Aug. 2, 1960

H. HEIL

2,947,898

COLOR PICTURE TUBE SCREEN

Filed March 16, 1956

2 Sheets-Sheet 1

FIG.1.

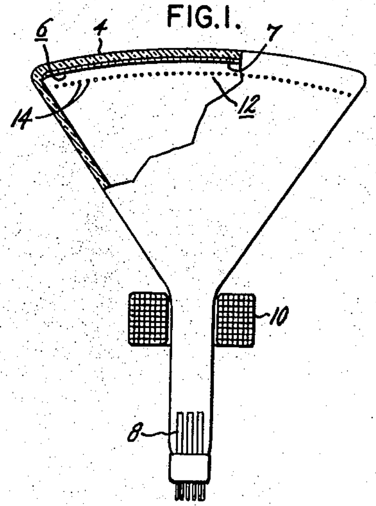


FIG.2.

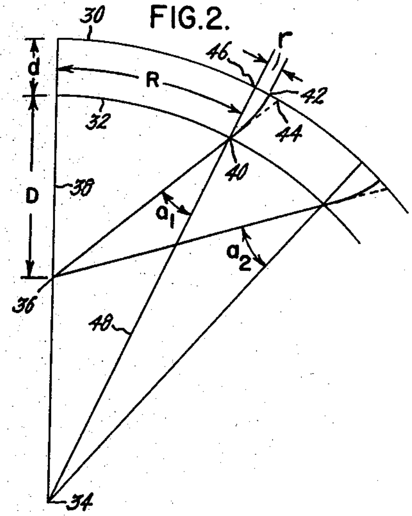


FIG.3.

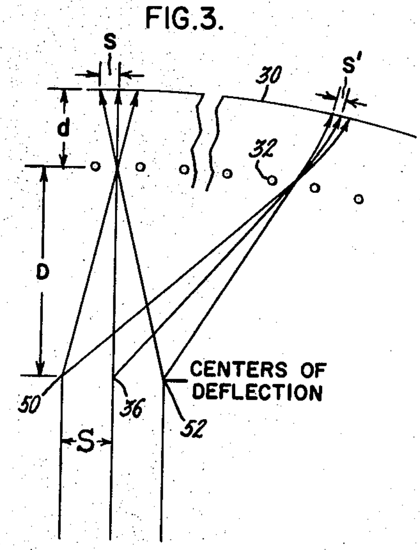


FIG.4.

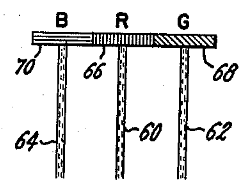
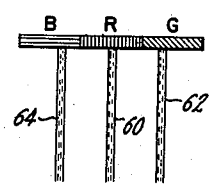


FIG.5.



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COLOR PICTURE TUBE SCREEN

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FIG.6.

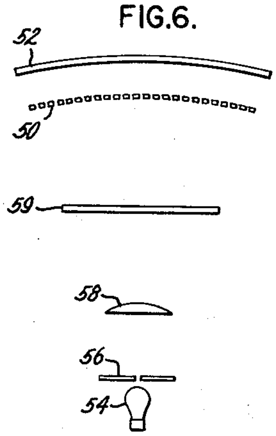


FIG.9.

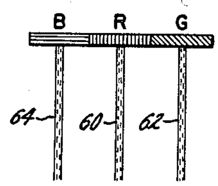


FIG.10.

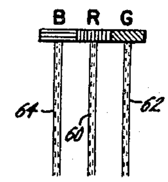


FIG.11.

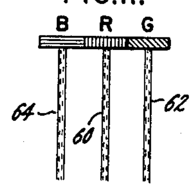


FIG.7.

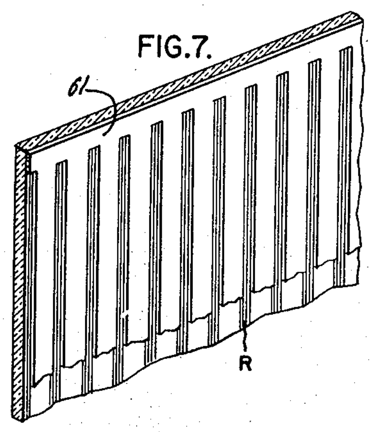


FIG.12.

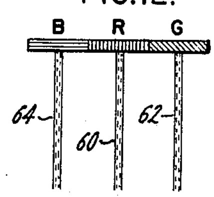


FIG.13.

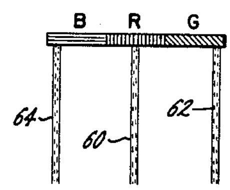


FIG.15.

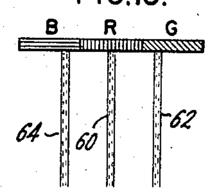


FIG.14.

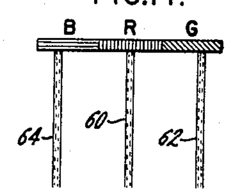
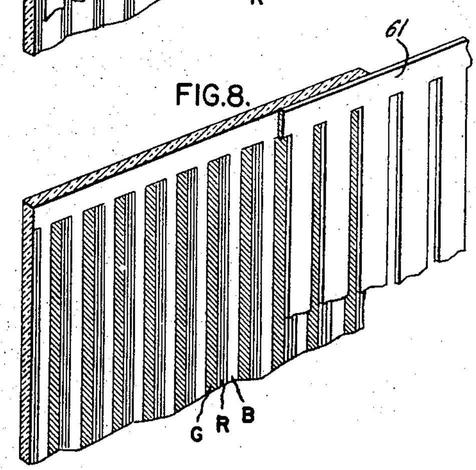


FIG.8.



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United States Patent Office

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COLOR PICTURE TUBE SCREEN

Hans Heil, Syracuse, N.Y., assignor to General Electric Company, a corporation of New York

Filed Mar. 16, 1956, Ser. No. 572,005

6 Claims. (Cl. 313—92)

This invention relates to improvements in multiple-phosphor mosaic screens for cathode ray tubes of the so-called post acceleration type.

In cathode ray tubes of the post acceleration type the electron beam is caused to pass through an accelerating field formed between the screen and an electron permeable grid or lens mask spaced therefrom, and the field changes the velocity of the beam to a desired level before impact with the screen. One advantageous form of screen for such tubes consists of a plurality of groups of line-like or dot-like areas of sub-elemental image dimension in at least one sweep coordinate of the electron beam or beams, the areas in each group consisting of a plurality of respective different color light emitting phosphors. The lens mask cooperating with such a screen has a plurality of openings or electron permeable areas so positioned with respect to the phosphor groups as to provide selective illumination of the different respective phosphor areas in each group by the electron beams from different respective electron guns. In one form of triphosphor color television picture tube, for example, each phosphor group of the mosaic screen consists of a set or triad of three parallel red, green, and blue phosphor lines, the lines being oriented parallel to the vertical sweep coordinate and having a width, or dimension as measured in the horizontal sweep coordinate, equal to a sub-elemental picture dimension. The lens mask consists of a grille of parallel uniformly spaced wires, with the wires arranged vertically and spaced so that there is one inter-wire spacing for each triad of lines. The grille is so positioned relative to the screen as to permit the beam from each of three electron guns to strike only the lines of the one color phosphor for which it is intended.

The post acceleration field in such cathode ray tubes causes a distortion or curvature of the electron beam trajectory in the space between the mask and screen, and thereby makes the pattern of the landing points of any one electron beam on the screen different from a simple Crookes shadow of the grid. This distortion increases with deflection angle, and for any one electron beam is rotationally symmetrical about a center of distortion located at the point at which the beam strikes the screen when undeflected, i.e. when its deflection angle is zero. In tubes employing a plurality of electron beams whose paths are spaced before deflection, this distortion causes a compression or reduction in the spacing of the landing points of the beams which increases with deflection angle. In other words the separation of adjacent beam landing points in each phosphor group becomes smaller, and the gaps between landing points of beams in adjacent phosphor groups become larger, as the sides of the picture area are approached. This compression is sufficient to be significant in tubes of television picture size and must be taken into account when laying down the phosphor increments of the screen in order to avoid beam-phosphor misregistry and consequent color impurity during tube operation.

Accordingly, a principal object of the present invention is to provide an improved method for laying down the phosphor areas of a mosaic multiple-phosphor screen for a post acceleration cathode ray tube which properly locates the individual phosphor areas in the direction of their sub-elemental image dimension so as to insure proper registry thereof with the scanning electron beams.

Another object is to provide an improved multiple-phosphor screen and method of making thereof for a post acceleration cathode ray tube which provides maximum tolerances for shifting of the electron beam landing points without causing beam-phosphor misregistry or color impurity.

These and other objects of my invention will be better understood from the description hereinafter, and the scope of the invention will be defined in the appended claims.

Briefly, the foregoing objects are accomplished according to a preferred aspect of the present invention by tailoring the sub-elemental image dimension and adjusting the location of the phosphor areas in each phosphor group in at least the marginal portions of the screen so that such phosphor areas coincide in location and spacing with the electron beam landing points thereon. That is, on the portion of the screen where the electron beam deflection angles are largest and the beam landing points are correspondingly most closely spaced, the sub-elemental image dimension of the individual phosphor areas is correspondingly reduced to provide a match between phosphor area size and beam landing point spacing which enable the electron beams to land exactly centered on the respective phosphor areas. In another preferred aspect of the invention the sub-elemental dimension of the phosphor areas is progressively decreased from the center to the edge of the screen in exact correspondence with the progressive decrease in beam landing point spacing from the center to the edge of the screen, thereby enabling the electron beam landing points to be exactly centered with respect to the sub-elemental image dimension on all phosphor areas throughout the screen.

Figure 1 is a view to a diminished scale of a post acceleration cathode ray tube to which the present invention may be applied;

Figure 2 is an enlarged diagrammatic view showing in an exaggerated fashion the geometrical relations of a portion of the tube of Fig. 1;

Figure 3 is a further enlarged diagrammatic fragmentary view of a portion of the tube of Figure 1;

Figure 4 is a diagrammatic view showing illustrative electron beam landing point positions on the screen of a cathode ray tube;

Figure 5 is a view similar to Figure 4 showing other beam landing point positions;

Figure 6 is a schematic view of a photographic arrangement suitable for use with the present invention;

Figure 7 is an enlarged fragmentary perspective view of one type of screen pattern transfer arrangement suitable for use in the present invention;

Figure 8 is a view similar to Fig. 7, showing a later stage in the transfer process;

Figure 9 is an enlarged fragmentary view showing one manner of registration of the electron beams of the tube with certain of the phosphor elements in the central portion of the screen;

Figure 10 is a view similar to Figure 9 illustrating the manner of electron beam-phosphor registry in another portion of the screen;

Figure 11 is a view similar to Figures 9 and 10 illustrating the manner of beam phosphor registry in still another portion of the screen;

Figure 12 is a view similar to Figure 9 showing another manner of registry of electron beams and phosphor elements;

Figure 13 is a view similar to Figure 12 showing beam-phosphor registry in another portion of the screen;

Figure 14 is a view similar to Figure 9 showing still another manner of beam-phosphor registry; and

Figure 15 is a view similar to Figure 14 showing registry in another portion of the tube.

Turning now to Figure 1 of the drawings, there is shown a post acceleration color television cathode ray picture tube of a type to which the present invention is particularly applicable. The tube includes an envelope **2** closed at its front end by a substantially cylindrical faceplate **4** on the inside surface of which is formed a screen **6** including a plurality of groups of discrete phosphor areas **7**, the areas in each group consisting of different color light emitting phosphors. For the sake of economy of description and ease of understanding, the phosphor areas will be described specifically hereinafter as line-like in shape and as having sub-elemental image dimensions, i.e. width, in only one sweep coordinate. It will be appreciated by those skilled in the art, however, that the invention embraces the formation of screens whose phosphor areas are either line-like or dot-like in shape, i.e. which have sub-elemental image dimensions in either one or two sweep cordinates. Each phosphor line group includes one line-shaped area of each of three primary color emitting phosphors, e.g. red, R, green, G, and blue, B, each line being deposited substantially parallel to the axis of the faceplate and having a width of the order of a sub-elemental picture dimension. In one practical embodiment of the tube, for example, of a size popularly referred to as 21 inch, the lines are approximately .010 inch in width. The tube also includes three electron guns **8** arranged side by side in a plane perpendicular to the phosphor lines, with the central gun being positioned so that its undeflected electron beam strikes the screen **6** at the approximate center thereof. A deflection yoke **10** provides angular deflection of the electron beams sufficient to sweep the screen both horizontally and vertically. The yoke is so oriented that the direction of vertical deflection is substantially parallel to the phosphor lines, while horizontal deflection is substantially perpendicular to the phosphor lines. The electron guns **8** are so spaced and arranged that the centers of the deflection of the beams (center of deflection is the point defined by the intersection of the path of a beam before and after deflection) are equally spaced and lie in a common plane, the plane of deflection, which is substantially normal to the axis of the center beam. Spaced from the screen **6** is a substantially concentric electron permeable mask or grid **12**, here shown as a grille of fine wires **14** arranged parallel to the phosphor lines and uniformly spaced to provide one inter-wire space opposite each phosphor line group. The screen is maintained by a suitable power supply (not shown) at a potential V_s substantially above the grille potential V_m, so that there is a substantial accelerating electric field between the grille and screen. The grille wires are so spaced and positioned with respect to the center of deflection of each beam that the beam from each gun illuminates only the phosphor stripes of the particular primary color for which it is intended.

Figure 2 shows diagrammatically the geometry of the tube of Figure 1. The surface of the screen is represented by line **30** while **32** denotes the plane of the grid, **34** designates the center of curvature of the screen and grid, point **36** the center of deflection of the center electron beam, and line **38** the trajectory of the undeflected center electron beam from its center of deflection to the screen. Point **40** represents the point at which the center electron beam passes through the grid after deflection in the horizontal sweep coordinate sufficient to give the beam an angle of incidence a_1, and point **42** is the point at which the electron beam passing through point **40** strikes the screen. The path of the electron beam from **40** to **42** is curved toward the center of the screen due to the effect of the post acceleration electric field between the grid and screen. Thus, the actual landing point of the electron beam on the screen is displaced toward the center of the screen from the point **44** at which the screen is intersected by the straight line projection of the path of the beam before reaching the grid. This displacement increases with increasing deflection angle. The term R represents the distance between the point at which the undeflected center electron beam strikes the screen and the point **46** at which the screen is intersected by a radius **48** drawn from the center of curvature **34** through point **40**. The term r represents the distance between the actual landing point of a beam on the screen and the intersection with the screen of a radius through the point at which the beam passes through the grid. Due to the increase in displacement of the beam by the accelerating field with increased deflection angle, the dimension r increases with increasing deflection angle, but at a decreasing rate.

As a result of this phenomenon, the three beams are effectively bunched or compressed, i.e. the spacing between their landing points is decreased, as deflection angle increases. This is best illustrated in Figure 3 wherein is shown in exaggerated fashion the deflection of all three beams in the horizontal sweep coordinate, the points **50** and **52** representing the centers of deflection of the left and right side beams, respectively. As may be seen from Figure 3, the spacing of the landing points of the center and two side beams at the center of the screen is

$$s=\frac{d_c S}{D}$$

where

$$d_c=d\cdot\frac{2}{g}(\sqrt{1+g}-1),\quad g=\frac{V_s-V_m}{V_m}$$

d is the grid-screen spacing, D is the distance from the center of deflection to the grid, and S is the color base, or spacing of the centers of deflection of adjacent beams. For deflection angles other than zero, however, it may be shown mathematically that the spacing of the landing points of adjacent beams having a color base S is reduced to a value

$$s'=\frac{dr}{dR}\cdot S$$

For tubes of television picture size it has been found that as a practical matter this decrease in spacing of the beam landing points may be as much as 20% at maximum deflection angles.

Since the spacing of the landing points of the separate electron beams is decreased toward the edges of the screen as shown in Figure 3, screens whose phosphor area sub-elemental dimensions are equal from the center to the edge of the screen will be impinged by the electron beams in such a manner that when the lines are located and dimensioned so as to be impinged at their centers by the undeflected beams, i.e. at the center of the screen as shown diagrammatically in Figure 4, the relative position of the beam landing points on lines of the same width at the edge of the screen will be as shown in Figure 5. The situation shown in Figure 5 is highly undesirable because when one of the beams such as the center beam shown is centered on its phosphor stripe the other two beams will land very near the inner edges of their respective phosphor stripes. Hence, only a slight displacement of the landing points of the two side beams is required to shift them over to the wrong color stripe and cause objectionable color impurity. Or, to put it another way, very close tolerances must be imposed on the beam landing point positions in the situation of Figure 5 in order to avoid color impurity.

According to the invention the phosphor areas of the screen are arranged and located so as to coincide with the above described distortions in the scan patterns of the electron beams and thereby insure substantially exact registry between the beam traces and phosphor areas or conversely, to permit greatest tolerances in shifting of beam landing points during tube operation without causing color impurity. In one form of the invention there is first formed a master pattern of one set of lines, or more properly of the correct location for one set of lines to insure exact registry with a trace of one electron beam. This master pattern may be formed in various ways, for example, by taking a shadow photograph of a mock grid **50**, as shown in Figure 6, which is positioned relative to the photographic plate **52**, an illuminating light source **54**, and a mask having a small aperture or slit **56** in a manner to simulate the relative positions of the screen, mask and electron beam deflection center in the actual tube. With this arrangement a suitable optical corrector **58** is required to provide the necessary light ray distortion for simulating electron beam curvature in the post acceleration field. Such apparatus is described more fully in the co-pending application of H. Heil, Serial No. 555,368, filed December 27, 1955, and assigned to the assignee of this application. The mock grid **50** may take any desired form such as a sheet of opaque material having light transmitting slits therein, a photographic plate having alternate opaque and transparent areas, or a transparent plate one side of which is coated with an opaque coating into which is scratched transparent lines. Another way of forming the master pattern is by direct electron beam exposure of a sheet of suitably electron sensitive material, such as a photographic emulsion, through an actual grid and under conditions simulating those in regular tube operation.

Once the master pattern of one set of lines is formed, an image of this master pattern is then transferred to or impressed upon the screen support member of the tube which in the tube shown is the faceplate **4**. The image is positioned on the screen support member so that its center of distortion coincides with the center of distortion of the trace of one of the electron beams in the tube, e.g. the red phosphor-illuminating beam. In this way the image transferred to the screen support member forms indicia of the positions of one set of the phosphor lines, e.g. those to be illuminated by the red beam. Transfer of the image of the master pattern to the screen support member may be accomplished in various ways. For example, the transfer may be made by making a photographic projection print or contact print of the master pattern on a photo-resist coating on the screen support member which is light sensitive and also capable of serving as an adhesive or mechanical binder facilitating application of phosphor. One such known photo-resist material is polyvinyl alcohol suitably light sensitized with ammonium dichromate. With this technique the indicia of the positions of the set of phosphor lines are formed in the photo-resist coating by means of relatively insoluble areas spaced by relatively soluble areas which are dissolved away. The phosphor itself may then be applied to the insoluble areas of the resist and will be retained thereby in proper location during completion of the manufacture of the screen. Other ways of transferring the image to the screen support member are by offset printing with a printing plate made from the master pattern or by stenciling with a stencil **61**, as shown in Figures 7 and 8, made from the master pattern, the printing "ink" in such cases being, for example, a suitable pressure sensitive adhesive to which the phosphor may subsequently be applied and which may later be conveniently removed as for example by evaporation during bake-out.

Still another way of forming indicia of the positions of a set of phosphor lines on the screen support member is to coat the screen support member with a photo-resist coating such as light sensitized polyvinyl alcohol, and then directly record on the coated screen support member

itself a shadow photograph of a mock grid **50**, in the manner of the shadow photograph technique above described and shown in Figure 6, using a light source and suitable optical corrector as taught in the Heil application Serial No. 555,368 previously mentioned.

Additional images of the master pattern are then transferred to the screen support member, to provide thereon indicia of each additional set of phosphor lines, e.g. blue and green. In accordance with the invention, however, each of these additional images is positioned so that its center of distortion coincides with the center of distortion of the trace of the corresponding electron beam. That is, the indicia of the green lines are so placed that their center of distortion coincides with the center of distortion of the trace of the green phosphor-illuminating electron beam, and the indicia of the blue lines are placed with their center of distortion coinciding with the center of distortion of the trace of the blue beam. Since the centers of distortion of the several electron beam traces are spaced a distance equal to the spacing of the centers of the deflection of the beams, which by definition is the color base S, the indicia for the successive sets of phosphor lines will likewise be successively displaced a distance of approximately S on the screen support member. For proper color selection the exact spacing of the successive indicia must also, however, be a multiple of the individual phosphor line with s, preferably a multiple of the form $[BN+(B-1)]$ where B is the number of different color phosphors employed and N is an integer. Thus in the present case B is 3 and the exact displacement of successive indicia, which we may term S′, should equal that value of the product $(3N+2)(s)$ which most closely approaches S.

The manner in which the relative displacement of the indicia of the several sets of lines may best be accomplished is dependent upon the particular method employed to transfer the images of the master pattern to the screen support member. If photographic contact printing from a light or electron beam exposed photographic master is employed, for example, all that is required to shift the indicia is that the position of the photographic negative be shifted relative to the screen support member a distance of S′ between successive transfers. If offset printing or stenciling is employed, as shown in Figures 7 and 8, the printing plate or stencil **61** should likewise be shifted S′ between successive image transfers.

Thus by the above described form of the invention all three sets of phosphor lines may be located on the screen support member with the use of but a single master pattern, and each set of lines will be properly positioned for exact registry with its respective illuminating electron beam. Once the indicia for a given set of lines is formed the phosphor itself may be applied thereto in any desired manner, as for example by application to the insolubilized portions of polyvinyl alcohol resist or to the pressure sensitive adhesive "ink" heretofore described. Alternatively, where the particular method of impressing the images of the master pattern on the screen support member permits, as for example where the image transfer is accomplished by stenciling, the phosphor may be applied to the screen support member through the same stencil and at the same time as the image transfer is being made, thus effectively combining phosphor line location and application.

In carrying out the foregoing method provision should preferably be made to reduce the sub-elemental image dimension, i.e. width, of the phosphor lines from the center to the edges of the screen as necessary to conform to the reduced spacing of the electron beam landing points as illustrated in Figure 3, in order to avoid line overlap when the phosphor is applied to the screen support member. Such line narrowing may be accomplished in a variety of ways depending on the particular method used to transfer the image of the master line pattern to the screen support member. For example, if a stencil **58** or printing plate is used to form the indicia on the screen support member, the openings in the stencil or the contact areas of the printing plate may be progressively narrowed from the center to the edge so as to conform to the progressively reduced spacing of the beam landing points from the center to the edge of the picture area. If the image transfer is accomplished photographically, the line width may be reduced by known photographic means as for example by inserting a variable density filter **59**, as shown in Figure 6, between the exposing light source and the photographic plate so as to reduce the light intensity and hence progressively narrow the exposed areas of the photographic emulsion from the center to the edge of the picture area.

The principal advantage of the above described screen printing method is that the phosphor lines are so placed on the screen support member as to register with the electron beam landing points in the central portion of the screen in the manner shown in Figure 9, where reference numerals **60**, **62**, and **64** designate the red, green and blue beams, respectively and **66**, **68**, **70** designate the red, green, and blue lines of one triad. At the side or edge portions of the screen, the lines will be narrower, but the electron beams will still center on the lines in the manner shown in Figure 10, while at intermediate points between the center and edge of the picture area, beam-phosphor registry will be as shown in Figure 11. Thus, it may be seen that accurate registration of the beams with the center of the sub-elemental image dimension of the phosphor areas throughout the entire screen is achieved by the technique above described. The invention thus provides maximum tolerances for any shift in beam landing point locations which might be caused by various unforeseen factors such as fringing of the post acceleration field or other nonhomogeneous effects without producing any color impurity.

In accordance with another form of the invention, conformance of the phosphor lines to the beam traces is accomplished by making the lines of uniform width

$$s=\frac{d_cS}{D}$$

throughout the picture area, and increasing the actual color base in the tube to a value, S_e, which is larger than the value S from which the dimension s is derived. Increasing the actual color base of the tube from S to S_e increases the spacing of the beam landing points all across the screen and preferably S_e is made sufficiently large so that the beam landing points are centered on the phosphor lines at the edges of the picture area as shown in Figure 12. The increased tolerances thus obtained in beam landing point position at the edge portions of the screen are gained at the expense of shift of the side beams toward the outside edges of their respective phosphor lines at the center of the screen as shown in Figure 13. However, non-centering of the beams on the phosphor lines can be more easily tolerated at the center of the screen than at the edges because there are fewer non-homogeneous effects on the beams in the center of the screen and hence the beam landing points can more easily be positioned to very close tolerances.

Optionally, the value S_e may be chosen so that the beam landing point spacing equals the line width s, and the beams will therefore center on the lines, at an intermediate point between the center and edge of the screen. The width of the lines may thus be said to be a compromise between the spacing of the beam landing points at the center of the picture area and at the edge of the picture area. When this is the case the beam-phosphor registry will be as shown in Figure 14 at the center of the screen and as shown in Figure 15 at the edge of the screen.

Lines of uniform width s may be conveniently laid down by simply displacing the successive images representing the successive indicia of the respective sets of phosphor lines a distance s on the screen support member. The manner in which this displacement may be achieved will depend upon the particular method employed to transfer the image of the master pattern to the screen support member and can be identical with any one of the methods hereinbefore described for shifting the successive images by the distance S'.

Thus there has been shown and described an improved multiple phosphor mosaic screen and method of forming the same wherein due account is taken of the distortion of an electron beam scan pattern due to influences of a post acceleration field, and wherein provision is made to locate each sub-elemental portion of the screen in a proper position to insure optimum color purity and maximum tolerances in electron beam landing point positions.

It will be appreciated by those skilled in the art that the invention may be carried out in various ways and may take various forms and embodiments other than those illustrative embodiments heretofore described. It is to be understood that the scope of the invention is not limited by the details of the foregoing description, but will be defined in the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a cathode ray tube, a screen having two coordinates, a plurality of electron guns arranged to illuminate the screen with electrons, an electron permeable mask between the guns and screen adapted to have a potential difference with respect to the screen such as to form an accelerating field in the path of said electrons, and a plurality of groups of phosphors on said screen, each phosphor group consisting of respective phosphor areas adapted to be illuminated by electrons from the respective guns, the phosphor areas in each group having a dimension and a center to center spacing decreasing with increasing deflection from the center of the screen in at least said one screen coordinate so as to correspond to the spacing in said one screen coordinate of the landing points of electrons thereon.

2. In a cathode ray tube, a screen, a plurality of electron guns arranged to illuminate the screen with a plurality of electron beams adapted to be swept across the screen in two coordinates, a single electron permeable mask between the guns and screen adapted to have a potential difference with respect to the screen such as to form a single accelerating field therebetween, and a plurality of contiguous groups of phosphors on said screen, each phosphor group consisting of respective phosphor areas adapted to be illuminated by the respective electron beams, the phosphor areas of said phosphor groups being contiguous and having an equal dimension in at least one sweep coordinate throughout the screen, said dimension being approximately equal to the spacing in said one sweep coordinate of the landing points of said electron beams on the portions of said screen illuminated at an intermediate value of deflection of said beams in said one sweep coordinate, said dimension being less than the spacing in said one sweep coordinate of said beam landing points at the minimum value of deflection of said beams and being more than the spacing of said beam landing points at the maximum value of deflection of said beams in said one sweep coordinate.

3. In a cathode ray tube, an image screen having two coordinates and comprising a plurality of groups of phosphors, each phosphor group consisting of respective phosphor areas adapted to be illuminated by electrons from different rsepective electron guns, the phosphor areas in each group having a dimension and a center to center spacing in at least one screen coordinate which decreases progressively from the center to the edge of the screen.

4. A screen for a cathode ray tube of the type having a plurality of electron guns and wherein the landing points of electron beams from the different guns on the screen are farther apart in the central portion of the screen than in the peripheral portion of the screen, said screen comprising a plurality of groups of phosphors arrayed in two coordinates, each phosphor group consisting of respective phosphor areas adapted to be illuminated by electrons from different respective guns, the phosphor areas in each group having an equal dimension in at least one screen coordinate, said dimension being approximately equal to the spacing in said one screen coordinate of the landing points of electron beams from said respective electron guns on the portions of said screen at the extremes of said one coordinate.

5. In a cathode ray tube, a screen, a plurality of electron guns arranged to illuminate the screen with electron beams directed at a plane of deflection between the guns and screen, an electron permeable mask between said guns and screen adapted to have a potential difference with respect to said screen such as to form an accelerating electric field therebetween, deflection means for sweeping each beam across the screen in two perpendicular coordinates by angular deflection from a center of deflection at the intersection of the beam with the plane of deflection, said centers of deflection of adjacent beams having a spacing S_e, a plurality of groups of phosphors on said screen, each group consisting of respective phosphor areas of sub-elemental image size in at least one sweep coordinate and adapted to be illuminated by the respective electron beams, the elemental phosphor areas of each phosphor group having a uniform dimension and a substantially uniform center to center spacing in said one sweep coordinate, s, equal to

$$\frac{d_c S}{D}$$

where D is the distance from the center of deflection to the mask

$$d_c = d \cdot \frac{2}{g}(\sqrt{1+g}-1)$$

d is the mask to screen spacing, g is

$$\frac{V_s - V_m}{V_m}$$

V_s=screen potential, V_m=mask potential, and S is less than S_e.

6. A cathode ray tube as defined in claim 5 wherein S=75 to 95% of S_e.

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