

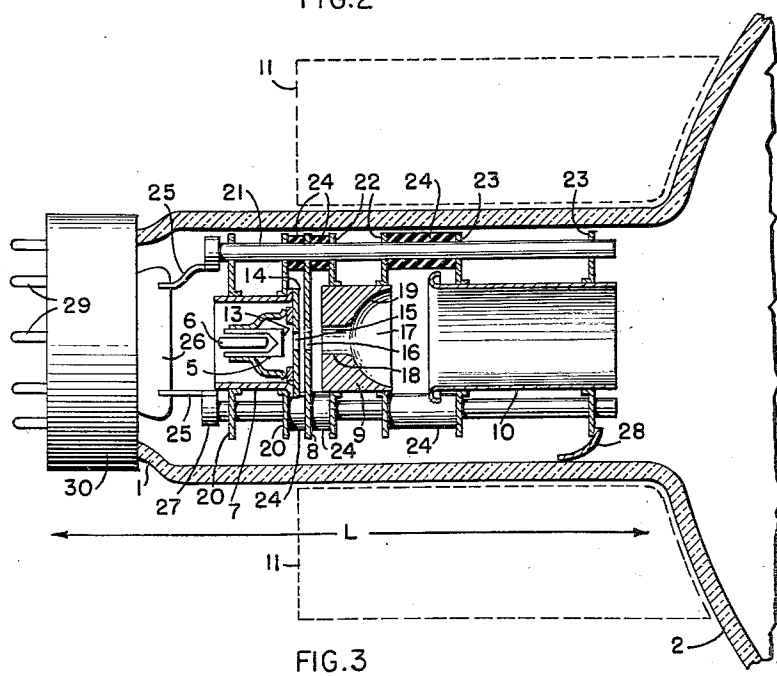
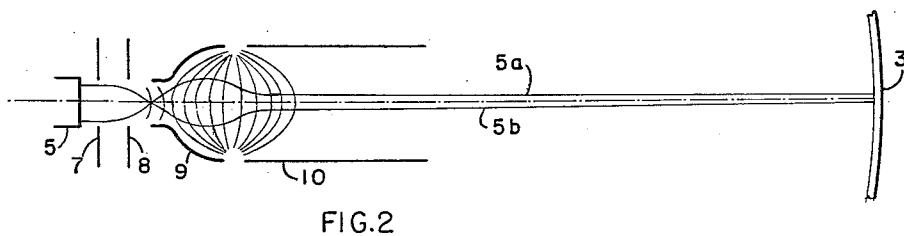
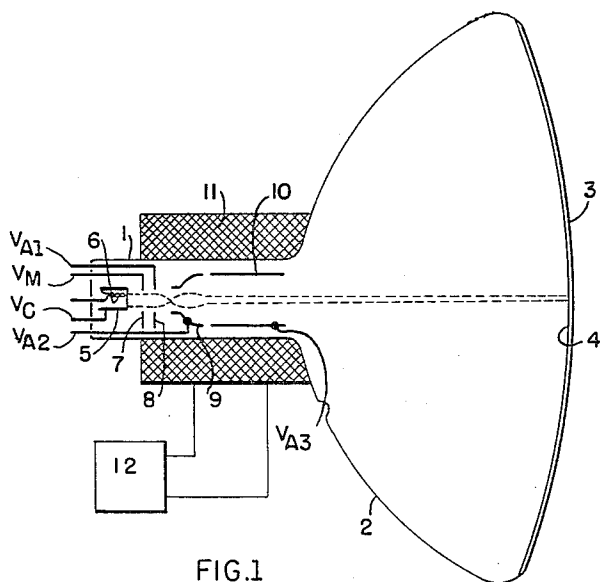
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ELECTROSTATIC FOCUSING SYSTEM

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ELECTROSTATIC FOCUSING SYSTEM

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General

This invention relates to electrostatic focusing systems and, particularly, to such systems useful in cathode-ray tube display devices for developing the required small diameter scanning spot on the phosphor display screen thereof.

In cathode-ray tubes heretofore proposed, especially those designed for television reception, the electrode assembly has hitherto usually been so constructed and operated that the electron beam first converges to form an electron crossover point a short distance from the cathode of the tube and then diverges to a diameter of several times the diameter at the crossover point, the beam subsequently being caused to converge so as to come to a focus on the display screen and produce a spot of the required small cross-sectional area. In this manner, the electrodes, in effect, constitute a two-lens system whereby the first lens is effective to cause the electrons leaving the cathode to pass through a common crossover point and the second lens is then effective to focus the image of this crossover point onto the display screen to produce the small scanning spot. Both electrostatic and magnetic lenses have been heretofore utilized in obtaining this focusing action. In the case of magnetic lenses, the magnetic focusing field is established by a suitable coil winding disposed adjacent the exterior of the tube envelope.

Both electrostatic and magnetic focusing systems heretofore proposed suffer from the disadvantage that they require a considerable axial length of the cathode-ray tube neck portion to render them effective. One reason for this in electrostatic focusing systems is that the rather large diameter of the beam while it is still within the focusing electrodes prevents scanning deflection of the beam from being carried out until after the beam has emerged from the focusing electrodes. An alternative form of focusing system which would require an appreciably shorter axial length of the cathode-ray tube neck would be advantageous as it would enable the over-all axial length of the cathode-ray tube to be reduced. Such reduction of axial length is especially desirable in television receiving apparatus for reducing the dimensions and cost of the cabinet required to house the apparatus.

In order to achieve a reduction in the axial length of the cathode-ray tube as a whole, by reducing the axial length of the flared-out portion thereof, there has recently been a tendency to increase considerably the angle of deflection of the electron beam. This has, however, with conventional cathode-ray tubes increased the incidence of a type of distortion known as deflection defocusing which results from the fact that the display screen is not in the form of a spherical surface concentric with the center of deflection. Usually, the curvature of the display screen has been much less than this ideal spherical curvature and, hence, the edges of the display screen are further from the center of deflection than is the middle of the display screen. As a result, an electron beam

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focused to a small spot at the middle is defocused to a large spot at the edges.

The present invention proposes to reduce the over-all length of a cathode-ray tube by providing a focusing arrangement which requires only a relatively short axial length of the cathode-ray tube neck to render it effective and which has the further advantage of being less subject to deflection defocusing than such structures heretofore proposed, hence, enabling reduction in the axial length of the flared-out portion of the cathode-ray tube. To accomplish the desired objectives, the present invention proposes to have the peripheral electrons leaving the cathode approach the crossover point at a relatively high beam angle, i. e., at a relatively large angle with respect to the longitudinal axis of the cathode-ray tube, a high beam angle being desirable for obtaining a small spot size on the display screen. In addition, the present invention proposes to squeeze or converge the electrons down to a narrow, substantially parallel-sided beam immediately after the electrons pass through the crossover point. As a consequence of the resulting narrowness of the beam, scanning deflection of the beam may be performed before the beam emerges from the focusing electrode structure, hence, giving rise to a tube neck of shorter axial length. Also, a narrow beam produces less deflection defocusing and hence enables use of greater deflection angles and shorter axial lengths of the flared-out portion of the tube. Less deflection defocusing occurs with a narrow beam because such a beam, being smaller, is in a more homogeneous region of the deflection field and, thus, all parts of the beam experience nearly the same angle of deflection.

Electrode systems have been heretofore proposed for converging electrons leaving a cathode source into a relatively narrow beam. In the previously proposed systems, however, strong converging fields are utilized and these fields extend back to the cathode region and, hence, adversely affect formation of the desired crossover point. In addition, the previously proposed electrode systems have not been concerned with the problem of tube length and, hence, have utilized more and lengthier focusing electrodes than is desirable.

It is an object of the invention, therefore, to provide a new and improved electrostatic focusing system which avoids one or more of the foregoing limitations of focusing systems heretofore proposed.

It is another object of the invention to provide a new and improved electrostatic focusing system which permits construction of cathode-ray tubes of shorter axial length.

It is a further object of the invention to provide a new and improved electrostatic focusing system which requires only a relatively short axial length of cathode-ray tube neck to render it effective and which has the further advantage of being less subject to deflection defocusing than other systems heretofore proposed.

In accordance with the invention, a minimum length electrostatic focusing system for a cathode-ray tube display device for focusing the electrons leaving the cathode thereof into a narrow beam within a minimum distance from the cathode comprises a first electrostatic lens system for producing a high-angle electron crossover point a minimum distance from the cathode. The focusing system also comprises a second electrostatic lens system positioned immediately adjacent the crossover point on the side thereof remote from the cathode for immediately converging the electrons into a narrow, substantially parallel-sided beam. The focusing system further includes electrode means disposed intermediate the first and second lens systems for minimizing interaction between electric fields of the first and second lens systems.

For a better understanding of the present invention, together with other and further objects thereof, reference

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is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring to the drawing:

Fig. 1 is a circuit diagram, partly schematic, of a complete cathode-ray tube including an electrostatic focusing system in accordance with the present invention;

Fig. 2 is a schematic diagram showing in more detail the focusing electrodes of the Fig. 1 cathode-ray tube, and

Fig. 3 is a schematic diagram showing in more detail the physical construction of the electrode assembly of a cathode-ray tube utilizing the present invention.

Description of Fig. 1 apparatus

Referring to Fig. 1 of the drawing, there is represented a cathode-ray tube having an envelope consisting of a cylindrical glass neck portion 1 and a flared-out or conical bulb portion 2 closed by a glass end plate 3 on the inner surface of which is deposited a fluorescent phosphor screen 4. The flared-out portion 2 is usually also of glass but may in some cases be made of metal. Shown within the neck of the cathode-ray tube is a thermionic cathode 5 which encloses a heater element 6 which serves to heat the cathode 5 and thereby cause the cathode to emit electrons. The cathode 5 is adapted to be energized by a suitable operating potential V_C .

Also shown within the neck portion 1 of the cathode-ray tube is an electrostatic focusing system constructed in accordance with the present invention. The focusing system comprises a first electrostatic lens system for producing a high angle electron crossover point a minimum distance from the cathode 5. This lens system includes the cathode 5, a control electrode 7, and an electrode 8 for modulating the electron intensity and for producing the desired high angle electron crossover point. The control electrode 7 may be, for example, in the form of an apertured plate located close to the cathode 5 and is adapted to be energized by a suitable operating potential V_M . The electrode 8 serves a dual purpose in the present invention and will be mentioned more fully hereinafter.

The focusing system further includes a second electrostatic lens system positioned immediately adjacent the crossover point on the side thereof remote from the cathode 5 for immediately converging the electrons into a narrow, substantially parallel-sided beam. This second lens system includes a cup-shaped electrode 9 having an aperture in the apex thereof, the apex being positioned immediately adjacent the crossover point on the side thereof remote from the cathode 5. The second lens system also includes a final high-potential electrode 10 for cooperating with the cup-shaped electrode 9 to produce a strong converging field within the cup region for converging the electrons into a narrow, substantially parallel-sided beam. The cup-shaped electrode 9 is adapted to be energized by a less positive operating potential, designated V_{A2} , than that supplied to an intermediate electrode 8 to be mentioned presently. In a similar manner, the high-potential electrode 10 is adapted to be energized by a potential, designated V_{A3} , which is many times more positive than that of the intermediate electrode 8.

The cup-shaped electrode 9 consists of a portion, designated the apex, of relatively small diameter nearer the cathode 5 which flares to a greater diameter in the direction away from the cathode 5. The inner surface of the cup-shaped electrode 9 may be, for example, in the form of a surface of revolution, the first portion being of cylindrical or conical shape and of relatively small diameter so as to surround the electron beam relatively closely at the end nearer the cathode 5 and this portion flaring outwardly to a diameter many times that of the beam at the opposite end of this electrode.

The cup-shaped electrode 9 may be, for example, in

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the form of a solid block of either conducting or insulating material with the inner region formed by hollowing out the center of the block in the proper fashion. Where a block of insulating material is used, the inner surface of the block is provided with an electrically conducting coating. Alternatively, the cup-shaped electrode 9 may be formed of sheet metal bent or pressed to the required shape.

The high-potential electrode 10 is preferably cylindrical in shape, aligned coaxially with the cup-shaped electrode 9, and of approximately the same diameter as the flared end of that electrode. This high-potential electrode 10, however, may, in some cases, be of a different form, for example, in the form of an apertured metal plate. Also, a graphite coating may be applied to the inner surface of the flared-out portion 2 of the cathode-ray tube envelope and connected to the high-potential electrode 10 by some suitable internal connection.

The electrostatic focusing system also includes electrode means disposed intermediate the first and second lens systems for minimizing interaction between electric fields of the first and second lens systems. This electrode means includes the electrode 8 which is adapted to be energized by a more positive potential, designated V_{A1} , than that supplied to the control electrode 7. This electrode 8 is shown in the form of an apertured metal plate located close to the control electrode 7 and may, in some cases, be provided by a partition extending across a suitable cylindrical electrode structure.

Around the neck portion 1 of the cathode-ray tube near its junction with the flared-out portion 2 are fitted conventional electromagnetic deflection coils 11 arranged for deflecting the electron beam in two mutually perpendicular directions in a conventional manner. In operation, the coils 11 are connected to a suitable sweep-signal generating means 12 for supplying the coils with the required scanning currents to cause the electron beam to scan the display screen 4 in a conventional manner.

Operating potentials V_C , V_M , V_{A1} , V_{A2} , and V_{A3} for the various electrodes are supplied by suitable voltage supply means (not shown) which may be coupled to the electrodes by way of suitable leads passing out through the envelope of the cathode-ray tube. Where the cathode-ray tube is to be utilized in a conventional television receiver, these operating potentials may be supplied by the usual voltage supply circuits thereof.

Operation of Fig. 1 apparatus

Considering the operation of the apparatus just described, reference will be had to Fig. 2 of the drawing which shows the various electrodes of the Fig. 1 apparatus in more detail, the same reference numbers being used for corresponding electrodes of the two figures. Initially, electrons are emitted from the heated cathode 5 and these electrons are subsequently shaped to form the desired electron beam. Representative electron paths are indicated by the rays 5a and 5b. These rays, being intended as representative only, are for the purposes of illustration somewhat exaggerated, particularly with respect to the diameter of the beam.

The control electrode 7, in addition to modulating the electron intensity in a conventional manner in order to produce the desired light patterns on the display screen 3, also operates in conjunction with the electrode 8 and cathode 5 to produce a focusing field for causing the electrons leaving the cathode 5 to pass through a crossover point on the axis of the tube a certain distance from the cathode 5. As is understood in the art, crossover "point" does not mean an infinitesimal "point" through which all the electrons actually pass. It would, of course, be ideal for all the electrons to pass through such an infinitesimal point, but in practice the precise point at which an electron crosses the tube axis depends on the initial direction in which the electron is emitted from the cathode. As a result, the electrons cross the tube axis

over a small area and not at a precise point. For convenience, the crossover point may be thought of as the point along the tube axis at which electrons emitted normal to the surface of the cathode cross the tube axis. The control electrode 7 is positioned so as to cause the crossover point to occur as close as possible to the cathode 5. In addition, the control electrode 7 is positioned and operated such that a well-defined crossover point is obtained in order that the diameter of the electron beam at the crossover point may be as small as possible. As a result, the majority of the electrons leaving the cathode 5 approach the crossover point at a relatively high beam angle.

The operating potentials supplied to the cup-shaped electrode 9 and high-potential electrode 10 serve to establish within the cup region a strong converging field as indicated by the representative equipotential lines shown in Fig. 2. It is desired to converge the electrons into a narrow beam; hence, this strong converging field is positioned as closely as possible to the crossover point so as to act on the electrons emerging from the crossover point before they have had an opportunity to diverge appreciably. As a result, the electrons are squeezed down to a narrow and substantially parallel-sided beam as indicated by the representative rays 5a and 5b. Actually, the electron beam, when properly focused on the display screen 4, is probably very slightly convergent after passing through this lens, but it is very narrow everywhere along its subsequent path and hence is, from a practical standpoint, substantially parallel sided. In addition to enhancing the converging action, the cup shape of electrode 9 also serves to shield the control electrode region from the strong converging field.

The electrode 8 which is positioned intermediate the control electrode 7 and the cup-shaped electrode 9 operates in conjunction with the control electrode 7 to produce a well-defined crossover point. In addition, the presence of electrode 8 serves to minimize the effect of the strong converging field within the cup-shaped electrode 9 on the shape of the crossover point and in this manner makes it possible to place the converging field as closely as possible to the crossover point and still maintain a well-defined crossover point. To achieve this, it has been found that the operating potential supplied to the electrode 8 should be somewhat more positive than the operating potential supplied to the cup-shaped electrode 9.

It is thus apparent that the main objectives of the present invention are to form a well-defined electron crossover point as close as possible to the cathode 5 and then to squeeze or converge the electrons into a narrow, substantially parallel-sided beam as soon as possible after they pass through the crossover point. Because the electrons are reduced to a narrow beam, scanning deflection may be performed on the beam while it is still within the focusing electrodes. This is indicated in the Fig. 1 drawing by the fact that the scanning coils 11 are shown disposed over the focusing electrodes. As a result, a shorter axial length of the neck portion 1 of the cathode-ray tube is required. The increase in diameter of the focusing electrode system due to the flare out of the cup-shaped electrode 9 is additionally helpful in that it serves to reduce the possibility of shadows due to the electron beam striking the electrode structure 10.

It will also be apparent that because of the electron beam being very narrow, the increased length of the beam resulting from deflection to an edge of the display screen 4 will not result in any appreciable increase in the area of spot on the display screen, except possibly that resulting from the obliquity of incidence. In other words, deflection defocusing is considerably minimized. This in turn permits utilization of larger deflection angles and, hence, permits construction of tubes wherein the axial length of the flared-out portion 2 is less for a given size of display screen.

Description of Fig. 3 apparatus

Referring now to Fig. 3 of the drawing, there is shown in detail, the physical construction of a cathode-ray tube which has been constructed in accordance with the present invention and which was especially designed for use in television reception. The cathode-ray tube there shown has a sealed and evacuated glass envelope consisting of a flared-out bulb portion 2 (only part of which is showing) in the approximate shape of a hollow truncated cone continued at the small end by a cylindrical neck portion 1 in which the electrode assembly of the tube is located. The tube is closed at the larger end (not shown) by a substantially flat glass end wall approximately 14 inches in diameter and carrying a coating of phosphor material on its inner surface.

The electrode assembly itself comprises a cathode 5 consisting of a hollow metal cylinder within which is located the cathode heater 6. The cathode cylinder, which is about 3 millimeters in diameter, is closed at one end and provided on the outer surface of the closed end with a coating 13 of electron emissive material. The cathode cylinder 5 is supported axially within a thin-walled cylindrical control electrode structure 7 which is 10 millimeters in diameter. The closed end of the cathode is located adjacent to a closed end 14 of the control electrode structure 7 and the combined assembly is located within the neck portion 1 of the cathode-ray tube envelope with the coated end of the cathode 5 facing the phosphor screen of the tube. The spacing between the closed ends of the cathode 5 and the control electrode structure 7 is 0.25 millimeter when the cathode is cold, this value decreasing to about 0.13 millimeter as the cathode attains its operating temperature. The closed end 14 of the control electrode structure 7 has a thickness of 0.2 millimeter and the end is perforated by a cylindrical hole 15 which is 0.8 millimeter in diameter and is located opposite the center of the coated end of the cathode 5 to allow passage of electrons therethrough during operation of the tube. For supporting the cathode control electrode assembly within the cathode-ray tube envelope and for aligning it with the other electrodes of the tube, two triangular metal flanges 20 are attached to the control electrode structure 7 near to its ends, the flanges extending radially outward and being provided near their apices with holes through which pass three parallel seatite support rods 21.

Between the closed end 14 of the control electrode structure 7 and the display screen is located a first electrode 8 in the form of a flat metal plate 0.2 millimeter thick. The electrode 8 is arranged parallel to, and 0.8 millimeter from the end 14 of the control electrode structure 7 and is perforated by a hole 16 coaxial with the hole 15 in the control electrode structure and of the same diameter. The electrode plate is itself substantially in the shape of a triangle the same size as the metal supporting flanges 20 on the control electrode structure 7, the outer part of the electrode plate itself providing the supporting flange for mounting the electrode 8 on the seatite support rods 21.

A cup-shaped electrode 9 is located on the side of the electrode 8 remote from the control electrode structure 7 and consists of a cylindrical metal block 6 millimeters in length and 10 millimeters in diameter. This block is arranged coaxially with respect to the cathode 5 and spaced 0.8 millimeter from the nearer surface of the electrode 8.

The end of the cup-shaped electrode 9 facing the display screen of the tube is recessed by a partially spherical depression 17 of 5 millimeters radius extending for a depth of about 4.2 millimeters into the metal block. A cylindrical hole 18, 3 millimeters in diameter and extending coaxially the rest of the way through the metal block, is provided to permit a passage for the electrons through this electrode during the operation of the tube. The part of the inner surface of the electrode 9 where the

end of the hole 18 meets the depression 17 is provided with a rounded edge 19 of 0.5 millimeter radius so that the surface of the hole merges smoothly into the surface of the recess, the center of curvature of the edge being located 1.3 millimeters from the end surface of the block facing the cathode 5. Triangular flanges 22 are attached to the electrode block 9 in a manner similar to the flanges 20 on the control electrode structure 7 for mounting the electrode 9 on the support rods 21.

A high-potential electrode 10 in the form of a thin-walled hollow metal cylinder 20 millimeters long and 10 millimeters in diameter is located between the cup-shaped electrode 9 and the display screen of the tube coaxial with the cup-shaped electrode 9 and spaced a distance of 3 millimeters from it. The high-potential electrode 10 is also mounted on the support rods 21 by means of triangular metal flanges 23 in a manner similar to the control electrode structure 7 and the cup-shaped electrode 9.

The axial spacing between the electrodes is effected by means of steatite spacing washers 24 of appropriate thickness placed on the support rods 21 between the electrode flanges and against which the flanges abut, the two outer flanges on the control electrode structure 7 and the high-potential electrode 10 being attached to the rods 21 by means of metal clamping clips to fix the position of the electrodes on the rods and to hold the flanges tightly against the washers 24 for preventing axial movement of the electrodes. For simplicity, the clips have not been shown in the drawing. The rods 21 themselves are axially positioned within the neck of the cathode-ray tube by means of stout support wires 25 which are sealed at one end into a glass pinch 26 at the end of the neck portion of the cathode-ray tube envelope. These support wires 25 are attached to the steatite support rods 21 by means of metal clamping clips 27. The support wires also prevent transverse movement at the control electrode end of the assembly the opposite end of the assembly being positioned centrally within the neck of the cathode-ray tube by means of metal spring fingers 28 which are welded to the flange 23 on the high-potential electrode 10 nearer to the display screen and which extend outwardly to abut resiliently against the inner surface of the neck portion 1.

Leads to electrodes, which have been omitted for simplicity, connect the electrodes to suitable terminals, in a conventional manner, the high-potential electrode being connected to a side contact (not shown) sealed into the wall of the bulb section 2 of the envelope and the other electrodes being connected to terminal pins 29 extending axially from an insulating cap 30 attached to the end of the neck portion 1.

In the operation of this cathode-ray tube, the following operating potentials have been found to give the desired performance:

Cathode 5 (V_C)	0 volt.
Control electrode 7 (V_M)	-30 volts (mean).
Electrode 8 (V_{A1})	350 to 450 volts.
Electrode 9 (V_{A2})	300 to 400 volts.
Electrode 10 (V_{A3})	14,000 volts.

The exact values of these potentials will, of course, vary according to the nature and spacing of the electrodes, and, consequently, it is not intended to limit the scope of the invention by a recitation thereof. With these applied potentials, an electron beam is produced having a crossover point between the electrodes 8 and 9. By suitable adjustment of the potential of the cup-shaped electrode 9, the electrons may be formed into a narrow, substantially parallel-sided beam by the electrostatic lens system formed between the electrodes 9 and 10. An approximate value for the electrode 9 voltage is 400 volts, the exact value varying for different tubes owing to slight variations in the shape and mounting of the electrodes during manufacture of the tubes. For this reason, the

voltage applied to the cup-shaped electrode 9 is preferably arranged to be controllable, in order to compensate for such variations and to enable the diameter of the beam to be adjusted to its optimum value for obtaining a beam spot on the display screen of minimum size.

In a cathode-ray tube constructed as described, a luminous beam spot having a minimum diameter of about 0.4 millimeter measured under picture conditions was obtained on the display screen. Little defocusing of the spot was apparent as the beam was deflected towards the edge of the display screen.

The length of the neck portion 1 of the cathode-ray tube envelope, between the part where the neck portion 1 joins the flared-out bulb portion 2 and the further end of the terminal cap 30 (as indicated by the line L is about 12 centimeters, whereas conventional tubes having known types of electrode systems including electrostatic focusing electrodes generally have a corresponding neck length of about 16-18 centimeters, so that a reduction of about 4-6 centimeters in the over-all length of the tube envelope was obtained. The primary aim in constructing this tube, however, was to determine the soundness and practicability of the basic ideas involved and, hence, no attempt was made to utilize the features of the present invention to a maximum degree.

From the foregoing description of the invention, it will be apparent that an electrostatic focusing system constructed in accordance with the present invention permits construction of cathode-ray tubes of reduced over-all axial length.

While there has been described what is at present considered to be 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 the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A minimum length electrostatic focusing system for a cathode-ray tube display device for focusing the electrons leaving the cathode thereof into a narrow beam within a minimum distance from the cathode, the focusing system comprising: a sharply convergent electrostatic lens system for producing a high angle electron crossover point a minimum distance from the cathode; an electrostatic collimating lens system positioned immediately adjacent the crossover point on the side thereof remote from the cathode for immediately converging the electrons into a narrow, substantially parallel-sided beam; and electrode means disposed intermediate the lens systems for minimizing interaction between electric fields thereof.

2. A minimum length electrostatic focusing system for a cathode-ray tube display device for focusing the electrons leaving the cathode thereof into a narrow beam within a minimum distance from the cathode, the focusing system comprising the following components disposed along the tube axis adjacent the cathode in the following order: a control electrode for modulating the electron intensity and for producing a high-angle electron crossover point a minimum distance from the cathode; an electrode for minimizing interaction between the electric field within the control-electrode region and electric fields developed by subsequent electrodes; a cup-shaped electrode having an aperture in the apex thereof, the apex being the part closest the cathode and the aperture being positioned immediately adjacent the crossover point on the side thereof remote from the cathode; and a final high-potential electrode for cooperating with the cup-shaped electrode to produce a strong converging field within the cup region for converging the electrons into a narrow, substantially parallel-sided beam immediately after the crossover point.

3. A minimum length electrostatic focusing system for a cathode-ray tube display device for focusing the elec-

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trons leaving the cathode thereof into a narrow beam within a minimum distance from the cathode, the focusing system comprising the following components disposed along the tube axis adjacent the cathode in the following order: a control electrode for modulating the electron intensity and for producing a high-angle electron crossover point a minimum distance from the cathode; a second electrode energized by a more positive potential than the control electrode for minimizing interaction between the electric field within the control-electrode region and electric fields developed by subsequent electrodes; a cup-shaped electrode energized by a less positive potential than that of the second electrode and having an aperture in the apex thereof, the apex being the part closest the cathode and the aperture being positioned immediately adjacent the crossover point on the side

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thereof remote from the cathode; and a final high-potential electrode energized by a potential many times more positive than that of the second electrode for cooperating with the cup-shaped electrode to produce a strong converging field within the cup region for converging the electrons into a narrow, substantially parallel-sided beam immediately after the crossover point.

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