Oct. 3, 1939. R. C. HERGENROTHER 2,174,580

CATHODE-RAY TUBE SYSTEM

Filed July 8, 1937

FIG. 1.

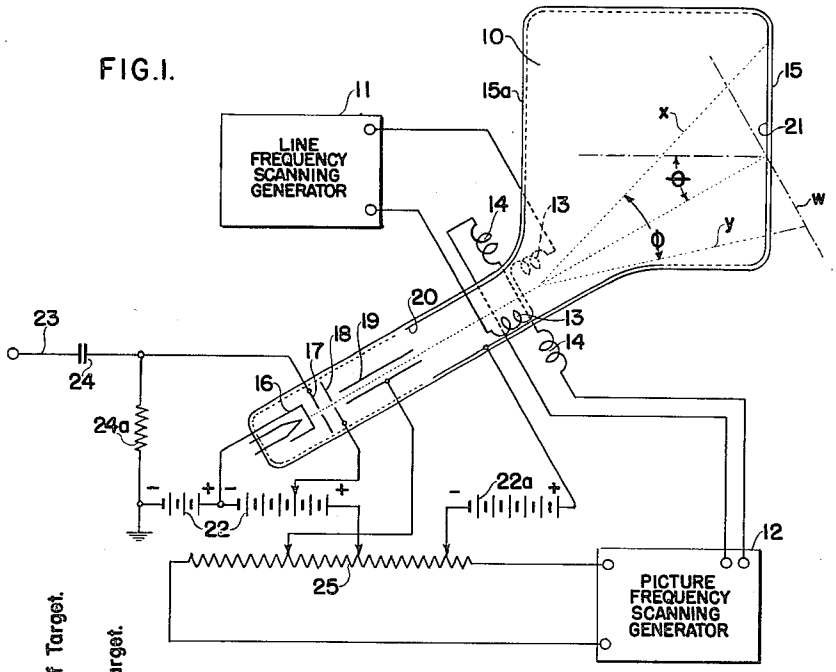


FIG. 2.

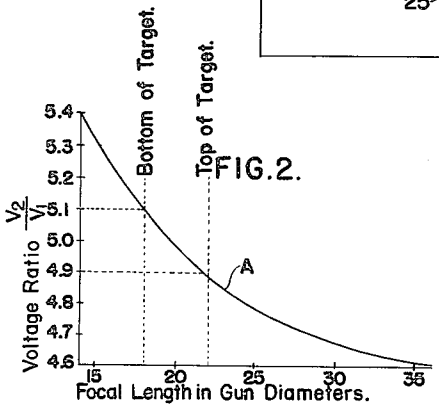


FIG. 3.

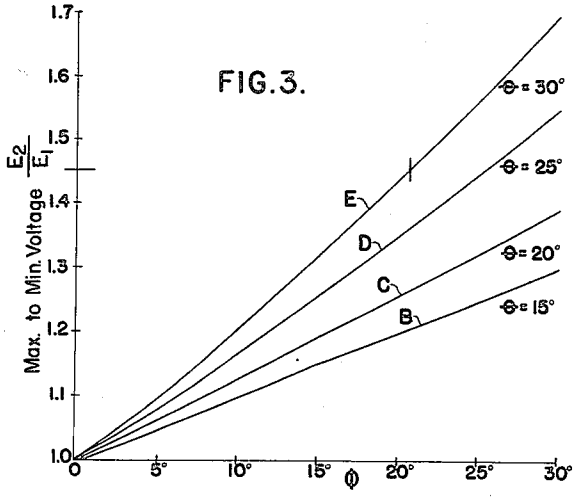
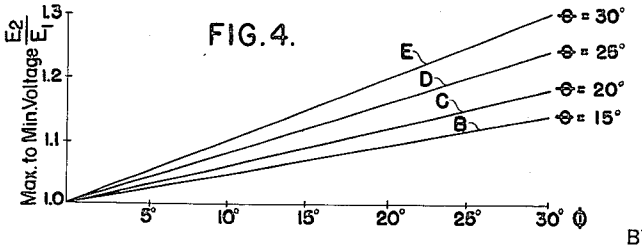


FIG. 4.



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CATHODE-RAY TUBE SYSTEM

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10 Claims. (Cl. 178—7.7)

This invention relates to cathode-ray tube systems and, more particularly, to cathode-ray tube systems useful in television transmitting and receiving systems.

Cathode-ray tubes of this type comprise, in general, an elongated envelope including at one end a plurality of electrodes, conventionally referred to as an electron gun, which serves to develop, focus, and accelerate a beam of electrons or cathode rays toward a target which is disposed in the envelope at the opposite end of the tube. In a signal-generating tube, the target includes a photosensitive surface and images of the scenes to be transmitted are focused thereon and produce photoelectric effects which vary over the extent of the target in accordance with the light intensity of corresponding portions of the images. Proper deflection of the cathode ray to scan the target develops video-frequency modulation voltages in the output circuit connected to the target. In a signal-reproducing tube, the target comprises a fluorescent screen which, when excited by the ray, becomes luminous. In this tube the intensity of the ray is modulated in accordance with the video-frequency components transmitted and the beam is deflected to scan the target in the same manner and in synchronism with the scanning system of the transmitter, so that the scene is reproduced on the fluorescent screen.

For effecting the desired scanning of the target by the cathode ray, either electrostatic or electromagnetic periodic fields are utilized to deflect the ray after it emerges from the electron gun. Ordinarily one field deflects the beam in one direction at a relatively high line frequency, while another field deflects the beam in a direction normal to that of the first field at a relatively low frame frequency, so that series of parallel lines, each series or frame representing a complete scene, are successively traced on the target.

For various reasons, it is frequently desirable to dispose the target at an angle to a plane perpendicular to the axis of the electron gun. For example, in the usual type of signal-generating tubes, the image is focused, through a transparent side of the tube, on the same side of the target as is scanned by the ray and in certain types of signal-receiving tubes, the luminous side of the target which is scanned by the ray is viewed, or the light therefrom is projected, through the transparent side of the tube. In such cases, in order that the electron gun will be out of the path of projection or view, the target is disposed at an angle of the order of 30 degrees to the axis of the electron gun. The gun is so adjusted that the beam, at its intermediate or undeflected position, is focused in the plane and approximately at the center point of the target. Due to the fact that points on the target spaced from this center point are at different distances from the electron gun, when the beam is deflected from this point it is correspondingly defocused with respect to the target. Where the target is disposed perpendicular to the axis of the electron gun, this defocusing is ordinarily not troublesome, but when the target is angularly disposed relative to a plane perpendicular to the axis of the gun, the angularity has two important undesirable effects owing to the fact that the different points thereof are substantially different distances from the focusing element of the electron gun: first, the defocusing of the beam, as explained above, becomes sufficient to cause substantial loss of definition of the signal developed by a signal-generating tube or in the scene reproduced by a signal-receiving tube; secondly, since in conventional scanning systems the deflecting fields cause the ray to scan a rectangular section perpendicular to the axis of the electron gun, when the target is angularly disposed a keystone configuration is scanned thereon, resulting in corresponding distortion in the configuration of the reproduced image.

It is an object of the present invention, therefore, to provide an improved cathode-ray tube system suitable for use in television signal-generating and signal-receiving systems, wherein the target is disposed at an angle to the axis of the electron gun and wherein undesirable effects, due to the angularity of the target, on the focusing of the beam and on the configurations scanned by the beam are compensated for and substantially avoided.

In accordance with the present invention, there is provided a cathode-ray tube system which comprises an electron gun, a target disposed at an angle to a plane perpendicular to the axis of the gun, and a scanning system for deflecting the ray to scan the target. Means are provided for controlling the focal length of the beam as a function of its deflection to compensate for the effect of the angularity of the target on the focusing of the beam. Means are also provided for controlling the axial component of the velocity of the beam as a function of this deflection to compensate for the effect of the angularity of the target on the configuration scanned thereon by the beam. By virtue of this arangement, the beam is maintained substantially in focus over the entire extent of the scanned portion of the

target and the desired rectangular pattern is traced thereon by the beam.

It has been found that the focal length of the beam is determined by, among other factors, the ratio of the voltages applied to focusing electrodes of the electron gun while the extent of the deflections of the beam produced by the scanning elements is dependent, among other factors, upon the velocity of the beam, which velocity is, in turn, determined by the potential applied to the focusing electrode nearest the target. In a preferred embodiment of the invention, therefore, the electron gun includes a cathode and a plurality of accelerating and focusing electrodes having suitable operating potentials applied thereto while the scanning system comprises means for generating saw-tooth waves which are applied to scanning elements to deflect the ray to scan the target in the conventional manner. A part of the saw-tooth voltage generated by the scanning system is applied between the focusing electrodes to adjust the ratio of their resultant potentials at the scanning frequency, thereby to vary the focal length of the beam in synchronism with the scanning action to maintain the beam in focus. A portion of this saw-tooth voltage is also applied between the focusing electrode nearest the target and the cathode thereby to effect the required control of the velocity of the beam.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, Fig. 1 is a schematic circuit diagram of a portion of a television receiver including a cathode-ray reproducing tube and scanning means and embodying the present invention, while Figs. 2, 3, and 4 are curves illustrating certain operating characteristics of the present invention to aid in the understanding thereof.

Referring now more particularly to Fig. 1 of the drawing, the portion of the television receiving system illustrated includes a cathode-ray reproducing tube **10** and line- and frame-frequency scanning generators **11** and **12** having their output circuits connected to deflecting coils **13** and **14**, respectively, of the tube **10**. The tube **10** comprises the usual evacuated envelope **15** having disposed therein an electron gun comprising, in the order named, an indirectly heated cathode **16**, a control grid **17**, a screen grid **18**, a first anode **19**, and a secod anode **20**, which generally comprises a conductive coating on the interior surface of the neck of the envelope. The electron gun serves to develop, accelerate, and focus a beam of electrons or cathode ray toward a fluorescent screen or target **21**, generally comprising a coating of fluorescent substance applied to the inner surface of the end of the tube, the successive elemental areas thereof becoming luminous when excited by the cathode ray during the scanning operation. The target **21** is disposed at an angle of approximately 30 degrees from a position normal to the axis of the electron gun, thereby permitting the inner surface of the target to be viewed through the opposite transparent end portion of the tube, or permitting the light image thereon to be projected through this portion of the tube, without obstruction from the electron gun.

Proper operating potentials are applied to the various electrodes of the cathode-ray tube from suitable sources, as, for example, batteries **22** and **22***a*, as shown. A lead **23** including a coupling condenser **24** and resistor **24***a* is provided for applying to the control grid **17** the video-frequency modulation voltages of the signal to be reproduced.

Since the operation of the system thus far described is well understood in the art, a detailed explanation thereof is unnecessary. Briefly, however, a cathode ray is developed, accelerated, and focused by the electron gun **16–20**, inclusive, toward the target **21** in the well-known manner. Scanning or deflecting currents developed by the generators **11** and **12** are supplied to the scanning coils **13** and **14**, respectively, to provide magnetic fields which deflect the ray horizontally and vertically, thereby to scan successive series or frames of horizontal parallel lines on the target. During this scanning action, the intensity of the ray is varied in accordance with the video-frequency modulation voltages applied to the control grid **17** by lead **23**, corresponding to different values of light and shade in successive elements of the images being transmitted, so that the images are reconstructed on the fluorescent screen by successive spots of light of varying intensity. Due to the angularity of the axis of the electron gun, the scene may be viewed through the opposite transparent side of the tube, indicated at **15***a*, or the light of the target may be projected therethrough on to a suitable screen structure, as desired.

While the arrangement as thus far described has proven generally satisfactory, the angularity of the target produces the objectionable effects on the focus of the beam and the configuration scanned on the target, as has been explained above.

In order to eliminate these defects, in the arrangement of Fig. 1, a voltage-dividing resistor **25** is included in the output circuit of the picture-frequency scanning generator **12**. By means of suitable adjustable taps, the cathode **16** of tube **15** is connected to an intermediate point on the resistor through a battery **22**, the second anode **20** is connected to a point near one terminal thereof by way of the battery **22***a*, and the first anode **19** is connected to a point near the opposite terminal thereof. By virtue of this arrangement, saw-tooth voltages of the scanning frequency and of predetermined amplitudes and opposite polarities with respect to the cathode **16** are applied to the first anode **19** and second anode **20**. The saw-tooth voltage applied to the second anode **20** is of such polarity and amplitude relative to cathode **16** as to adjust the velocity of the electron beam, and thereby its horizontal deflection, in accordance with the vertical deflection thereof and to the proper extent to compensate for the keystone effect normally caused by the angularity of the target. The saw-tooth voltage applied to the first anode **19** is of such polarity and amplitude relative to the second anode **20** that the ratio of the potentials of the anodes **19** and **20** varies in such manner that the focal length of the beam is adjusted in accordance with the vertical deflection thereof and to the proper extent to maintain the beam properly focused with respect to the target for all vertically deflected positions thereof. At the same time, the variation of the potential of anode **19** has no appreciable effect on the axial component of the velocity of the beam so that the two controls are substantially independent of each other. It will be noted that the voltages applied to the anodes

19 and 20, for effecting the desired corrections, are of opposite polarity with respect to the cathode 16. This difference in polarity, as well as the proper adjustment of the amplitudes of the correction voltages, is readily obtained in an extremely simple manner by means of the arrangement just described.

As mentioned above, in order to obtain the desired corrections, it is necessary for the correcting saw-tooth voltages to be of the proper amplitudes. Such amplitudes are dependent upon the geometry of the particular tube in connection with which the invention is utilized. These relations may be best explained with reference to the diagram of Fig. 1 and the curves of Figs. 2, 3, and 4. In Fig. 1 a plane normal to the axis of the gun is indicated by a broken line w, while the limiting vertical positions of the cathode ray are indicated by dotted lines x and y, clearly showing the difference in the distances of the different points on the target from the electron gun. A convenient unit of measurement in cathode-ray tube structures, for determining relative required proportions of the elements, has been found to be the diameter of the orifice of the electron gun. Hence, the distances from the gun to different points on the angularly disposed target 21 may be expressed in terms of gun diameters. Curve A of Fig. 2 illustrates the relation between the focal length of the beam and the ratio (V_2/V_1) of the voltage of the second anode 20 to that of the first anode 19, the abscissae representing the focal length of the beam, in gun diameters, and the ordinates representing the ratio of the voltage of the second anode to that of the first anode with respect to the cathode. It will be seen that, with the target angularly disposed so that the bottom thereof is, for example, a distance of approximately 18 gun diameters from the gun and its top at a distance of approximately 22 gun diameters therefrom, the voltage ratio must be varied from approximately 4.9 to approximately 5.1 as the beam is deflected from the top to the bottom of the target. Thus, in this instance, if the unidirectional potential on the second anode is maintained at 500 volts, when the beam is directed to the top of the target the voltage on the auxiliary anode should be approximately 102 volts (a voltage ratio of 4.9). The auxiliary anode voltage should be varied linearly as the beam is deflected from the top to the bottom of the target so that when it is directed to the bottom the first anode voltage is approximately 98 volts (a voltage ratio of 5.1). Hence, under these conditions a saw-tooth wave of approximately 4 volts in amplitude between anodes 19 and 20 is required to give the proper correction of the focal length and this may be obtained by properly adjusting the tap on the voltage divider 29 connected to the first anode 19.

The variation of the second anode voltage required for modifying the axial component of the velocity of the beam, in order to correct the keystone effect, is dependent upon both the angle of inclination of the target to a plane perpendicular to the axis of the electron gun and the vertical scanning angle, these angles being indicated as θ and ϕ, respectively, in Fig. 1. It has been found that the required voltage variation with electromagnetic scanning is determined by the formula:

$$\frac{E_2}{E_1}=\left[\frac{\cos\left(\theta-\frac{\phi}{2}\right)}{\cos\left(\theta+\frac{\phi}{2}\right)}\right]^2$$

where E_1 is the minimum second anode voltage and E_2 the maximum. In the case of electrostatic scanning, the above formula becomes:

$$\frac{E_2}{E_1}=\left[\frac{\cos\left(\theta-\frac{\phi}{2}\right)}{\cos\left(\theta+\frac{\phi}{2}\right)}\right]$$

In Fig. 3, there is shown a group of curves B, C, D, and E, each representative of angles of inclination, θ, of the target of 15°, 20°, 25°, and 30°, respectively. In this figure, the abscissae represent vertical scanning angles ϕ and the ordinates indicate the voltage ratio E_2/E_1. Referring, for example, to the curve E, representing a target inclination of 30°, if the arrangement is such that the vertical scanning angle is 20°, it will be seen that the required saw-tooth voltage is one which will effect a variation in the second anode voltage from maximum to minimum values having a ratio, E_2/E_1, of approximately 1.45; that is, a saw-tooth component of approximately 38% of the normal unidirectional operating voltage.

In Fig. 4, there is shown a group of curves corresponding to those of Fig. 3, but for an electrostatic scanning system. Substantially the same principles apply, but the required saw-tooth voltages are substantially less, when electrostatic scanning is employed.

In the embodiment of the invention illustrated, means are shown for correcting only the undesirable effects on the focus of the beam and the configuration of the scanning pattern due to the vertical angularity of the target. It will be apparent, however, that the principles of the present invention and circuits equivalent to those above described may be equally well employed to correct for the undesired effects horizontal angularity of the target.

While there has been described what is at present considered the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from this invention, and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A cathode-ray tube system comprising an electron gun, a plane target, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including the axis of said gun, whereby the length of the ray varies as a function of its deflection, and means for controlling the axial component of the velocity of said ray as a function of its deflection in said one of said directions to compensate for the effect of said variations in the length of said ray on the reconstructed image on said target.

2. A cathode-ray tube system comprising an electron gun, a plane target, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including the axis of said gun, whereby the length of the ray varies as a function of its deflection, and means for controlling the focal length of the ray and the axial component of its velocity as a function of its deflection in said one of said directions to maintain the ray in focus with respect to said

target and to compensate for the effect of said variations in the length of said ray on the reconstructed image on said target.

3. A cathode-ray tube system comprising an electron gun, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for controlling the axial component of the velocity of said beam as a function of its deflection in said one of said directions to compensate for the effect of the angularity of said target on the configuration scanned thereon by said ray.

4. A cathode-ray tube system comprising an electron gun, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for controlling simultaneously the focal length of said ray and the axial component of its velocity as independent functions of its deflection in said one of said directions, thereby to compensate for the effects of the angularity of said target on the focus thereon of said ray and the configuration scanned thereon by said ray.

5. A cathode-ray tube system comprising an electron gun including a cathode and a plurality of electrodes having suitable operating potentials applied thereto, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for adjusting the potential applied to the electrode nearest said target relative to said cathode at a scanning frequency to vary the axial component of the velocity of said ray as a function of its deflection in said one of said directions, thereby to compensate for the effect of the angularity of said target on the configuration scanned thereon by said ray.

6. A cathode-ray tube system comprising an electron gun including a cathode and a plurality of electrodes having suitable potentials applied thereto and including a pair of focusing electrodes, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for adjusting at a scanning frequency the ratio of the operating potentials applied to two of said electrodes and for simultaneously and independently adjusting the potential applied to the electrode nearest the target with respect to the cathode to vary the focal length of said ray and the axial component of its velocity as functions of its deflection in said one of said directions, thereby to compensate for the effects of the angularity of said target on the focus thereon of said ray and the configuration scanned thereon by said ray.

7. A cathode-ray tube system comprising an electron gun including a cathode and a pair of focusing electrodes having suitable potentials applied thereto, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for deriving from said scanning system a saw-tooth voltage and applying it between the electrode nearest the said target and said cathode to vary the axial component of the velocity of said ray as such a function of its deflection as to compensate for the effect of the angularity of said target on the configuration scanned thereon by said ray.

8. A cathode-ray tube system including an electron gun comprising a cathode and a plurality of electrodes including a pair of focusing electrodes having suitable operating potentials applied thereto, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for deflecting the ray in two directions normal to each other to scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, means for deriving from said scanning system a saw-tooth voltage and applying it between said focusing electrodes to adjust the ratio of the operating potentials, thereby to vary the focal length of said beam as such a function of its deflection in said one of said directions, as to compensate for the effect of the angularity of said target on the focus thereon of the beam, and means for applying a saw-tooth voltage between the electrode nearest said target and said cathode to vary the axial component of the velocity of said beam as such a function of its deflection in said one of said directions as to compensate for the effect of the angularity of said target on the configuration scanned thereon by said beam.

9. A cathode-ray tube system comprising an electron gun including a cathode and a plurality of electrodes having suitable potentials applied thereto, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system comprising means for generating a saw-tooth current, magnetic deflection coils and means for applying said current to said coils to deflect the ray in two directions normal to each other to scan said target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for deriving from said scanning system a saw-tooth voltage at said scanning frequency and applying it between the one of said focusing electrodes nearest said target and said cathode to control the axial component of the velocity of said beam as a function of its deflection in said one of said directions, thereby to compensate for the effect of the angularity of said target on the configuration scanned thereon by said ray.

10. A cathode-ray tube system including an electron gun comprising a cathode and a plurality of electrodes having operating potentials applied thereto and including a pair of focusing electrodes, a target disposed at an angle to a plane perpendicular to the axis of said gun, a scanning system including means for generating a saw-tooth current magnetic deflecting coil and means for applying said current to said coils to deflect the ray in two directions normal to each other and scan the target, one of said directions lying substantially in a plane normal to said target and including said axis, and means for deriving from said scanning system a saw-tooth voltage and applying at least a portion of said voltage with one polarity between said focusing electrodes

to adjust the ratio of their operating potentials, and for simultaneously applying at least a portion of said voltage with an opposite polarity between the one of said electrodes nearest the target and said cathode to control the focal length of said beam and the axial component of its velocity, as functions of its deflection, in said one of said directions, thereby to compensate for the effects of the angularity of said target on the focus thereon of said beam and the configuration scanned thereon by said beam.

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