

1.194.023

PATENT SPECIFICATION

DRAWINGS ATTACHED

1.194.023



Date of Application and filing Complete Specification: 6 June, 1967.

No. 26138/67.

Application made in United States of America (No. 557663) on 15 June, 1966.

Complete Specification Published: 10 June, 1970.

Index at acceptance: —H1 D(4A4, 4A7, 4K4, 4K7, 4K8, 4GY, 4G6, 4HY, 4H1, 4F2Y, 4F2B)

International Classification: —H 01 j 29/30

COMPLETE SPECIFICATION

Cathode Ray Tube and Method of Manufacture

We, RCA CORPORATION, formerly Radio Corporation of America, a Corporation organized under the laws of the State of Delaware, United States of America, of 30, Rockefeller Plaza, City and State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to cathode ray tubes, and to the manufacture thereof, and particularly to shadow mask type color cathode ray tubes comprising a plurality of electron guns, a multi-apertured shadow mask, and a mosaic screen of systematically arrayed color phosphor deposits, or dots.

The phosphor dots of the screen of such a tube may be laid down in groups of dots of different color-emitting phosphors by a direct photographic printing technique wherein a photosensitive coating on the faceplate panel of the tube is exposed through the apertures of the mask to a point source of light. The coating is then developed, as by washing off the unhardened unexposed portions, leaving a desired pattern of exposed hardened dots. This process is repeated for each color-emitting phosphor. The shadow mask is preferably detachably mounted on the faceplate panel so that it can be easily removed and replaced in exactly the same position every time. Phosphor powder may, e.g., be mixed directly with each photosensitive coating before application to the faceplate, or else applied to the coating after the latter has been exposed.

In the operation of the tube, the electron beams are subjected to electrostatic or magnetic fields to provide horizontal and vertical deflection of the beams and to maintain convergence of the beams near the screen during deflection. These fields affect the electron beam paths and hence the landing points or spots of the beams on the screen in ways that the screen-printing light rays are not affected. Thus, unless compensation is made for the differences between the beam paths and the light ray paths, series misregister of the beam spots with the phosphor dots will result. Hereinafter, the electron spots and phosphor dots will usually be referred to simply as spots and dots, respectively.

A well-known shadow mask tube for color television has three guns in a triangular arrangement around the tube axis and a different trio of different color emitting phosphor dots on the screen for each aperture through the mask. The phosphor trios have a triangular arrangement, with each dot of a trio substantially aligned through the associated aperture with a different one of the electron beams. However, a misregister of the beam spots with the corresponding phosphor dots occurs when a trio of beam spots is shifted as a unit radially outwardly from the screen center away from its associated dot trio. This is caused by an axial shift of the deflection centers of the beams toward the screen with increasing angles of deflection and is termed "radial misregister".

Misregister of beam spots and phosphor dots also occurs when the individual spots of a spot trio are all moved away from each other. This is caused primarily by the application of dynamic convergence fields and is termed "degroupping misregister". Misregister occurs when the beam spots are distorted away from equilateralism. This

is due to the non-uniform effect of the rectangular raster-scanning deflection fields on the off-axis beams. Misregister also occurs when the phosphor dots of a trio are distorted away from equilateralism because of inherent characteristics of the dot printing system. These types of misregister are termed "astigmatic misregister".

5 Misregister occurs when a phosphor dot and its associated beam spot are individually moved different distances relative to the centers of their respective trios due to an apparent decrease of the spacing of the dot printing light sources and of the electron beams from the central axis at increasing angles of deflection. This misregister is termed "foreshortening misregister". 5

10 Other sources of misregister of the spots and dots include the effect of the earth's magnetic field upon the paths of the electron beam, and the effect of distortion of the faceplate when the tube is evacuated. 10

15 In the commercial manufacture of prior art tubes of the type described, compensation for radial, degrouping and foreshortening misregisters has, to a degree, been provided in the form of selected tube geometry and in the use of unique screen printing methods and apparatus. One example of such compensation is taught in United States Patent 2,885,935 issued on May 12, 1959. This patent teaches that an optimum correction for degrouping and radial misregister can be obtained by (a) using a mask-to-screen assembly wherein the spacing between the mask and the screen varies in a particular manner from a maximum along the central tube axis to a minimum near the edge of the assembly at a given distance from the center of the screen, (b) interposing, in the path of light from the light source to the mask in the screen printing apparatus, or "lighthouse", in a special light refracting device, or lens, having a single central plane of symmetry. However, such a lens provides acceptable register of the beam spots and phosphor dots in color tubes having a maximum beam deflection angle of around 70° and only along said line of symmetry. With respect to tubes using larger deflection angles, e.g. 90° , and having a non-circular shaped screen, e.g. rectangular, the amount of misregister produced by light refracted by the lens in regions not on the line of symmetry may exceed desirable tolerances. 15 20 25

30 According to the present invention there is provided a method of photographically fabricating a mosaic phosphor screen for a cathode ray tube by projecting light from a source through an optical refracting member and a multi-aperture mask to expose discrete areas of a photosensitive phosphor layer on a support, and developing the layer to produce the mosaic array of discrete elements on the support, wherein the refracting surface of the optical member has been determined by operating a prototype tube having a multi-apertured mask electrode and a phosphor screen comprising an array of discrete phosphor dots photographically produced through the mask electrode, including the steps of determining the misregister between the phosphor dots and the correspondings electron beam impingement spots at each of a multiplicity of points distributed over the entire screen of the tube; determining from the respective misregisters at the multiplicity of points the respective slopes, at points corresponding to the multiplicity of points on the screen, of portions of an ideal refractive surface of an optical member which would print discrete phosphor elements at the corresponding impingement spots of the electron beam of the prototype tube; and determining with the slopes of a continuous refractive surface for the optical member closely approaching the ideal refractive surface. 30 35 40 45

50 The fabrication of the tube by the method of the invention includes printing the phosphor dot screen in a light house which uses one or more special lenses designed in accordance with this invention to produce acceptable correction or compensation for all of the causes of misregister over the entire surface of the screen. In the case of a three-color kinescope with three beams, a different lens is used to print the dot pattern for each color. However, the invention could be used to make a dot screen for a tube having only one beam and one kind of phosphor dot. 50

55 An embodiment of the invention includes the method of fabricating a cathode ray tube having a mosaic phosphor screen comprising an array of discrete phosphor elements, a multi-apertured shadow mask spaced from said screen, and means for projecting an electron beam through the apertures of said mask and onto said screen, by a direct photographic process comprising the steps of (a) applying a photosensitive layer to said screen support, (b) projecting light rays from a substantially point source along paths through said apertures, (c) optically refracting said rays between said source and said layer to expose a discrete area of said layer at each of a multiplicity of predetermined points distributed over the entire screen area in such manner as to provide acceptable compensation for all conditions that would otherwise cause misregister between said discrete areas and the impingement spots thereon of the 55 60

electrons of said beam, and (d) developing said layer to produce said array of discrete elements on said support.

The lens embodying the invention for use in printing one color dot pattern on the screenplate of a tube of given kind as, for example, a 19" rectangular color kinescope with 90° deflection, may be made by the following steps:

- (1) A faceplate of given curvature, e.g. spherical, is fabricated;
- (2) A multi-apertured shadow mask of desired curvature is fabricated;
- (3) A phosphor dot pattern is printed on the faceplate by applying a photosensitive layer to the faceplate, assembling the faceplate and mask in predetermined spaced relation, exposing the photosensitive layer to light rays passing through the mask apertures, and developing the layer to remove the unexposed portions;
- (4) The mask and exposed faceplate are incorporated into a complete, operative cathode ray tube;
- (5) While the tube is operated with an electron beam scanning the printed dot pattern, the direction and amount of misregister of the beam spots and corresponding phosphor dots is measured at each of a multiplicity of data points distributed over the entire surface of the screen;
- (6) The total number of data points may be multiplied, e.g. to 250—300 points, by interpolating additional data points located between the measured points;
- (7) For each of the data points in steps (5) or (6), using the corresponding misregister of the beam spot at phosphor dot at that point there is determined the three-dimensional slope required at a corresponding point on the surface of a theoretical lens, which, if used in a subsequent printing operation, would compensate or substantially correct the misregister at that data point. These slopes are preferably converted to vectors normal to the lens surface;
- (8) The theoretical lens surface of step (7) is approximated by fitting a bi-variant polynomial to the calculated slopes or normal vectors to obtain a description of a continuous surface of the lens to be made;
- (9) The bivariate polynomial surface description of step (8) is converted to one or more tapes for controlling a numerical-control (NC) milling machine;
- (10) A lens mold is fabricated by the NC machine and tape to the desired lens surface; and
- (11) The desired lens is sagged on the mold.

The printing step (3) may be carried out with no lens used in the lighthouse, in which case the lens produced could be used alone in a lighthouse to print the phosphor screen (one color) for a commercial tube. However, the method is practiced by using at least one lens of known configuration in step (3), in which case the description of this lens is incorporated in step (7), and the resulting new lens is used in combination with the first lens to make commercial tubes. Alternatively, one or more lenses could be used in step (3) and a new lens could be fabricated to be substituted for one or more of the first lenses in manufacturing tubes, which new lens would incorporate the refractive properties of the original lens of step (3).

In the process of fabricating corrective lenses for use in making three-color tubes, step (3) is repeated to print each color dot pattern to step (4), and the misregister measurements of step (5) are preferably made simultaneously for all three colors. However, the subsequent steps are carried out independently for each color, to produce three different lenses, one for each color.

Each final lens resulting from the process described briefly above is tested, before being used commercially, by using it to print a dot pattern on the faceplate of an experimental tube, operating the tube, and again measuring the misregister at the same or different points. In most cases, the amount of misregister is within predetermined limits or tolerances, and hence, commercially acceptable. In the event that the residual misregister in this test is not acceptable, the entire process is repeated using in step (3) the last lens fabricated, to produce a new lens capable of producing tubes with acceptable register over the screen surface.

An embodiment of the invention will be described in greater detail in connection with the accompanying drawings, wherein:

FIGURE 1 is a schematic illustration of a three-beam shadow mask cathode ray tube showing the causes of radial and degroupping spot-dot misregister;

FIGURE 2 is a partial axial section of a lighthouse apparatus that may be used in practicing the method of the invention;

FIGURE 3 is a plan view of cathode ray tube faceplate showing a distribution of points at which misregister may be measured;

FIGURES 4 and 5 are schematic views, partly in section in the plane of FIGURE 2, to be used in explaining the dot printing operation;

FIGURE 6 is a transverse section through a lens mold made according to the invention and a glass plate to be sagged onto the mold;

5 FIGURE 7 is a view similar to FIGURE 6 after the sagging operation; and

FIGURE 8 is a transverse section of the finished lens.

10 FIGURE 1 illustrates a cathode ray tube of the type described which comprises an envelope 10 containing therein three electron guns 11, 12 and 13, which may, for example, be disposed co-planar or in a triangular array, for projecting three electron beams towards a faceplate panel 14. A delta triangular array symmetrically disposed about the central axis A—A of the tube is commonly used.

15 For a delta gun array, mask 15 is formed with a large number of equispaced apertures of uniform size. A mosaic screen 14a is provided on the inner surface of the faceplate panel 14 and comprises a multiplicity of phosphor dots similarly arrayed, with a trio of three dots, each of a different color emitting phosphor, being provided for each aperture 15a in the mask 15.

20 In operation of the tube, three separate electron beams are projected from the three guns 11, 12 and 13 and are directed to converge at a cross-over point near the screen 14a by virtue of the mechanical disposition of the guns and/or convergence forces generated by convergence means 16. The three beams are simultaneously scanned over the screen surface forming a rectangular raster. The beams approach the mask 15 and portions thereof pass through the mask apertures 15a. Each beam excites a different color-emitting dot of each dot trio.

25 In FIGURE 1, the numerals 18, 20 and 22 indicate the paths of three beams passing through a central apertures of the mask when no deflection forces are applied to the beams. With zero beam deflection, centers of deflection 24, 25 and 26 of the beams 18, 20 and 22 lie in a plane P—P perpendicular to the central tube axis A—A, which plane is approximately at the axial center of the deflection yoke 17. This plane is referred to as the plane of deflection of the tube at zero beam deflection.

30 When the beams are deflected away from the paths 18, 20, 22 to assume the positions of beam paths 28, 29, 30, the beams will, in the absence of dynamic convergence fields applied thereto, converge to a cross-over before they reach the screen 14a. To prevent such a premature cross-over, the beams are spread apart by dynamic convergence fields established by a convergence means 16. For example, the dashed lines 28' and 30', by comparison with the beam paths 18 and 22 illustrate the spread that the beams from guns 11 and 13 are given when they are deflected by the deflection means 17 to follow the paths 28 and 30.

35 For a deflected beam, the center of deflection is defined as the point of intersection of the undeflected beam path and the rearward projection of the beam path after the beam leaves the influence of the deflecting field. Thus, the deflection centers of the deflected electron beams following paths 28, 29 and 30 are respectively indicated by the points 32, 33 and 34.

40 As noted in FIGURE 1, when the electron beams are deflected from the center of the screen, and proper convergence beam-spread is provided, the centers of the deflection of the beams move both forward and outward to the new points 32, 33, 34 and the plane of deflection P—P moves forward a corresponding distance to a new plane P'—P'. The center of deflection of each beam thus defines a locus of points along a path. The forward shift of the centers of deflection along the tube axis A—A is caused by the deflection of the beams by the yoke 17 away from the central portion of the screen and the outward shift away from the axis A—A is caused by the spreading of the beam paths by the dynamic convergence fields produced by the convergence means 16.

45 As a result of the forward axial shift of the centers of deflection, the landing spots of the three beams are shifted radially outward from the center of the screen 14a, the radial shift being substantially equal for each spot of a given trio. This forward shift of the deflection centers with outward deflection of the beams will result in misregister of the beam spots with respect to phosphor dots printed in a lighthouse having the light source at the zero deflection center for each color, with no corrective lens.

50 As a result of the outward shift of the deflection centers away from the tube axis, the trio of beam spots will be spread apart, or de-grouped, at the outer portions of the screen 14a. Unless compensated for, the trios of beam spots in these portions of the screen will be larger than the printed phosphor dots causing degrouping misregister. Both radial and degrouping misregister increase as a function of increasing distance from the center of the screen.

65

65

In order to photographically print phosphor dot screens with acceptable register of the beam spots and phosphor dots, it is necessary to incorporate one or more corrective lenses in the screen printing lighthouse to compensate for all of the various causes of misregister. As pointed out above, substantial compensation and register have been produced in the prior art only for the average degrouching along a single section of the lens used, with only partial compensation over the remainder of the lens (and screen).

FIGURE 2 illustrates a typical lighthouse apparatus of the type normally used for printing a phosphor dot screen of a cathode ray tube. The lighthouse 110 comprises an open-top cabinet 111 having a shoulder 112 on which the bowl-shaped faceplate panel 14 of the cathode ray tube is disposed. The panel 14 is adapted to be subsequently sealed at its open end 115 to another member (not shown in FIGURE 2) to form a completed cathode ray tube bulb. The panel 14 includes a surface 14b for supporting the phosphor screen 14a of FIGURE 1 and a plurality of studs 118 on which the apertured shadow mask 15 (FIGURE 1) is removably mounted. Prior to mounting the panel 14 on the cabinet 111, the surface 14b is coated with a conventional photoresist material, such as polyvinyl alcohol sensitized with ammonium dichromate. On the external surface of the panel 14 are a plurality of bosses 119 which cooperate with mating recesses in the cabinet 111, whereby the panel 14 may be positioned in a prescribed orientation on the lighthouse 110.

At the base of the cabinet 111 is a housing 120 which contains a lamp 121 and a tapered light conductor or collimator 122. The lamp 121 may, for example, be an ultraviolet light emitting device such as a General Electric Company 1 kilowatt, high pressure, mercury arc lamp, Type BH6. The collimator 122 is positioned above the UV lamp 121 and tapers away therefrom to a small area or "point" 124. The point 124 is positioned in a selected plane of deflection at a predetermined distance d from the central axis A—A of the panel 14. The section of FIGURE 2 is taken in the plane passing through the central axis A—A and the point source 124. The housing 120 may, as shown, be mounted on a rotatable table 125 which can be indexed at a plurality of predetermined positions. Means including a spring-loaded plunger 126 is provided which cooperates with mating depressions in the rim of the table 125 to fix the table in these positions. Such indexing of the table 125 and housing 120 is designed to selectively position the light source 124 at a different location for each of the dot-printing exposures required.

A bracket 127 disposed between the light source 124 and the panel 14 is supported on a plurality of legs 128 from the table 125. The bracket 127 has an opening 129 therein, opposite the light source 124, across which a light refracting element or lens 130 may be disposed. The lens 130 is thus maintained in a fixed angular relationship to the light source 124 when the latter is moved.

Alternatively, the table 125 may be omitted, the housing 130 mounted directly on the base of cabinet 111, and the bracket 127 mounted directly on the wall of the cabinet. In such case the light source 124 and lens 130 are fixed. A plurality of such light-houses 110 are then provided for making the plurality of required dot printing exposures on a given faceplate panel 14.

According to usual screen printing methods the light source for each phosphor dot exposure is located substantially at a "first order color center" of the beam. A first order color center may be defined as the intersection of a line extending through the centers, respectively of a given phosphor dot and its associated mask aperture with the plane of deflection associated with the given phosphor dot. The term associated aperture refers to the same aperture that the beam passes through to excite the given phosphor dot. United States Patent 3,282,691 which issued November 1, 1966, discloses a method of dot screen printing in which the light source is disposed at a second (or higher) order color center, displaced laterally in the plane of deflection a predetermined distance, from which the light rays pass through a mask aperture different from the electron beam aperture associated with the dot being printed. This arrangement inherently compensates for most of the degrouching effects and improves the register of individual spots and dots at the screen.

The present invention may be used with either first or higher order color center printing. In the example shown and described, first order color center printing will be used for simplicity. Thus, in FIGURE 2, the light source 124 is located substantially at a first order color center. This center is displaced a distance d from the central

axis A—A, as determined from the formula $q = \frac{L}{3d}$, where q is the mask to screen spacing along the central axis, L is the distance between the color center and the

screen surface 14b on the central axis, and a is the spacing between mask apertures.

The lens 130 in FIGURE 2 could be any known lens which is usable for partial correction or compensation of the various beam or printing errors involved. Preferably, a lens is selected which is known to produce as much correction as possible, thereby minimizing the additional correction required. In the present example, it will be assumed that lens 130 is a known lens fabricated according to the United States Patent 2,885,935 to provide substantial correction for both radial and degroupping errors along its line of symmetry.

The first step in the process of developing a new lens for a new tube type, such as a 19" rectangular 90° color tube, is the selection and/or fabrication of a faceplate panel 14 of given contour. The faceplates for the 19" and 15" tubes are nearly spherical, as compared to the complex contour of the earlier 25" tube faceplates. For example, the internal surface 14b may have a spherical radius of 26.812 inches. Next, a shadow mask 15 for use with the chosen faceplate 14 is fabricated. Preferably, the contour of the mask 15 is made such that when mounted on the panel the spacing q' therebetween, as measured along the beam path, varies from a predetermined maximum value, e.g. about 0.4 inch, at the center to a predetermined smaller value at a given radius near the edge of the screen. This variation in q' results in the size of the beam spot trios and phosphor dot trios in the finished tube being substantially the same over the entire screen surface. A mask having a spherical radius of 27.27 inches may be used with the panel radius given above.

The selected panel 14 and mask 15 are mounted in the lighthouse with the lens 130, as in FIGURE 2, with a photosensitive coating on the faceplate surface 14b and a dot pattern is printed and developed in conventional manner on the surface 14b. This may, for example, be the green-emitting dot pattern. Then, the printing process may be repeated to add the red and blue dot patterns. The same lens 130 may be used for each pattern in this step, if desired.

The assembly of the printed panel 14 and mask 15 is then combined with the bulb funnel, stem and other parts, and processed to produce an operative, evacuated, shadow mask color tube. The tube is operated in normal manner, scanning the screen with the beam (or beams, if all three colors are screened), and the misregister between the electron spots and phosphor data is measured at a multiplicity of points or locations distributed over the entire face of the tube. FIGURE 3 shows an example of a distribution of points P_1, P_2, P_3 , etc., on the faceplate 14 at which the misregister may be measured. The points shown are arranged on circles concentric with the axis A—A of FIGURES 1 and 2, and on radial lines at the several clock positions. At each point, the measurement of the misregister includes the three-dimensional location of the point in space, and the magnitude and three dimensional direction of the misregister. The location of the points in space may be with respect to any given point of reference.

One method that can be used to measure and record the misregister is as follows. At each of 63 points distributed over the screen, a photomicrograph is taken of a small group of phosphor dots during operation of the tube. The points are recorded by clock positions, which are later converted to azimuthal angles in radians from a given axis. Each photograph covers an area of about 6 by 7 rows of dots. First, the centers of three pairs of phosphor dots and electron spots in the central area of each photograph are determined. Then, the magnitude and direction of misregister are measured and recorded for each pair of spots and dots, for each color of dots. The three misregister vectors for each color are averaged (by averaging vector components).

Preferably, the actual mask to screen spacing q parallel to the beam path is measured at each point to determine the variation, if any, from the correct value of q' . Then, if necessary, the measured misregister vectors for each color are corrected for the variation from the correct value of q' .

Misregister measurements are usually made on five substantially identical tubes printed by the same lens 130, and the corrected misregister vectors for each color at each corresponding point on the five tubes are averaged. In the above sample, this results in 63 average misregister vectors for each color. Since the subsequent calculations require a larger number of data points, additional data points are obtained by interpolating points located between the measured data points up to a total of about 250 vectors for each color.

The next step in the process is the determination of the location in space of the mask aperture associated with the dots and spots at each data point. This is done, as shown in FIGURE 4, by first determining the path of a light ray from the position B of the light source, through the lens 130, to the position D of each data point.

in printing the dot D of FIGURE 4, a light ray BEFCD entered the lens at some point E, at an angle θ_1 with the normal EG to the lens surface at that point, and was refracted to path EF within the lens, at an angle θ_2 with the same normal extended (EH). In leaving the lens 130, the ray was again refracted from path EF to new path FD. Since the lens 130 is wedge-shaped the two paths BE and FD are not parallel. Determining the point of intersection C of the ray path FD with the mask 15 will determine the location of the corresponding mask aperture.

The point D in space has been determined and point B is known, as well as the positions of the lens surfaces. It is thus necessary to determine the ray path BEFCD. This is done by approximation by drawing a straight line BD between points B and D (shown dashed). From the point of intersection E' of this line BD with the lens 130, the path can be determined of an actual light ray following path BE' and through the lens along the path E'F' and to a point D' on the screen. This is done by using Snell's Law, $N_1 \sin \theta_1 = N_2 \sin \theta_2$, wherein N_1 is the index of refraction of the first medium (air) and N_2 is the index of refraction of the second medium (glass).

The vector DD', which represents the error due to the straight line approximation, is then subtracted vectorially from the straight line BD giving the point D''. A second straight line is drawn from B to D'' and a new corrected ray path through the lens is determined which should give the location of a point between D'' and D. This series of approximations is continued until the error between a point on the screen of a calculated light ray and the point D is not more than 50 microinches. The final calculated ray will substantially coincide with the path BEFD. Knowing the position of this final calculated light ray and the position of the mask 15 at the point where the calculated ray passes through the mask, the aperture C through which the calculated ray passes to the strike the point D can be determined.

The location C of the mask aperture for each data point is similarly determined. These values are used to determine the surface contour of a new lens for each color, to be used with the lens 130 to print cathode ray tube screens with acceptable registry of spots and dots over the entire screen surface. FIGURE 5 shows the lens 130 in the same position relative to the mask 15 and screen 14a as in FIGURES 2 and 4. For example, C and D represent the same aperture and dot, respectively, as in FIGURE 4. Point S is the measured center of the electron spot corresponding to dot D, hence DS is the measured misregister therebetween. The object is to determine the elemental slope at a corresponding point L on a theoretical lens 132 which, if used in combination with lens 130, would print a dot at point S, instead of D. A straight line is drawn from spot S back through aperture C striking lens 130 at point J. The path JK of a refracted ray passing through lens 130 is then determined, using Snell's Law. Then the path KL of this ray through lens 132 is determined. If the two lenses are in optical contact and made of the same index of refraction material, path KL will merely be a straight line continuation of path JK. Points S and C have been determined. This point J and the path JL can be determined such that the position in space of point L is thus determined.

Having determined the location of point L in space, the elemental slope of the surface of lens 132 at point L necessary to refract a light ray BL along the path LK through the lens can be calculated. Point B is a light source and may be, but is not necessarily, at the same point as in FIGURES 2 and 4. The elemental slopes of the lens 132 at selected data points x, y, z on its surface may be expressed in terms of

$\frac{\partial z}{\partial x}$ and $\frac{\partial z}{\partial y}$, in the coordinate system shown in FIGURE 4, where the z axis is parallel to the axis A—A, and x and y are rectangular coordinates in a plane perpendicular to the z axis. The slope of the lens surface at each lens data point is converted to a vector normal to the elemental plane of the surface corresponding to each screen data point.

The next step is to prepare a description of a continuous lens surface which approximates as nearly as possible the contour of the surface defined by the multiplicity of normal vectors obtained from the measured misregister data. This continuous lens surface may be expressed as a bivariate polynomial.

$$z = \sum_{i,j} v_{i,j} x^i y^j \quad (1)$$

where z is the height or distance of the lens surface at each point (x, y) thereon from a selected x—y plane, i and j are the exponents of x and y, respectively, in each

term of the polynomial, and $v_{i,j}$ represents all of the coefficients of the $(x^i y^j)$ terms in the desired polynomial. Equation (1) may be expressed

$$z = \sum_{i,j} \alpha_{i,j} P_{i,j}(x,y), \quad (2)$$

wherein $\alpha_{i,j}$ are the expansion coefficients, and $P_{i,j}(x,y)$ are bivariate polynomials in x and y .

In order to simplify the equations involved, a mapping of (i,j) into integers is introduced as follows

$$I(i,j) = j + \frac{(i+j)(i+j+1)}{2}. \quad (3)$$

Thus, the values of $I(i,j)$ for the integral values of i and j shown in Equation (2) are:

$$\begin{array}{cccccc} i=0 & 1 & 0 & 2 & 1 & 0 & 3 \\ j=0 & 0 & 1 & 0 & 1 & 2 & 0 \\ I(i,j)=0 & 1 & 2 & 3 & 4 & 5 & 6 \end{array}$$

Let $N=i+j$. Then the surface z_N is of degree N if all (i,j) pairs in Equation (2) satisfy the condition $I(i,j) \leq I(0,N)$, and if $I(i,j) > I(0,N-1)$ for at least one (i,j) pair. For example, for $N=10$, $I(0,N)=65$ and $I(2,8)=63$.

Now Equation (2) is written for a surface of degree N , as follows

$$z_N = \sum_{i,j}^{(N)} \alpha_{i,j} P_{i,j}(x,y), \quad (4)$$

where i and $j \leq N$.

Then the partial derivatives of z_N with respect to x , y and z are

$$\frac{\partial z}{\partial x} = \sum_{i,j}^{(N)} \alpha_{i,j} P_{i,j}^x(x,y) = \sigma_x \quad (5a)$$

$$\frac{\partial z}{\partial y} = \sum_{i,j}^{(N)} \alpha_{i,j} P_{i,j}^y(x,y) = \sigma_y \quad (5b)$$

$$\frac{\partial z}{\partial z} = \sigma_z = 1 \quad (5c)$$

where p^x represents the $\frac{\partial}{\partial x}$, the P^y represents the $\frac{\partial}{\partial y}$. The vector having σ_x , σ_y , and

σ_z as direction numbers represents the vector normal to the surface z . In the least square sense, one would like to minimize the differences between the above vector and the set of normal vectors given by the data. Thus, one would like to find the $\alpha_{i,j}^N$ such that

$$\sum_{i=1}^m \left[\left(\left. \frac{\partial z}{\partial x} \right|_i - \sigma_x \right)^2 + \left(\left. \frac{\partial z}{\partial y} \right|_i - \sigma_y \right)^2 \right] = \text{minimum}, \quad (6)$$

where l represents a particular data point, m is the total number of lens data points,

and $\frac{dz}{dx}$ and $\frac{dz}{dy}$ represent the elemental slopes determined from each lens data point.

Substitution from Equation (5) to Equation (7) yields

$$\sum_{l=1}^m \left[\left(\frac{dz}{dx} \right)_l - \sum_{i,j} \alpha_{i,j}^{(N)} p_{i,j}^x \right)^2 + \left(\frac{dz}{dy} \right)_l - \sum_{i,j} \alpha_{i,j}^{(N)} p_{i,j}^y \right)^2 = \text{minimum} \quad (7)$$

Forming the normal equations for the expansion coefficients $\alpha_{i,j}^{(N)}$, one gets

$$\sum_{l=1}^m \left(\frac{dz}{dx} \right)_l \left[p_{\mu,\nu}^x - \sum_{i,j} \alpha_{i,j}^{(N)} p_{i,j}^x \right] p_{\mu,\nu}^x + \left(\frac{dz}{dy} \right)_l \left[p_{\mu,\nu}^y - \sum_{i,j} \alpha_{i,j}^{(N)} p_{i,j}^y \right] p_{\mu,\nu}^y = 0 \quad (8)$$

where $I(\mu, \nu) = 0, 1, \dots, I(0, N)$. After rearrangement of terms, equation (8) becomes

$$\sum_{l=1}^m \left(\frac{dz}{dx} \right)_l p_{\mu,\nu}^x + \left(\frac{dz}{dy} \right)_l p_{\mu,\nu}^y = \sum_{i,j} \alpha_{i,j}^{(N)} \left[\sum_{l=1}^m \left(p_{i,j}^x p_{\mu,\nu}^x + p_{i,j}^y p_{\mu,\nu}^y \right) \right] \quad (9)$$

The system of equations defined by Equation (9) will decouple if

$$\sum_{l=1}^m \left(p_{i,j}^x p_{\mu,\nu}^x + p_{i,j}^y p_{\mu,\nu}^y \right) = 0 \quad (10a)$$

$$I(i,j) \neq I(\mu,\nu) \quad (10b)$$

If conditions (10) are met by proper determination of the $P_{i,j}$'s, then one can solve Equation (9) for the individual expansion coefficients $\alpha_{i,j}^{(N)}$. Under conditions (10) all of the $\alpha_{i,j}^{(N)}$ terms in the summation of (9) vanish except those for which $I(i,j) = I(\mu, \nu)$, and Equation (9) can be written

$$\alpha_{\mu,\nu}^{(N)} = \frac{\sum_{l=1}^m \left(\frac{dz}{dx} \right)_l p_{\mu,\nu}^x + \left(\frac{dz}{dy} \right)_l p_{\mu,\nu}^y}{\sum_{l=1}^m \left[\left(p_{\mu,\nu}^x \right)^2 + \left(p_{\mu,\nu}^y \right)^2 \right]} \quad (11)$$

Shown below is a way in which the $P_{i,j}$'s may be determined so that conditions (1) will indeed hold.

$$P_{i,j} = xP_{i-1,j} + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k, \text{ for } i \neq 0; \quad (12a)$$

$$P_{i,j} = yP_{i,j-1} + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k, \text{ for } i = 0, \quad (12b)$$

5 where $\beta_k^{(i,j)}$ are coefficients to be determined.
Then,

5

$$P_{i,j}^x = xP_{i-1,j}^x + P_{i-1,j} + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k^x, \text{ for } i \neq 0, \quad (13a)$$

$$P_{i,j}^y = xP_{i-1,j}^y + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k^y, \text{ for } i \neq 0. \quad (13b)$$

10 Multiplying Equation (13a) by $P_{\mu,\nu}^x$ and Equation (13b) by $P_{\mu,\nu}^y$, adding the resulting equations, and summing over the data, one gets when $i \neq 0$,

10

$$\begin{aligned} \sum_{l=1}^m \left(P_{i,l}^x P_{\mu,\nu}^x + P_{i,l}^y P_{\mu,\nu}^y \right) &= \sum_{l=1}^m \left[\left(xP_{i-1,l}^x + P_{i-1,l} \right. \right. \\ &\quad \left. \left. + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k^x \right) P_{\mu,\nu}^x + \left(xP_{i-1,l}^y + \sum_{k=0}^{I(i,j)-1} \beta_k^{(i,j)} P_k^y \right) P_{\mu,\nu}^y \right] \end{aligned} \quad (14)$$

By virtue of conditions (10), the left side of Equation (14) is zero. Rearranging the right side gives when $i \neq 0$,

$$\begin{aligned} \sum_{l=1}^m \left[\left(xP_{i-1,l}^x + P_{i-1,l} \right) P_{\mu,\nu}^x + \left(xP_{i-1,l}^y \right) P_{\mu,\nu}^y \right] \\ = - \sum_{k=0}^{I(i,j)-1} \left[\beta_k^{(i,j)} \sum_{l=1}^m \left(P_k^x P_{\mu,\nu}^x + P_k^y P_{\mu,\nu}^y \right) \right] \end{aligned} \quad (15)$$

15 Since the inside sum on the right side of Equation (15) is zero by conditions (10) unless $k=I(\mu, \nu)$, one can solve for the required $\beta_k^{(i,j)}$ for the condition $i \neq 0$ by substituting $k=I(\mu, \nu)$.

15

$$P_{\mu,\nu}^{(i,j)} = \frac{\sum_{l=1}^m \left[\left(x P_{i-1,j}^x + P_{i-1,j} \right) P_{\mu,\nu}^x + \left(x P_{i-1,j}^y + P_{i-1,j} \right) P_{\mu,\nu}^y \right]}{\sum_{l=1}^m \left[\left(P_{\mu,\nu}^x \right)^2 + \left(P_{\mu,\nu}^y \right)^2 \right]} ; (16a)$$

where $I(\mu, \nu) = 1, \dots, I(i, j) - 1$ and $i \neq 0$.

Equations corresponding to equations (13), (14) and (15) can be similarly derived from equation (12b) for the condition $i=0$, and the equation corresponding to Equation 15 can be solved for $\beta_k^{(i,j)}$, yielding

$$B_{\mu,\nu}^{(i,j)} = \frac{\sum_{l=1}^m \left[\left(y P_{i,j-1}^x + P_{i,j-1} \right) P_{\mu,\nu}^x + \left(y P_{i,j-1}^y + P_{i,j-1} \right) P_{\mu,\nu}^y \right]}{\sum_{l=1}^m \left[\left(P_{\mu,\nu}^x \right)^2 + \left(P_{\mu,\nu}^y \right)^2 \right]} (16b)$$

where $I(\mu, \nu) = 0, 2, 5, 9 \dots$ and $i=0$.

Equation (4) for the desired lens surface can now be evaluated to any desired degree, using the key equations (11), (12), (13a), (13b), and (16), for $\alpha_{i,j}^{(N)}$, $P_{i,j}$, $P_{i,j}^x$, $P_{i,j}^y$, and $\beta_k^{(i,j)}$, respectively. In designing a lens, the calculations are preferably carried out to obtain a polynomial of degree $N=10$, which has been found to provide a lens surface approximating the elemental slopes determined from the measured mis-register data closely enough to produce a printed phosphor dot pattern on the cathode ray tube screen having acceptable spot-dot register over the screen surface.

As a relatively simple example, the procedure for evaluating the surface z of Equation (4) for the first four terms only, i.e., to the $P_{2,0}$ term, will be evaluated, as follows

$$z_N = \alpha_{0,0} P_{0,0} + \alpha_{1,0} P_{1,0} + \alpha_{0,1} P_{0,1} + \alpha_{2,0} P_{2,0} \quad (4a)$$

Since $P_{0,0}=1$, the first term is $\alpha_{0,0}$, which is a constant which determines the z location of the central point on the lens surface. Now take $P_{1,0}=x$ and $P_{0,1}=y$, noticing that condition (10) is satisfied by this initial choice; thus $P_{1,0}^x=1$, $P_{0,1}^x=0$, $P_{1,0}^y=0$, and $P_{0,1}^y=1$. From Equation (11),

$$\alpha_{1,0} = \frac{\sum_{l=1}^m \left(\left. \frac{\partial z}{\partial x} \right|_l p_{1,0}^x + \left. \frac{\partial z}{\partial y} \right|_l p_{1,0}^y \right)}{\sum_{l=1}^m \left[\left(p_{1,0}^x \right)^2 + \left(p_{1,0}^y \right)^2 \right]}$$

$$= \frac{\sum_{l=1}^m \left(\left. \frac{\partial z}{\partial x} \right|_l \right)}{\sum_{l=1}^m (1)} = \frac{1}{m} \sum_{l=1}^m \left. \frac{\partial z}{\partial x} \right|_l$$

$$\alpha_{0,1} = \frac{\sum_{l=1}^m \left(\left. \frac{\partial z}{\partial x} \right|_l p_{0,1}^x + \left. \frac{\partial z}{\partial y} \right|_l p_{0,1}^y \right)}{\sum_{l=1}^m \left[\left(p_{0,1}^x \right)^2 + \left(p_{0,1}^y \right)^2 \right]}$$

$$= \frac{\sum_{l=1}^m \left(\left. \frac{\partial z}{\partial y} \right|_l \right)}{\sum_{l=1}^m (1)} = \frac{1}{m} \sum_{l=1}^m \left. \frac{\partial z}{\partial y} \right|_l ; \text{ and}$$

$$\alpha_{2,0} = \frac{\sum_{l=1}^m \left(\left. \frac{\partial z}{\partial x} \right|_l p_{2,0}^x + \left. \frac{\partial z}{\partial y} \right|_l p_{2,0}^y \right)}{\sum_{l=1}^m \left[\left(p_{2,0}^x \right)^2 + \left(p_{2,0}^y \right)^2 \right]}$$

From Equation (12a), where $i \neq 0$,

$$P_{2,0} = x P_{1,0} + \beta_{1,0}^{2,0} P_{1,0} + \beta_{0,1}^{2,0} P_{0,1}$$

$$= x^2 + x \beta_{1,0}^{2,0} + y \beta_{0,1}^{2,0}$$

5

5

From Equation (16a), where $i \neq 0$,

$$p_{1,0}^{2,0} = \frac{\sum_{j=1}^m \left[(x p_{1,0}^x + p_{1,0}) p_{1,0}^x + (x p_{1,0}^y) p_{1,0}^y \right]}{\sum_{j=1}^m \left[(p_{1,0}^x)^2 + (p_{1,0}^y)^2 \right]}$$

$$= \frac{\sum_{j=1}^m (2x)}{\sum_{j=1}^m (1)} = \frac{1}{m} \sum_{j=1}^m 2x$$

and

$$p_{0,1}^{2,0} = \frac{\sum_{j=1}^m \left[(x p_{1,0}^x + p_{1,0}) p_{0,1}^x + (x p_{1,0}^y) p_{0,1}^y \right]}{\sum_{j=1}^m \left[(p_{0,1}^x)^2 + (p_{0,1}^y)^2 \right]} = \frac{0}{m} = 0$$

$$\text{Therefore, } p_{2,0} = x^2 + \frac{x}{m} \sum_{j=1}^m 2x$$

$$p_{2,0}^x = 4x + \frac{1}{m} \sum_{j=1}^m 2x$$

$$p_{2,0}^y = 0$$

$$\alpha_{2,0} = \frac{\sum_{j=1}^m \left[\frac{\partial z}{\partial x} \Big|_j \left(2x + \frac{1}{m} \sum_{j=1}^m 4x \right) \right]}{\sum_{j=1}^m \left(4x + \frac{1}{m} \sum_{j=1}^m 2x \right)^2}$$

Now all of the terms of the Z_N polynomial of equation (4a) up to and including the $P_{2,0}$ term are known and one can write

$$z_N = \alpha_{0,0} + \frac{x}{m} \sum_{l=1}^m \left. \frac{\partial z}{\partial x} \right|_l + \frac{y}{m} \sum_{l=1}^m \left. \frac{\partial z}{\partial y} \right|_l + \frac{\left(x^2 + \frac{x}{m} \sum_{l=1}^m 2x \right) \sum_{l=1}^m \left[\left. \frac{\partial z}{\partial x} \right|_l \left(4x + \frac{1}{m} \sum_{l=1}^m 2x \right) \right]}{\sum_{l=1}^m \left(4x + \frac{1}{m} \sum_{l=1}^m 2x \right)^2} \quad (4b)$$

Assume, for example, that the data points and slopes on the assumed lens surface are as follows:

	$l=$	1	2	3	4	5	6	7	8	9
5	$x=$	0	2	0	-2	0	+4	0	-4	0
	$y=$	0	0	2	0	-2	0	+4	0	-4
	$\frac{dz}{dx}=$	0	-.2	.1	.2	-.2	.1	.2	0	-.1
	$\frac{dz}{dy}=$	0	-.1	-.1	.1	-.1	.1	-.2	-.1	.2

Substituting these values in Equation (2), one gets

$$\begin{aligned} z_N &= \alpha_{0,0} + \frac{x}{9}(0-.2+.1+.2-.2+.1+.2+0-.1) \\ &+ \frac{y}{9}(0-.1-.1+.1-.1+.1-.2-.1+.2) \\ &+ \frac{2x^2(0-.4+0-.0+0+.4+0+0+0)}{16(0+4+0+4+0+16+0+16+0)} \\ &= \alpha_{0,0} + \frac{1}{90}x - \frac{2}{90}y - \frac{1}{800}x^2. \end{aligned}$$

If the X—Y plane is taken at the center of the lens surface, $\alpha_{0,0}$ is zero, and

$$z_N = \frac{1}{90}x - \frac{2}{90}y - \frac{1}{800}x^2.$$

When z_N is evaluated to degree $N=10$, for which $I(O,N)=65$, the total number of terms is 66 minus the one which drop out as zero. Obviously, it would be impractical if not impossible to evaluate such an equation and utilize it to fabricate the desired lens without the use of a computer.

To evaluate z_N to the desired degree, an RCA-604 computer, for example, is programmed to perform the mathematical operations involved in equations (4), (11),

(12), (13a), (13b) and (16) from the input data $\frac{az}{ax}$ and $\frac{az}{ay}$ at the various points

(x,y) on the ideal lens determined from the misregister data, up to the desired degree N. The output from the computer is a description of the surface of the desired lens surface on magnetic tape in APT language. APT (Automatically Programmed Tools) is the designation given to a known system or series of computer programs that will: (a) read-in APT language statements; (b) perform the calculations ordered or implied by these statements; calculate cut vectors to machine a part described by the APT statements; and output a punched tape to machine the part on the NC (Numerical Control) machine specified.

The APT language tape output from the computer is then fed into a computer which has been programmed in the APT system, for example, an IBM 7094 computer, to convert the surface description to an NC tape for controlling the particular NC milling machine to be used to fabricate the part, which machine may, for example, be a Pratt and Whitney machine with a Bendix controller.

The NC tape from the computer is then used to control the specified machine to cut the desired surface on a metal plate of stainless steel, for example, which will be used as a mold for fabricating the desired lens. Figure 6 shows a transverse section of such a mold 140 with an upper surface 142 cut by the NC machine to the surface contour of the desired lens.

The desired lens, as well as the first lens 130 if used, may be made of any suitable transparent optical material, such as glass or clear plastic.

There are several ways in which the mold 140 can be used to fabricate the desired lens. One way is to use a sagging technique in which the mold surface is suitably treated to prevent glass from sticking to it, and a flat plate 150 of optical glass is placed on the mold and heated in an oven to the softening temperature of the glass to cause the glass to sag by gravity into intimate contact with the mold surface 142, as shown in FIGURE 7. In this sagging operation, the upper surface of the plate 150 is given a surface contour 162 substantially identical with the surface contour 142 of the mold. The plate 150 is then removed from the mold 140 and formed into the desired lens 160 (shown in FIGURE 8) by grinding flat or otherwise removing the bottom side, which was in contact with the mold, along the plane indicated by the dashed line 164 in FIGURE 7.

Since the surface 162 of lens 160 is substantially the surface described by Equation (4), it is a sufficiently close approximation to the theoretical lens surface

defined by the normal vectors $(\frac{az}{ax}, \frac{az}{ay})$, as determined in connection with FIGURE

5, that the lens 160 can be used in combination with lens 130 in a lighthouse to print a phosphor dot screen of one color with acceptable spot-dot register over the entire surface of the screen.

Alternatively, the refractive properties of the two lenses 130 and 160 can be combined in a single lens for use in the lighthouse.

As pointed out above, three separate lenses, one for each color, are designed and fabricated from the misregister data, and the three different color dot patterns are sequentially printed with the three lenses, each alone or in combination with a lens 130.

WHAT WE CLAIM IS:—

1. The method of photographically fabricating a mosaic phosphor screen for a cathode ray tube by projecting light from a source through an optical refracting member and a multi-apertured mask to expose discrete areas of a photosensitive phosphor layer on a support, and developing the layer to produce the mosaic array of discrete elements on the support, wherein the refracting surface of the optical member has been determined by operating a prototype tube having a multi-apertured mask electrode and a phosphor screen comprising an array of discrete phosphor dots photographically produced through the mask electrode, including the steps of determining the misregister between the phosphor dots and the corresponding electron beam impinging spots at each of a multiplicity of points distributed over the entire screen of the tube; determining from the respective three-dimensional misregisters at the multiplicity of points the respective slopes, at points corresponding to the multiplicity of



(12), (13a), (13b) and (16) from the input data $\frac{az}{ax}$ and $\frac{az}{ay}$ at the various points

(x,y) on the ideal lens determined from the misregister data, up to the desired degree N. The output from the computer is a description of the surface of the desired lens surface on magnetic tape in APT language. APT (Automatically Programmed Tools) is the designation given to a known system or series of computer programs that will: (a) read-in APT language statements; (b) perform the calculations ordered or implied by these statements; calculate cut vectors to machine a part described by the APT statements; and output a punched tape to machine the part on the NC (Numerical Control) machine specified.

The APT language tape output from the computer is then fed into a computer which has been programmed in the APT system, for example, an IBM 7094 computer, to convert the surface description to an NC tape for controlling the particular NC milling machine to be used to fabricate the part, which machine may, for example, be a Pratt and Whitney machine with a Bendix controller.

The NC tape from the computer is then used to control the specified machine to cut the desired surface on a metal plate of stainless steel, for example, which will be used as a mold for fabricating the desired lens. Figure 6 shows a transverse section of such a mold 140 with an upper surface 142 cut by the NC machine to the surface contour of the desired lens.

The desired lens, as well as the first lens 130 if used, may be made of any suitable transparent optical material, such as glass or clear plastic.

There are several ways in which the mold 140 can be used to fabricate the desired lens. One way is to use a sagging technique in which the mold surface is suitably treated to prevent glass from sticking to it, and a flat plate 150 of optical glass is placed on the mold and heated in an oven to the softening temperature of the glass to cause the glass to sag by gravity into intimate contact with the mold surface 142, as shown in FIGURE 7. In this sagging operation, the upper surface of the plate 150 is given a surface contour 162 substantially identical with the surface contour 142 of the mold. The plate 150 is then removed from the mold 140 and formed into the desired lens 160 (shown in FIGURE 8) by grinding flat or otherwise removing the bottom side, which was in contact with the mold, along the plane indicated by the dashed line 164 in FIGURE 7.

Since the surface 162 of lens 160 is substantially the surface described by Equation (4), it is a sufficiently close approximation to the theoretical lens surface

defined by the normal vectors $(\frac{az}{ax}, \frac{az}{ay})$, as determined in connection with FIGURE

5, that the lens 160 can be used in combination with lens 130 in a lighthouse to print a phosphor dot screen of one color with acceptable spot-dot register over the entire surface of the screen.

Alternatively, the refractive properties of the two lenses 130 and 160 can be combined in a single lens for use in the lighthouse.

As pointed out above, three separate lenses, one for each color, are designed and fabricated from the misregister data, and the three different color dot patterns are sequentially printed with the three lenses, each alone or in combination with a lens 130.

WHAT WE CLAIM IS:—

1. The method of photographically fabricating a mosaic phosphor screen for a cathode ray tube by projecting light from a source through an optical refracting member and a multi-apertured mask to expose discrete areas of a photosensitive phosphor layer on a support, and developing the layer to produce the mosaic array of discrete elements on the support, wherein the refracting surface of the optical member has been determined by operating a prototype tube having a multi-apertured mask electrode and a phosphor screen comprising an array of discrete phosphor dots photographically produced through the mask electrode, including the steps of determining the misregister between the phosphor dots and the corresponding electron beam impinging spots at each of a multiplicity of points distributed over the entire screen of the tube; determining from the respective three-dimensional misregisters at the multiplicity of points the respective slopes, at points corresponding to the multiplicity of

points on the screen, of portions of an ideal refractive surface of an optical member which would print discrete phosphor elements at the corresponding impingement spots of the electron beam of the prototype tube; and determining with the slopes a continuous refractive surface for the optical member closely approaching the ideal refractive surface.

5

5

2. A method in accordance with claim 1, wherein the respective slopes are determined from the three-dimensional misregisters and from the location of the mask aperture associated respectively with each one of the multiplicity of points, and the position of the light source used to print the screen of the prototype tube.

10

10

3. A method in accordance with claim 1, wherein the continuous surface of the refracting member is determined by fitting a bivariate polynomial to said calculated slopes and fabricating the light refractive device having the continuous curved surface described by said polynomial.

15

15

4. A method in accordance with claim 1 or claim 2, wherein the continuous surface of the refracting member is described by the bivariate polynomial:

$$z = \sum_{i+j \geq 2} \alpha_{i,j} P_{i,j}(x,y),$$

where z is the distance of said surface at any point (x,y) thereon from a given $X-Y$ plane, $P_{i,j}(x,y)$ are orthogonal bivariate polynomials in x and y , $\alpha_{i,j}$ are the expansion coefficients of the terms of $P_{i,j}(x,y)$, and the values of $\alpha_{i,j}$ and $P_{i,j}(x,y)$ are determined from the calculated slopes.

20

20

5. A method in accordance with any one of claims 1—4, wherein the phosphor screen includes three mosaic patterns of respectively different colour phosphor dots, characterised by deriving a different refracting surface from each one of the mosaic patterns.

25

25

6. A method of fabricating a mosaic phosphor screen in accordance with claim 1 substantially as described with reference to the drawings.

7. A cathode ray tube including a mosaic phosphor screen fabricated by the method claimed in any one of the preceding claims.

A. A. THORNTON & CO.,
Chartered Patent Agents,
Northumberland House,
303/306 High Holborn,
London, W.C.1.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1970.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.



* C L M S *