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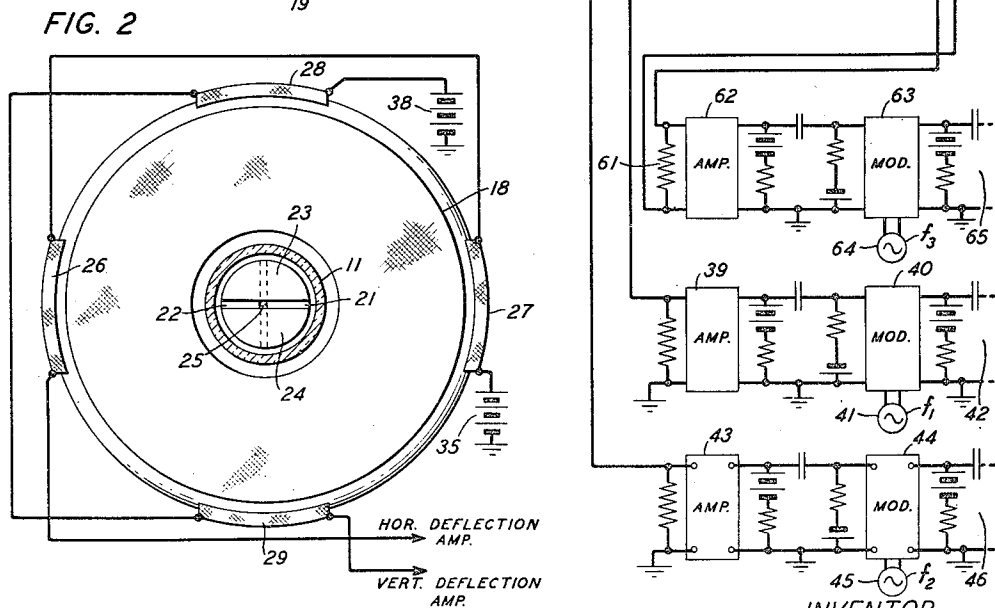
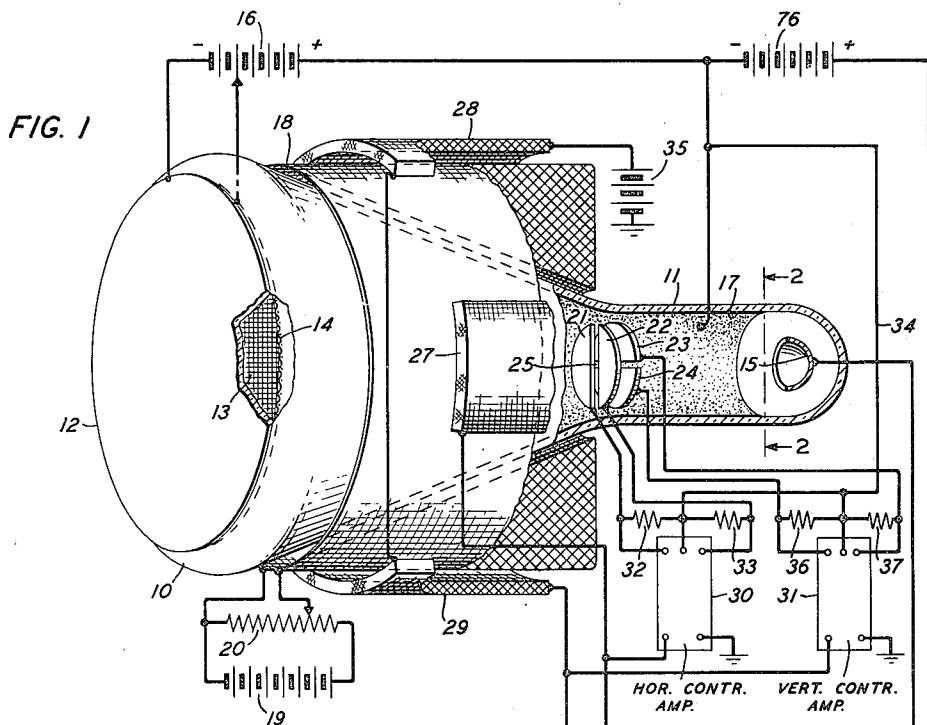
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2,515,057

ELECTRONIC TRACING SYSTEM

Filed Aug. 14, 1947

2 Sheets-Sheet 1



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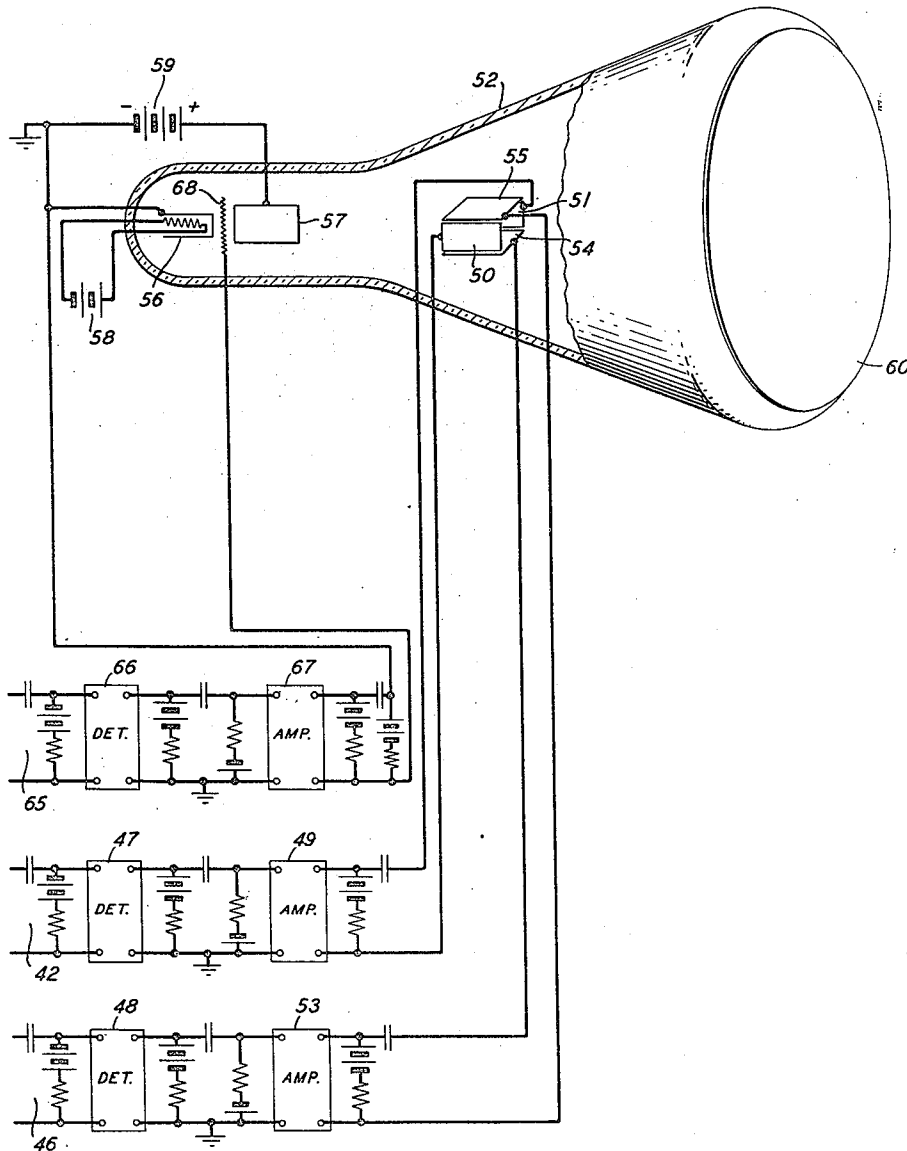
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FIG. 3



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ELECTRONIC TRACING SYSTEM

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8 Claims. (Cl. 178—19)

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This invention relates to systems for the electrographic transmission of images and, more particularly, to systems in which writing or graphic material may be reproduced at a receiving station while being formed at a transmitting

station. In a copending application of L. Espenschied, filed June 4, 1946, Serial No. 674,395, there is disclosed a system for producing currents representative of an image to be reproduced at a remote receiving point. The transmitting device comprises an electron discharge tube having a photosensitive mosaic which yields electrons whenever a light is projected upon an adjacent, transparent writing surface. The electrons so yielded are collimated into a stream by a magnetic field and move toward an anode under the influence of an electrostatic field. The electron stream passes between two pairs of plates in such a manner that signals representative of the position of the stream within the region formed by the plates is developed on the plates. As the position of the light source is moved around the mosaic the path of the electron stream through the pick-up plates is altered so that the intensity of the signals at the plates will vary in accordance with the position of the moving point of light. Thus by incorporating the light source into a pencil or other sketching device it is possible to provide signals indicative of the coordinate position of the pencil, and the signals may be transmitted to a remote receiving device which will in turn reproduce the movements of the pencil at the transmitter.

In a system such as that described the signals derived from the pick-up plates are a function not only of the position of the path of the electron beam between the pick-up plates but also of the intensity. Thus any factors which may tend to cause a variation in beam intensity tend to manifest themselves as a distortion in the received images and great care is required to produce a system in which such errors do not obviate the usefulness of the system. Accordingly, it is an object of the present invention to provide an improved transmitting device in which the signals representative of the sketches to be transmitted are independent of variations in the electron beam intensity.

In accordance with one embodiment of the invention, the electrons emitted by a photocathode adjacent a writing surface are collimated and formed into an electron stream of high current density by a field coil which produces a magnetic field of progressively increasing intensity along

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the path of the electron stream. The electron stream is caused to pass through an aperture formed by two pairs of plates or electrodes, each pair of plates forming a slit, the two slits and the path of the electron stream being mutually perpendicular. The pairs of plates are connected to amplifiers which in turn are arranged to control the current through electromagnetic deflection coils, the normal current through the coils being balanced so that electrons originating at a point on the mosaic which is axially aligned with the aperture will follow a path centrally through the aperture. As the electron emitting portion of the cathode moves in accordance with the motion of the writing stylus, the path of the electron stream will tend to shift accordingly, thus altering the conduction current to the respective electrodes and hence the voltage applied to the amplifiers. The amplified currents are applied to the electromagnetic deflection coils so as to return the electron stream to a path extending centrally through the aperture. It is an important feature of the invention that the control electrodes in conjunction with the amplifiers and deflection coils effectively form a feedback loop so that by the use of amplifiers having high gain and the proper phase shift, the magnitudes of the deflection coil currents are made proportional to the amount of translation of the writing stylus from the position of axial alignment with the aperture. The deflection coil currents may, under such conditions, be utilized to control a remote reproducing instrument.

Other features and aspects of the invention will be apparent from the following description and claims. In the drawing:

Fig. 1 is a schematic representation of a transmitting apparatus incorporating a specific embodiment of the invention;

Fig. 2 is a cross-sectional view taken at the line 2—2 of Fig. 1 and showing the control electrodes and deflection coil assembly of the cathode ray tube of Fig. 1; and

Fig. 3 is a schematic representation of a receiver which may be used with the transmitter of Fig. 1.

Referring to Figs. 1 and 2, the transmitting apparatus comprises a cathode ray tube 10 capable of translating the motion of a luminous writing instrument into electromotive forces representative of the position of the instrument and associated circuits for transmitting the forces to a remote receiver. The cathode ray tube 10 comprises an evacuated envelope 11 having a substantially plane end surface 12 of translucent

material which forms a writing surface. The inner face of the end surface 12 is provided with a coating 13 of a photosensitive, electron-emitting substance which will, when excited by light, emanate electrons at the region of exposure to the light source. The coated inner face thus forms a light-sensitive cathode which may include a matrix or extremely thin coating of silver or other conducting material to provide an effective electrical connection to the entire cathode area. In the operation of the transmitting apparatus of Fig. 1 and of which the cathode ray tube 10 forms a part, it is intended that the graphic representation to be transmitted be traced on the plane end surface 12 as a writing surface by means of a stylus capable of emitting a concentrated beam of visible light or other radiation. This radiation passes through the transparent writing surface to release electrons from the portion of the cathode 13 adjacent the stylus. Thus the emissive portion of the cathode varies as the stylus progresses over the writing surface.

The electrons emitted by the cathode 13 are accelerated by a grid 14 positioned immediately adjacent the cathode and move in a stream toward the anode 15 at the opposite end of the tube. A positive potential is applied to the anode 15 with respect to the cathode 13 by the batteries 16 and 76. The anode 15 is connected to the positive terminal of battery 76 through resistor 61 for a reason that will be hereinafter described. A conductive coating 17 on the inner surface of the evacuated envelope 11, also connected to the potential source 16, serves both to accelerate the electron stream and to shield the stream from the effect of external electrostatic fields.

The electron stream is collimated by a longitudinal magnetic field formed by a field coil 18 connected to a potential source 19 through a potentiometer 20. The field coil 18 is preferably proportioned so as to provide an increasing field intensity along the path of the electron stream. Hence, the magnetic field serves to produce an electron stream of small cross-sectional area as well as collimating the electrons randomly emitted at the active portion of the cathode 14.

In order to accomplish the intended function of the cathode ray tube 10, there is provided in accordance with the invention two pairs of oppositely disposed control electrodes 21 and 22, and 23 and 24 forming an aperture 25 through which the collimated electron stream must pass in order to reach the anode 15. Currents derived from the control electrodes 21, 22, 23 and 24 by reason of a variation in the path of the electron stream are utilized to control currents through the deflection coils 26 and 27, and 28 and 29, which cooperate to maintain the path of the electron stream centrally through the aperture 25. The manner in which such action takes place may be more fully understood by a consideration of the operation of horizontal control electrodes 21 and 22, the horizontal deflection coils 26 and 27, and the horizontal control amplifier 30.

In considering the operation of the control circuits, it will be realized that high current density electron streams are of non-uniform density distribution throughout the cross-section of the stream. In such electron streams the density of the stream is maximum at the center or core of the stream while decreasing in density with increasing distance from the center. For a discussion of this phenomena, reference may be made to an article entitled "Limiting Current

Densities in Electron Beams" by J. R. Pierce, 10, Journal of Applied Physics 715 (1939).

The pairs of control electrodes are so spaced that when the electron stream is passing centrally through the aperture, the outermost portions of the stream strike the control plates. Thus there is normally a conduction current from the horizontal control electrodes 21 and 22 through the coupling resistors 32 and 33, a return conductor 34 and the potential source 16 to the cathode 13. When the path of the electron stream is centrally through the aperture 25 the potentials developed across the coupling resistors are equal and the horizontal control amplifier has no output. However, as the path of the electron stream shifts horizontally due to the motion of the writing stylus, the current to the one electrode will increase, while the current to the other electrode will decrease, thus increasing the potential drop across one coupling resistor and decreasing the potential drop across the other. This potential unbalance is amplified by the horizontal control amplifier 30 and the current supplied to the deflection coils 26 and 27 by the potential source 35 is altered in a proper sense to return the electron stream to a path centrally through the aperture 25. It is understood, of course, that the current through the deflection coils 26 and 27 is initially adjusted so that when the writing stylus is positioned at a point on the writing surface corresponding to the longitudinal axis of the tube, the electron stream will pass along the axis and centrally through the aperture 25.

The vertical deflection control system functions in the same manner for the vertical components of motion of the writing stylus as does the horizontal deflection control system just described for the horizontal components of the motion of the writing stylus. Unbalanced potentials developed across the coupling resistors 36 and 37 by reason of the vertical components of the displacement of the path of the electron beam through the aperture 25 are amplified by the vertical control amplifier 31 to vary the current through the vertical deflection coils 28 and 29 supplied by the potential source 38.

In the operation of the transmitting apparatus of Fig. 1, the control amplifiers 30 and 31 serve as feedback amplifiers in the respective deflection control circuits. It is necessary that the complex gain of the control amplifiers be of very large magnitude and of such a phase shift that negative feedback action occurs. Under such conditions the deflection coil currents are proportional to the amount of translation of the writing stylus from center of the writing surface, i. e., a point corresponding to the longitudinal axis of the tube. Since the theory of feedback circuits is well known in the wave transmission art, no further discussion is deemed necessary in the interests of brevity. However, reference may be made to a text entitled "Network Analysis and Feedback Amplifier Design" by H. W. Bode, Van Nostrand, 1945 and to United States Patent 2,102,671 issued December 21, 1937, to H. S. Black.

Since the control signals which are applied to the deflection coils correspond to the successive positions of the writing stylus as it moves across the writing surface 12, they may be utilized to control a remote reproducing instrument. The potential variations may be transmitted over independent circuits, or, as is shown in the drawing, may preferably be utilized to modulate high frequency carrier waves before transmission. Thus the output of the horizontal control am-

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plifier 39 may be connected through an amplifier 39 to a modulator 40 which is supplied by a source of carrier waves 41 of frequency f_1 and the modulated carrier waves transmitted over a line 42 to a remote station. In a similar manner the output of the vertical control amplifier 31 may be connected through an amplifier 43 to a second modulator 44 which is supplied with carrier waves of a frequency f_2 by a source 45 and the modulated waves transmitted over a line 46 to the remote station.

Referring now to Fig. 3, the modulated carrier waves received over lines 42 and 46 are detected by detectors 47 and 48 of well-known type to produce potentials which correspond in wave form to the control signals which are applied to the horizontal and vertical deflection coils of the transmitting cathode ray tube 1. The potentials indicative of the horizontal position of the transmitting stylus are derived from the detector 47, amplified by an amplifier 49, and the resulting potentials impressed upon the horizontal deflection plates 50 and 51 of the cathode ray tube 52. Similarly the potentials indicative of the vertical position of the transmitting stylus are derived from the detector 48, amplified by an amplifier 53, and the resulting potentials impressed upon the vertical deflection plates 54 and 55 of the cathode ray tube 52. The cathode ray tube 52 includes the usual electrode gun comprising a cathode structure 56, a modulating electrode 58, and a tubular anode 57. The cathode 56, heated by a potential source 58, and the source 59, connected between the cathode 56 and the anode 57, serve to form an electron beam which passes through the space formed by the deflecting electrodes 50, 51, 54 and 55 to strike the screen 60. It follows that the electron beam will be deflected electrostatically by the potentials impressed upon the electrodes 50, 51, 54 and 55 to produce upon the screen 60 a reproduction of the graph or diagram traced upon the face 12 of the transmitting cathode ray tube 10.

There is provided, as an additional feature of the invention, a separate channel for the control of the electron beam which impinges upon the face 60 of the receiving cathode ray tube 52 in accordance with the activity of the writing stylus at the transmitting station. Thus, when the writing stylus is applied to the surface 12 of the transmitting cathode ray tube 10, electrons leaving the photo-sensitive cathode 13 are directed through the aperture 25 so that a substantial portion of them reach the anode 15, as has been explained. The resultant current flow through the resistor 61 forms a control potential which is amplified by an amplifier 62. The output of the amplifier 62 is connected to a modulator 63 which serves to impress the control potentials upon a carrier of frequency f_3 supplied by a carrier source 64. The modulated carrier is transmitted over a line 65 to the remote station where the control potentials are derived from a detector 66, amplified by an amplifier 67, and applied to the control electrode 68 to permit the passage of an electron stream through the focusing anode 57 while writing is in progress. It will be seen that during inactive periods the intensity of the electron stream is greatly reduced so as to prevent the burning of the fluorescent screen 60.

It is, of course, unnecessary to use individual transmission lines since the modulated carrier waves, if their frequencies f_1 , f_2 and f_3 be sufficiently separated, may be readily transmitted over a common transmission line and separated by fil-

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ters in well-known manner. Moreover, in lieu of the transmission lines 42, 46 and 65, individual radio channels or a common radio channel may be employed. In the latter case, the modulated waves of frequencies f_1 , f_2 and f_3 may be used to modulate the principal radio frequency carrier wave.

While the invention has been described in connection with the reproduction of tracings or other graphic material which may be formed upon the face of the transmitting cathode ray tube by a special stylus or other radiation emitting device, it will be realized that the principle of the system described is by no means limited to such use. For example, a simplified version of the transmission apparatus might be well utilized for translating information recorded as strip graphs into electrical signals for the control of machine tools or other devices.

What is claimed is:

1. In an electrical control system, a large area photocathode adapted to emit electrons from any portion thereof, an anode associated with said cathode, means adjacent said anode for forming the electrons emitted from any portion of said cathode into an electron stream, means to generate voltages indicative of the portion of said cathode from which the stream originates comprising electrodes positioned to intercept a portion of said stream, and means adjacent said stream at a point relatively remote from said cathode for deflecting said stream to reduce to a minimum the lateral movement of said stream in the vicinity of said anode.

2. The invention in accordance with claim 1, in which said electrodes comprise a plurality of electrode elements between which the stream is passed before impinging on said anode, adapted to have variable voltages induced on them as variations occur in the lateral position of said stream, and means coupling said electrodes to the stream deflecting means.

3. An electrical wave transmission system comprising an electron discharge device having a large area photo-sensitive cathode, an anode, means for forming a concentrated stream of electrons from any given portion of said cathode to said anode and to vary the portion of the cathode at which the stream originates in continuous manner in accordance with a graph or trace to be transmitted, a first pair of plates positioned between said cathode and said anode, and relatively nearer to the anode, spaced to form an elongated slit in a plane perpendicular to the path of the electron stream, a second pair of plates adjacent and in a plane parallel to said first pair of plates to form a slit perpendicular to that formed by said first pair of plates, output circuits connected to said pairs of plates, and stream-deflecting means connected to said output circuits to receive currents therefrom and positioned adjacent said stream for maintaining the path of the electron stream centrally through the opening formed by the said pairs of plates.

4. In a facsimile system, cathode means for emitting electrons at successively varying distances from a reference axis, means for forming the electrons so emitted into a concentrated stream, electron stream deflecting means, electrodes positioned to form a central aperture coinciding with said axis at a point along the axis relatively remote from said cathode, said electrodes receiving induced voltages from the stream varying in magnitude with displacement of the stream from said axis, means to apply said volt-

ages to said deflecting means in proper sense to cause the stream to pass through said aperture regardless of the point on said cathode at which the stream originates, and means to transmit said voltages to a distant receiving point.

5. In a facsimile transmission system, a large area photo-sensitive cathode adapted to emit electrons from limited areas of the cathode at any instant, means for forming electrons so emitted into a concentrated stream, electron stream deflecting means, stream centering electrodes on the far side of said deflecting means from the cathode, connections from said electrodes to said deflecting means to maintain the stream displacements relative to said centering electrodes at a minimum, and cathode ray means for forming graphs in accordance with the currents applied to the said deflecting means.

6. In a system for transmitting graphical information, a large area cathode adapted for emission of electrons as a point source from different parts of its surface in accordance with a graph or trace, means to project the emitted electrons in a concentrated stream toward an anode, means to deflect the stream, means to generate voltages indicative of the point on the cathode from which the stream originates comprising means to derive from lateral movement of the stream voltages sufficient when applied to the deflecting means to effect restoration of the stream to substantially its normal position in the vicinity of said anode, and means to transmit said derived voltages to a distant point for use thereat in reproducing the graph or trace.

7. In a facsimile system, in combination, a transmitting station including an electron discharge device comprising a large-area cathode adapted to emit electrons from any point of its surface in response to impinging radiations, means to form the emitted electrons into a beam, an anode, and means to translate lateral movements of said beam into voltage variations, a receiving station including a cathode beam device

having beam-forming means, beam deflecting means, and voltage-controlled means for determining the intensity of the beam therein, means to apply said voltage variations to said beam deflecting means to correlate the beam movements in said devices, and means to apply to said voltage-controlled means a voltage derived from the flow of electrons from said cathode to said anode.

8. A transmitting system for graphic material comprising an elongated tube having an enlarged end coated with electron emissive material responsive to incident radiation to release electrons from the position exposed to such radiation, means to form the emitted electrons into a concentrated stream, an anode at the other end of the tube, electrodes adjacent the stream path near the anode, deflecting means between the cathode and said electrodes, connections including amplifiers from said electrodes to said deflecting means, said stream inducing on said electrodes voltages varying in accordance with the location of the point on the cathode from which the stream originates, said amplifiers applying the variable voltages so induced to the deflecting means to phase opposition to the stream movements to reduce movement of the stream relative to said electrodes to a minimum, and means to transmit said voltages for use in reproducing the graphic material.

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