June 11, 1957 D. GABOR 2,795,729

CATHODE RAY TUBE

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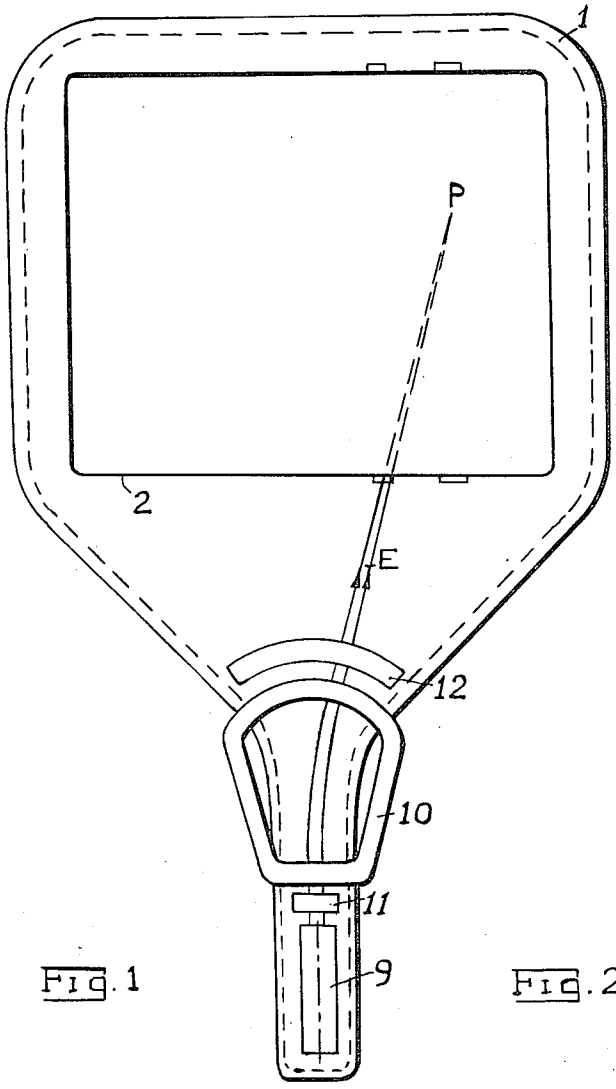


FIG. 1

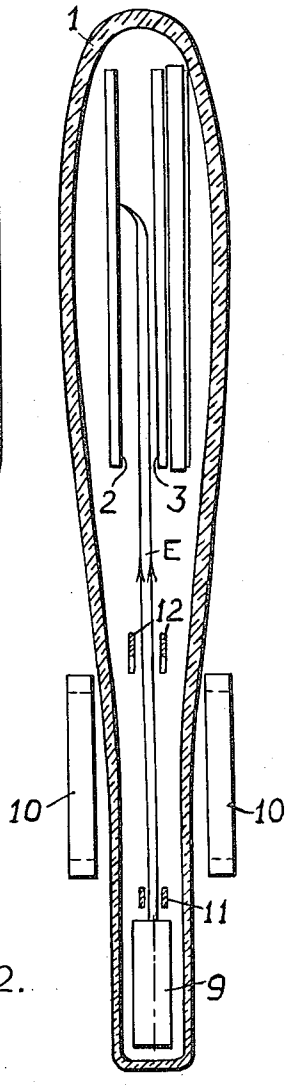


FIG. 2.

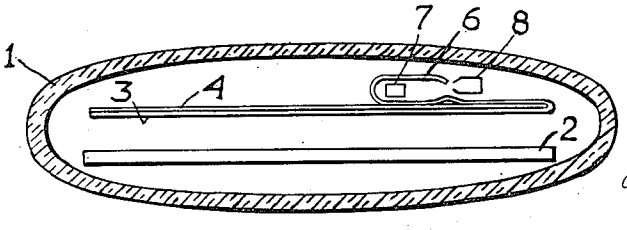


FIG. 3

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

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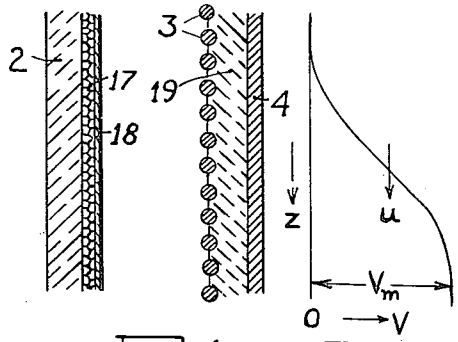


Fig. 4. Fig. 5.

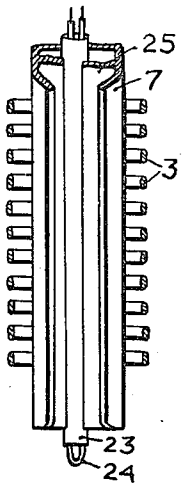


Fig. 7.

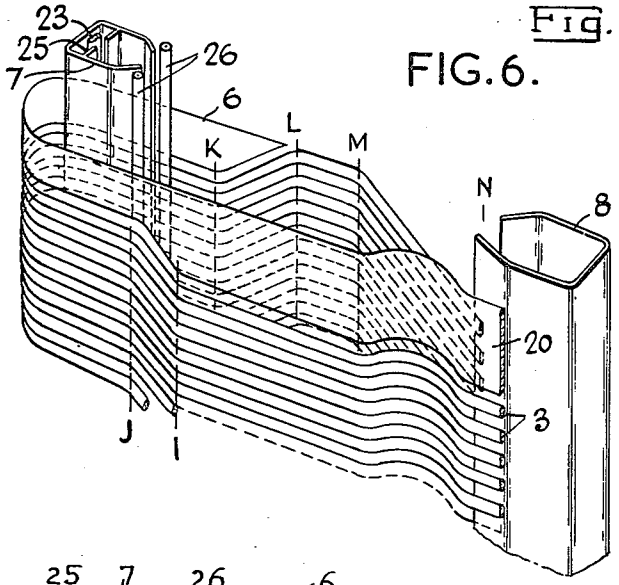


FIG. 6.

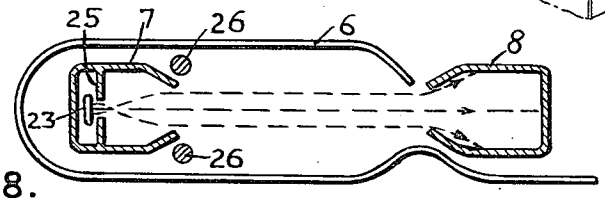


Fig. 8.

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

ATTORNEYS

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CATHODE RAY TUBE

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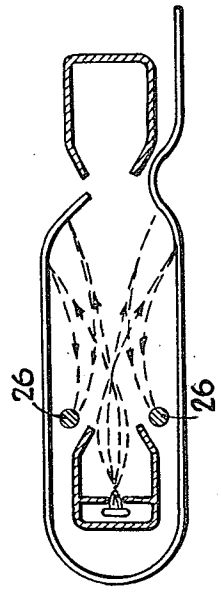


FIG. 10.

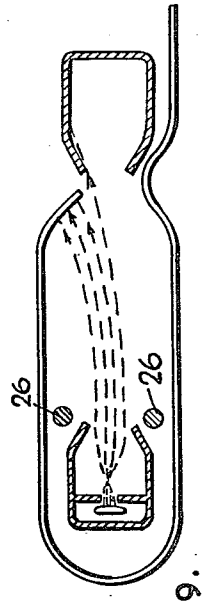


FIG. 9.

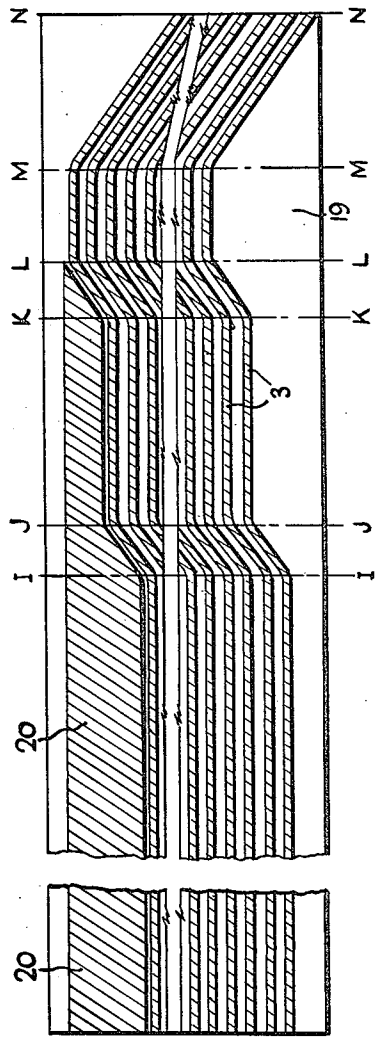


FIG. 11.

INVENTOR
Dennis Gabor

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ATTORNEYS

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CATHODE RAY TUBE

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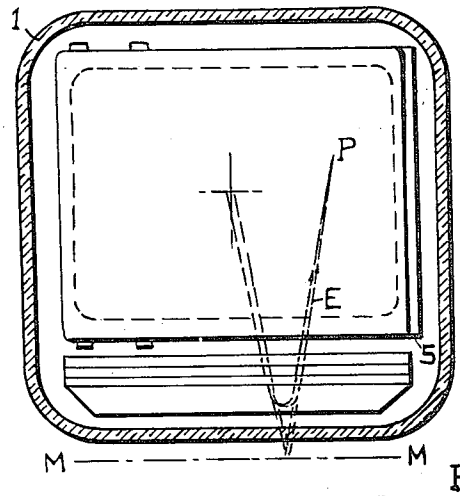


FIG. 12

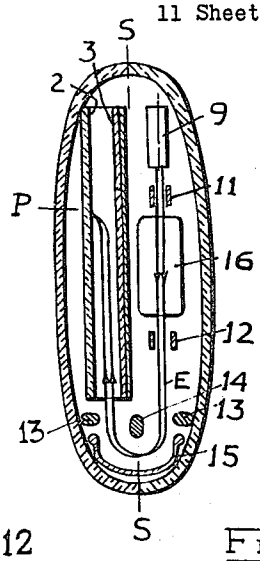


FIG. 13.

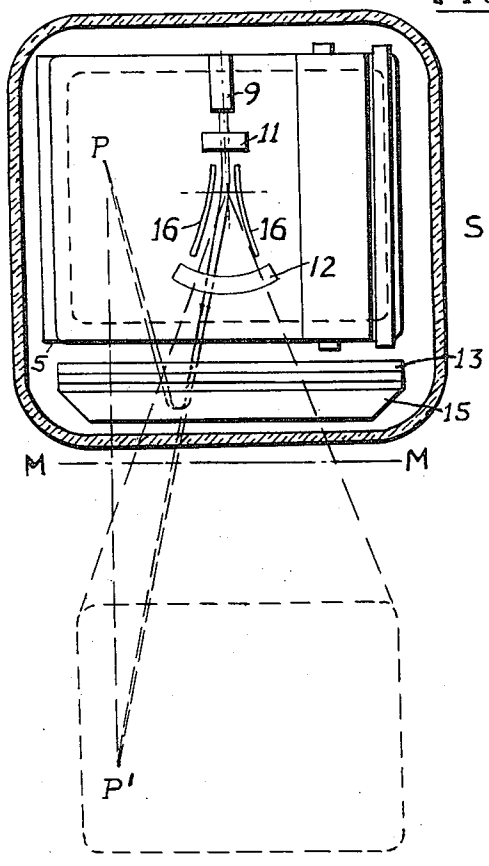


FIG. 14.

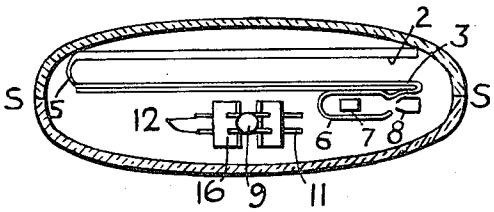


FIG. 15.

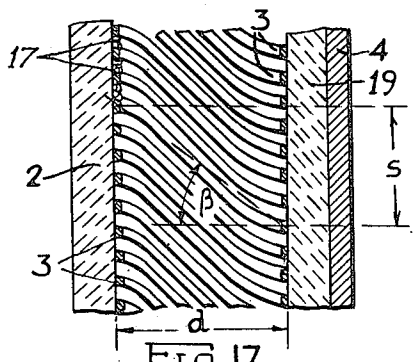


FIG. 17.

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

ATTORNEYS

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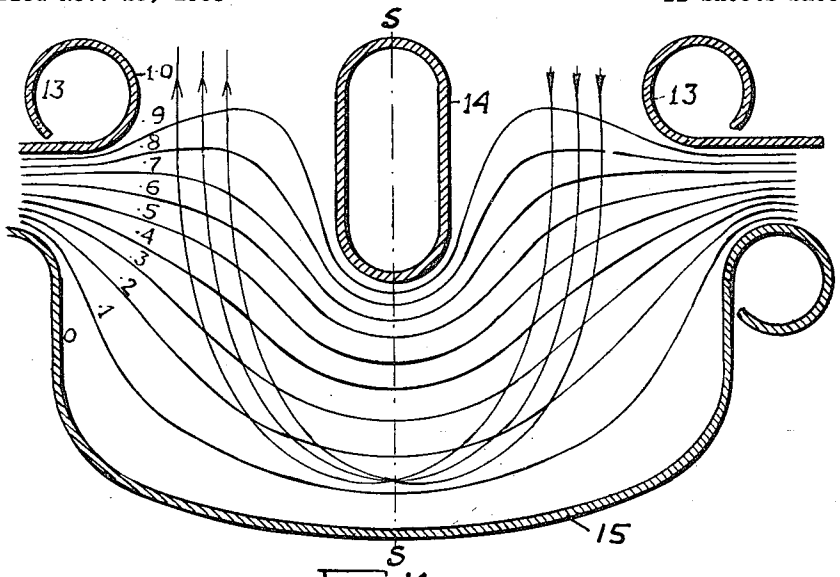


Fig. 16.

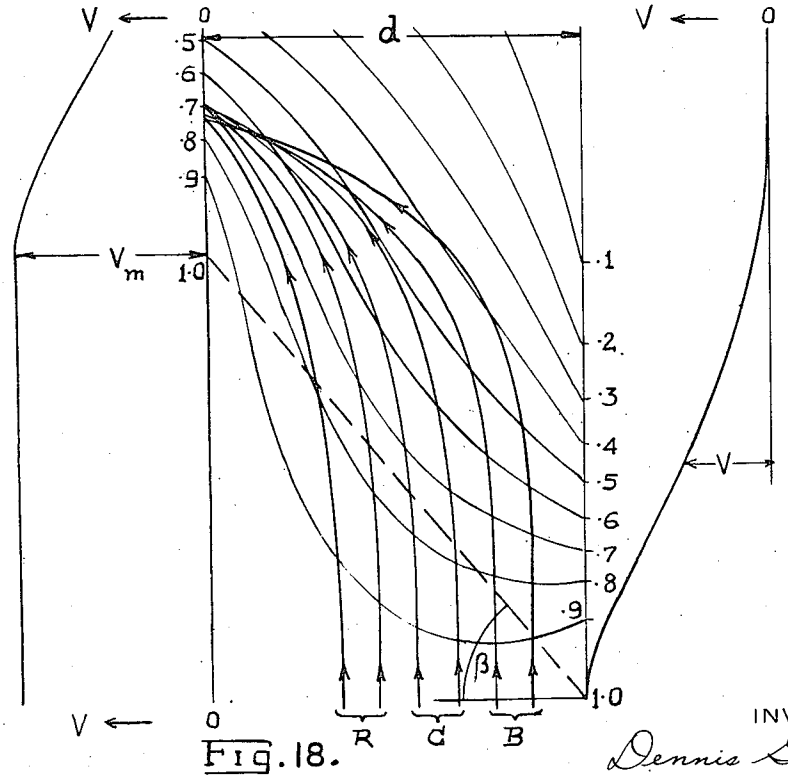


Fig. 18.

INVENTOR
Dennis Gabor

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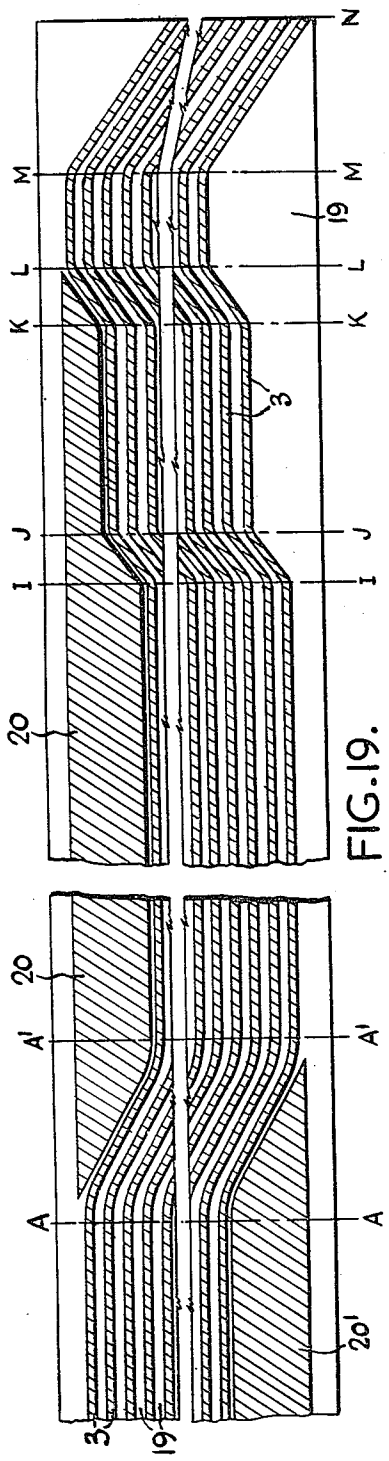


FIG. 19.

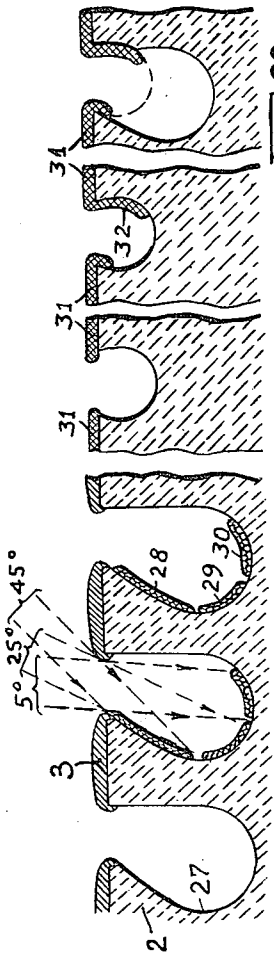


FIG. 20.

FIG. 21

FIG. 22.

FIG. 23.

INVENTOR
Dennis Gabor

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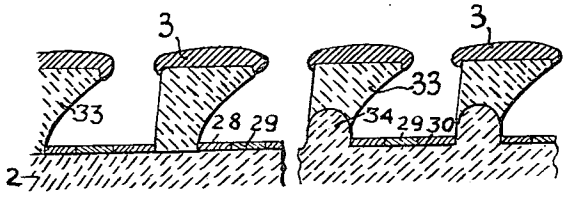


FIG. 24.

FIG. 25.

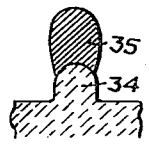


FIG. 26.

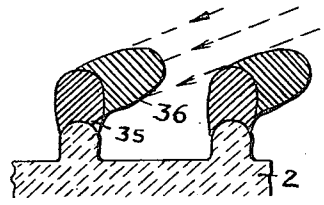


FIG. 27.

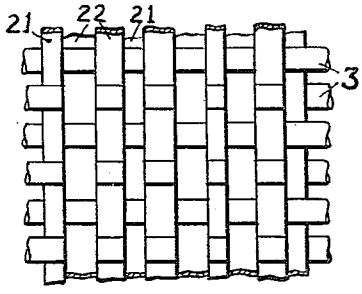


FIG. 28.

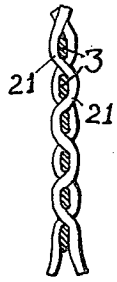


FIG. 29.

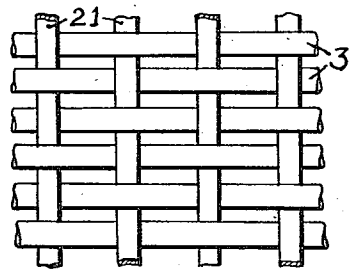


FIG. 30.

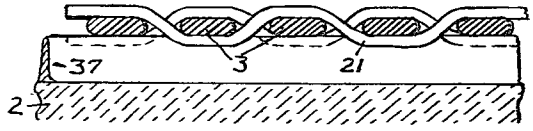


FIG. 31

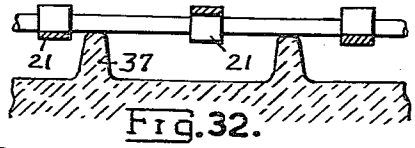


FIG. 32.

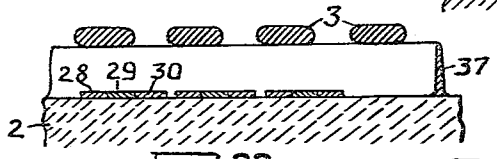


FIG. 33.

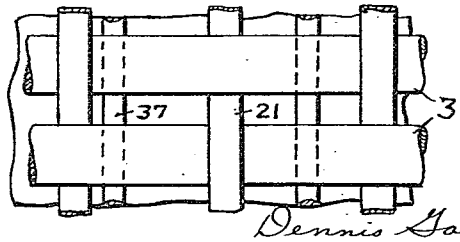


FIG. 34.

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

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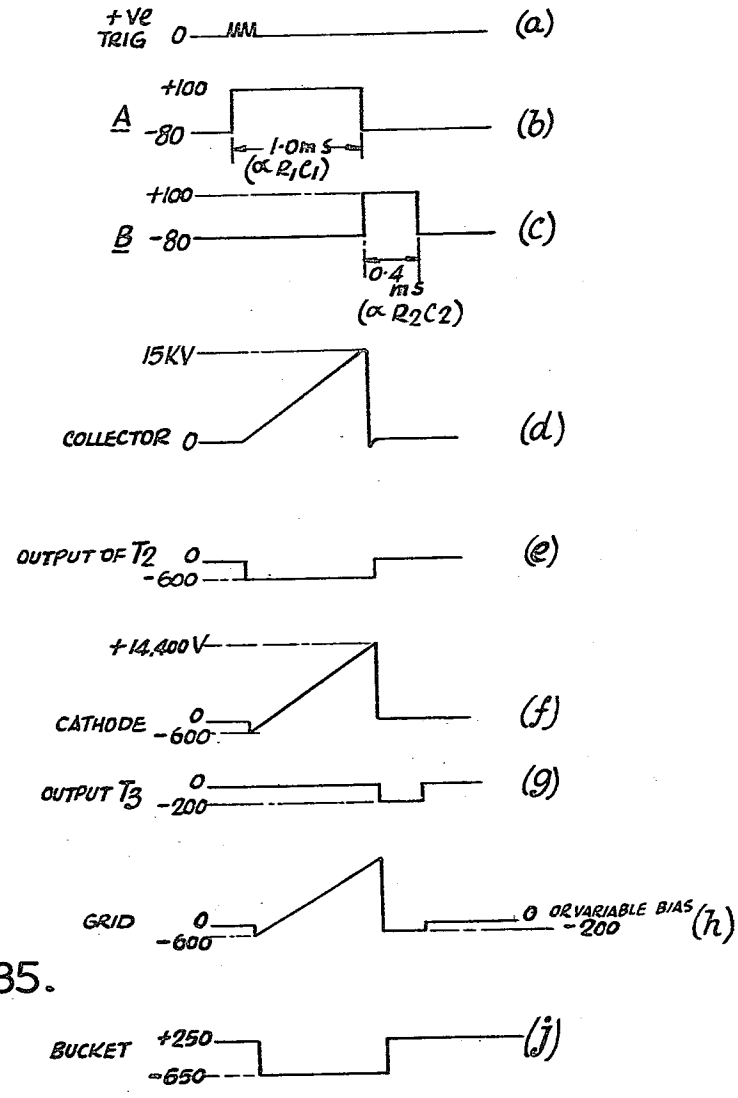


FIG. 35.

INVENTOR
Dennis Gabor
BY Cameron, Kerkam & Sutton
ATTORNEYS

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CATHODE RAY TUBE

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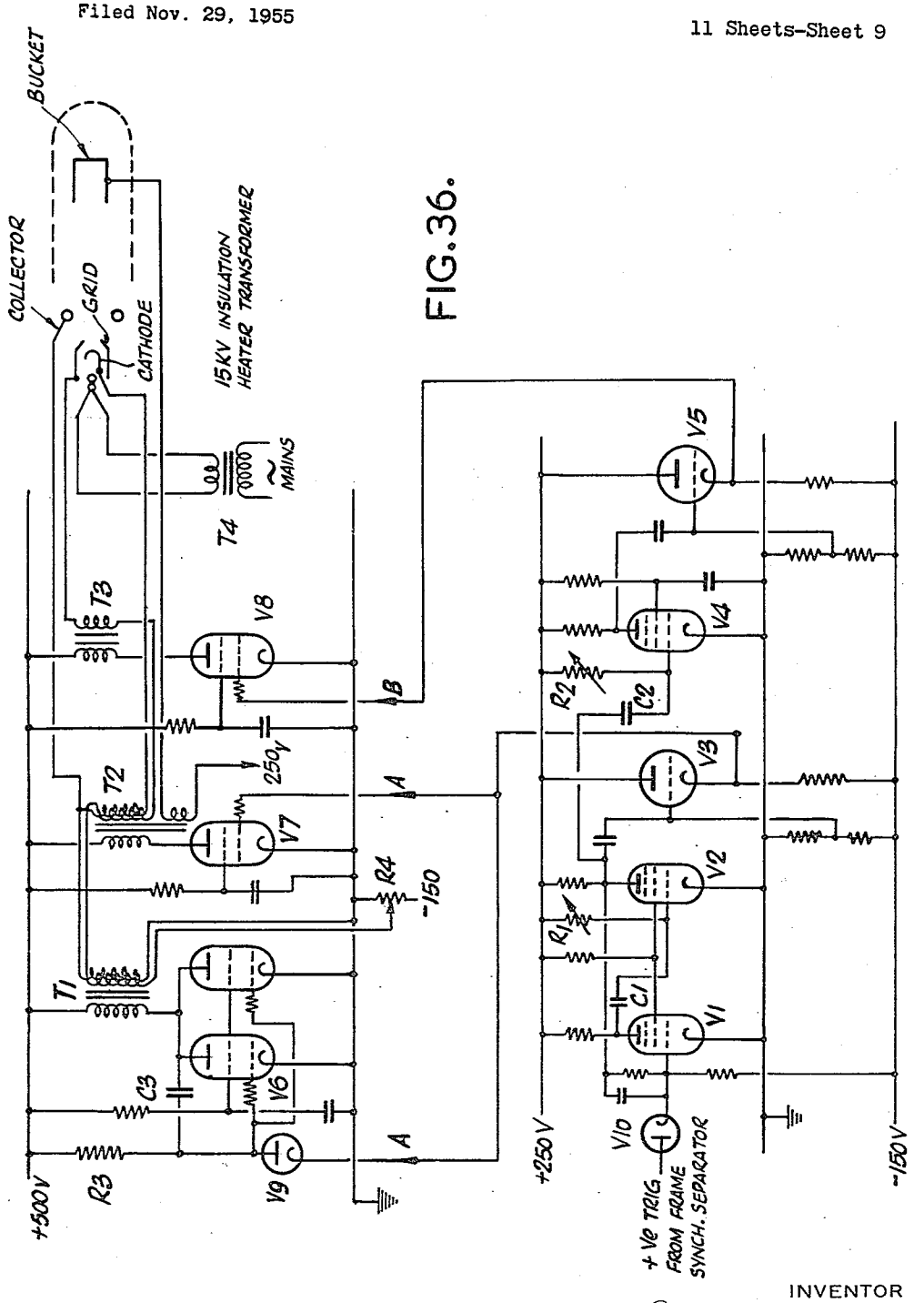


FIG. 36.

INVENTOR
Dennis Gabor
BY Cameron, Kerkam & Sutton
ATTORNEYS

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CATHODE RAY TUBE

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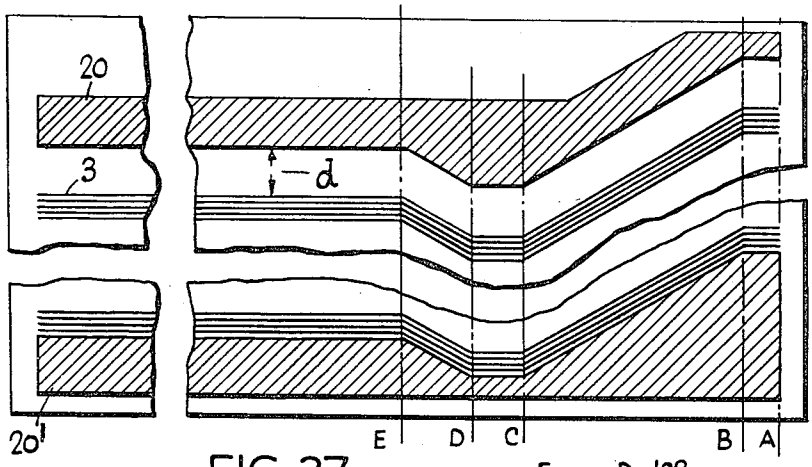


FIG. 37.

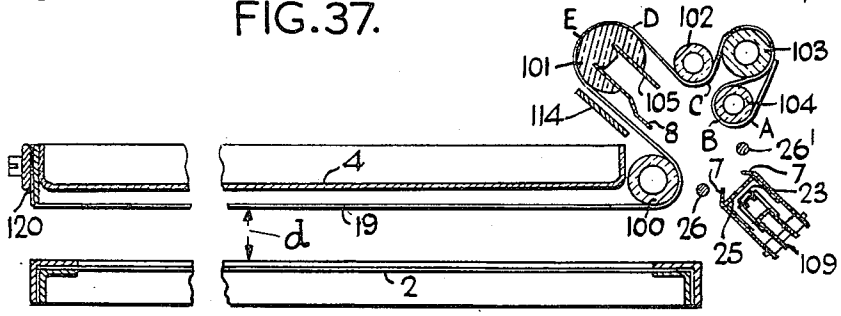


FIG. 38.

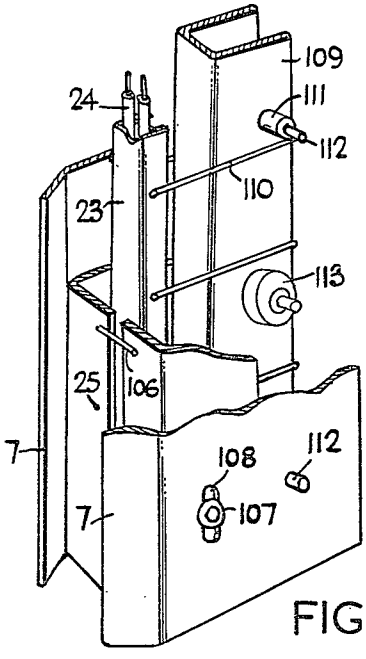


FIG. 39.

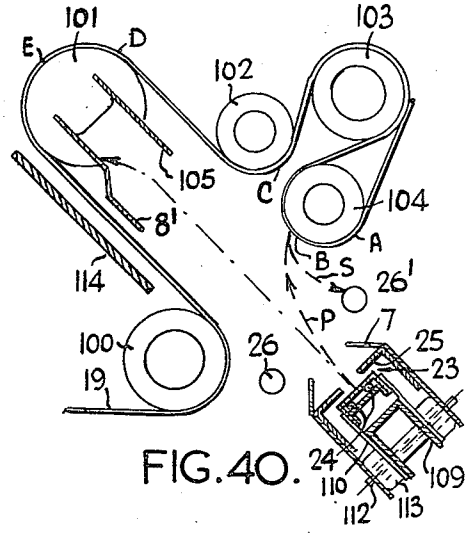


FIG. 40.

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

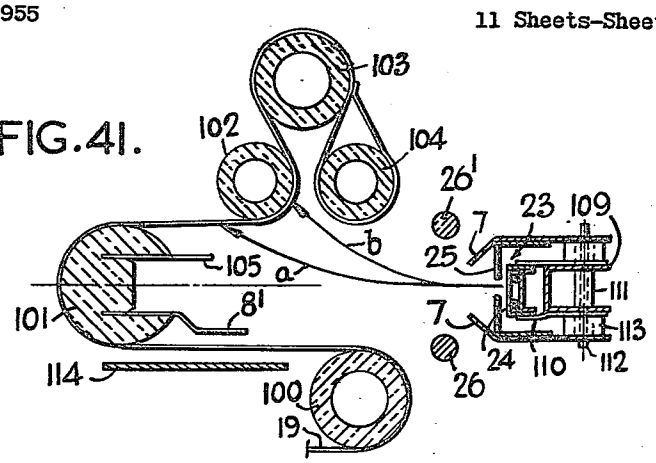
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FIG. 41.



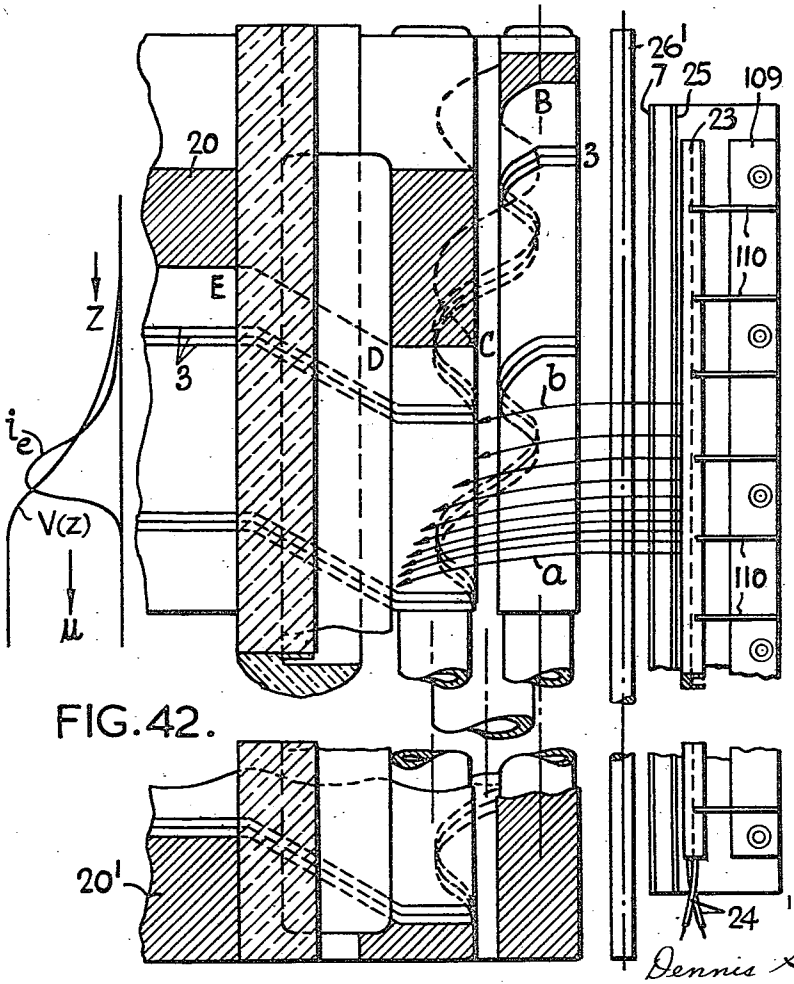


FIG. 42.

INVENTOR

Dennis Gabor

BY Cameron, Kerkam & Sutton

ATTORNEYS

United States Patent Office

2,795,729

Patented June 11, 1957

2,795,729

CATHODE RAY TUBE

Dennis Gabor, London, England, assignor to National Research Development Corporation, London, England, a British corporation

Application November 29, 1955, Serial No. 549,712

58 Claims. (Cl. 315—13)

The present invention relates to cathode ray tubes and more particularly to a new form of tube primarily suitable for television. The tube according to the invention has particular advantages for the production of television in color.

This is a continuation-in-part of application Serial No. 309,677, filed September 15, 1952, now abandoned.

In the known types of cathode ray tube it is usual to employ an electron gun positioned at a distance from a fluorescent screen so as to direct an electron beam towards the screen along an axis substantially normal to the plane of the screen, like a straight pointer. The point of impact of the electron beam is moved over the screen by deflecting the beam in two directions parallel to the fluorescent screen and symmetrically about a mean axis so that such tubes normally assume a substantially conical shape, the screen forming the base of the cone. It follows that the larger the screen to be employed, the deeper the tube must be in the axial direction of its conical shape in order that the beam may not be required to be deflected over too wide a solid angle.

The present invention has for its primary object to provide a cathode ray tube of relatively small depth in the direction normal to the screen.

A further object of the invention is to provide a cathode ray tube of novel form which is especially well adapted for the production of television pictures in color.

Another object is to provide a new type of cathode ray tube having a plane screen.

Yet another object of the invention is to provide a cathode ray tube which will be compact and not greatly exceed in any of its dimensions the dimension of the picture screen.

Further objects will appear as the description proceeds.

In the cathode ray tube of the present invention the picture producing electron beam is first deflected in one direction only, parallel to the screen surface, and then proceeds in a direction which is also substantially parallel to the screen, at a relatively small distance from its surface. When the beam reaches a certain zone, it is strongly deflected towards the screen by a locally applied electric field, so that it forms a curved pointer, meeting the screen at the desired point. According to the invention this localized electric field extends over a substantially linear zone which always intercepts the beam, irrespective of its first mentioned deflection, and is shaped in such a way that the beam is focused by said field at the same time as it is deflected thereby. In the application of the invention to television, the linear zone of the electric field is in the direction of the line scan, while the frame scanning is achieved by moving said field parallel to itself, in the direction of the frame scan.

It follows from this functional principle of the invention that, as the beam moves substantially parallel to the screen and close to it, the new tube can be made very flat. No "throw" at right angles to the screen is required, as in all conventional cathode ray and television tubes.

A further advantage is that the deflecting and focusing electric field acts like a cylindrical electron lens of short focal length, which makes it possible to achieve a convergence angle of the electron trajectories at the screen many times larger than in conventional tubes. This, by the known laws of electron optics, enhances the specific brightness of the spot, because a larger current can be concentrated into a smaller screen area with a given gun design and prescribed screen potential.

Another advantage of the new design is that the large final convergence angle makes it eminently suitable for color television. Color tubes are known in which the color is varied by changing the incidence angle of one or several electron beams by means of a grid or sieve disposed at a certain distance from a fluorescent screen with locally varying color response, in such relative position that a ray passing in a certain direction through an aperture of said grid or sieve falls on a spot of the screen which has a definite color response. The wide convergence angle in the new tube allows dispensing with a special foraminated organ, spaced and positioned in accurate relation to the screen, and makes it possible to produce a definite color response by suitable shaping of the screen surface, as will be described later in more detail.

The functional principle of the invention may be translated into structural terms in the following manner. Within a glass envelope there is provided a substantially plane fluorescent picture screen adapted to be maintained at a maximum positive potential of the order 5–15 kv. An array of linear conductors is arranged in a plane parallel to the screen, the conductors being substantially parallel to one another and to the direction of the line scan, insulated from one another and preferably associated with a common capacitive backing plate. This array of conductors may be called the scanning array. An electron gun is positioned in the envelope and arranged so as to project an electron beam into the space between the scanning array and the screen. If the array is charged up to a maximum positive potential, equal to the potential of the fluorescent screen, there is no electric field between said array and the screen, and the cathode ray beam will pass through between them without being deflected. If, however, a zone of the array is discharged, so that in the zone successive conductors assume a graduated range of potentials extending from the maximum positive potential down to a potential in the neighborhood of that of the cathode of the electron gun, the electrons will be repelled by said zone and thrown towards the fluorescent screen. If the conductors of the array are discharged, one by one, progressively across the array in the direction towards the electron gun, the zone will travel across the array so that the beam will be thrown on the screen after a progressively diminishing length of travel, and this effect may be used to provide the frame scan for a television picture presentation employing the tube. The discharge should not be abrupt but gradual; that is to say, the conductors should not be fully discharged one by one, but the discharging process is caused to be spread over a plurality of conductors constituting the deflecting zone so that an electric field wave of a certain desired shape travels across the array, the wave shape being such that it focuses the beam on the screen at the same time as it deflects the beam towards the screen. This wave can be made to run at a constant speed, i. e., the speed required for the frame scan.

In a preferred form of the invention a second, similar array of substantially parallel conductors is disposed at or in close proximity to the surface of the fluorescent screen so that the electron beam passes between the two arrays. The conductors of this second-mentioned array are electrically connected one by one or in small groups with the conductors of the first-mentioned array, the in-

terconnection being so effected that the conductors of one array are staggered in relation to the conductors of the other array to which they are connected. Corresponding conductors therefore do not face one another across the gap at right angles to the path of the electron beam but are displaced relatively, so that the conductor on the screen side is beyond its electrically connected fellow on the other side, looking in the direction of the electron beam. Such a double array may be made as a single array folded upon itself, and has the advantage, compared with the simple scanning array previously described, that it enables more precise focusing of the end portion of the beam and focusing of a wider beam to be achieved.

The discharging of the conductors to form the electric field wave may be achieved by a special organ which will be called the scanning valve, contained in the vacuum space of the tube itself. The scanning valve, to be described below, comprises a further array of substantially parallel conductors, which may be made continuous with the conductors of the other array or arrays referred to above. The scanning valve conductors are arranged in a special pattern on an approximately U-shaped cylindrical surface and form the outer electrode of the valve. Associated with this further array are a cathode, at least one electrode acting as a grid, and at least two electron-collecting electrodes. All these electrodes extend over the whole length of the valve.

At the far end, looking in the same direction as that in which the picture producing electron beam travels, the scanning array is terminated or bounded by a plate-like electrode permanently at or near the potential of the electron gun cathode, and at the near end by a second plate-like electrode permanently at maximum positive potential. The scanning valve array is similarly terminated or bounded by electrodes which may be continuations of those of the scanning array.

The scanning valve effects both the frame scanning operation and the flyback. In the scanning phase the electrons emitted by the scanning valve cathode discharge the array in such a way that a potential wave of the desired shape runs down its length, at constant speed. The speed is determined by the capacity of the array to the backing plate, and by the electron current, which in turn is determined by the design of the valve, and can be controlled by the grid potential. In the flyback phase the whole array may be raised to the maximum positive potential by releasing secondary electrons from its conductors, the secondary electrons being collected by one or more of the electron-collecting electrodes.

Apart from the novel method of effecting the frame scan, the operation of the new tube is similar to that of conventional television tubes, the line scan being effected by magnetic or electrostatic deflection means operating on the picture producing electron beam in known manner.

The invention will be better understood from the following description given with reference to the accompanying drawings in which:

Figures 1, 2 and 3 are a front view, a partly sectioned elevation and a partly sectioned plan view, respectively, all somewhat diagrammatic in character, of one form of cathode ray tube according to the invention, designed for the presentation of television pictures.

Figure 4 is an enlarged fragmentary vertical section of one form of screen and scanning array according to the invention.

Figure 5 is a diagram, showing the distribution of the potential over the array conductors of Figure 4, at one instant.

Figure 6 is a perspective view of a part of the scanning valve of the tube illustrated in Figures 1–3, and Figure 7 a longitudinal section thereof looking into the grid electrode.

Figures 8–10 are transverse sections showing the electron trajectories in three phases of operation of the scanning valve of Figures 6 and 7.

Figure 11 shows the conductor array and associated plate-like electrode of the tube of Figures 1–3 in unrolled or developed form.

Figures 12, 13, 14 and 15 are a front view, a side view, a rear view and a plan view, respectively, all partly sectioned and somewhat diagrammatic in character, of another form of tube embodying the invention, in which the space requirements have been reduced to a minimum.

Figure 16 is an enlarged vertical section through the electron lens used in the tube illustrated in Figures 12–15.

Figure 17 is an enlarged fragmentary vertical section of the folded array of Figures 12–15.

Figure 18 is a diagram of the equipotential lines and of the electron trajectories in the field of a folded array such as that shown in Figure 17, and illustrates the principle of color control.

Figure 19 is a developed view of the folded conductor array and associated plate-like electrodes employed in the embodiment of Figures 12–17.

Figure 20 is an enlarged cross section of one type of color screen according to the invention, and Figures 21–23 illustrate three phases in the manufacture thereof.

Figures 24 and 25 are similar sections of two other types of color screen, while Figures 26 and 27 illustrate two stages in the manufacture of a third type.

Figures 28–30 illustrate two stages in the manufacture of one type of scanning array embodying the invention.

Figures 31–34 are three sections and one face view of a preferred type of color screen.

Figure 35 is a series of waveform diagrams illustrating the operation of the scanning valve of Figures 6–10, while Figure 36 is a diagram of a circuit which may be used for operating said valve.

Figure 37 is a developed view of the conductor array and associated plate-like electrodes of the modified form of tube illustrated in Figure 38.

Figure 38 is a horizontal cross section of the scanning valve, array, screen, and associated electrodes of a modified form of tube embodying the invention.

Figure 39 is a fragmentary perspective view of the electron gun of the modified scanning valve of Figure 38.

Figures 40 and 41 are enlarged cross sections of the modified scanning valve of Figure 38 illustrating two phases of the operation of this organ.

Figure 42 is a schematic view of the modified scanning valve of Figures 38–41, partly opened out and showing the electron trajectories in the scanning zone.

In Figure 1 the vacuum envelope **1**, which has approximately the shape of a hand mirror, consists of glass on the side from which the screen **2** is viewed, while the other parts may be made of glass or metal. The fluorescent screen **2** is in the form of a phosphor coating on a sheet of suitable material such as glass, or glass cloth suitably tensioned, and may be backed with the now widely used metallic layer. Facing the screen, and at a relatively small distance from it, is arranged the scanning or rear array **3**, details of which are shown in Figures 4 and 11. The array is backed, at least in part, by the metal plate **4**, which may be used as support for the rear array but is insulated therefrom and constitutes the common capacitive backing of the array. The scanning array is folded round the backing plate **4**, and into a loop **6** which forms the outer electrode of the scanning valve, whose grid **7** and collecting electrode **8** are also shown, and which will be more fully described later.

The electron beam E is formed by the electron gun **9**, which may be of conventional design, and is not shown in detail. In the drawings the electron beam E is shown as if it were astigmatic; focused at the point P in the plane of Figure 1, while in the plane of Figure 2 it is shown collimated by the gun, i. e. focused at infinity. In this plane the beam is brought to a focus only by the local deflecting field. This representation has been chosen chiefly for simplicity and clarity. Though an astigmatic gun may be advantageous, it is not essential

for the invention. It will be shown later that the focus of the beam in the plane of Figure 2, i. e. at right angles to the screen, is not at all critical.

The line scan, that is to say the deflection parallel to the fluorescent screen, in the plane of Figure 1, is effected by magnetic deflection coils **10**, **10**.

Two pairs of small deflector electrodes **11** and **12** are provided which operate in opposition to one another so as to displace the beam parallel to itself. For a tube operating only in black and white these electrodes are given fixed potentials adjusted to direct the electron beam exactly into the narrow gap between the screen **2** and the array **3**, thus correcting for small inaccuracies in the mounting of the electron gun relative to said gap. In color tubes they have the additional function of color control, to be explained later.

As the beam has to proceed for an appreciable distance in the relatively narrow space between screen **2** and array **3**, it is essential to eliminate stray magnetic field components at right angles to the plane of Figure 2. Magnetic screening can be effected, as usual, by a screen outside the tube, or preferably by making the backing plate **4** of material of high magnetic permeability.

Figure 4 is a cross section of a portion of the fluorescent screen **2** and of the scanning array **3** on a larger scale. Screen **2** with its fluorescent coating **17** is covered by a thin layer **18** of aluminum or the like, and is maintained at the maximum positive potential of the tube, hereinafter designated V_m, as well known in the art. The scanning array **3** of this embodiment is formed by a row of metal wires of round cross section, partly embedded in an insulating plate **19**, which in turn is backed by the metal plate or layer **4**, forming the common capacitive backing of the array. The deflection of the end portion of the electron beam E towards the screen **2** at different vertical levels to provide the frame scan is achieved, as above described, by setting up a potential distribution between the wires of the electrode array **3** in a small vertical zone, and causing this zone to move progressively across the array at the desired frame scanning speed. The effect is as of a wave of discharge running down the array.

Figure 5 is a diagram of the potential distribution in the region of this wave, potential being plotted horizontally against vertical distance z (transverse to the array wires). Strictly this is a stepped function, but if the array wires are sufficiently fine and closely packed it is admissible to consider V as a smooth function of z at all but extremely small distances from the plane of the array. Though in principle the wave could run in either direction, it is preferable to make it run against the beam, with a speed u. The reasons for this preference are that, first, the beam has to traverse only a completely field-free region, not affected by the charge-residues of those parts of the picture which have been already drawn, and, second, it is more convenient to operate the scanning valve in such a way that it discharges the array during the scan and re-charges it to a positive datum level during the flyback. Assuming then that the electrons travel upwards in Figure 4, the wave V travels downwards with a speed u, which is the speed of the frame scan. Below the wave-zone the potential is the positive maximum V_m; above it the potential is at or near the potential of the electron gun cathode, which has been denoted by O in Figure 5.

The charge and discharge of the conductors of the rear or scanning array **3** is achieved by means of the organ which has been referred to above as the scanning valve. This organ includes a further array of conductors formed as a continuation of the scanning array, bent round into a loop **6** as shown in Figure 3. Associated with this array are a cathode, a grid electrode, a "bucket" electrode and one or more collector electrodes, all of which extend the full vertical height of the array, and the arrangement of which is best shown in Figures 6, 7, 8, 9 and 10.

Figure 6 is a perspective view of a portion of the array of conductors constituting the outer electrode **6** of the scanning valve, together with parts of the electrodes associated therewith. For simplicity the conductors are shown without any insulating backing or fibres or other supporting means. The conductors **3** are arranged on a cylindrical surface, with a base-line approximately in the form of a letter U, with a constriction at the opening. At the near side of the loop as seen in Figure 6 the conductors, which come from the scanning array, run horizontally to the vertical line I, where they turn upwards. At the line J they turn horizontal again, and run level to the line K, where they again turn upwards. After running horizontally between L and M, the conductors dip until at the terminating line N they reach a level below that at which they started. On the near side the scanning valve array is terminated or bounded at the top by an electrode **20**, permanently at or near the potential of the cathode of electron gun **9**, which also extends over the conductors of the scanning array. A similar electrode (not shown) may be provided at the bottom of the array on the far side of the structure as seen in Figure 6, and permanently maintained at the maximum positive voltage V_m. The array of conductors and electrode **20** are also shown in Figure 11 developed into a flat pattern which will produce the configuration of Figure 6 when bent into the cross-sectional form shown in Figures 8–10.

In lieu of using metal wires partly embedded in an insulating plate as represented in Figure 4, the conductor array may be formed by printing conducting lines on a flexible insulator, such as mica, which can be bent into the configuration of Figure 6, or by cementing insulating rods to a fabric of the character illustrated in Figure 28 and hereinafter described, displacing the rods longitudinally until the desired shape is obtained, and then destroying the unwanted fibres of the fabric.

Figure 7 is a vertical section through the scanning valve, at about the lines J, K, showing some of the associated electrode structure. The electrode **7**, referred to as the grid, is a long box-like electrode with a slotted partition **25**. Behind the partition **25** is the long hot cathode **23**, with heater **24**. Full horizontal sections through the valve are shown in Figures 8–10. These figures show, in addition to the grid **7** and "bucket" electrode **8**, already shown in Figure 3, the rods **26**, **26** which serve as collectors for secondary electrons liberated in the flyback phase of operation of the valve, and schematically illustrate the following explanation of the operation of the valve.

The operation of the scanning valve is required to do two things. The first is to charge the conductors **3** of the scanning array to the maximum H. T. voltage, V_m. This charging operation takes place during the interval between television frames in a television picture presentation system and will, therefore, be called the flyback phase. The second is to produce the wave of potential variation referred to above, which must be made to sweep across the array in the direction transverse to the conductors, so as to provide a deflecting field for the electron beam serving to turn the end of the beam over towards the screen at a progressively varying level across the screen so that successive line scans are executed one below the other to produce the normal picture raster. This will be called the scanning phase.

To start with, consider the conductors of the scanning valve array (and therefore, of course, the conductors of the scanning array) to be fully charged to V_m. Consider the cathode **23** to be heated to operative temperature by its heater **24** and to be held at or near the potential of the picture producing gun cathode, the grid **7** to be held at a low voltage just sufficient to cut off any

electron flow from the cathode, and the "bucket" electrode **8** to be held at a positive potential sufficiently high to collect electrons from the cathode **23** when they are released by the grid **7**. The collector electrodes **26**, which are in the form of rods extending the full length of the scanning valve, are employed during the flyback phase for the purpose of collecting secondary electrons emitted from the conductors; during the scanning phase, they may be at or about the potential of the cathode of the scanning valve.

If now the potential of the grid **7** is raised a beam of electrons will be released from cathode **23** in the form of a ribbon or sheet electron beam which will pass straight through between the two sides of the scanning valve array (all at V_m) and will be collected by the "bucket" electrode **8**, as illustrated in Figure 8. This ribbon beam of electrons extends over the full length of the scanning valve. However, at the top end of the array, on the near side as seen in Figure 6, the electrode **20** lies opposite the top conductors of the array on the far side between L and M, and is maintained permanently at or about the potential of the cathode of the picture producing electron gun **9**. There will, therefore, exist at the top of the scanning valve a transverse electric field between the electrode **20** and the top conductors of the array which are at V_m. This transverse field will serve to deflect the top portion of the electron stream towards the far side of the array as seen in Figure 6, as illustrated in Figure 9, providing a current flow operating to discharge these top conductors, lowering their potential towards cathode potential. Since, however, by virtue of the vertical stagger introduced into the conductors between the two sides of the scanning valve array, the parts of the top conductors on the near side are opposite portions of lower conductors on the far side, a transverse field such as previously existed between electrode **20** and the top conductors will now exist between the top conductors on the near side and the opposite conductors on the far side, which field will serve to deflect a lower portion of the electron stream towards the lower conductors on the far side, thus discharging them. Clearly, this effect is progressive, and the electron flow from cathode **23** towards "bucket" **8** will be deflected towards the conductors of the array at progressively lower levels down the array.

If the electron flow to the conductors is sufficient they will, of course, be discharged to cathode potential so that both sides of the array will assume cathode potential, though it is not absolutely necessary that complete discharge should be achieved. The electron stream at portions of the array where this condition is reached will tend to be cut off, but any residual electron flow will find itself in a region free from transverse field and will therefore flow to the "bucket" electrode **8**.

At any given time during a frame scan, therefore, the electron discharge from cathode **23** can be divided into three zones, namely, the upper zone where the electron stream is cut off, or passes between at least partially discharged conductors to the "bucket" electrode **8** (conditions as in Figure 8), a scanning zone in which the electron flow from cathode **23** is deflected to the conductors of the scanning valve array (conditions as in Figure 9), and a lower zone in which the electron stream passes between fully charged conductors straight through to the "bucket" electrode **8** (conditions as in Figure 8).

As described above, the scanning zone moves progressively downwards, and clearly the speed at which it does so will depend upon the intensity of the electron stream and the capacity to earth to the scanning array which will determine the rate at which the potential of the array is reduced for any given level of electron flow. It will be appreciated that the potential of any given conductor in the scanning zone will depend upon the time for which electrons have been flowing to it, so that the conductors nearest the lower undischarged zone will be nearly at V_m and there will be a gradation of potential over the scanning zone, the potential of successive conductors falling off in the direction towards the discharged upper zone. This vertical potential gradient gives rise to the transverse gradient between the conductors on opposite sides of the scanning valve array by virtue of the stagger of the conductors above described. The conditions affecting the wave shape of the potential gradient in the scanning zone will be discussed below.

When the discharge wave reaches the bottom of the scanning valve array so that the whole array is discharged, the flyback phase is initiated. For the flyback phase (illustrated in Figure 10), the voltages on the cathode **23** and grid **7**, **25** are lowered to about −600 v. and the voltage on the "bucket" electrode **8** is dropped a little more to, say, −650 v. so that it will be negative to the cathode **23** and will no longer collect electrons. The effect is that the electrons emitted from the cathode structure are no longer collimated as shown in Figure 8, but become over-focused as indicated in Figure 10, so that they diverge and are directed towards the array of conductors on both sides of the valve. Moreover, by virtue of the increased voltage between the cathode and the array, the velocity of the electrons is raised to such an extent that secondary electron emission takes place from the conductors at a secondary emission ratio greater than 1. For this purpose the conductors may be coated with any suitable material which increases the secondary electron yield, such as a phosphor or magnesium oxide smoke. The secondary electrons emitted are collected by the rods **26**, as shown in Figure 10, so that the array tends to charge itself and stabilize its potential to that of the collectors **26**. The potentials of electrodes **23**, **7**, **25** and **26** are now raised together while maintaining between them the potential differences which provide the conditions just described. The potential of the array thus follows the potential of collectors **26**. When collectors **26** reach V_m, therefore, the charging of the array is complete, and the potentials of the cathode, grid and collector electrodes can all be restored to those required for the scanning phase which then starts immediately, as above explained.

Operation of the scanning valve is required to be synchronised with television signals supplied from a television receiver. These signals arrive at the end of the frame scan, before the flyback, and may be employed to lock the oscillations of a multivibrator controlling the generation of the waveforms applied to the scanning valve electrodes to the incoming synchronising signals. This will be more clearly understood later, when a circuit for controlling the operation of the scanning valve is described.

The above description deals with the mechanism of the scanning valve and explains how the scanning wave is propagated down the array and the array subsequently re-charged. It is now necessary to consider how the vertical potential gradient may be caused to correspond at least approximately to the desired wave shape discussed above with reference to Figure 5.

As has been explained, the transverse potential gradient is set up by the vertical stagger between the parts of the conductors on either side of the scanning valve array. The part of the electron current collected by the conductors of the array is therefore roughly proportional to the vertical potential gradient. The condition for the propagation of an undistorted wave along a line uniformly loaded with capacity is that the discharging current must be proportional to the longitudinal voltage gradient. Thus, if according to the above elementary explanation the total electron beam current were constant, and a fraction proportional to the gradient were collected, any wave shape could be propagated, which indicates that there is no tendency of the wave to assume a certain state; in other words, there is instability. This is also confirmed by a more accurate mathematical anal-

ysis. But this analysis also shows that stability can be obtained if two conditions are satisfied. One is that the total beam current must increase with more than the first power of the potential at the entrance of the grid 7, or that the fraction of the ribbon beam current collected by the array increases more than linearly with the deflecting gradient. This condition is automatically satisfied, because in the case of a space-charge limited strip cathode the current increases initially with the 5/2 power of said potential. The second condition of stability is that the electrons must be collected at a potential somewhat below the entrance potential, i. e. below the potentials at the points J, K in Figure 6. This makes it necessary to dip the conductors at N below the level at K. A certain addition must be made to this dip, because the electron trajectories will not lie in a horizontal cross section, but will be deflected downwards by the vertical potential gradient. With a suitable value of dip it can be shown that not only will the wave shape be stable, but it will approach very closely the optimum form obtained from electron-optical considerations.

A further small addition to the dip of the conductors between K and N may be necessary in order to counteract the effects of secondary emission by the conductors. This has the effect that the current appears to be collected at a higher potential because the secondary electrons will be drawn towards the next conductor, but the effect is small, as the secondary yield of most pure metals falls to small values between 1 and 2 kev. electron energy (the second crossover point), while the favored operating voltages V_m are of the order 5–15 kv.

Instead of a slit-shaped aperture in the partition 25, a series of round apertures may be used with advantage, as this increases the mechanical stability of the grid electrode, and also because the emission in this type of electron gun increases at least initially with the 7/2 power of the impressed electric field.

It has been stated above that the speed of the frame scan is determined by the capacity of the array to earth and by the scanning valve current. More exactly the duration of the frame scan is the time in which said capacity, charged up to the potential V_m, is discharged by the electron current collected by the array. The capacity of the array to earth is mainly its capacity to the backing plate 4. It is preferable to make this capacity so large that the current required to discharge it is a multiple, say 10–20 times or more, of the mean electron beam current which produces the television picture, at least in the type of tube illustrated in Figures 12–19 wherein the array extends over the screen. The reason for this is that, in this type of tube, the picture beam current also assists in discharging the array since the screen, the scanning array and the scanning valve array are all connected together, the effect of the picture beam being variable with picture brightness. If, however, the picture beam current is made less than about 5% of the scanning valve current the variable stretching of the picture in the frame scan direction becomes unnoticeable. The reason is that, though a change in the frame height of the order of 5% would be noticeable if it appeared suddenly and by itself, such a large change, corresponding to the doubling of the mean brightness of the picture or to total blackout, must be necessarily connected with a sudden change of the scene or of a large part of it. However, two consecutive interlaced frames very rarely differ in more than a small fraction of their average brightness.

Even these small effects can be eliminated by the following method. The current of the scanning valve is made more than sufficient to achieve the required speed of frame scan, so that it need flow only during a fraction of the time of a frame sweep. A negative bias is then applied to the valve grid 7, say once during every line scan, thus arresting the frame scan for a suitable period. This period can be made a function of the picture beam current, so that the scanning speed becomes independent of the picture brightness. This may be done by integrating, by means well known in the art, the beam current over a line period, and blacking out the scanning valve for a time proportional to the integrated sum, for instance by adding a voltage proportional to the integrated sum as a negative bias to a negative sawtooth voltage having the period of the line scan. It is preferable to perform this arresting operation during the line flyback.

In the type of tube as illustrated in Figures 1–4, in which the screen is an equipotential screen, not connected with the scanning array, but directly supplied from a high voltage source, there is no need for the discharge current in the scanning valve to exceed the beam current. Consequently, the array capacity can be kept much smaller than in a tube of the other type, and the total power consumption of the scanning valve can be much reduced.

In the embodiment of the invention shown in Figures 12–19, the vacuum envelope 1 has the shape of a flat box, approximately square, little larger than the television picture. This great saving in space is made possible by the introduction of an electron lens or mirror of novel construction, shown in detail in Figure 16. In the form illustrated, the lens comprises two cylindrical electrodes 13, 13 placed one on each side of a third electrode 14, also cylindrical, located in the symmetry plane S—S. All three of these electrodes are connected to a positive potential, preferably the highest positive potential in the tube V_m. Associated with electrodes 13, 13 and 14 is a hollow cylindrical electrode or trough 15, which is positioned symmetrically beneath the other electrodes and is kept at or near the potential of the cathode of the picture beam electron gun 9. These electrodes are so designed that the electric field between them brings a parallel electron beam to a focus in the symmetry plane, and the emerging beam is again collimated. The system is best regarded, therefore, as an electron lens system with a curved optical axis.

Figure 16 shows the equipotential lines, numbered in terms of V/V_m, where V_m is the potential applied to electrodes 13, 13 and 14, and the potential of electrode 15 is assumed to be zero, i. e. the potential of the gun cathode. The figure shows also three electron trajectories. It is evident by inspection that if the incoming, collimated beam is focused in the symmetry plane, the outgoing beam will be again collimated and parallel to the original direction. A more accurate analysis reveals that in order to obtain this result it is not necessary to focus a wide beam exactly in one point of the symmetry plane. It is found that it is sufficient if the focus of that thin bundle of trajectories which meets the symmetry plane at right angles is focused in the said plane. The central trajectory of this thin bundle is the optical axis. It is found that trajectories which enter the lens at some larger distance from the optical axis will meet the symmetry plane a little above its intersection with the optical axis, and at an incidence angle, relative to the normal, which may be positive or negative. In first approximation the small height difference will be a quadratic function of the incidence angle. This, however, means that in this region a ray which meets the symmetry plane at a height h, at incidence angle $+\alpha$, will continue at the other side as the ray which has the incidence angle $-\alpha$ and will also emerge parallel to the symmetry plane. In other words, the present system, by its symmetry properties, has no "second order error" and therefore retains its property illustrated in Figure 16 for quite wide beams.

Another valuable property is that a beam which is not collimated will emerge from the system with the same angle of convergence or divergence as that with which it entered. This follows from the fact that the system as shown in Figure 16 is what is known in optics as a "telescopic system." Finally, thanks to the near optimum

properties of the electric field shown in detail in Figure 16, a slight departure from the correct shape is of little consequence, and can be corrected by a small D. C. bias, applied to the electrode **15**.

Strictly speaking, a cylindrical system will retain the properties described only for electron trajectories which are nearly parallel to the plane of the drawing in Figure 16. Electrons of an energy corresponding to V_m, which have been deflected by the line deflector system **16, 16** (see Figures 12–15) at some angle α relative to the plane of the paper, will behave as if they had only the energy $V_m \cos^2 \alpha$ in that plane. They will be overfocused and will emerge as somewhat diverging bundle. This effect can be completely avoided if a voltage $V_m \sin^2 \alpha$ is applied to the electrode **15**, so that the voltage drop in the lens is $V_m(1-\sin^2 \alpha)=V_m \cos^2 \alpha$. This correcting voltage may be obtained, by means well known in themselves, by squaring the voltage applied between the line deflectors **16, 16**.

An alternative method of correction is to depart slightly from exact cylindricality of the electrode system, preferably by bending the central electrode **14** somewhat, so that its distance from **15** is a little larger at the ends than in the middle of the mirror system.

In this embodiment of the invention the picture beam electron gun **9**, the line scanning, and, if provided, the trimming and color controlling electrode systems are arranged at the back of the scanning array **3** and the backing plate **4**, being so positioned as to direct the beam downwardly into the lens **13, 14, 15**.

The line scan in this case is effected by a pair of electrostatic deflecting plates **16, 16**. It is known that electrostatic deflection is rather unsuitable for wide scanning angles, but the present design enables the scanning angle to be reduced to a low value; $\pm 19°$ in the example illustrated. As shown in Figures 12 and 14, the effect of the electron lens **13, 14, 15**, viewed in the plane of these drawings, is the same as specular reflection on a line M—M, which is well outside the physical boundaries of the lens. Thus the deflectors **16** must be so adjusted as to scan the mirror image of the fluorescent screen relative to said line M—M, as illustrated in Figure 14. As in the design of Figures 1–3, trapezium correction must be applied to the scan, and a corresponding correction applied to the focus, at least in the plane of Figures 12 and 14. Such techniques have been employed in the operation of previously known cathode ray tubes in which the screen is inclined relative to the tube axis. On the other hand, no "keystone correction" need be applied in the present case because the line in which the electron beam meets the screen is substantially predetermined by the deflecting zone, set up by the deflection array, which is straight. A minor correction for line curvature will be discussed later.

Before and behind the deflection zone of electrostatic deflecting plates **16** there are arranged two pairs of deflecting electrodes **11** and **12** which operate in opposition, so that the beam is displaced parallel to itself, in order to effect the color control, as will be explained in detail in connection with Figure 18.

The frame scan in the tube of Figures 12–19 is achieved by means of the scanning valve **6, 7, 8**, etc., just as in the previously described embodiment of Figures 1–11.

This type of tube is eminently suitable for manufacture, because the fluorescent screen, the scanning array, the backing plate, the gun and deflector system and the electron lens or mirror may be fixed relative to one another by suitable beams, struts and spacers, well known in the art of electron tube manufacture, so as to form one composite structure. The envelope **1** is preferably made of two dish-shaped halves, divided in the symmetry plane, S—S as shown in Figures 13 and 15, and the composite structure above referred to is sealed between them, preferably supported by studs which project between the two half-dishes, in pre-moulded grooves, not shown in the drawings. The electrode leads are also preferably sealed in at the joint between the two halves. Thus great accuracy of manufacture can be achieved, because the internal structure can be completely assembled in jigs, and the relative positions of the parts are not affected by the subsequent glass sealing operations. The most critical adjustments are those which affect the parallelism of the beam and the fluorescent screen. These, however, can be made after the tube is completed. If the plane in which the beam is scanned for the line scan happens to be tilted around a horizontal axis, so that it runs at an angle instead of parallel to the screen, the bias of the trimming deflectors **11** or **12** may be slightly altered to correct it. If this plane is twisted round a vertical axis, e. g. by imperfect positioning of the deflectors **16**, the twist can be compensated by a weak vertical magnetic field, produced by a few turns of a current-carrying wire wound round the tube, say at the level of the electrodes **13**.

If the electron optics of the arrangement shown in Figure 4 are examined, it is found that unless the distance between the screen and the array is made very small and the gradient of V very large, the electrons will hit the screen at rather small glancing angles and the angular range in which focusing can be achieved is small. This is acceptable for black-and-white television, but in color television steeper incidence and a wider convergence angle are desirable. This is achieved in the present embodiment by means of a double or folded array, already mentioned above, and shown in detail in Figure 17. In this example the conductors **3** of the array are in the form of conducting strips printed in conducting paint or otherwise suitably formed on an insulating foil support **19** which is preferably made thin enough to be flexible, so that it can be folded over in a loop **5**, as shown in Figures 12, 14 and 15, to form the front and rear arrays, and is made in one piece with a further portion **6** adapted to form the scanning valve array. The complete foil and conductor array supported thereby are shown in the flat in Figure 19 and have to be folded round the lines A—A and A'—A' in order to form the folded scanning array, and round the lines J—J and K—K to form the scanning valve array. The part of the foil to the left of the line A—A forms the fluorescent screen. The luminescent powder **17** (Figure 17) can be applied between the conductors, but it makes little difference if the conductors themselves are also covered by it.

Although the scanning array could be made rather coarse without adversely affecting its beam deflecting function, it is essential that, in a double or folded array, the array on the screen side be made so fine that it cannot be resolved by the eye from a normal viewing distance. In principle it is possible to connect the conductors at the two sides of the gap in a folded array in groups, rather than one-to-one, which would permit the use of a coarse array on one side and a fine array on the other. However, it is preferable to avoid such group connections and to use a continuous array of relatively fine conductors on both sides.

It is an essential part of the invention that the opposing conductors of the folded scanning array be staggered, as shown, by a distance s (Figure 17), the part of the conductor in the front array (on the screen side) being beyond the part in the rear array (on the backing plate side), when viewed in the direction of the picture producing electron beam. This stagger is best characterised by the angle β, as illustrated in Figure 17.

As in the previous embodiment the rear array and part of the scanning valve array are terminated at the top, as shown in Figure 19, by a conducting surface or plate electrode **20**, which is kept permanently at or near the potential of the cathode of electron gun **9**. The part of this electrode in the scanning valve envelope serves for starting the discharge wave, as above described. Correspondingly, at the base of the scanning array and on the screen

side, the array is terminated by a conducting surface or plate electrode 20' of similar shape, kept permanently at maximum positive potential V_m. This electrode 20' serves to collect the picture beam current when the frame scan has reached the end of its run down, if the beam is not immediately blacked out.

The operational principle of the folded array is illustrated in Figure 18 which shows the electric field and the electron trajectories in a plane corresponding to that of Figure 17. The electric field is fully determined by the vertical potential distribution $V(z)$ at one of the sides of the folded array, and by the angle of stagger β. At the other side the vertical potential distribution $V(z)$ is repeated, but shifted by a distance $s=d \tan \beta$, where d is the width of the gap between the two sides of the array. The field must be such that it focuses into a small spot as wide an electron beam as possible. It has been found that the best fields can be obtained when the angle β is within the limits 45° to 55°. The example illustrated in Figure 18 corresponds to $\beta=50°$. In addition the function $V(z)$ must also be suitably determined. A favorable field is illustrated in Figure 18 in terms of its equipotential lines which are numbered in fractions of the maximum positive voltage V_m as $V/V_m=0, 0.1 \ldots 0.9, 1$. The maximum gradient dV/dz must be approximately equal to V_m/d. Moreover, in order to obtain the best result, the wave must not be symmetrical with respect to the mean voltage $V_m/2$, but must tail off more gently at its low-potential end. In other words, the inflection point must not be at $V_m/2$, but above it. If these conditions are satisfied the exact shape of the $V(z)$ curve is not very critical. In particular it does not matter much whether V descends exactly to zero or only to a level somewhat above the gun potential, because the picture beam does not penetrate into the top region of the deflecting field.

As illustrated in Figure 18, with a suitable field it is possible to focus a beam somewhat wider than $d/2$ into a zone of only $d/20$ width, with incidence angles ranging from 5° to 50° to the normal. The focus is at about $V/V_m=0.7$, which means that the electrons arrive at the screen with 70% of the energy which they would have obtained at V_m, the maximum voltage available in the tube. The ratio V/V_m can be called the voltage efficiency. By reducing the voltage efficiency somewhat, even better focus and more nearly normal incidence can be obtained. With $\beta=45°$ the spot can be reduced to $d/50$, with incidence angles from 5% to 45° at the cost of a drop in voltage efficiency from 70% to 58%. On the other hand with $\beta=53°$ the voltage efficiency can be raised to 80%, at the cost of a slightly less perfect focus. The efficiency off the central line of the screen is even better, because the electrons are deflected somewhat below the zone as shown in Figure 18, and reaches practically 100% at the edges.

A voltage efficiency less than 100% means that at a given voltage V_m and given electron current the screen brightness is somewhat less than in conventional tubes. But in the new tube it is possible to increase the electron current far more than is necessary to outweigh this loss. As is well known, the limiting feature in cathode ray tubes is the maximum current density in the spot, which in turn is given by the current density at the gun cathode, by the screen potential, and by the convergence angle at the screen. With a given type of cathode the current density is proportional to the produce of the screen potential of the two convergence angles in the beam, at right angles to one another. In the new tube the convergence angle in the plane at right angles to the plane of Figure 18 can be considered as the same as in conventional tubes, but in the plane of the drawing it can be made at least 10 times larger at its ends where it is focused and bent over by the scanning wave. This means that for a given V_m the beam current can be increased in such a proportion as to obtain a screen brightness several times that in ordinary tubes, even if the voltage efficiency is less than 50%. The beam current can be increased without introducing difficulties in respect of cathode loading by making the cathode aperture non-circular, e. g. by making it in the form of a slot which is narrow in the direction parallel to the screen and long in the direction at right angles thereto. The beam then becomes a ribbon beam which is converged onto the screen into a round spot by the astigmatic focusing effect produced by the scanning array. Thus the cross-sectional area of the beam is increased and hence the current in the beam may be increased without increasing the cathode loading.

This advantage is due to the deflecting field acting as a short-focus electron lens, with a focal length of the order d. An upper limit to d is set by the consideration that the spot width, which is $d/20$ in the example illustrated, must be less than a line width. With 500 lines definition this means that d should be preferably less than $1/25$ of the height of the picture. A lower limit is set by the thickness of the electron beam, and by the manufacturing accuracy.

It can now be explained why it is not necessary to collimate the beam, i. e. make it parallel, in the plane at right angles to the screen. As shown, the zonal deflecting field acts like a lens with a focal length of perhaps $1/25$ of the screen height. On the other hand the gun lens, even if it focuses at the near end of the screen, has the effect of a lens of a focal length at least twice the screen height, compared with the adjustment when it focuses at infinity. Thus by the laws of lens optics, a focusing of the gun even at minimum distance will shift the final focus only by about $1/50$ or 2% of the shorter focal length, of the order d, i. e. by about $d/50$, which is absolutely negligible. Thus it is not necessary to collimate the beam in the plane at right angles to the screen although it is shown so in all the drawings for simplicity of explanation. Indeed it is even advantageous to apply some convergence to the beam in this plane so that it is focused at or near the spot, as this enables the best utilization to be made of the gap width d.

Figure 18 applies to the case of a beam which is launched at right angles to the array, i. e. one with zero deflection in the line direction. If an electron is deflected in the line direction by an angle α, its energy in the plane of the drawing will be only $Vm \cos^2\alpha$; hence it will be deflected a little before the electron launched at $\alpha=0$. The effect is that though these sideways deflected beams will still be well focused, they will meet the screen a little earlier, that is to say, a little lower. Taking the example of Figures 12–15, in which the maximum value of α is 19°, the smallest value of $\cos^2\alpha$ is 0.895, and it is found that the focus for these maximally deflected electrons is about $d/10$ below that shown in Figure 18. As the line width is about $d/20$, this means that in the two corners at the bottom of Figure 12 the scanning line curves down by about two line widths. At the top the effect is less than one line. These are negligible distortions, but if desired they can be compensated by curving the conductors in the folded array, or in the scanning array only, upwards by the same amount.

Figure 18 illustrates also how the angle of incidence of the beam on the screen may be controlled so that the tube may be employed for color television according to the invention. The trajectories are grouped so as to indicate three thinner beams, labelled R, G and B, which may stand e. g. for red, green and blue, separated by gaps. At the screen their angles to the screen normal are about 45°, 25° and 10°, respectively. Thus it is possible to vary the incidence angle within rather wide limits by displacing the beam sideways. As explained above, it is not necessary to displace the whole beam parallel to itself; it is sufficient to displace the point at which it meets the local deflection zone. The displace-

ment from one group to the next in Figure 18 is $d/5$ which in the previous example corresponds to 5 line widths. Thus no excessive accuracy is required. The displacement of the beam for this purpose is effected by means of the two pairs of deflector plates **11** and **12** of Figures 13 and 14, placed one before and one beyond the line deflector plates **16** in the direction of the picture beam. It is evident that only one of the two deflector pairs **11**, **12** need be used for the color control, though it is preferred to have two in order to compensate errors of manufacture, as above described, and in order to operate always with the same color changing signal, irrespective of the position of the scanning line.

Instead of employing a single beam and displacing it sideways for the purpose of color control, there are other possibilities. For example, three separate electron guns could be provided each modulated for its appropriate color and each providing a beam in the appropriate location. Alternatively, a common cathode could be employed having three apertures providing one beam for each color, the individual beams being appropriately modulated by separate grid electrodes for the three colors.

The translation of incidence angle into color will now be explained in connection with Figures 20–27, which show various types of screen which may be used for this purpose.

In the screen shown in Figure 20, asymmetrical grooves **27** are produced in a glass plate **2** which constitutes the screen. The ridges between the grooves are topped by the metallic conductors **3** constituting the front scanning array. The inside of each groove is coated with strips **28**, **29** and **30** of different fluorescent powders, corresponding e. g. in turn to red, green and blue. Alternatively these strips could be of three different pigments, acting as color filters, coated with white fluorescent powder. These powders of pigments may be applied by spraying, at the same angles as the incidence angles of the electron beam in operation. The shape of the grooves shown in Figure 20 favors accurate spraying, because their air resistance is great, and a stagnant air cushion is formed, but spraying in vacuo or at reduced pressure is preferable. Pigment strips can also be formed photographically, as known in the art. The tops of the ridges may be metallicly coated in any suitable manner, e. g. by means of an elastic roller with a conducting paint, and thickened by galvanoplastic deposition or metal spraying.

Figures 21–23 illustrate three stages in the manufacture of the grooves by etching. Strips **31**, **31** of a suitable resist are first applied, by printing or by a photomechanical method, to those portions of the glass screen plate which ultimately become the tops of the ridges between grooves. Figure 21 shows the first stage of etching, in which a symmetrical, approximately circular-cylindrical groove is formed. In order to produce the required asymmetry, more resist **32** is then sprayed on the right-hand side of each groove, as shown in Figure 22, and the resist is melted down a little at both sides, to avoid undercutting. The etch now starts asymmetrically, as shown in Figure 23, and will continue asymmetrically until the shape **27** of Figure 20 is reached. This design has the disadvantage that the color strips **28**, **29**, **30** face the screen at different angles, thus producing a color effect dependent on the direction of viewing. This may be reduced by making the surface layer of the screen **2** of diffusing opal glass.

Figure 24 is an improved version of the above-described type of screen, in which the color strips **28**, **29**, **30** all face the screen surface in parallelism therewith. This is achieved by making the surface **33** of the screen plate of a more easily soluble glass than the base **2**. The etching will now continue up to a certain point as shown in Figures 21–23, but will stop in the plane of the relatively insoluble base **2**.

Figure 25 represents a further improvement, wherein the base surface is fitted with ridges **34** which fix the shape of the etched grooves more accurately, and reduce the danger of undercutting the projections.

Figures 26 and 27 show a further variety of screen, whose manufacture starts with the same type of base as shown in Figure 25. The aperturing projections, however, are made of metal, in two steps. After coating the ridges **34** with a conducting paint, e. g. by means of an elastic roller, projections **35** are formed by galvanoplastic deposition in an electrolyte of small throwing power. As shown in Figure 27, these projections are subsequently sprayed with metal, in an inclined direction, forming the projections **36**.

It has been stated above that the front and rear scanning arrays and the scanning valve array may be produced all in one, as shown in Figure 19, in the form of an insulating foil supporting the conducting strips constituting the arrays. There are several alternative methods of producing the arrays, and some examples which involve the production of a composite fabric of metallic fibres and insulating fibres will now be described.

Figures 28–30 illustrate one method which may be employed. The starting point in the making of this array is a fabric whose warp is metal while its weft consists at least partly of destructible insulating fibres, or vice versa. Figure 28 illustrates an example of such a fabric. In this fabric the weft is of metal tape **3**, while the warp consists partly of glass tape or fibres **21** and partly of fibres **22** of a material, such as cotton, nitrocellulose, rayon or the like, which is destructible by means which leave the metal and the glass fibres intact; i. e., cotton by burning, nitrocellulose by explosive disintegration, and rayon, sodium alginate or the like by dissolving in suitable solvents. The destructible fibres serve only for accurate fixing of the relative positions of the non-destructible warp and weft fibres, and are preferably destroyed after the array has been arranged in its final position. The remaining fabric, after destruction of the unwanted fibres, is shown in section in Figure 29 and in face view in Figure 30. Only enough glass fibres **21** are left for supporting the metal tapes **3** safely, without covering much of their surface. This fabric can be freely supported in a frame, or it can be cemented onto an insulating surface, for instance, by means of enamel glass or "glass solder."

If the array is ultimately backed by an insulator, it is possible to destroy the non-metallic warp altogether. In this case it is preferable to use two sorts of warp fibres, which are destructible by different agencies. As an example, part of the fibres may consist of cellulose acetate, and part of cotton. The fabric is fixed in its ultimate shape in a frame, and the cellulose acetate fibres are dissolved in a solvent which does not affect the cotton. Now the frame is pressed against the insulating backing, coated with a suitable cement such as sodium silicate. Finally the cotton is destroyed by some oxidizing agency, leaving only the metal tapes adhering to the insulating base.

It is an advantage of this type of array that the fabric can easily be twisted and deformed into the forms required by the invention. For instance, if it is intended to produce the structure shown in Figure 17, the glass plate **2** and the insulator plate **19** are laid down, displaced relative to one another by a distance s, with a suitable gap between them. The fabric is now laid straight across the two plates, and cemented to them. When the plates are brought into line and face to face, the conductors are brought into the shape shown in Figure 17. It may be advantageous to use a sufficient number of non-destructible, glass fibres in the loop **5** (Figures 12, 14 and 15) to provide adequate support for the conductors at this point, while in those parts of the fabric which are ultimately in contact with solid insulating plates all the transverse fibres can be made of destructible material.

The required configuration of the array as a whole can

be realized by taking a fabric, such as has just been described, and cementing insulating rods to it at the lines corresponding to I, J, K, L, M and N of Figure 19. These rods are then displaced longitudinally, so that the desired shape is obtained.

A further method of forming the arrays of conductors for the scanning arrays and the scanning valve consists of first laying down on a suitable insulating support, such as mica, glass cloth, or silicone varnished glass cloth, by one of the known printing techniques, the required pattern of conductors, for example, the pattern shown in Figure 19. The sheet so printed is then folded into the required shape in which it is held on suitable supports. Alternatively, such a printed sheet may be produced on a support of material capable of being dissolved away or otherwise removed. Supporting fibres, of glass yarn for example, extending transversely to the conductors are then attached to this sheet in such a way as to hold the conductors in their relative positions when the supporting material is removed. For example, the printed sheet may be crimped onto glass yarn fibres at suitable small intervals. A machine for performing this operation is described in co-pending application Serial No. 480,407, filed January 7, 1955. The supporting material may then be dissolved away, leaving a composite fabric consisting of the metal conductors crimped onto the glass yarn fibres. This material is then mounted in the desired folded configuration on suitable supports.

The use of a fabric made by one of the above methods for the scanning arrays provides a further possibility for the production of a color screen for the tube. The color screens described above with reference to Figures 20–27 have the disadvantage that their conductors **3** have to be connected electrically, either singly or in groups, with the corresponding conductors of the rear scanning array.

The type of color screen illustrated in Figures 31–34 is free from this disadvantage. In this screen the conductors **3** of the front array, which are mounted on the screen, are continuous with those in the rear scanning array and in the scanning valve array. A fabric produced as above described with reference to Figures 28–30 has the portion of it which is to form the front array mounted on a suitable insulating support in spaced relation to the screen base **2**. The base **2** is fitted with ridges **37**, preferably blackened. The fabric e. g. in the original state as shown in Figure 28, is applied and cemented to the ridges by means of a suitable adhesive, such as sodium silicate. The unwanted warp fibres are now destroyed, preferably while the fabric is still under pressure, so that the metal tapes **3** are made to adhere to ridges **37**. This may be done e. g. by pressing through blotting paper, soaked with a solvent. Finally the remaining insoluble warp fibres may be also eliminated, by one of the means previously discussed, though a small number can remain without harm. Figures 31 and 32 are two sections at right angles to one another of the resulting screen, while Figure 34 is a top view of the same. Alternatively, all warp fibres can be made destructible in that part of the fabric which covers the screen, so that finally only the metal tapes are left after the first operation. Figure 33 is a section of such a screen, containing only equally spaced metal tapes **3** on the ridges **37**. The color strips **28, 29, 30** may now be produced by any of the methods previously discussed, i. e. by spraying, or photographically. During the preparation of the screen, that part of the fabric which is to form the scanning array and the scanning valve array can be rolled up in a tight roll. Conversely, the screen may be prepared last, if preferred.

The tube according to the invention, with the color screens as described, is suitable for operation with any of the known systems of color television transmission. In a point-sequential system the frame scan is operated in the same way as in black-and-white television. This applies also to simultaneous systems, with the difference that the single electron gun, as illustrated in the previous example, must be replaced by three guns, one for each color. In line-sequential systems the operation is somewhat different, because here the line must be arrested while it is scanned in succession in three different colors. Thus the frame scan is best operated once in every three line flybacks.

Tubes embodying the present invention can be operated as television picture tubes to a large extent from conventional circuits commonly employed in television receivers. Thus the line scan, which is controlled by the deflector plates **16** in the embodiment of Figures 12–19, may be produced by a simple voltage sawtooth waveform, although some departure from the simple sawtooth may be introduced in known manner to correct trapezium distortion as has been mentioned above. The picture beam intensity modulation can be effected by grid or cathode modulation applied to the picture beam electron gun in the conventional manner.

For the frame scan, however, the part of the tube described above and called the scanning valve must be fed with waveforms not normally employed in conventional television picture tube operation. The operation of the scanning valve has already been described in detail, and it will be remembered that during the scanning phase, the scanning array is progressively discharged by the ribbon electron beam, a part of which is deflected towards the scanning valve portion of the array at progressively lower levels. The operation is entirely automatic, and the voltages applied to the various scanning valve electrodes during this phase may be constant. For the flyback, however, it is necessary to recharge the scanning array, and this is effected by causing the electron beam in the scanning valve to set up secondary emission from the conductors constituting the scanning valve array so as to charge the array positively. The first stage in the flyback phase, therefore, consists in setting up between the electrodes of the scanning valve the relative voltage differences required to produce secondary emission from the conductors at a ratio of secondary to primary electrons greater than unity, i. e. 1:1. These conditions involve:

1. Lowering the potential of cathode **23** and grid **7** with respect to the potential of the collector electrodes **26** so as to increase the velocity of the electrons leaving the cathode and defocus the electron stream.

2. Lowering the potential on the "bucket" electrode **8** so that it will not collect electrons.

Having set up these conditions, the array conductors will stabilize themselves at a potential slightly below that of the collector electrodes **26**. This potential is initially well below the maximum H. T. potential V_m to which the array must ultimately be charged. It is now necessary, therefore, to raise the potentials of the cathode, grid, and the collector electrodes of the scanning valve up to V_m while maintaining between them the relative potentials initially set up so that secondary emission from the array will be maintained. When this raising of potential has reached the point where the electrodes **26** are at V_m, the voltage on the array will have been raised to substantially the same voltage, that is nearly to V_m.

When the charging of the array has been completed in this way, the potential on the collector electrodes **26** can be dropped to zero, as can the potential on the cathode and grid. At the same time, the potential on the "bucket" electrode **8** can be raised to the voltage at which it operates during the frame scan so that it is ready to collect the electron stream over those parts of the scanning valve where the array is fully charged. The next scanning phase can then start immediately.

The waveforms which these operations represent are shown in Figure 35 of the drawings, which also shows

other waveforms employed in the circuit about to be described with reference to Figure 36. The waveform applied to the collector electrodes amounts to no more than a simple sawtooth rising from zero to V_m which for the present purpose is taken as being 15 kv. The cathode waveform consists of an initial negative-going step followed by a positive-going sawtooth matching that applied to the collector electrodes. The grid voltage waveform is similar to the cathode waveform but includes a negative-going square wave portion immediately following the sawtooth. The "bucket" electrode waveform is merely a negative-going square wave.

In Figure 36 the circuit is shown divided into two parts. The first part, comprising tubes V_1, V_2, V_3 and V_4, provides two square waves which are employed in the second part of the circuit controlling the generation of the various waveforms required.

Tubes V_1 and V_2 are voltage amplifier pentodes cross-connected, the anode of one to the grid of the other, to form a conventional mono-stable flip-flop circuit, the normal resting condition of which is with V_2 conducting and V_1 cut off. When a positive-going synchronising signal, Figure 35(a), from the frame synchronizing separator of the television receiver is applied to the grid of V_1 through diode V_{10} the circuit flips into the reverse condition so that the anode of V_2 rises and the circuit relaxes, after a time determined by the values of resistor R_1 and capacity C_1, to its initial state. The output from the anode of V_2 is therefore a positive-going square wave of duration matched to the required duration of the flyback by suitable adjustment of R_1, C_1. This waveform is applied to the grid of triode V_3 which is connected as a cathode follower so that waveform A, Figure 35(b), can be derived from the cathode of V_3. The output from the anode of V_2 is also applied through a differentiating circuit C_2, R_2 to V_4 which therefore generates on its anode a square wave, waveform B, Figure 35(c), the duration of which is determined by the setting of R_2, and hence the value of R_2, C_2. This square wave is cathode followed in V_5 which provides waveform B on its cathode.

Waveform A is applied through diode V_9 to the grid of V_6 which is shown as two tetrodes connected in parallel since relatively heavy current will be required to be drawn from this stage. The anodes of the two tubes called V_6 are back coupled through C_3 to their grids which are connected to a positive H. T. supply through resistor R_3 so that the circuit forms a "Miller" run-down circuit generating a sawtooth voltage across the primary of pulse transformer T_1. The secondary of T_1 is a bifilar winding the two parts of which are separately employed so that it will be convenient later to consider the two windings separately. For the moment, it is sufficient to say that both windings provide across their terminals a voltage sweep extending over approximately 15 kv., which voltage sweep provides the sawtooth voltage sweep for the collector electrodes, the cathode and the grid.

The waveform A is also applied to the grid of V_7, the anode circuit of which comprises the primary of a second pulse transformer T_2. The voltage across this primary will clearly be a negative-going square wave, Figure 35(e), of the same duration as waveform A. Transformer T_2 has three secondary windings, a bifilar winding and a separate individual winding. It is convenient to mention now that this individual winding merely generates the negative-going square wave, Figure 35(j), applied to the bucket electrode **8**.

The waveform B is applied to the grid of V_8, the anode circuit of which comprises the primary of pulse transformer T_3 the voltage on which, therefore, is an inverted (i. e. negative-going) version of waveform B.

The secondary of T_3 is connected on one side to the grid electrode of the scanning value; on its other side it is connected through one of the bifilar secondaries of T_2 and one of the bifilar secondaries of T_1 to an adjustable negative bias picked up on potentiometer R_4. Thus the waveform appearing on the grid will be the sum of the waveforms generated in the secondaries of T_1, T_2 and T_3, superimposed on the negative bias. This amounts to the waveform shown in Figure 35(h) which is made up of a negative-going step supplied by T_2, the positive-going sawtooth supplied by T_1, and the negative-going square wave supplied by T_3.

The scanning valve cathode is connected through one bifilar secondary of T_2 and one bifilar secondary of T_1 to ground. The waveform applied to the cathode, Figure 35(f), is therefore the sum of the waveforms generated in the secondaries of T_1 and T_2 and comprises the negative step supplied by T_2 and a positive-going sawtooth supplied by T_1.

Finally, the collector electrodes **26** are connected through one bifilar secondary of T_1 to ground so that they receive only the sawtooth waveform, Figure 35(d), generated in T_1.

It will be appreciated that the circuit which has just been described is only one example. There are many possible circuits by which the desired voltages may be applied to the scanning valve electrodes so as to achieve operation in the desired manner.

A modified and improved form of the scanning valve is illustrated in Figures 37–42. A characteristic feature of this modified form is that the electron gun which produces the ribbon-shaped beam is outside, instead of inside, the fold of the array which constitutes the envelope of the scanning valve, thus reducing heating thereof by the scanning valve cathode. Another feature is the use of a suppressor electrode for the suppression of secondary emission during the scanning phase, and a third is the use of a metal strip capacitively associated with the scanning array for reporting the state of its discharge during the scanning phase.

Figure 37 shows in developed form the system of conductors and plate electrodes constituting the scanning array and the envelope of the modified scanning valve as adapted for use in a tube of the type in which the fluorescent screen is independent of the scanning array. Unlike the solid insulator plates as shown in Figures 4 and 17, the insulating support **19** for the conductors of this embodiment consists of thin, flexible material, preferably glass cloth, impregnated with a highly heat resistant silicone, such as the Dow-Corning silicone varnish MS 994. The conductors **3** and plate electrodes **20** and **20'** are printed on this support by printed circuit techniques, as known in the art. The left-hand end of the system shown in Figure 37 forms the scanning array, while the right-hand end is adapted to be folded as hereinafter described to form the scanning valve array. A gap is provided between the electrode **20** and the top conductors **3**, approximately of width d, so that the discharge wave starts approximately with the right shape at the beginning of the frame scan. As in the previously described tube of Figures 12–19, electrode **20** is permanently maintained at the potential of the cathode of the picture beam electron gun, while electrode **20'**, which in this instance extends beneath the array conductors throughout their length, is maintained at V_m.

Figure 38 illustrates how flexible sheet **19** is fixed in the assembly. It is not in contact with, but is separated by an air gap from, the capacitive backing plate and magnetic shield **4**, which latter is in the form of a tray, suitably reinforced with ribs and grooves (not shown) to give it rigidity. By using an air gap instead of an insulating plate to separate the array from plate **4**, the amount of insulating material which must be outgased in the manufacture is greatly reduced, while maintaining sufficient capacity between the array and the backing plate **4**.

The fluorescent screen **2** is also formed of a thin sheet, preferably also of glass cloth or of silicone impregnated glass cloth, held stretched on a metal frame.

The envelope of the scanning valve is formed by threading the sheet **19** over the cylindrical insulators **100**, **101**,

102, 103 and 104 in the manner indicated in Figure 38. The right-hand end of the sheet is shaped into a loop surrounding the insulator **104** and is anchored in place, e. g. by cementing with silicone varnish, while the rest of the sheet is stretched tight by the tensioning clamp **120** shown at the left of Figure 38. Letters A–E, corresponding to those in Figure 37, indicate the positions of the lines at which the array conductors change their angle in relation to the edge of the sheet. The purpose of the loop around insulator **103** is to produce a large vertical step in the height of the conductors between the rather closely-spaced insulators **102** and **104**, without having to employ a very steep angle of rise of the printed conductors, which would produce high potential gradients between them. The purpose of this large step will be explained later.

The specially profiled insulator **101** carries two strip-electrodes, one of which, **8'**, corresponds to the bucket-shaped collector electrode of the previous embodiments. The other, **105**, is a suppressor electrode, held permanently at the potential of the scanning valve cathode so that electrons can never land on it. These strip-electrodes are arranged inside the loop of the scanning valve array, while the electron gun, as well as the rod-shaped collector electrodes **26** and **26'**, are outside the loop, a reversal of the previously described arrangements.

Constructional details of the scanning valve electron gun are shown in Figure 39, which is a fragmentary exploded perspective view. The outside strips of grid **7** are shaped substantially the same as in Figures 6–10, so as to produce an approximately parallel ribbon beam. Inside these are fixed two L-shaped metal strips **25**, forming a narrow slit between them. To ensure that the edges of this slit are parallel, thin wires **106** are welded across the slit at intervals. As the parts **7** and **25** may be at rather different temperatures during operation, they are preferably not welded together, but are fixed by eyelets **107**, sliding in elongated holes **108**, to allow for differential expansion.

The gun cathode **23** consists of two channel-shaped thin nickel strips, welded together and containing between them the hairpin heater **24**, with sufficient play to allow for expansion. In order to allow for the heat expansion of the long cathode **23**, without distortion or displacement, it is fixed on a strong beam **109** of channel cross section by means of thin wire struts **110**, preferably of Nichrome or some other metal with low heat conductivity, welded at intervals to the side walls of **23** and to the side walls of **109**.

The beam **109** is supported in an insulating manner between the side strips of grid **7** by means of bushes **111** of alumina or the like, which pass through holes in the walls of beam **109**, and through which pass metal rods **112**. Alumina washers **113** ensure the centering of beam **109**. The metal rods **112** project through holes in the grid strips **7**, and may be riveted in, if necessary.

This design has the advantage of considerable heating economy, because the parts **7** and **25** form in effect a double radiation shield. Experience shows that, though two such metal sheets may be in mechanical contact, they are practically insulated from one another as far as radiation is concerned, except where their spacing is of the order of one micron, which is the case over only a small fraction of the area. It is preferable to give all the metal parts a high reflection coefficient, by using bright materials, to reduce radiation losses.

Figure 38 shows also a metal strip **114**, mounted parallel to the outside of the scanning valve, at a small distance therefrom, running along its whole length. The purpose of this organ is to indicate the state of the field scan. As strip **114** has a large capacity relative to the scanning array compared with its capacity to other parts of the tube, such as the plate **4**, its potential will follow and be proportional to the charges on the scanning array. It will therefore follow a sawtooth curve, indicating the discharging of the array in the scanning phase, and its re-charging in the flyback phase. The potential of strip **114** may be used for two purposes. One is to correct the focus of the picture beam electron gun **9**, according to the level reached by the frame scan at any instant. The other is to regulate the speed of the frame scan itself, which can be effected once per frame scan by comparing the time at which the discharge is complete, or has reached a certain datum level, with the timing of the synchronising signals. Synchronisation could be looped more often, for instance by comparing the run-down of the potential of plate **114** with a sawtooth curve produced by a conventional multivibrator itself locked to the television synchronising signals, so that the frame scan is arrested, preferably at the end of every line, as soon as the frame scan has appreciably overrun the standard sawtooth. Plate **114** does not form a part of the scanning valve, and could be associated equally well with any other part of the rear array.

Figures 40–42 illustrate the operation of the modified scanning valve.

In Figure 40 the dot-dashed line indicates the path of the ribbon beam in the quiescent phase, when the potentials on the opposite sides of the scanning valve envelope are equal, so that there is no deflecting field. The beam then runs straight until it reaches the space between the collector **8'** and the suppressor electrode **105**. Here it is suddenly deflected and collected by **8'**. The suppressor **105**, held at scanning valve cathode potential, prevents the emission of secondary electrons from **8'**.

In the same figure the dashed line *p* indicates the path of the primary electrons in the flyback phase, and *s* the path of the secondary electrons. The operation differs from that previously explained in that the potential of the collector **8'** and that of one of the collector rods, **26**, need not be changed during flyback. The potential of the other rod, **26'**, only must be raised, so that it produces a strong deflection and throws the primary electrons into impact with the array in the region of line B. Since at this point they are under the influence of the field of collector **26'**, which is the most positive electrode, the secondary electrons escape to, and charge up the array gradually to the potential of, collector **26'**. It is preferable to coat the array in the region B with magnesium oxide, by smoking or other known methods, to enhance the secondary emission.

Figures 41 and 42 illustrate the operation in the scanning phase. Figure 41 is a horizontal cross section, like Figure 40, but in Figure 42, to make matters clearer, the near side of the envelope of the scanning valve is shown unfolded and laid out parallel to the plane of the drawing. Inside the valve the array now appears substantially as seen by the electrons.

In Figure 42 the curved horizontal arrows show the electron trajectories in the scanning zone, that is to say, in the zone in which they reach the envelope and discharge it. These trajectories are derived from accurate numerical tracings in an electrolytic tank model of the scanning valve. The active trajectories start at *a* and practically end at *b*. In Figure 41 only these two trajectories are shown. In Figure 42 ten trajectories are shown, spaced so that their density is proportional to the electron current density i_e which, at the left in Figure 42, is plotted against the array conductors by which it is collected. The potential shape $V(z)$ is obtained by integrating the current density, because potential and current are in the relation

$$i_e = C.udV/dz$$

where C is the capacity of the array per unit height difference *z*, and *u* is the velocity of propagation of the discharge wave.

In the electrolytic tank experiments in which these trajectories were obtained, the applied potential distribution had the shape $V(z)$ as shown in Figure 42. Hence

the trajectories, and therefore also the current densities, are in agreement with the field which produces them, which means that the wave of the shape shown will propagate without distortion down the array. If the wave should start with a somewhat different shape, it will right itself, that is to say, conform to the form shown, by the time it has run a short distance. By leaving a gap between electrode **20** and the top conductor **3** as shown in Figures 37 and 42, the wave will be launched approximately in the right shape, hence the whole height of the array can be utilized.

The suppressor electrode **105** has two purposes. First, as may be seen in Figure 41, the trajectories land on the array in a region in which the field of the suppressor prevents the emission of secondary electrons. Second, the suppressor increases the stability of the wave, by making the current flowing to the array a strongly nonlinear function of the gradient. In fact a rather weak transverse field, which arises in the neighborhood of the trajectory *a*, is sufficient to throw the whole beam current at the array instead of on the collector **8'**. The suppressor **105** acts like a sort of knife-edge which forces the beam to flow either to one side of it, or to the other. Figure 42 shows that in fact the strongest current, a little above *a*, will start in a region of rather weak transverse field. It shows also that, by reason of the dip between B and C, this current will be collected just where it is required, i. e. at the point of maximum slope of $V(z)$.

It has been stated above that in the arrangement of Figure 4 the electrons will hit the screen at rather small glancing angles and the angular range in which focusing can be achieved is small unless the gradient of V is very large and the spacing between the screen and the array is made very small, and that for color tubes rather larger incidence angles of the beam on the screen are desirable. It will be appreciated, however, that this does not mean that arrangements such as that of Figure 4 may not be used for color. If a discharge wave of suitable shape is employed in arrangements using a single array of deflecting conductors, the angle of incidence can be made steep enough and can be controlled by displacement of the beam in a direction normal to the screen as with the double, or folded array, so that color screens of the kinds described with reference to Figures 20–27 may be employed. In this case, the conductors **3** will be connected together and to the highest positive potential in the tube V_m. These conductors will then operate simply to intercept parts of the electron beam travelling towards color zones on the screen which are not required to be bombarded at any given time. In other words, the arrangements of color screen above described can be employed with the conductors **3** maintained permanently at V_m and not connected to the conductors of the rear deflection array at all, provided that the angles of incidence of the electron beam are made suitable, the variation in angle of incidence great enough and the focus sharp enough by suitable control of the voltage gradient in the discharge wave and suitable spacing of the rear deflection array from the screen.

It will be understood that, though in this specification the conductor arrays produced out of fabric and the various forms of color screens have been described only in conjunction with other structural and operational features of the present invention, the fabric, the arrays derived therefrom and the color screens are themselves novel in the design of cathode ray tubes and electronic devices in general, and may be used with advantage by those skilled in the art independently of other features of the present invention.

What is claimed is:

1. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane parallel to said screen, an array of substantially parallel linear conductors arranged in a plane substantially parallel to said screen and separated therefrom by a gap through which said beam passes, said conductors being arranged crosswise to the direction of said beam and insulated from one another, a common capacitive backing plate associated with said conductors, and a cathode additional to that of said electron gun so arranged as to spray portions of the conductors in said array with electrons from said cathode.

2. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel linear conductors on the surface of said screen, said conductors being arranged crosswise to the direction of said beam and insulated from one another, a second array of conductors substantially parallel to those of said first array arranged in a plane parallel to said screen and separated therefrom by a gap through which said beam passes, each conductor of said first array being electrically connected with one conductor of said second array and each conductor of said second array being electrically connected with at least one of said first array, said conductors being so arranged that, when viewed in the direction of said beam as it passes between the two arrays, of each pair of connected conductors the one of the first array is beyond the one in the second array, a common capacitive backing plate associated with said conductors, and a cathode additional to the cathode of said electron gun so arranged as to spray portions of said conductors with electrons from said cathode.

3. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel linear conductors arranged in a plane substantially parallel to said screen and separated therefrom by a gap through which said beam passes, a common capacitive backing plate associated with said conductors, said conductors being insulated from one another and having continuations which form a parallel line pattern on a cylindrical surface, and a set of cylindrical electrodes partly surrounded by and associated with the continuations of said conductors, said set including a hot cathode, a modulating beam-forming grid electrode and at least two electron-collecting electrodes, the line pattern of said conductor continuations on said cylindrical surface being such that the individual conductors are not completely contained in plane cross sections at right angles to the axis of said cylinder, but are so displaced that a longitudinal potential gradient along the conductors parallel to said cylinder axis produces also a transverse potential gradient in said cross sections effective to deflect the electron beam produced by said cathode and issuing from said grid, so that in the presence of a longitudinal potential gradient along said conductors at least part of said last named electron beam falls on portions of said conductors and discharges them.

4. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel linear conductors arranged in a plane substantially parallel to said screen and separated therefrom by a gap through which said beam passes, a common capacitive backing plate associated with said conductors, said conductors being insulated from one another and having continuations which form a parallel line pattern on a cylindrical surface, and a set of cylindrical electrodes partly surrounded by and associated with the continuations of said conductors, said set including a hot cathode, a modulating beam-forming grid electrode and at least two electron-collecting electrodes, at least one of said electron-collecting electrodes being so arranged as to collect secondary electrons released at the conductor continuations by impingement thereon of pri-

mary electrons issuing from said cathode and grid, whereby the array conductors may be charged up to more positive potentials by the excess of secondary over primary electrons.

5. A cathode ray tube according to claim 2 including means for deflecting the electron beam produced by said gun in a plane parallel to said screen, and additional deflecting means for displacing said beam in a direction at right angles to said screen and thereby varying the incidence angles of the electrons at said screen.

6. A cathode ray tube according to claim 2 wherein the relative displacement in the direction of the electron beam of corresponding conductors in said first and second arrays is such that a plane through two such conductors forms an angle with the common normal to both planes between 40° and 55°.

7. A cathode ray tube according to claim 2 wherein said fluorescent screen is so shaped that a part of its surface is sunk below the level of said first array of conductors, and which includes on locally separated portions of the sunk part of said screen surface three different types of luminescent coating each having a definite color response to electron bombardment, said coatings being so arranged that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the gaps between the conductors of said first array.

8. A cathode ray tube according to claim 2 wherein said fluorescent screen includes a plurality of projecting insulating ridges extending crosswise to the conductors of said first array and to which said conductors are adherent at the crossing points, the part of the surface of said screen below the level of said ridges carrying, locally separated, three different types of luminescent coating, said coatings being so arranged that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the gaps between the conductors of said first array.

9. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel linear conductors opposite said screen and facing the latter across a parallel gap through which said beam passes, said array being formed by a plurality of conducting strips arranged crosswise to the direction of said beam on the surface of a flexible insulating foil, said foil being backed at least in part by a common capacitive backing plate, and a cathode additional to that of said electron gun so arranged as to spray portions of the conductors in said array with electrons from said cathode.

10. A cathode ray tube comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel linear conductors opposite said screen and facing the latter across a parallel gap through which said beam passes, said array being formed by the metallic threads of a woven fabric arranged crosswise to the direction of said beam and crosswise interwoven with insulating threads, and a cathode additional to that of said electron gun so arranged as to spray portions of the conductors in said array with electrons from said cathode.

11. A cathode ray tube according to claim 2 wherein the conductors of both arrays are formed by the metallic threads of a sheet of woven fabric having insulating threads at right angles to the metallic threads.

12. A cathode ray tube according to claim 2 adapted for television reception including means for deflecting the electron beam in a plane parallel to said fluorescent screen for effecting the line scanning operation, the frame scanning operation being effected by a potential wave running substantially undistorted across the conductor arrays with the speed of the frame sweep, said potential wave having at the side thereof at which said beam enters the gap between said arrays a maximum positive potential which drops towards its opposite side to a small fraction of said maximum potential, the maximum gradient in said wave being approximately equal to said maximum potential divided by the spacing between the two arrays while at the conductor at which the gradient is a maximum the potential is more than one-half of said maximum potential, said wave being produced by the electron current from said cathode which so sprays portions of said conductors that the electron current collected by said conductors is proportional to the gradient along the array at said conductors.

13. A cathode ray tube for television reception comprising a plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane parallel to said screen for effecting the line sweep, and means for effecting the frame scan including at least one array of substantially parallel linear conductors arranged in a plane substantially parallel to said screen and separated therefrom by a gap through which said beam passes, said conductors being arranged crosswise to the direction of said beam, and means for producing a potential wave running, substantially undistorted, across said array with the average speed of the frame sweep, said last named means including a cathode additional to that of said electron gun so arranged as to spray portions of the conductors in said array with electrons from said cathode and thereby discharge the array, said potential wave being arrested at periodic intervals for times which are proportional to the charge collected by said array from the electron beam, while during the remainder of the time said array is discharged at a constant speed by the electrons emitted by said cathode, so that the average frame sweep speed is independent of the changeable brightness of the television picture.

14. A cathode ray tube according to claim 2 adapted for color television reception including means for deflecting the electron beam in a plane parallel to said fluorescent screen, and additional deflecting means for displacing the beam at right angles to said screen so as to vary its angle of incidence at said screen, said screen being so shaped that a part of its surface is sunk below the level of said first array of conductors, said sunk part of the screen surface carrying, locally separated, three different types of luminescent coating each having a definite color response to electron bombardment, said coatings being so arranged that for each of at least three different angles of incidence of said beam one, and only one, of said different coatings is accessible to electrons passing through the gaps between the conductors of said first array, thereby producing a definite color response controlled by said additional deflecting means.

15. A cathode ray tube comprising a substantially flat fluorescent screen, a plane array of substantially parallel linear conductors associated with said screen and insulated from one another, a second array of substantially parallel linear conductors insulated from one another and arranged in a plane substantially parallel to and spaced from said first array, the conductors of said second array being connected to the conductors of said first array in staggered relation, means for producing an electron beam passing through the space between said arrays in a direction transverse to the conductors thereof and such that the conductors of said first array lie beyond the conductors of said second array to which they are connected in the direction of electron flow in said beam, means for deflecting said beam in a plane parallel to said screen, and means for so controlling the potential distribution on the conductors of said arrays as to deflect an end portion of said beam towards and into impact with said screen within a desired region defined by a group of adjacent conductors.

16. A cathode ray tube as claimed in claim 15 where-

in the displacement in the direction of the electron beam of the conductors of said first array with respect to the conductors of said second array to which they are respectively connected is so related to the spacing between the two arrays that the plane containing the respective conductors makes an angle with the common normal to the planes of said arrays of from 40° to 55°.

17. A cathode ray tube as claimed in claim 15 wherein the means for controlling the potential distribution on the conductors of said arrays includes an additional electron source so arranged in relation to said conductors as to spray portions thereof with electrons from said source.

18. A cathode ray tube as claimed in claim 17 wherein the conductors of said second array are so extended as to provide an envelope for the electron beam emitted by said further electron source.

19. A cathode ray tube as claimed in claim 17 including at least one additional electrode associated with said further electron source and so positioned as to receive electrons liberated by secondary electron emission from said conductors.

20. A cathode ray tube as claimed in claim 17 wherein the conductors of said second array are so extended as to provide an envelope of substantially U-shaped cross section, and said further electron source comprises a cathode extending substantially the length of, and embraced within, said envelope and a control electrode substantially surrounding said cathode between the latter and said envelope and so shaped as to direct electrons emitted from said cathode toward the mouth of said U-shaped envelope, and which includes another electrode positioned adjacent the mouth of said envelope adapted to receive electrons emergent therefrom, and at least one additional electrode extending adjacent the array conductors within said envelope adapted to receive secondary electrons emitted from said conductors under the effect of electron bombardment by said cathode.

21. A cathode ray tube as claimed in claim 20 wherein the conductors forming said envelope are so arranged that the conductors on one side of the envelope are displaced relative to the conductors on the other side to which they are connected so that a potential gradient axially of the envelope gives rise to an electrostatic field transverse to the envelope, whereby electrons discharged from said cathode falling on certain conductors of the envelope to change their potential will initiate a potential wave to be propagated through the array.

22. A cathode ray tube as claimed in claim 21 wherein the configuration and dimensions of the conductors in said envelope are such as to provide a speed of propagation for said potential wave which is related to the frame scanning speed of a television receiver.

23. A cathode ray tube as claimed in claim 15 including a backing electrode capacitively associated with the conductors forming said arrays.

24. A cathode ray tube as claimed in claim 15 wherein said arrays are formed from a fabric comprising the array conductors interwoven with fibers of insulating material.

25. A cathode ray tube as claimed in claim 15 including means for displacing the electron beam in a direction normal to the plane of said screen to vary the angle of incidence of said beam upon said screen.

26. A cathode ray tube as claimed in claim 25 wherein said screen is provided with fluorescent surfaces displaced from the plane of said first conductor array and beyond the latter in the direction of electron flow, each of said surfaces being divided into discrete zones providing differently colored fluorescence in response to electron bombardment and so arranged as to be selectively accessible by the electron beam at different angles of incidence thereof.

27. A cathode ray tube as claimed in claim 26 wherein the fluorescent surfaces of said screen are provided on the inside walls of grooves formed in said screen, and said first conductor array is formed on the surface of the screen between said grooves.

28. A cathode ray tube as claimed in claim 25 wherein said screen comprises a base having spacing ribs projecting from one face thereof, the conductors of said first array extending transversely to said ribs and being supported thereon, the surface of said base between said ribs carrying fluorescent materials arranged in zones allotted to a plurality of different color responses, said zones being so located with respect to the conductors of said first array as to be accessible by the electron beam selectively according to the angle of incidence of said beam.

29. A conductor array of the character described for use in a cathode ray tube consisting of a thin, flexible sheet of glass cloth impregnated with a heat resistant silicone having on one surface thereof a pattern of substantially parallel linear conductors.

30. A cathode ray tube comprising a substantially plane electron sensitive screen, a strip of insulating material substantially parallel to and spaced from said screen and carrying on the surface thereof adjacent said screen an array of substantially parallel linear conductors, means for projecting an electron beam into the space between said screen and said strip in a plane substantially parallel to said screen, said strip having an extension at one end thereof formed into a generally U-shaped cylindrical envelope, said array of conductors also extending along the surface of said strip forming the inside surface of the envelope, an electron gun positioned outside said envelope and so arranged as to direct a ribbon-shaped beam of electrons into the mouth of said envelope adapted to bombard portions of said conductors at one side of said envelope, an electrode positioned within said envelope adapted to collect those electrons emergent from said electron gun which do not impinge on said conductors, and at least one other electrode positioned outside said envelope adjacent the mouth thereof adapted to receive secondary electrons emitted from said conductors under the effect of electron bombardment by said gun.

31. A cathode ray tube as claimed in claim 30 including another electrode positioned within said envelope adapted to suppress the secondary emission of electrons from said first-named electrode and from adjacent parts of said array.

32. A cathode ray tube as claimed in claim 30 including means for indicating the amount of charge on the conductors of said array comprising a metal strip parallel to the axis of said envelope and capacitively associated with said conductors.

33. A cathode ray tube as claimed in claim 30 including a capacitive backing plate substantially parallel to and spaced from the surface of said insulating strip opposite that on which the array conductors are carried.

34. A cathode ray tube as claimed in claim 30 wherein said insulating strip consists of a thin, flexible sheet of glass cloth impregnated with a heat resistant silicone, and which includes a plurality of cylindrical insulators around which the extension of said strip is placed to form said envelope.

35. A cathode ray tube as claimed in claim 30 wherein said electron sensitive screen comprises a thin sheet of glass cloth mounted in a metal frame.

36. A cathode ray tube as claimed in claim 30 wherein the conductors of the array on the inside surface of the envelope are arranged in a staggered pattern such that the portion of each conductor at one side of the envelope is displaced axially of said envelope with respect to the portion of the same conductor at the other side of said envelope, whereby a potential gradient axially of the envelope gives rise to an electrostatic field transverse to said envelope.

37. A cathode ray tube comprising a substantially plane electron sensitive screen, at least one electron gun so arranged as to produce an electron beam in a plane substantially parallel to the plane of said screen, means

for deflecting said beam in the plane parallel to said screen in one dimension thereof, and means for deflecting an end portion of said beam towards and into impact with said screen at a position which is controllable in another dimension in the plane of said screen, said last named means including an array of substantially parallel conductors arranged in a plane substantially parallel to and spaced from the plane of said screen and arranged crosswise to the direction of said beam, an electrode extending substantially parallel to the conductors of said array in the same plane therewith and positioned at the far end of said array with respect to the direction of electron flow in said beam, said electrode being adapted to be permanently maintained at approximately the potential of the cathode of said electron gun, and means operable to set up a potential wave traversing said array so as to produce a beam deflecting electric field between said array and said screen.

38. A cathode ray tube as claimed in claim 37 wherein said electrode is separated from the adjacent conductor of the array by a gap substantially equal to the space between the plane of said array and the plane of said screen.

39. In a cathode ray tube, an electron gun for producing a ribbon-shaped beam of electrons comprising an elongated hollow metal cathode having a heating element housed therein, a metallic cathode supporting member extending substantially parallel to said cathode in spaced relation thereto, a plurality of longitudinally spaced metal struts of low heat conductivity welded to said cathode and said supporting member, a grid electrode partially surrounding said cathode and having a beam shaping opening extending the length of said cathode, insulated members supporting said cathode supporting member from said grid electrode, and a pair of metal strips fixed to said grid electrode and extending inwardly toward one another between said opening and said cathode, the inner edges of said strips being parallel to one another and forming a relatively narrow slit therebetween through which the electrons from said cathode emerge.

40. An electron gun as claimed in claim 39 wherein said cathode comprises a pair of channel-shaped nickel strips having their side flanges welded together to form a housing for said heating element.

41. An electron gun as claimed in claim 39 including a plurality of wires extending transversely across said slit and welded to said metal strips at longitudinally spaced intervals for maintaining the edges of the slit in parallel relationship.

42. A cathode ray tube comprising a fluorescent screen having on one surface thereof three different types of luminescent coating each having a definite color response to electron bombardment, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane substantially parallel to said screen, a plurality of substantially parallel, laterally spaced linear members arranged in substantially parallel, overlying relationship to portions of the said surface of said screen, and means for deflecting the electrons of said beam towards said screen at various angles of incidence, said coatings being so arranged that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the spaces between said members.

43. A cathode ray tube comprising a fluorescent screen having on one surface thereof three different types of luminescent coating each having a different color response to electron bombardment, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, an array of substantially parallel beam intercepting members arranged in laterally spaced relationship on a surface substantially parallel to and closely adjacent the said surface of said screen, means for sweeping said beam parallel to said screen, and means for applying forces effective to deflect the electrons of said beam towards said screen and at the same time focus said beam at the screen, whereby some of said electrons pass through the spaces between said beam intercepting members and into impact with said coated surface at different angles of incidence relative to said surface.

44. A cathode ray tube comprising a substantially plane fluorescent screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, a plurality of substantially parallel linear members arranged in laterally spaced relationship in a plane substantially parallel to and closely adjacent said screen, means for deflecting said beam in a plane parallel to said screen, means for deflecting said beam towards and into impact with said screen, and means for displacing said beam in a direction normal to the plane of said screen to vary the angle of incidence of said beam upon said screen, said screen being provided with locally separated fluorescent surfaces displaced from the plane of said members and beyond the latter in the direction of electron flow, each of said surfaces being divided into discrete zones providing differently colored fluorescence in response to electron bombardment and so arranged as to be selectively accessible by the electron beam at different angles of incidence thereof.

45. A cathode ray tube comprising a fluorescent screen having on one surface thereof a plurality of different types of luminescent coating each having a definite color response to electron bombardment, means for producing a plurality of electron beams in planes substantially parallel to the plane of said screen, means for sweeping said beams parallel to said screen, a plurality of beam intercepting members arranged in substantially parallel, laterally spaced relationship in a plane substantially parallel to and closely adjacent the said surface of said screen, and means for deflecting said beams toward the coated surface of said screen at different angles of incidence, said coatings being so arranged that each different coating is accessible to the electrons of one, and only one, of said beams passing through the spaces between said beam intercepting members.

46. A cathode ray tube comprising a fluorescent screen having on one surface thereof three different types of luminescent coating each having a definite color response to electron bombardment, means for producing three electron beams in planes substantially parallel to the plane of said screen, means for sweeping said beams parallel to said screen, a plurality of beam intercepting members arranged in substantially parallel, laterally spaced relationship in a plane substantially parallel to and closely adjacent the said surface of said screen, and means for producing an electrostatic field having a component normal to said screen effective to deflect the end portions of said beams towards the coated surface of said screen at different angles of incidence, said coatings being so arranged that each different coating is accessible to the electrons of one, and only one, of said beams passing through the spaces between said beam intercepting members.

47. A cathode ray tube comprising a fluorescent screen having on one surface thereof a plurality of different types of luminescent coating each type having a different color response to electron bombardment, said different types of coating being arranged in groups each group occupying a linear zone extending across said screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane substantially parallel to said screen, a plurality of substantially parallel laterally spaced linear conductors mounted on and supported by said screen in substantially parallel spaced relationship thereto with the conductors extending substantially parallel to said linear zones of said luminescent coatings, and means for deflecting the electrons of said beam towards

said screen at various angles of incidence, said conductors being so positioned in relation so said zones that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the spaces between said conductors.

48. A cathode ray tube comprising a fluorescent screen having on one surface thereof three different types of luminescent coating each having a definite color response to electron bombardment, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane substantially parallel to said screen, a plurality of substantially parallel, laterally spaced linear conductors arranged in substantially parallel, overlying relationship to portions of the said surface of said screen, an array of substantially parallel linear conductors opposite said screen and facing the latter across a parallel gap through which said beam passes, means operable to set up a potential wave traversing said array adapted to deflect the electron beam towards the screen at progressively varying distances across said screen so as to strike the screen at various angles of incidence, said coatings being so arranged that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the spaces between said conductors.

49. A cathode ray tube as claimed in claim 48 including means for displacing said beam in a direction normal to the plane of said screen to vary the angle of incidence at which said beam approaches said screen.

50. A cathode ray tube comprising a fluorescent screen having on one surface thereof a plurality of different types of luminscent coating each type having a different color response to electron bombardment, said different types of coating being arranged in groups of areas each group consisting of an area of one each of said different types and each group occupying a linear zone extending across said screen, mounted on said screen in substantially parallel spaced relation thereto, a grid of conductors having spaces therebetween, means for producing a plurality of electron beams, one for each of said different types of coating, in planes substantially parallel to the plane of said screen and displaced from one another in a direction normal to the plane of said screen, means for sweeping said beams parallel to said screen, and means for producing an electrostatic field having a component normal to said screen effective to deflect the end portions of said beams towards the coated surface of said screen at different levels thereof and at different angles of incidence, said areas of said coatings being so arranged in relation to the spaces between the conductors of said grid that the areas allotted to each type of coating are accessible to the electrons of one, and only one, of said beams passing through the spaces between said conductors.

51. A cathode ray tube comprising a fluorescent screen having on one surface thereof a plurality of different types of luminescent coating each type having a different color response to electron bombardment, said different types of coating being arranged in groups of areas each group consisting of an area of one each of said different types and each group occupying a linear zone extending across said screen, mounted on said screen in substantially parallel spaced relation thereto, a grid of conductors having spaces therebetween, means for producing a plurality of electron beams, one for each of said different types of coating, in planes substantially parallel to the plane of said screen and displaced from one another in a direction normal to the plane of said screen, means for sweeping said beams parallel to said screen, an array of substantially parallel linear conductors opposite said screen and facing the latter across a parallel gap through which said beams pass, means operable to set up a potential wave traversing said array adapted to deflect the electron beams toward the screen at progressively varying distances across said screen so that each beam strikes the screen at a different angle of incidence, said areas of said coatings being so arranged in relation to the spaces between the conductors of said grid that the areas allotted to each type of coating are accessible to the electrons of the appropriate one, and only the appropriate one, of said beams passing through the spaces between said conductors.

52. A cathode ray tube comprising a fluorescent screen having on one surface thereof three different types of luminescent coating each having a definite color response to electron bombardment, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane substantially parallel to said screen, a grid of conductors adjacent to and in substantially parallel overlying relationship to portions of the said surface of said screen, and means for deflecting the electrons of said beam towards said screen at various angles of incidence, said coatings being arranged in groups of areas each group consisting of an area of one each of said different types and lying behind spaces between the conductors forming said grid so that for each of at least three different angles of incidence areas of one, and only one, type of coating are accessible to electrons passing through said spaces.

53. A cathode ray tube comprising a fluorescent screen having on one surface thereof a plurality of different types of luminescent coating each type having a different color response to electron bombardment, said different types of coating being arranged in groups each group occupying a linear zone extending across said screen, at least one electron gun so arranged as to produce an electron beam substantially parallel to said screen, means for deflecting said beam in a plane substantially parallel to said screen, a plurality of substantially parallel laterally spaced linear conductors arranged in substantially parallel overlying relationship to portions of the said surface of said screen with the conductors extending substantially parallel to said linear zones of said luminescent coatings, and means for deflecting the electrons of said beam towards said screen at various angles of incidence, said conductors being so positioned in relation to said zones that for each of at least three different angles of incidence one, and only one, of said different coatings is accessible to electrons passing through the spaces between said conductors.

54. In an electron space discharge device, an electron beam source for delivering a beam along a predetermined path, deflection means comprising a plurality of successively disposed portions arranged adjacent said beam path operative in response to changing of the potential on a first one of said portions by registration of the beam with said first portion to provide a moving field which bends the beam out of said predetermined path into registration with each succeeding portion of the deflection means in a cyclic manner, and control means for initially deflecting said beam from said path into registration with said first portion of the deflection means to initiate each cycle of said deflection means.

55. An electron space discharge device as set forth in claim 54 which includes an electron sensitive target disposed adjacent said deflection means for presenting a visual signal during each cycle of said deflection means.

56. An electron discharge device as set forth in claim 54 which includes an electron sensitive target disposed in adjacent spaced relation with a second portion of the deflection means other than the portions struck by said beam, and a second beam source means for delivering a second beam between said target and the second portion of the deflection means.

57. In an electron space discharge device, deflection means arranged in a plurality of levels operative in response to the change of the potential condition of a particular level thereof to sequentially effect the change of the potential condition of each successive level thereof in a cyclic manner, an electron sensitive target disposed

in spaced relation with at least a portion of said deflection means, whereby a traveling wave moves across the target, and means for delivering a beam into the space between said target and said deflection means for deflection by said traveling wave into registration with successive levels of said target.

58. In a cathode ray tube having an electron gun for delivering a beam in a given plane, means for producing a moving beam deflecting electric field comprising an array of substantially parallel laterally spaced conductors arranged in a first plane substantially parallel to that in which the beam is delivered, said conductors having extensions so formed that portions of the extensions lie in a second plane substantially parallel to and opposite said first plane but separated therefrom by a space through which said beam is delivered, the extended portion of each conductor lying in said second plane being so displaced relative to that portion of the same conductor lying in said first plane that said portions lie in different planes perpendicular to said first and second planes.

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2,449,339	Sziklai	Sept. 14, 1948
2,461,515	Bronwell	Feb. 15, 1949
2,480,848	Geer	Sept. 6, 1949
2,558,019	Toulon	June 26, 1951
2,571,991	Snyder	Oct. 16, 1951
2,573,777	Sziklai	Nov. 6, 1951
2,577,368	Schultz et al.	Dec. 4, 1951
2,605,434	Homrighous	July 29, 1952
2,623,190	Roth	Dec. 23, 1952
2,625,734	Law	Jan. 20, 1953
2,691,116	Allwine	Oct. 5, 1954