting the potentiometer 97, the magnitude and polarity of the vertical sawtooth voltage may be varied.

The vertical convergence control voltage generator 65 also includes an output electron tube 98. The control grid of the tube 98 is connected as shown to the potentiometer 97. In this manner a component of the vertical sawtooth wave is impressed upon the tube 98. The control grid of this tube also is connected through a resistor 99 to a variable point on a resistor 101 to which the input coupling capacitor 66 is connected. By this means a suitable component of the parabolic wave at the vertical deflecting frequency is impressed upon the tube 98. The cathode of this tube includes a self-biasing network including a resistor 102 and a bypass capacitor 103. Space current for the tube is supplied through a choke coil 104.

The output circuit of the tube 98 includes the primary winding 105 of a transformer 106. This winding is coupled to the anode of the tube 98 by a capacitor 107. The transformer is provided with a secondary winding 108, one terminal of which is connected to the ungrounded terminal of the primary winding 105 and the other terminal of which is connected to the horizontal voltage control generator 67.

The horizontal voltage generator 67 is substantially similar in form to the vertical control generator 65. The chief differences between the two generators are in the values of the circuit components required for the different operating frequencies. Accordingly, the details of the generator 67 which are similar to those of the generator 65 will not be specifically described.

The input tube 109 of the horizontal control voltage generator 67 is coupled between the synchronizing signal channel 45 and an output electron tube 111. This latter tube also is connected to the synchronizing signal channel for the suitable combination of the sawtooth and parabolic waves at the horizontal deflecting frequency. The output circuit of the tube 111 includes the primary winding 112 of a transformer 113. This transformer also has a secondary winding 114 having one terminal connected to the secondary winding 108 of the vertical control voltage generator 65. The other terminal of the winding 114 is coupled by the capacitor 71 to the dynamic convergence control anode 55.

Reference now will be made to Figure 5 of the drawings which shows an embodiment of this invention used in conjunction with a color kinescope having a single electron gun for providing the plurality of electron beam components. The television receiver in this form of the invention includes a color kinescope 115. In general, this tube is of the same character as the color kinescope 46 of Figure 4. It comprises a luminescent screen 116 and an apertured masking electrode 117 similar to the screen 51 and electrode 53 of Figure 4. It also is provided with a deflecting yoke 118 capable, when suitably energized, to deflect the electron beam components both horizontally and vertically to scan a predetermined pattern or raster at the electrodes 116 and 117. This tube, however, is provided with a single electron gun 119 to produce an electron beam which is modulated in intensity in accordance with received color video signals by means of a suitable connection to the video signal channel 44. It will be understood that the electron beam produced by the gun 119 also may be keyed at the color-changing or other suitable frequency in order to produce a plurality of electron beam components capable respectively of exciting the luminescent screen 116 to produce the different image colors.

A typical example of a tube of this character forms the subject matter of the copending U. S. application of Russell R. Law previously referred to. In this type of tube, the plurality of electron beam components by which selective color excitation of the luminescent screen may be effected is produced by rotating or spinning the beam about the central or other predetermined longitudinal axis of the tube. Accordingly, the tube is provided with a circular deflection yoke 121. The yoke is energized by energy derived from a rotating field generator 122. The energization of the yoke is suitable to produce a rotating field in the path of the electron beam so that the beam is caused to continuously rotate about the axis of the tube. The rotating field generator 122 is controlled by suitable signals derived from the synchronizing signal channel 45. For example, the control signals for the rotating field generator 122 may be the horizontal synchronizing pulses derived from the synchronizing signal separator.

The deflecting yoke 118 is energized in a conventional manner by means of horizontal and vertical deflection generators 123 which are synchronized in the usual manner by suitable connections to the synchronizing signal channel 45.

Also, conventionally provided with the kinescope 115 is a magnetic beam convergence coil 124. This coil may be conventionally energized from a suitable power supply indicated as a battery 125. A variable resistor or rheostat 126 connected in series between the power supply 125 and the coil 124 serves to control the magnitude of the coil energization.

Also, in this form of the invention the dynamic convergence of the plurality of electron beam components is controlled by a coil 127. As in the other form of the invention previously described, the dynamic electron-optical system comprising the coil 127 is energized variably by an electric current which varies as a function of the horizontal and vertical deflection of the electron beam components over the luminescent screen of the tube. In this case, the coil 127 is coupled to a control voltage generator 128. Vertical and horizontal synchronizing pulses are impressed upon the input circuit of the generator 128 by means including capacitors 129 and 131.

The operation of the color kinescope 115 in this embodiment of the invention is substantially similar to that described in conjunction with the apparatus of Figure 4.

The mean difference in the two modes of operation is in the derivation of the plurality of electron beam components by which the luminescent screens are excited. Instead of having a beam component available for approach to the screen from any one of three different angles as in the preceding case, the spinning action of the single electron beam provides such components at predetermined successive time intervals. As indicated in the Law application referred to, the rotating electron beam may be keyed so that it is effective only when it is coming from predetermined points from which it may approach the target electrode from desired angles. In any case, the beam components are subject to the influence of the dynamic convergence coil **127** so that, irrespective of to which part of the target electrode they are deflected by the yoke **118**, all components converge substantially at the same point.

Again, in this form of the invention, representative circuit details of the control voltage generator **128** by which the dynamic convergence coil **127** is energized, are shown by way of example only. The pulses derived from the synchronizing signal channel **45** at the vertical deflection frequency are impressed by capacitor **129** upon a resistive-capacitive network consisting of series resistors **132**, **133** and **134** and shunt capacitors **135** and **136**. The output terminal of this network is coupled to the control grid **137** of a combining electron tube **138**. The cathode of this tube is connected to ground through a series arrangement of variable resistor **139** and fixed resistor **140**. The fixed resistor is bypassed by a capacitor **141**. The screen grid **142** is connected to a positive potential point +B through a resistor **143** and is bypassed to ground by a capacitor **144**.

The pulses derived from the synchronizing signal channel **45** as the horizontal deflecting frequency are impressed by the capacitor **131** upon a grounded potentiometer **145**. Preferably, these pulses have parabolic wave forms. As previously described, they may be derived from the booster-damper storage capacitor. The potentiometer **145** is coupled by a capacitor **146** to the control grid **137** of the tube **138**. A grid-leak resistor **147** also is provided.

Space current for the tube **138** is provided by means of the connection of the dynamic convergence coil **127** between the source of positive potential +B and the anode of the tube.

The described apparatus forming the convergence control generator **128** functions to convert the pulses derived at horizontal and vertical deflection frequencies from the synchronizing signal channel **45** into a composite voltage for energizing the dynamic convergence coil **127**. In view of the fact that the composite voltage is derived from the horizontal and vertical deflection voltage sources, it is seen that the energization of the coil **127** varies as a function of the deflection of the electron beam components over the target electrode of the kinescope **115**.

This invention provides convergence of a plurality of electron beam components substantially at all points in the plane of a target electrode. This result is achieved even though the beam components emanate from different points spaced from the central or other longitudinal axis of a cathode ray tube. Electron beam components of this character are particularly useful in multi-color kinescopes for color television systems.

Also, the electron beam components may be produced by a plurality of electron guns or by a single gun. The electronic energy produced by the gun or guns may be continuous or pulsating.

Furthermore, deflection of the electron beam components to form a television or other raster at the target electrode may be either electromagnetic or electrostatic. The dynamic convergence of the electron beam components may be either electromagnetic or electrostatic. The deflection and dynamic convergence systems may both be of the same kind or not, as desired.

The nature of the invention may be determined from the foregoing disclosure of several embodiments thereof. The scope of the invention is set forth in the following claims.

What is claimed is:

1. In a cathode ray tube having a target electrode, an electron beam-controlling system comprising, means for generating a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said target electrode, a beam-deflecting system disposed in a region spaced from said target electrode, means for directing said electron beam components into said deflecting region in such a manner that they are differently affected by said beam-deflecting system, means for variably energizing said deflecting system to cause all of said beam components to scan a predetermined raster on said target electrode and an electron-optical system adjacent the paths of said beam components and energizable as a function of said beam deflection to maintain predetermined relative positions of said beam components at all points of said raster.

2. In a cathode ray tube having a target electrode, an electron beam-controlling system comprising, means for generating a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said target electrode, a beam-deflecting system disposed in a region spaced from said target electrode, means for directing said electron beam components into said deflecting region in mutually spaced relationship, means for variably energizing said deflecting system to cause all of said beam components to scan a predetermined raster on said target electrode, an electron-optical system adjacent the paths of said beam components and energizable to maintain predetermined relative positions of said beam components at all points of said raster, and means for variably energizing said electron-optical system as a function of the variable energization of said deflecting system.

3. In a cathode ray tube having a substantially flat target electrode, means for generating a plurality of mutually spaced electron beam components, an electron beam-controlling system comprising a beam-deflecting system disposed in a region spaced from the plane of said target electrode, means for directing said electron beam components into said deflecting region at different angles, means producing horizontal and vertical beam-deflecting energy components for variably energizing said deflecting system to cause all of said angular beam components to scan a predetermined raster on said target electrode, an electron-optical system adjacent the paths of said beam components and energizable to converge all of said beam components at all points of said raster, means varying as a function of said horizontal beam-deflecting component for energizing said electron-optical system to control said beam components vertically, and means varying as a function of said vertical beam-deflecting component for additionally energizing said electron-optical system to control said beam components horizontally.

4. An electron beam-controlling system as defined in claim 1, wherein one of said beam-deflecting and electron-optical systems is electromagnetic and the other is electrostatic.

5. An electron beam-controlling system as defined in claim 1, wherein both of said beam-deflecting and electron-optical systems are electromagnetic.

6. An electron beam-controlling system as defined in claim 1, wherein said beam-deflecting system is electromagnetic and said electron-optical system is electrostatic.

7. An electron beam-controlling system as defined in claim 1, wherein said cathode ray tube also includes a plurality of electron guns for producing said respective electron beam components.

8. An electron beam-controlling system as defined in

claim 1, wherein said cathode ray tube also includes a single electron gun for producing all of said electron beam components.

9. In a color kinescope having a luminescent screen including a multiplicity of groups of sub-elemental dimensioned phosphor areas capable respectively of producing differently colored light when electronically excited, a masking electrode disposed in spaced relationship to said luminescent screen, said masking electrode having an aperture for each of said groups of phosphor areas, means for developing and directing a plurality of electron beam components toward said luminescent screen through successive apertures of said masking electrode to selectively excite said different color-producing phosphor areas, means for variably deflecting all of said beam components to scan a predetermined raster at said masking electrode, said electron beam components having non-uniform characteristics whereby they are diversely affected by said deflection, an electron-optical system disposed adjacent the paths of said beam components, and means for variably energizing said electron-optical system as a function of the variable electron beam deflection to converge all of said beam components at all points of the raster scanned at said masking electrode.

10. In a color kinescope having a substantially flat luminescent screen including a multiplicity of groups of subelemental dimensioned phosphor areas capable respectively of producing differently colored light when electronically excited, a masking electrode disposed in spaced relationship to and substantially parallel to said luminescent screen, said masking electrode having an aperture for and in substantial register with each of said groups of phosphor areas, means for developing and directing electron beam components toward said luminescent screen from different angles through successive apertures of said masking electrode to selectively excite said different color-producing phosphor areas, a beam-deflecting system disposed in a region between said beam-developing means and said masking electrode, means for variably energizing said deflecting system to cause all of said beam components substantially concurrently to scan a predetermined raster at said masking electrode, an electron-optical system disposed adjacent the paths of said beam components between said beam-developing means and said deflecting system, and means for variably energizing said electron-optical system as a function of the variable energization of said deflecting system to converge all of said beam components at all points of the raster scanned at said masking electrode.

11. In a color kinescope having a luminescent screen including a multiplicity of groups of sub-elemental dimensioned phosphor areas capable respectively of producing differently colored light when electronically excited, a masking electrode disposed in spaced relationship to said luminescent screen, said masking electrode having an aperture for each of said groups of phosphor areas, means including a plurality of electron guns respectively for developing and directing a plurality of mutually spaced electron beam components toward said luminescent screen through successive apertures of said masking electrode to selectively excite said different color-producing phosphor areas, means for variably deflecting all of said beam components to scan a predetermined raster at said masking electrode, an electrostatic electron-optical system disposed adjacent the paths of said beam components, and means for variably energizing said electron-optical system as a function of the variable electron beam deflection to converge all of said beam components at all points of the raster scanned at said masking electrode.

12. In a color kinescope having a luminescent screen including a multiplicity of groups of sub-elemental dimensioned phosphor areas capable respectively of producing differently colored light when electronically excited, a masking electrode disposed in spaced relationship to said luminescent screen, said masking electrode having an aperture for each of said groups of phosphor areas, means including a single electron gun for developing an electron beam, means for rotating said beam about a longitudinal axis of said kinescope to produce a plurality of mutually spaced electron beam components directed toward said luminescent screen through successive apertures of said masking electrode to selectively excite said different color-producing phosphor areas, means for variably deflecting all of said beam components to scan a predetermined raster at said masking electrode, an electromagnetic electron-optical system disposed adjacent the paths of said beam components, and means for variably energizing said electron-optical system as a function of the variable electron beam deflection to converge all of said beam components at all points of the raster scanned at said masking electrode.

13. In a color television image-reproducing system including a cathode ray tube having a luminescent screen of a type producing light of the component colors of an image when impinged by electron beam components approaching it from different angles and deflected to scan a raster at said screen, apparatus for controlling the convergence of said beam components in a plane in the vicinity of said screen, said apparatus comprising, means producing a plurality of electron beam components traversing pre-deflection paths that are spaced respectively about the longitudinal axis of the tube, means located adjacent said pre-deflection beam paths and energizable to effect said beam convergence, and means energizing one of said two first-mentioned means as a function of said beam deflection to vary said beam convergence angle in a manner to maintain beam convergence in said plane at all points of the scanned raster.

14. In a cathode ray tube image-reproducing system wherein a plurality of electron beams traverse predeflection paths that are spaced respectively about the longitudinal axis of the tube, electron beam-controlling system comprising, apparatus energizable to angularly deflect said beams both horizontally and vertically to scan a raster in a predetermined plane, electron beam convergence apparatus located adjacent said predeflection paths and energizable to influence said beams so as to effect substantial convergence of said beams at all of the scanned raster, and convergence control means coupled to said deflection apparatus so as to derive energy therefrom, said control means also being coupled to said convergence apparatus so as to energize it as a function of said angular beam deflection.

15. Electron beam-controlling system as defined in claim 14 wherein, said covergence control means is coupled to said horizontal beam deflection apparatus to derive energy at horizontal deflection frequency.

16. Electron beam-controlling system as defined in claim 14 wherein, said convergence control means is coupled to both said horizontal and vertical beam deflection apparatus to derive energy at both horizontal and vertical deflection frequencies.

17. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of electron beam components respectively having different characteristics; deflection apparatus for angularly deflecting said plurality of beam components to scan a raster of predetermined configuration on said screen; the respective characteristics and mutual relationship in position of said screen and said electron beam producing means being such that the positional relationships of said beam components at said screen are not constant at all points of said scanned raster; means located adjacent the paths of said plurality of beam components and energizable to produce a desired positional relationship of said beam components at said screen; and means for energizing one of said two producing means as a function of said beam

deflection angle in such a manner as to maintain said desired positional relationship of said beam components at said screen at all points of said scanned raster.

18. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of electron beam components respectively having different characteristics; means for angularly deflecting said plurality of beam components to scan a raster of predetermined configuration on said screen; the respective characteristics and mutual relationship in position of said screen and said electron beam producing means being such that the positional relationship of said beam components at said screen are not constant at all points of said scanned raster; means located adjacent the paths of said plurality of beam components and energizable to produce a desired positional relationship of said beam components at said screen; and means for energizing said last-named means as a function of said beam deflection angle in such a manner as to maintain said desired positional relationship of said beam components at said screen at all points of said scanned raster.

19. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, means for producing a plurality of electron beam components respectively having different characteristics, and means for focussing said individual beam components substantially at said luminescent screen; means for angularly deflecting said plurality of beam components to scan a raster of predetermined configuration on said screen; the respective characteristics and mutual relationship in position of said screen and said electron beam producing means being such that the positional relationship of said beam components at said screen are not constant at all points of said scanned raster; and electron-optical means located adjacent the paths of said plurality of beam components and having an effect upon said beam components which varies as a function of said beam deflection angle in such a manner as to maintain said desired positional relationship of said beam components at said screen at all points of said scanned raster.

20. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said luminescent screen; means located between said effective points of beam component origin and said screen for angularly deflecting said plurality of beam components to scan a raster of predetermined configuration on said screen; and electron-optical means located adjacent the paths of said plurality of beam components in a region between said effective points of beam component origin and said screen and having a directing effect upon said beam components which varies as a function of said beam deflection angle in such a manner as to produce a desired reduced mutual spacing of said beam components at all points of said scanned raster.

21. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said luminescent screen; means including field producing apparatus having beam entrance and beam exit portions for deflecting said plurality of beam components to scan a raster of predetermined configuration on said screen; and electron-optical means located between said effective points of beam component origin and the beam exit portion of said deflecting field producing apparatus and having a directing effect upon said beam components which varies with said beam deflection in such a manner as to effectively eliminate the mutual spacing of said beam components at all points of said scanned raster.

22. In a cathode ray tube image-reproducing system, the combination including: means for generating a plurality of electron beam components; a target electrode; deflection apparatus for angularly deflecting said beam components in a manner to cause them to scan a raster of predetermined configuration on said target electrode; said beam component generating means and said target electrode having such respective characteristics and being so related in position to one another that normally the positional relationships of said electron beam components at said target electrode are not constant at all points of said raster; means located adjacent the paths of said plurality of beam components and energizable to produce a desired positional relationship of said beam components at said target electrode; and means deriving energy from said deflection apparatus for energizing said last-named means as a function of said beam deflection angle in such a manner as to maintain said desired positional relationship of said beam components at said target electrode at all points of said scanned raster.

23. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said luminescent screen; horizontal and vertical deflection apparatus for angularly deflecting said beam components both horizontally and vertically to scan a raster of predetermined configuration on said screen; electron-optical means located adjacent the paths of said electron beam components and energizable to have a directing effect upon said beam components so as to produce a desired positional relationship of said beam components at said screen; and means deriving energy from said horizontal deflection apparatus for energizing said electron-optical means as a function of said horizontal beam deflection angle in such a manner as to maintain said desired positional relationship of said beam components at said screen at all points of said scanned raster.

24. In a color television receiver, the combination including: a cathode ray image-reproducing tube having a luminescent screen of a character to produce light of component colors of an image when impinged by electron beam components, and means for producing a plurality of mutually spaced electron beam components the effective points of origin of which being at different respective distances from substantially all points on said luminescent screen; horizontal and vertical deflection apparatus for angularly deflecting said beam components both horizontally and vertically to scan a raster of predetermined configuration on said screen; electron-optical means located adjacent the paths of said electron beam components and energizable to have a directing effect upon said beam components so as to produce a desired positional relationship of said beam components at said screen; and means deriving energy from said horizontal and vertical deflection apparatus for energizing said electron-optical means as respective functions of said horizontal and vertical beam deflection angles in such a manner as to maintain said desired positional relationship of

said beam components at said screen at all points of said scanned raster.

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