March 16, 1954 J. E. EVANS 2,672,574

MAGNETIC BEAM CONTROLLING SYSTEM

Filed March 19, 1952 5 Sheets-Sheet 1

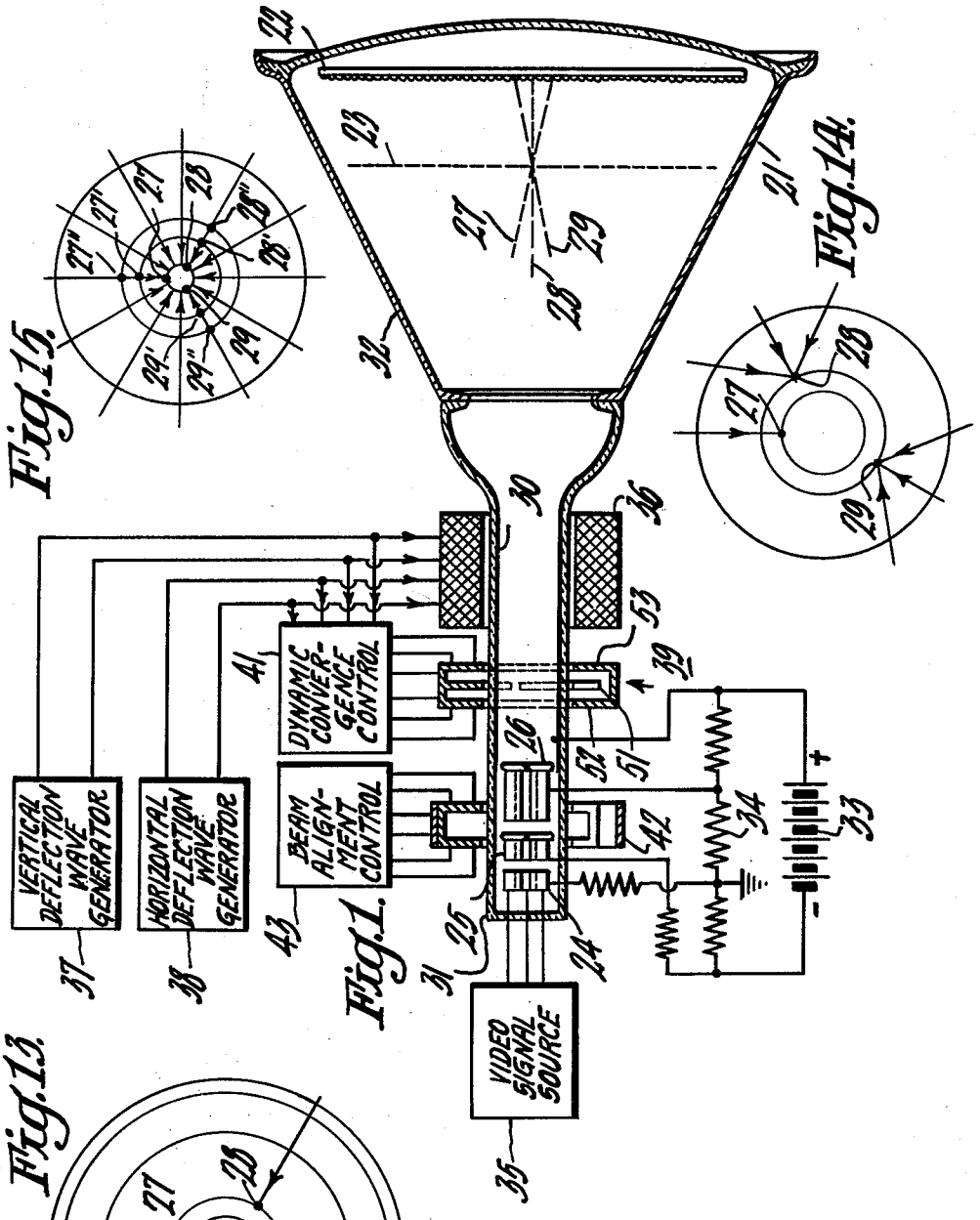


Fig. 1.

Fig. 15.

Fig. 14.

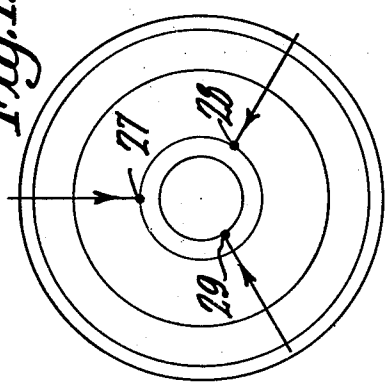


Fig. 13.

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MAGNETIC BEAM CONTROLLING SYSTEM

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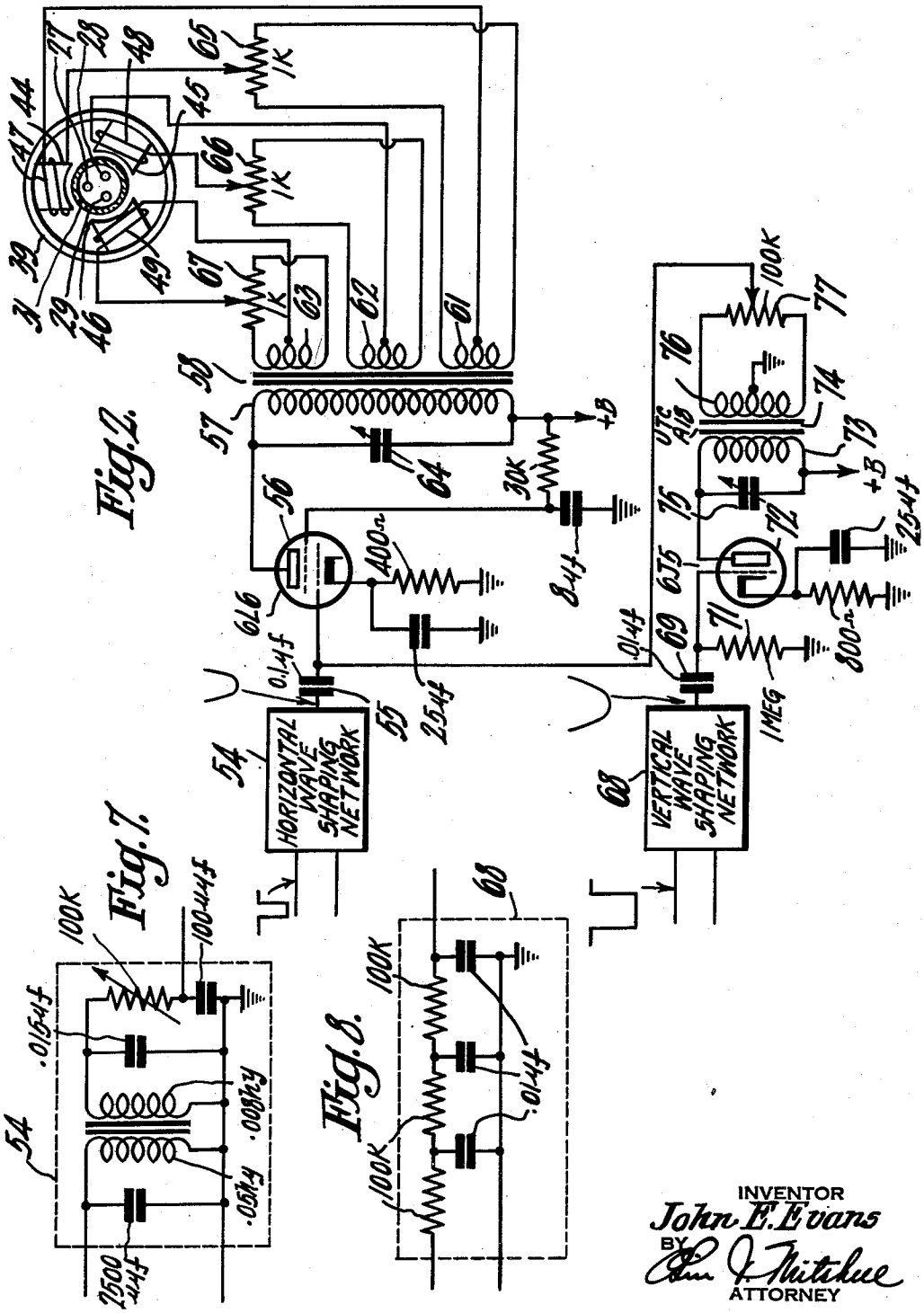


Fig. 2.

Fig. 7.

Fig. 8.

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MAGNETIC BEAM CONTROLLING SYSTEM

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Fig. 4.

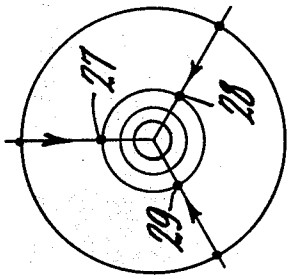


Fig. 5.

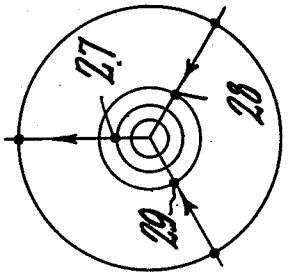


Fig. 6.

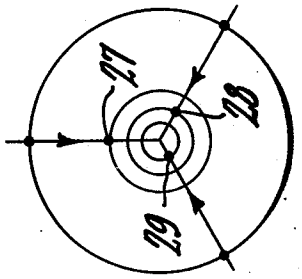
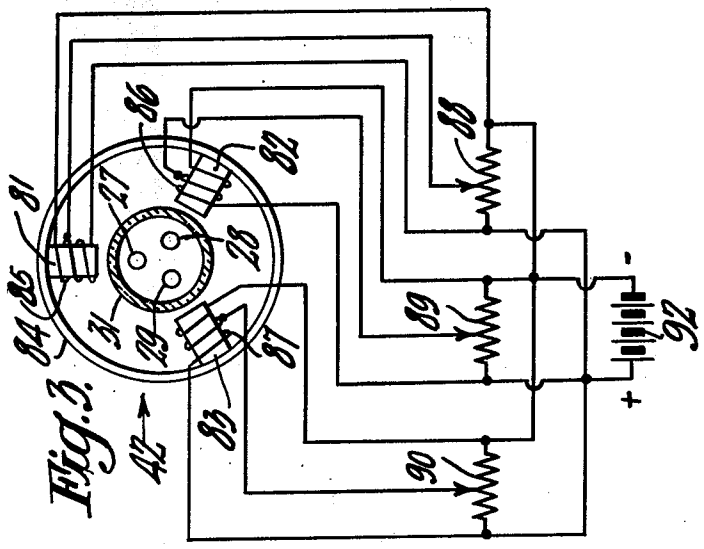


Fig. 3.



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MAGNETIC BEAM CONTROLLING SYSTEM

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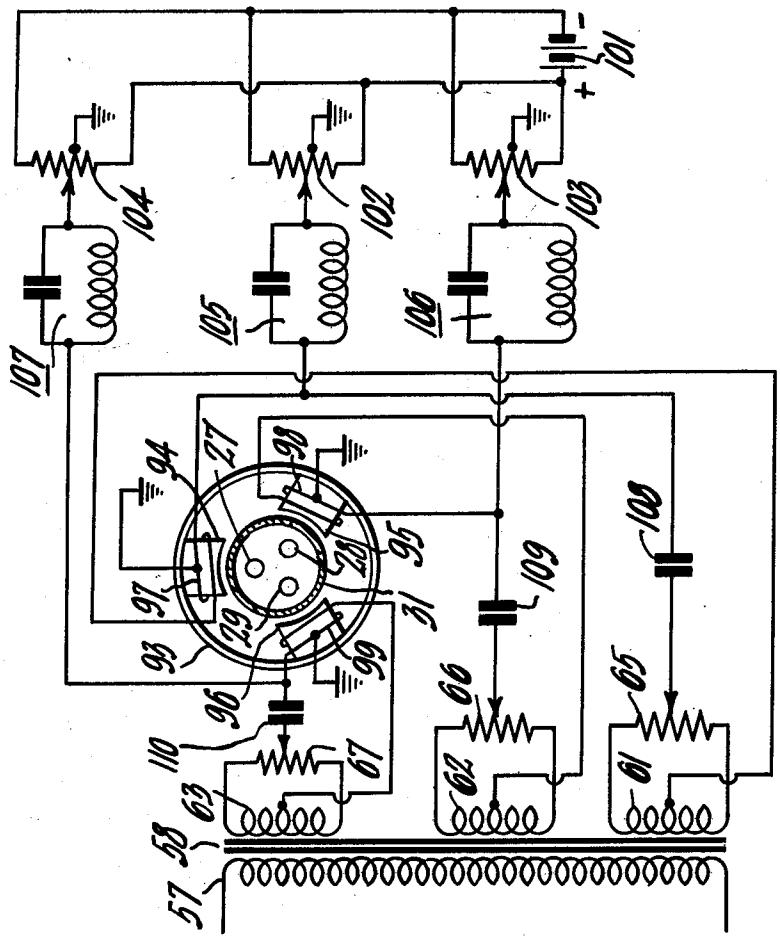


Fig. 10.

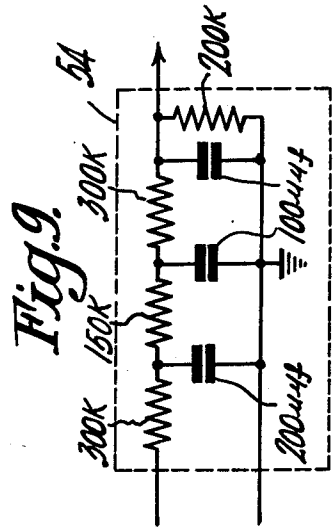


Fig. 9.

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Fig. 12.

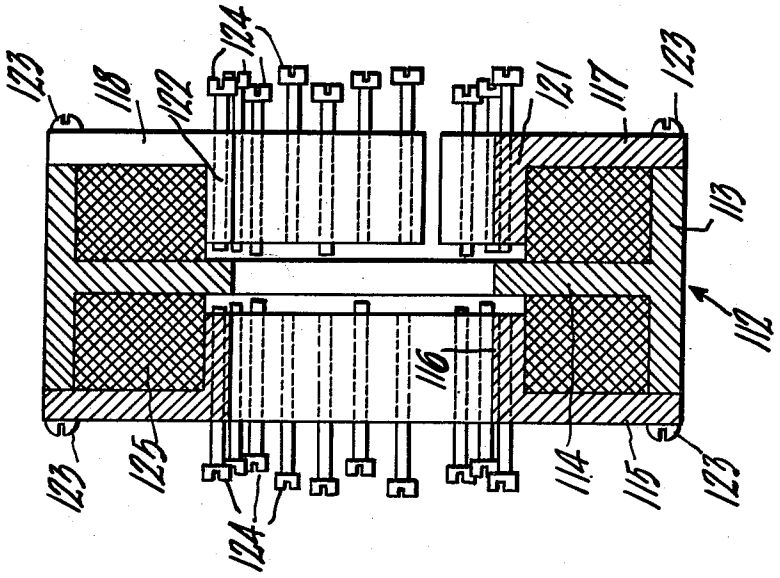
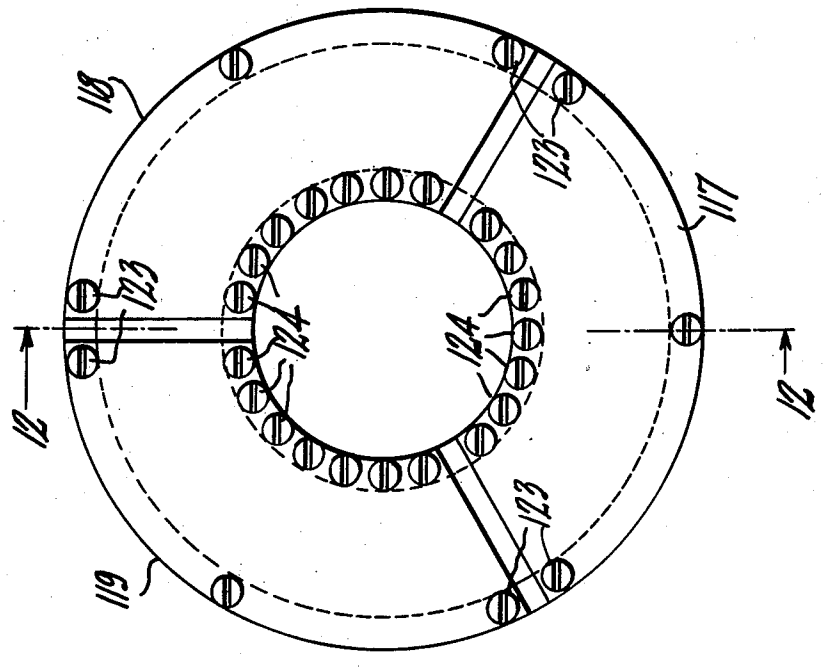


Fig. 11.



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UNITED STATES PATENT OFFICE

2,672,574

MAGNETIC BEAM CONTROLLING SYSTEM

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Application March 19, 1952, Serial No. 277,490

16 Claims. (Cl. 315—13)

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This invention relates to systems for controlling the electron beams of cathode ray tubes. It pertains particularly to the control of a plurality of electron beam components used in television kinescopes so as to effect substantial convergence of the components at all points of a raster scanned in a predetermined plane.

One type of cathode ray tube in which there is encountered the problem of maintaining substantial convergence of a plurality of beam components in the plane of a target electrode is a color kinescope such as that disclosed in a paper by H. B. Law titled "A Three-Gun Shadow-Mask Color Kinescope" published in the Proceedings of the IRE, vol. 39, No. 10, October 1951, at page 1186. Such a tube has a luminescent screen consisting of a multiplicity of phosphor areas of sub-elemental dimensions. Different ones of the phosphor areas are capable of producing light of the component image colors when excited by electron beam energy. In this tube, the different light-producing phosphor areas are excited respectively by a plurality of electron beams, or by a plurality of components of a single beam, approaching the screen from different angles through an apertured masking electrode. Color selection is secured by the angle at which the electron beam components approach the screen. A tube of the kind described forms the subject matter of a copending U. S. application of Alfred C. Schroeder, Serial No. 730,637, filed February 24, 1947, and titled "Picture Reproducing Apparatus," now Patent No. 2,595,548, granted May 6, 1952.

The expression "electron beam components" as used in this specification and claims will be understood to denote the phosphor exciting electronic energy produced either by a single or by a plurality of electron guns. This energy may be continuous or pulsating as required without departing from the scope of the invention. An example of color kinescope in which different components of a single electron beam are used to excite a phosphor screen of the kind described is disclosed in a paper by R. R. Law titled "A One-Gun Shadow-Mask Color Kinescope" published in the Proceedings of the IRE, vol. 39, No. 10, October 1951, at page 1194. Such a tube 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 successful operation of a multi-color kinescope of the type referred to requires that the plurality of electron beam components be made to converge substantially in the plane of the masking electrode at all points in the scanned

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raster. In view of the fact that the different points of the target electrode are at different distances from the point or region of the electron beam deflection, it is necessary to provide a field-producing means which is variably energized to produce the desired dynamic convergence control. One such electron beam control system is disclosed in a paper by Albert W. Friend titled "Deflection and Convergence in Color Kinescopes" published in the Proceedings of the IRE, vol. 39, No. 10, October 1951, at page 1249. Such a system forms the subject matter of a copending U. S. application of Albert W. Friend, Serial No. 164,444, filed May 26, 1950, and titled "Electron Beam Control System." In the Friend system, electron-optical apparatus is energized both statically and dynamically to produce the desired result. By means including the static energization of the optical apparatus, the Friend system effects initial convergence of the electron beam components substantially at the center of the raster to be scanned. The dynamic energization of the electron-optical apparatus is effected as functions of both the horizontal and vertical beam deflection. Essentially these functions are parabolic. In the Friend and other systems previously employed, comparatively complicated apparatus has been required to effect the desired results.

It is an object of the present invention to provide an improved and simplified electron beam control system for multi-beam kinescopes.

Another object of the invention is to provide an improved electron beam convergence system, whereby to effect accurate registration of substantially all parts of a plurality of images produced by the beams.

A further object of the invention is to provide novel electromagnetic apparatus which may be energized in a unique manner to effect substantial convergence of a plurality of electron beam components in all parts of a raster scanned thereby.

The electron beam convergence system, in accordance with the present invention, is primarily for use in connection with a cathode ray image-reproducing tube wherein a plurality of electron beam components, which traverse predeflection paths that are spaced respectively about the longitudinal axis of the tube, are angularly deflected both horizontally and vertically to scan a raster in a predetermined plane. The beam convergence system comprises a double magnetic lens and individual field-producing means respectively functioning to influence the electron beams. The lens is located adjacent to the pre-

deflection paths of the beams. Also, there is provided means controllable to selectively vary the individual beam-influencing fields produced by the magnetic lens so as to direct the beams relative to one another and to the longitudinal axis of the kinescope that there is effected substantial convergence of the beams at all points of the scanned raster. The means by which the individual beam-influencing fields are selectively varied may be either mechanical or electrical. In the case of the mechanical control means the different beam-influencing fields are shaped and maintained substantially constant for all angles of deflection of the electron beams. In the case of the electrical control means, a dynamic variation may be effected for different angular deflections of the beams. Furthermore, in the electrical form of control means, a unidirectional excitation of substantially constant magnitude may be employed to effect a predetermined orientation of the beams relative to one another and to the longitudinal tube axis, which orientation is maintained substantially constant for all angular deflections of beams.

In accordance with another form of the invention, the predeflection orientation of the beams relative to one another and to the longitudinal tube axis is effected by a beam alignment magnetic structure which preferably is electrically controlled and is located adjacent to the electron beam paths ahead of the region in which they are subjected to the convergence control.

In accordance with another feature of the invention, the energy for the excitation of the dynamic beam convergence apparatus is derived directly from the horizontal and vertical deflection waves impressed upon the electromagnetic yoke by which the angular deflection of the beams is effected. The energy so derived is shaped suitably by comparatively simple apparatus and impressed upon the electromagnetic beam convergence apparatus.

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 advantages thereof will best be understood from the following description when read in connection with the accompanying drawings.

In the drawings:

Figure 1 is a view showing the general arrangement of image-reproducing apparatus embodying one form of an electron beam convergence system in accordance with this invention;

Figure 2 is a circuit diagram showing one form of control apparatus which may be employed for the energization of the beam convergence system shown in Figure 1;

Figure 3 is another circuit diagram showing the structural arrangement of one of the components of the beam alignment apparatus used in one form of the beam convergence system in accordance with the present invention such as that shown in Figure 1;

Figures 4, 5, and 6 are diagrams showing different typical results of the operation of the beam convergence system of Figure 1;

Figure 7 shows a representative form of a horizontal wave-shaping network;

Figure 8 shows a representative form of vertical wave-shaping network;

Figure 9 illustrates an alternative type of horizontal wave-shaping network;

Figure 10 shows an arrangement of electromagnetic field-producing apparatus which may be energized both statically and dynamically in such a manner as to produce beam alignment and dynamic beam convergence;

Figures 11 and 12 illustrate the structural arrangement of a beam convergence apparatus in which the field-shaping is effected by mechanical means, Figure 12 being a sectional view taken on the line 12—12 of Figure 11; and,

Figures 13, 14 and 15 are diagrams showing typical operations of the apparatus of Figures 11 and 12.

Reference first will be made to Figure 1 of the drawings for a brief description of a representative form of image-reproducing apparatus in which the electron beam convergence system in accordance with this invention may be embodied. The system includes a tri-color kinescope 21 which may be of the same general type as that disclosed in the H. B. Law paper previously referred to. It will be understood, however, that the kinescope alternatively may be of other types such as that shown in the R. R. Law paper. In either case, however, the kinescope preferably has a substantially flat luminescent screen 22 provided with a multiplicity of small phosphor areas arranged in groups and capable respectively of producing light of the different primary colors in which the image is to be reproduced when excited by an electron beam. In back of, and spaced from the screen 22 there is an apertured masking electrode 23 having an aperture for and in alignment with each group of phosphor areas of the screen 22. In the particular tube illustrated, the kinescope also has a plurality of electron guns, equal in number to the number of primary colors in which the image is to be reproduced. Each of these guns may be conventional, consisting of a cathode, a control grid and a focussing electrode. Since the three-guns are identical, the different parts thereof will be referred to collectively as the cathodes 24, the control grids 25, and the focussing electrodes 26. The three electron guns produce beams represented at 27, 28 and 29 by which to energize, respectively, the green, red and blue phosphor areas of the screen 22. When these electron beams are properly converged in the plane of the masking electrode 23 they pass through the apertures thereof from different directions and impinge upon different phosphor areas of the various groups so as to produce green, red and blue light. It is to be noted that the size of the phosphor areas, the angles between the beams and the spacing of the mask 23 from the screen 22 as compared with the length of the tube are exaggerated for better illustration of the operation of the kinescope.

The electron-optical apparatus of the kinescope 21 also includes a beam-accelerating electrode consisting, in the present instance, of a conductive wall coating 30 formed on the inner surface of the tubular glass neck 31 of the kinescope extending from the region adjacent to the outer end of the focussing electrodes 26 to the conical section 32 of the tube which in this case is metallic. Suitable electrical connection is made at the junction of the wall coating with the metal cone 32. Preferably, the target electrode structure, including the masking electrode 23 and the luminescent screen 22 which for this purpose may be metallized, is electrically connected to the metal cone 32 by suitable means (not shown). Metallization of a luminescent screen of the character described may be effected in the man-

ner disclosed in a paper by D. W. Epstein and L. Pensak titled "Improved Cathode-Ray Tubes with Metal-Backed Luminescent Screens" published in the RCA Review, vol. VII, March 1946, at pages 5 to 10.

The described electrode structure of the kinescope may be energized in a conventional manner such as that illustrated. The source of energy is represented by a battery **33** across the terminals of which there is connected a voltage divider **34**. The cathodes **24** are connected to the grounded point of the voltage divider and the control grids **25** are connected to a point which is somewhat negative relative to ground. Similarly, the focussing electrodes **26** are connected to a point on the voltage divider which may conventionally be at a potential of approximately 3000 volts positive relative to the grounded cathodes. Also the beam-accelerating anode, including the wall coating **30** and the metal cone **32**, is connected to the voltage divider **34** at a point which may conventionally be approximately 18,000 volts positive relative to the grounded cathodes.

The electron beams represented at **27**, **28** and **29** are modulated suitably in intensity under the control of color-representative video signals derived from a source **35**. It will be understood that the video signal source is represented herein entirely diagrammatically since it does not form an essential part of the present invention. The signal source **35** usually will be part of a signal receiver and may be understood to include a signal detector, or equivalent device, together with one or more stages of video signal amplification. Alternatively, the video signal source may be a color television camera in the event that the kinescope **21** is employed as a monitor, for example. Also it will be understood that the illustrated connection of the video signal source **35** to the electron guns of the kinescope **21** is merely diagrammatic and accordingly these connections may or may not be made directly to the cathodes **24**. Instead, it will be understood that they may be made to the grids **25** or, in accordance with some modes of operation of color image-reproducing apparatus, the video signal source may be connected both to the cathodes and to the control grids of the electron guns.

Also associated with the color kinescope **21** is a deflection yoke **36** which may be entirely conventional including two pairs of suitably placed coils electrically connected together in such a manner that, when properly energized, electromagnetic fields are produced whereby to effect both horizontal and vertical angular deflections of the electron beams so as to scan the usual rectangular raster. Energization of the deflection coils comprising the yoke **36** may be effected by conventional vertical and horizontal deflection wave generators **37** and **38**, respectively. It will be understood that this apparatus which may be the same as or similar to that disclosed in a paper by Antony Wright titled "Television Receivers" published in the RCA Review of March 1947 at page 7. Such apparatus will be understood to function suitably to produce substantially sawtooth energy at both horizontal and vertical deflection frequencies so that the fields produced by the yoke **36** are varied in a substantially sawtooth manner.

The present invention which is employed with apparatus of the character described in its present form includes a double magnetic lens **39** mounted around the neck **31** of the kinescope **21** in the region between the focussing electrodes **26** and the deflection yoke **36**. The structure of one form of double magnetic lens in accordance with this invention will be described subsequently. For present purposes, however, it will be understood that the lens **39** is a structure having three salient pole pieces located respectively adjacent to the paths followed by the electron beams emanating from the respective focussing electrodes **26**. In such a case, each of the beams is subject to individual control by the salient pole pieces of the lens **39** which is adjacent thereto. Means also to be described are provided for selectively energizing the different salient pole pieces whereby to selectively influence the different beams.

The selective energization of the pole pieces of the lens **39** is effected by dynamic convergence control apparatus **41**, a representative form of which will be described subsequently. In general, the dynamic convergence control apparatus derives energy from either the horizontal deflection circuit or from both the horizontal and vertical deflection circuits as indicated to produce three substantially independent waves to energize respectively salient pole pieces of the lens **39**.

It is to be understood that lens **39** is of the double magnetic type and is arranged so that the two elements thereof produce fields tending to affect the electron beams in opposite senses. A magnetic field, by reason of the axial character thereof, produces a spiral movement of electrons generally in the same longitudinal direction as the field. In the present instance, the effect of a single magnetic lens upon the three axially spaced electron beams is to rotate the beams about the longitudinal axis of the tube. Since the color selection is dependent upon the particular angle of approach of an electron beam to the luminescent screen, it will be seen that the rotation of the beams about the tube axis changes this angle of approach and, therefore, is likely to produce incorrect colors. Hence, the lens **39** is provided with another element of a substantially identical character as the first element so as to produce a rotational effect upon the beams which is equal and opposite to that produced by the first element. Hence, so far as the rotational effect produced by the double magnetic lens **39** upon the electron beams is concerned, one lens element counteracts the other thereby producing a net beam rotational effect of zero.

In the form of the invention illustrated in Figure 1, the apparatus also includes a beam alignment magnet **42**. The structure of this apparatus component will be described in greater detail subsequently. Briefly, it functions to produce in the vicinity of each of the electron beams a magnetic field extending longitudinally of the tube and of such a character that the individual beams may be oriented relative to one another and to the axis of the tube suitably so that, so far as the deflection apparatus is concerned, they appear to originate at points symmetrically disposed relative to the tube axis. The beam alignment magnet **42** consists of individual electromagnets which may be selectively energized to move their associated beams relative to one another and to the tube axis to effect the desired alignment thereof. The beam alignment magnet **42** may be energized by unidirectional energy derived from a beam alignment control **43**. This apparatus may consist essentially of a power sup-

ply of unidirectional energy together with suitable individual control apparatus by means of which the individual parts of the beam alignment magnet 42 may be variably energized. A representative form of beam alignment control apparatus will be described subsequently.

Reference now will be made to Figure 2 of the drawings for a description of one form of dynamic beam convergence control apparatus. The double magnetic lens 39 which is mounted around the neck 31 of the kinescope comprises three salient pole pieces 44, 45 and 46 disposed respectively adjacent to the paths traversed by the electron beams 27, 28 and 29. The pole pieces 44, 45 and 46 are provided respectively with windings 47, 48 and 49. It will be understood that these windings are placed around the central legs of the double magnetic lens core structure. As a result, the core structure is energized in such a manner that as viewed in Figure 1, the central legs 51 of each of the pole pieces have one magnetic polarity such as that corresponding to a south pole, for example, while the outer legs 52 and 53 have opposite polarity such as north poles.

Reverting now to Figure 2, the magnetic lens windings are energized individually as functions of either the horizontal deflection frequency or the horizontal and vertical deflection frequencies combined. Energy at the horizontal deflection frequency is derived as shown in Figure 1 from the circuits leading to the horizontal coils of the deflection yoke 36. Since this energy is essentially current having a substantially sawtooth waveform and voltage having a substantially rectangular waveform, it is impressed upon a horizontal wave-shaping network 54 for conversion into a waveform suitable to control the convergence apparatus. As previously indicated, such a waveform is substantially parabolic. Accordingly, it will be understood that the wave-shaping network 54, representative examples of which will be referred to subsequently, functions to perform the desired wave-shaping. The substantially parabolically-shaped wave derived from the network 54 is impressed, by a coupling circuit including a capacitor 55, upon the control grid of an electron tube 56. This tube performs some degree of amplification of the parabolically shaped wave, but serves primarily as an impedance inverter.

In the output circuit of the tube 56 is the primary winding 57 of a transformer which also includes a ferrite core 58 and three secondary windings 61, 62 and 63. The primary winding 57, for example, may consist of 400 turns of No. 41 wire and each of the secondary windings may consist of 200 turns of No. 38 wire. The primary winding 57 also is tuned by a shunt capacitor 64 for resonance substantially at the horizontal deflection frequency.

The terminals of the secondary windings 61, 62 and 63 are connected respectively to the resistive elements of control potentiometers 65, 66 and 67. The windings 47, 48 and 49 of the double magnetic lens 39 are connected respectively between the sliding contacts of potentiometers 65, 66 and 67 and the center taps of the associated secondary windings 61, 62 and 63. By this means, the magnitude and polarity of the fields produced by the different pole pieces 44, 45 and 46 of the double magnetic lens may be varied independently of one another.

If it is also desired to vary the fields produced by the double magnetic lens 39 as functions of the vertical electron beam deflection, there also may be included a vertical wave-shaping network 68, representative details of one form of which will be disclosed subsequently. It is connected to the vertical deflection circuit and functions to convert the vertical deflection energy to a substantially parabolic form. The parabolic vertical energy derived from the network 68 is impressed by a coupling including a capacitor 69 and a grid resistor 71 upon the control grid of an electron tube 72. This tube also functions as an amplifier as well as an impedance inverter. The primary winding 73 of an output transformer 74 is coupled in the anode circuit of the tube 72. This transformer may be somewhat conventional, as, for example, a commercially available component identified as UTC–A18. The primary winding 73 may be tuned for resonance substantially at the vertical deflecting frequency by a shunt connected capacitor 75. The secondary winding 76 of the vertical output transformer has a grounded center tap and the terminals connected to the resistive element of a potentiometer 77. The adjustable contact of this potentiometer is coupled as shown to the control grid circuit of tube 56 previously referred to.

By the described means, a component of the vertical parabolically shaped energy derived from the potentiometer 77 is combined in the input circuit of the tube 56 with the horizontal parabolic wave energy. It has been found in practice that, in most cases, only a comparatively small component of the vertical energy is required, and in many cases, may be entirely omitted without noticeably affecting the performance of the apparatus. It will also be noted that the resistive portion of the potentiometer 77 serves as a grid resistor for the tube 56. It will be understood that in cases where no energy is to be supplied for dynamic electron beam convergence control at the vertical deflection frequency the apparatus just described may be omitted, in which case a suitable grid resistor for the tube 56 may be supplied to replace the potentiometer 77.

Reference now will be made to Figure 3 of the drawings for a description of the type of beam alignment magnet 42 used in the illustrative embodiment of the invention shown in Figure 1. It includes a plurality of substantially U-shaped pole pieces disposed in the general manner indicated in Figure 1 so that the two legs thereof are spaced longitudinally along the axis of the kinescope. As in the case of the double magnetic lens 39, there preferably are provided as many pole pieces as there are electron beams. Accordingly, in the present illustrative embodiment of the invention utilizing three electron beams, there are provided three beam alignment pole pieces 81, 82 and 83 disposed about the neck 31 of the kinescope so as to be respectively adjacent the electron beams 27, 28 and 29. The pole pieces may be mechanically supported in any suitable manner such as being mounted in a common retaining ring 84 which preferably is made of a non-magnetic material. Also, in a convenient place such as on one of the legs of the pole pieces 81, 82 and 83 there are mounted energizing coils 85, 86 and 87 respectively. Each of these coils is provided with two end terminals and a center tap.

The coils 85, 86 and 87 are connected respectively to control potentiometers 88, 89 and 90. As indicated, the terminals of each of the coils are connected to the respective terminals of the resistive elements of the potentiometers and the center taps of the coils are connected to the mov-

able contacts of the associated potentiometers. The terminals of the potentiometers are connected to the respective terminals of a source of unidirectional energy such as indicated by the battery 92.

It may be seen that, by means of the described apparatus there may be produced in the vicinity of each of the electron beams 27, 28 and 29 magnetic fields of such character that the individual beams may be positioned relative to one another and to the longitudinal axis of the tube substantially in any desired way. The strength of the magnetic fields as well as the polarity thereof may be controlled by suitable adjustment of the control potentiometers.

It has been found advantageous, in the operation of apparatus embodying the present invention, to initially align the beams by means of apparatus such as that shown in Figure 3 so that beam convergence is effected at the corners of the raster instead of at the center thereof as usually practiced heretofore. The advantage of such a procedure is that the corner convergence is effected by unidirectional energy so that the dynamic energization of the beam convergence apparatus needs to be sufficient only to modify the relative beam positions as they are deflected back toward the center of the raster. In effect, this is accomplished by applying the dynamic energization in opposition to the unidirectional energization. The result of this method of operation is that, where beam convergence is the most difficult, it is produced by unidirectional energization of the apparatus which ordinarily is maintained static or constant in magnitude, whereas in prior art modes of operation this additional energization had to be supplied dynamically.

Figure 4 represents the usually desired alignment of the electron beams, if it is considered that the center of the concentric circles shown in this figure coincides with the longitudinal axis of the kinescope. It is seen that the three electron beams are symmetrically disposed relative to the tube axis, both angularly and radially.

Figure 5 represents a condition where the beams 28 and 29 are positioned angularly as desired, but the beam 27 is radially displaced from the desired position. Its angular relationship to the other two beams is assumed to be correct. Accordingly, in the control of the beam alignment apparatus of Figure 3, the potentiometer 88 will need to be adjusted suitably to energize the coil 85 so that the magnetic field produced by the pole piece 81 is of a character to move the beam 27 radially away from the longitudinal axis of the kinescope.

Similarly, in Figure 6 which is representative of another possible arrangement of the electron beams 27, 28 and 29 as they emerge from the apparatus producing them, it is assumed in this instance that the beam 27 is positioned as desired. It is further assumed that all three of the beams are angularly positioned relative to one another in the desired manner. However, the beam 28 is located closer to the axis than the beam 27 and the beam 29 is located even closer to the kinescope axis. Accordingly, the winding 86 is required to be energized by a suitable adjustment of the associated potentiometer 89 so that the magnetic field produced by the pole piece 82 is of a suitable polarity and strength to move the beam 28 away from the kinescope axis so that its radial displacement therefrom is equal to that of the beam 27. Similarly the potentiometer 90 needs to be adjusted so that the energization of the coil 87 is suitable to effect the production by the pole piece 83 of a magnetic field having substantially the same polarity as that produced by the pole piece 82. However, in this case, the strength of the field produced by the pole piece 83 is required to be substantially twice that of the field produced by the pole piece 82. By such adjustment of the apparatus shown in Figure 3, the electron beams 27, 28 and 29 may be aligned substantially in any desired manner.

A brief reference now will be made to Figures 7, 8 and 9 for a consideration of representative types of wave-shaping networks suitable for use as the networks 54 and 68 of Figure 2. Typical valves of the components are indicated and with which the networks have been successfully operated. Figure 7 discloses an LC type of wave-shaping network which has been found suitable for use as the horizontal wave-shaping network 54. Figure 8 illustrates an RC type of wave-shaping network which has been found suitable for use as the vertical wave-shaping network 68. It is to be understood that the present invention is not necessarily limited to any particular types of wave-shaping networks. Those skilled in the art are familiar with various other forms of networks which may be employed at both the horizontal and vertical deflection frequencies for the conversion of substantially rectangular wave energy to waves having approximately parabolic forms. Figure 9, for example, shows an RC type of wave-shaping network which may be used as a horizontal wave shaping network 54 as an alternative to that shown in Figure 7.

As previously indicated it is not essential in all cases to effect beam alignment and dynamic beam convergence by separate devices. Reference will now be made to Figure 10 of the drawings for a description of a single apparatus which may be operated in such a manner as to effect both beam alignment and dynamic beam convergence. The apparatus includes an electromagnetic yoke 93 which, in the case of a three electron beam kinescope, has three salient pole pieces 94, 95 and 96 positioned respectively adjacent to the electron beams 27, 28 and 29. The pole pieces 94, 95 and 96 are provided respectively with energizing windings 97, 98 and 99. Each of these windings is center-tapped and grounded at these points as indicated.

In order to effect both beam alignment and dynamic beam convergence by this apparatus the windings are energized both by unidirectional and dynamic components. The unidirectional energization of these windings is effected by control apparatus connected to a source of unidirectional energy such as represented by a battery 101. For this control of the windings 97, 98 and 99, the terminals of the energy source 101 are connected respectively to the terminals of the resistive elements of potentiometers 102, 103 and 104. The mid-points of these resistive elements are grounded as shown. The movable contacts of the control potentiometers 102, 103 and 104 are connected through parallel resonant LC networks 105, 106 and 107 respectively to one terminal of each of the windings 97, 98 and 99 respectively. The parallel resonant circuits are tuned to prevent the feedback of energy from the electromagnet windings at the horizontal deflection frequency.

The dynamic energization of the electromagnet windings may be effected by apparatus including a transformer 58 which may be the same as that shown and described in connection with

Figure 2. The primary winding 57 is coupled by the described means to the deflection circuits. The individual secondary windings 61, 62 and 63 are center tapped and provided respectively with control potentiometers 65, 66 and 67 as in the previously described embodiment of the invention. In this case as in the apparatus of Figure 2, the center taps of the secondary windings 61, 62 and 63 are connected respectively to one terminal of the windings 97, 98 and 99. The adjustable contacts of the potentiometers 65, 66 and 67 are coupled respectively by capacitors 108, 109 and 110 to the other terminals of the windings 97, 98 and 99 respectively. These capacitors serve as blocking capacitors to prevent the unidirectional energy derived from the source 101 from mixing with the dynamic energy derived from the transformer 53.

The operation of this unitary apparatus is substantially the same as the independent operation of the separate devices previously described. The unidirectional components of energy supplied to the windings in accordance with the adjustments of the potentiometers 102, 103 and 104 produce fields by which the individual electron beams 27, 28 and 29 are separately influenced for positioning them suitably with respect to one another and to the longitudinal axis of the kinescope in the desired manner. As in the previously described apparatus, the polarity and magnitude of each of the fields produced by the unidirectional energizing apparatus may be independently adjusted to produce the desired beam alignment, either at the center of the raster or at the corners thereof as previously described. The dynamic energization of the windings 97, 98 and 99 is substantially similar to that described in connection with Figure 2.

Reference now will be made to Figures 11 and 12 of the drawings for a description of a type of beam convergence apparatus in which the necessary field-shaping is effected by mechanical means. Such apparatus may be employed advantageously in cases where dynamic beam convergence is unnecessary or not desired. This apparatus also comprises a double magnetic lens. As in the electromagnetic form of double magnetic lens previously described, this apparatus has two like pole pieces on the outer sides and a pole piece of the other polarity located intermediate thereof.

The double magnetic lens includes a center pole piece 112 which has a generally annular flange portion 113 and an inwardly extending rib portion 114. The rib portion extends only part way toward the center of the device and forms one of the pole pieces which in the present instance will be assumed to be a south pole. One end of the device is formed of a plate 115 having a configuration which is generally disc-like and an inwardly extending hub portion 116 forming one of the outer pole pieces which in the assumed case is a north pole. The plate 115 is substantially unbroken throughout the entire 360° thereof. The other end plate of the double magnetic lens is formed of three segments 117, 118 and 119. In this instance the segments are approximately 120° in extent being separated from one another as shown in Figure 11 sufficiently to provide for the creation of three independently adjustable portions of the field produced by the device. The segmented plates 117, 118 and 119 are also provided with respective inwardly extending hub portions such as 121 on the segment 117 and 122 on the segment 118. Each of these segmented hubs forms another north pole of the double magnetic lens. The outer plates 115, 117, 118 and 119 are attached to the annular pole piece 113 by suitable means such as a plurality of screws 123.

A plurality of adjustable field-varying elements such as screws 124 are threaded into the hub portions of the two outer pole pieces 115, 117, 118 and 119. Briefly, these screws are of soft iron so that the introduction thereof into the gap produced between the pole pieces effects a distortion of the field produced in this gap.

The magnetic structure formed substantially in the manner described may be either of the permanent magnet or of the electromagnet type. In the latter case, a coil 125 may be mounted in the spaces provided between the outer and inner pole pieces substantially as indicated in Figure 12. In this case, the pole pieces preferably are formed of soft iron materials. In the case of a permanent magnetic device, the pole pieces themselves will be the permanent magnets.

By adjusting the screws 124 so that they extend to suitable points in the magnetic field produced by the outer and inner pole pieces, the shape of the resultant field may be controlled in such a manner as to effect the desired orientation of the electron beams of the kinescope. The apparatus of Figures 11 and 12 is made in such form that it envelopes the neck portion of the kinescope so that the electron beams are subjected to the influence of the field produced by the apparatus.

Reference is made to Figures 13, 14 and 15 for typical examples of the manner in which the apparatus of Figures 11 and 12 operates. In Figure 13, for example, where the electron beams 27, 28 and 29 are in the positions shown, the angular relationship between them is as desired. Also the radial positions of the beams 27 and 28 are satisfactory. The radial position of the beam 29, however, is closer to the axis of the kinescope than desired. Accordingly, the adjustment of the screws 124 of the apparatus of Figures 11 and 12 should be such as to alter the field in the vicinity of the beam 29 suitably from that in the vicinity of beams 27 and 28 to effect a movement of the beam 29 radially outward to the same distance as that at which the beams 27 and 28 are located from the center.

In Figure 14 the positions of the beams 27, 28 and 29 are such that the beams 28 and 29 are at suitable radial distances from the axis of the tube but the beam 27, however, is not sufficiently spaced from the axis of the tube. If it is assumed that the beam 27 is correctly positioned angularly, the beams 28 and 29 are improperly positioned in this respect. Accordingly, the adjustment of the field-shaping screws 124 is required to be such that the beam 27 will be moved outwardly from the axis of the tube. The fields produced by two adjacent pole pieces of the apparatus is required to be such that both of them influence the beam 28 suitably to rotate it about the central axis sufficiently to place it in proper angular relationship to the beam 27. Similarly, the field produced by two other adjacent segmented pole pieces is required to be such that components of each influence the beam 29 to rotate it so that it occupies the desired angular relationship to the other two beams.

Figure 15 to which reference now will be made shows another aspect of the relationship of the electron beams to one another and to the central axis of the tube under other conditions. If

it be assumed that the three electron beams 27, 28 and 29 are symmetrically located with respect to one another and to the axis of the tube, either as they issue from their respective electron guns or as a result of a suitable control of the magnetic lens apparatus such as that shown in Figures 11 and 12, for example, in which the adjusting screws 124 are manipulated to produce the described positioning of the beams, then Figure 15 illustrates the arrangement of the beams 27, 28 and 29 under strong magnetic lens influence. If this influence be uniformly decreased as, for example, by reducing the exciting current in the coil 125, then the electron beams will assume positions such as indicated at 27', 28' and 29'. Similarly, a further decrease of the magnetic lens effect will result in the further movement of the beams away from the central axis of the tube so that they take positions such as indicated at 27'', 28'' and 29''.

It may be seen from the foregoing description of a number of illustrative embodiments of this invention that there is provided an improved and considerably simplified system for effecting the desired electron beam control for multi-beam kinescopes whereby there is effected substantial convergence of the beams. In cases where the required beam convergence is to be effected substantially at all points of a target electrode in a raster of moderate dimensions, the beam control apparatus may provide satisfactory performance without any dynamic energization thereof. In such cases the initial beam convergence may be effected by suitable control of the different portions of a magnetic field to which the beams are subjected, either by the introduction of field-distorting elements or by adjustment of the electromagnetic apparatus by which the fields are produced.

The invention further provides a control apparatus by which the beam-controlling fields may be varied as functions of the beam deflections. In accordance with the apparatus embodying the present invention, this dynamic control of the magnetic lens is effected by energy derived directly from the circuits energizing the deflection yoke coils and utilized with a minimum of shaping or other control, thereby requiring a minimum of additional apparatus.

Furthermore, in accordance with this invention, there is provided apparatus by means of which a suitable control of the electron beam components may be effected whereby to initially position the beam components relative to one another and also to the central axis of the kinescope to produce the desired effects, such as color selection in a color kinescope, and subsequently to produce the desired beam convergence, not only at a predetermined point in the scanned raster, but at substantially all points therein by suitable dynamic control of the beam components.

In accordance with a further feature of the invention, the control of the electron beam components, whereby substantial convergence thereof in all points of a raster scanned in a plane of a target electrode, is effected in a simpler manner than heretofore by first producing beam convergence at a non-central point of the raster, such as at one corner thereof, and then subjecting the beams to a dynamic convergence control for all other points in the scanned raster as functions of the beam deflection. Still another feature of this invention is the provision of a unitary apparatus forming a magnetic lens which may be energized both statically and dynamically to effect both the functions of initial beam alignment and also the convergence of the beam components for all other deflected positions thereof. It will be appreciated that, by reason of provision of one or more of the features of the present invention, beam convergence both static and dynamic in a multi-beam kinescope is effected in a more efficient and more effective manner than heretofore.

The nature of the invention is set forth in the foregoing description of a number of illustrative embodiments thereof. The scope of the invention is set forth in the appended claims.

What is claimed is:

1. In a cathode ray tube image-reproducing system wherein a plurality of electron beams, which traverse pre-deflection paths that are spaced respectively about the longitudinal axis of the tube, are angularly deflected both horizontally and vertically to scan a raster in a predetermined plane, an electron beam convergence system comprising, a double magnetic lens having individual field-producing means respectively influencing said electron beams, said lens being located adjacent said pre-deflection paths of said beams, and means controllable to selectively vary the individual beam-influencing fields produced by said magnetic lens to direct said beams relative to one another and to said longitudinal tube axis so as to effect substantial convergence of said beams at all points of the scanned raster.

2. In a cathode ray tube image-reproducing system wherein a plurality of electron beams, which traverse pre-deflection paths that are spaced respectively about the longitudinal axis of the tube, are angularly deflected both horizontally and vertically to scan a raster in a predetermined plane, an electron beam convergence system comprising, a double magnetic lens having individual field-producing pole pieces respectively positioned radially to influence said electron beams, said lens being located adjacent said pre-deflection paths of said beams, and means associated respectively with said pole pieces and controllable to selectively vary the individual beam-influencing fields produced by said magnetic lens to direct said beams relative to one another and to said longitudinal tube axis so as to effect substantial convergence of said beams at all points of the scanned raster.

3. An electron beam convergence system as defined in claim 1 wherein, said magnetic lens comprises electromagnetic field-producing means.

4. An electron beam convergence system as defined in claim 1 wherein, said magnetic lens comprises electro-magnetic field-producing means, and includes additionally individual pole pieces having movable elements by which to provide individual fields shaped suitably to effect the desired direction of said beams.

5. An electron beam convergence system as defined in claim 4 wherein, said field-shaping elements are threaded members adapted to be moved into and out of the respective air gaps of said double magnetic lens.

6. An electron beam convergence system as defined in claim 1 wherein, said magnetic lens comprises a plurality of individual electromagnetic field-producing means including individual pole pieces having energizing windings located respectively thereon and energizable individually to provide individual fields shaped suitably to effect the desired direction of said beams.

7. An electron beam convergence system as defined in claim 6 wherein, said coils are variably energized as a function of said angular beam deflection.

8. An electron beam convergence system as defined in claim 7, and including additionally means including a source of uni-directional energy to excite magnetic lens coils individually to effect a predetermined orientation of said beams relative to one another and to said longitudinal tube axis.

9. In a cathode ray tube image-reproducing system wherein a plurality of electron beams, which traverse predeflection paths that are spaced respectively about the longitudinal axis of the tube, are angularly deflected both horizontally and vertically to scan a raster in a predetermined plane, an electron beam convergence system comprising, an initial beam alignment coil array having individual field-producing elements located respectively adjacent to sources of said electron beams, said individual elements being separately controllable to effect a predetermined orientation of said beams relative to one another and to said longitudinal tube axis, a double magnetic lens having individual field-producing means for influencing each of said electron beams, said lens being located adjacent the paths of said beams before entering the deflection region, and means controllable to selectively vary as a function of said angular beam deflection the individual beam-influencing fields produced by said magnetic lens to direct said beams relative to one another and to said longitudinal tube axis so as to effect substantial convergence of said beams at all points of the scanned raster.

10. In a cathode ray tube image-reproducing system wherein a plurality of electron beams, which traverse pre-deflection paths that are spaced respectively about the longitudinal axis of the tube, are angularly deflected both horizontally and vertically to scan a raster in a predetermined plane, an electron beam convergence system comprising, means energizable to effect a predetermined orientation of said beams relative to one another and to said longitudinal tube axis, whereby to produce initial static convergence of said beams, means including a source of unidirectional energy to energize said beam-orienting means in a manner to effect said initial beam convergence at an eccentric point of said raster, and means dynamically energizable to influence said beams so as to effect substantial convergence of said beams at all points of said raster.

11. An electron beam convergence system as defined in claim 10 wherein, said said uni-directional energization of said beam-orienting means is of such a character to effect said initial beam convergence in a corner of said raster.

12. An electron beam convergence system as defined in claim 10 wherein, said beam-orienting means and said beam convergence means include a common electromagnetic device located adjacent to said pre-deflection beam paths.

13. An electron beam convergence system as defined in claim 12 wherein, said common electromagnetic device is provided with individual field-producing pole pieces respectively positioned to influence individual ones of said beams.

14. An electron beam convergence system as defined in claim 10 wherein, said beam-orienting means and said beam convergence means include respective electromagnetic devices located at points spaced along the longitudinal tube axis adjacent to said pre-deflection beam paths.

15. An electron beam convergence system as defined in claim 14 wherein, both of said electromagnetic devices are provided with individual field-producing pole pieces respectively positioned to influence individual ones of said beams, and all of said pole pieces being independently energizable.

16. In an image-reproducing system embodying a color kinescope having a luminescent screen including a multiplicity of groups of phosphor areas capable respectively of producing differently colored light when electronically excited, a masking electrode located in a plane spaced from said luminescent screen and having an aperture for each of said groups of phosphor areas and in which means are provided for developing and directing electron beam components toward said luminescent screen through successive apertures of said masking electrode to selectively excite said different color producing phosphor areas, an electron beam convergence system comprising, deflection apparatus energizable to angularly deflect said beam components both horizontally and vertically to scan a predetermined raster at said masking electrode, electromagnetic means located adjacent to said electron beam-developing means and having individual field-producing pole pieces respectively positioned and energizable to effect a predetermined orientation of said beam components relative to one another and to said longitudinal tube axis, means including a source of unidirectional energy to energize said beam-orienting means in a manner to effect initial static convergence of said beam components at a predetermined point of said raster, a double magnetic lens having individual field-producing pole pieces respectively positioned radially to influence said electron beam components, said lens being located between said electron beam-developing means and said deflection apparatus, and means including windings for each of said pole pieces coupled to said deflection apparatus for energization and controllable to selectively vary the individual beam-influencing fields to effect dynamic convergence of said beams at all points of said scanned raster.

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