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M. SADOWSKY ET AL

2,870,010

METHOD OF MANUFACTURING ELECTRICAL APPARATUS

Filed Feb. 4, 1954

2 Sheets-Sheet 1

FIG. 1.

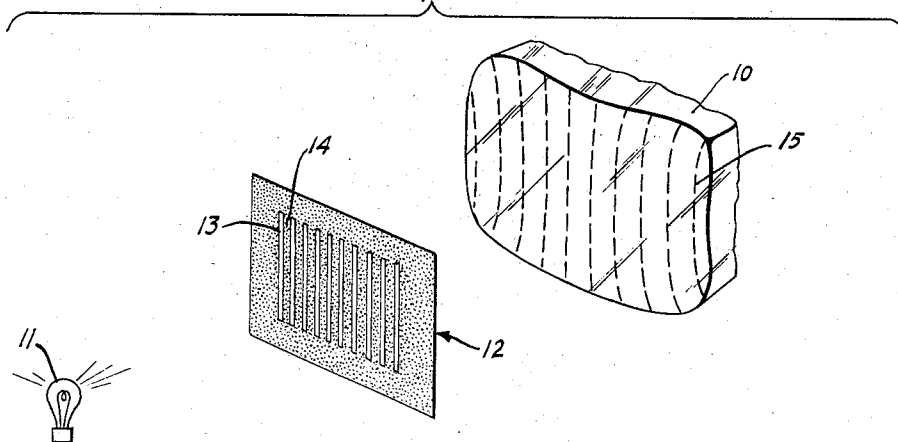
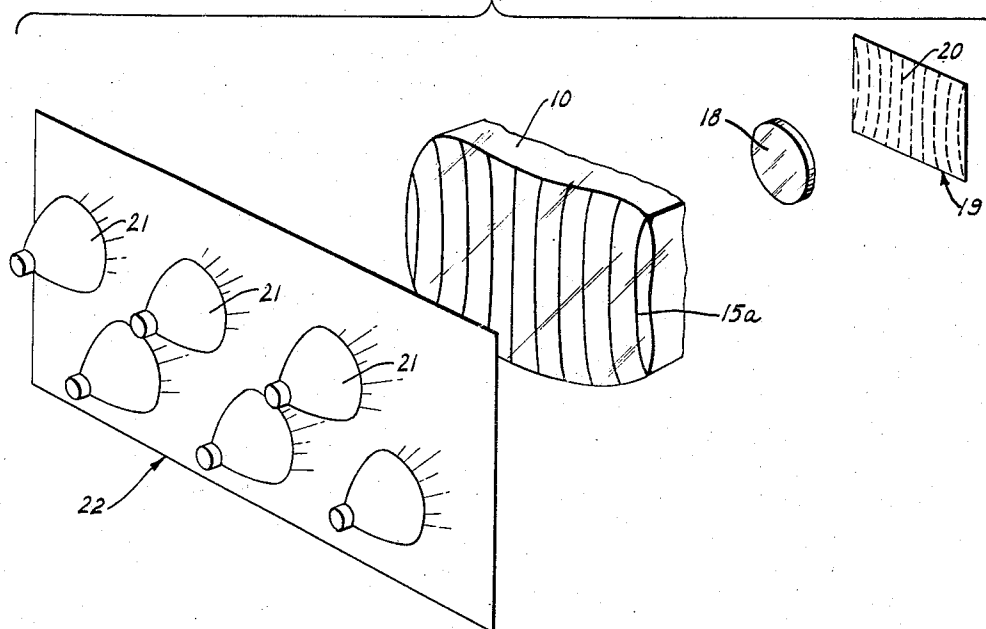


FIG. 2.



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2 Sheets-Sheet 2

FIG. 3.

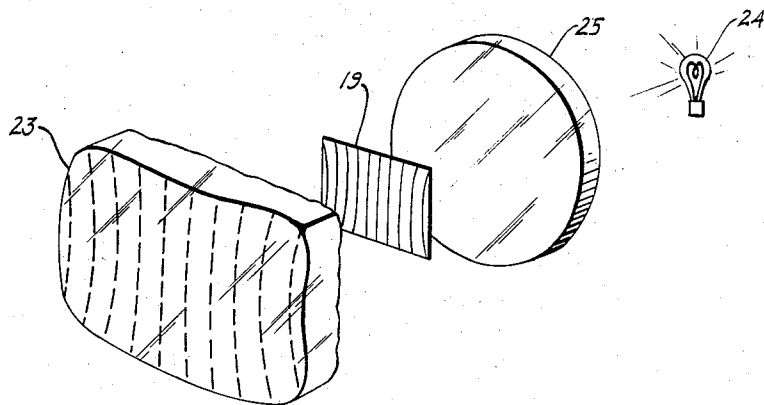
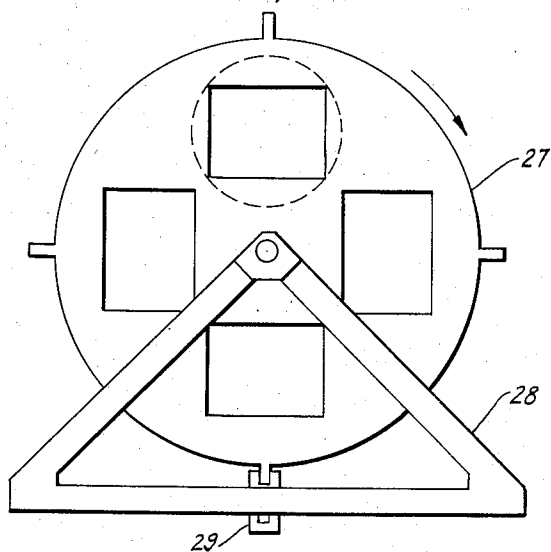


FIG. 4.



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METHOD OF MANUFACTURING ELECTRICAL APPARATUS

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Application February 4, 1954, Serial No. 408,219

8 Claims. (Cl. 96—35)

The invention relates to improvements in methods of manufacturing screen structures for cathode ray tubes and, more particularly, to improvements in methods of manufacturing cathode ray tube screen structures which are suitable for the reproduction in color of televised images.

In its preferred form such a screen structure includes many minute elements, adjacent ones of which are constituted of phosphors emissive of light of different colors, and all of which are deposited, side-by-side, on the face plate of the cathode ray tube. The individual screen elements are preferably in the form of long, narrow strips having their longitudinal axes oriented generally perpendicularly to the direction of horizontal deflection of the electron beam with which the screen structure is designed to be scanned. It is apparent that, when such a screen structure is scanned with an electron beam whose intensity is representative of different color intelligence at closely adjacent intervals, there exists the possibility that the electron beam may impinge upon any given element at the wrong time, i. e. when the beam is not representative of intelligence concerning the color which the element is capable of reproducing. This danger can be eliminated most conveniently by including in the screen structure so-called "indexing" elements, which are generally similar in form to the phosphor strips and which are located in predetermined geometrical relationship to the phosphor strips. These indexing elements are further characterized by being responsive to electron beam impingement to produce indications which may be electrical, optical, or of some other form, and which distinguish beam impingement upon indexing elements from beam impingement upon other elements of the screen structure. For example, each indexing element may be constituted of a long, narrow strip of magnesium oxide deposited in alignment with a phosphor strip emissive of light of a particular color, say blue, different indexing elements being in alignment with different blue phosphor strips. Magnesium oxide is suitable as an indexing material because it has a secondary electron emissivity which is substantially in excess of that of other materials which are normally found in cathode ray tube screen structures. Alternatively the indexing elements may be made of a material which is emissive of light in response to electron impingement. In this latter case, the material is preferably one which emits light of a wavelength which is substantially different from the wavelength of the light which is emitted by any of the image-forming phosphors themselves. For example, a material emissive of ultra-violet light in response to electron impingement is suitable for use in light-emissive indexing elements. In any case, the indexing elements are preferably separated from the image-forming phosphor strips by a layer of optically reflective, electrically conductive material, such as aluminum, both for the usual purpose of intensifying the reproduced image and also for the purpose of rendering the response

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of the indexing elements more nearly independent of that of the image reproducing phosphor strips.

It is known that a screen structure of this general type can be conveniently constructed by the use of photodeposition techniques which involve the steps of depositing a layer of photosensitive material on the face plate of the cathode ray tube, exposing this photosensitive material to illumination through a mask having translucent portions in alignment with the portions of the face plate on which it is desired to form screen elements of a particular kind, applying the particular material to be deposited at this stage of the process to the surface of the photosensitive material, and washing the entire assembly, thereby to remove unexposed portions of the photosensitive material and also so much of the additionally applied material as is deposited on these unexposed portions. By contrast, exposed portions of the photosensitive material and the material deposited on these exposed portions remain in place. The foregoing process is repeated for each of the different types of material which it is desired to deposit on the face plate, the optical mask being repositioned before each exposure of photosensitive material so as to yield several patterns of exposed portions in the locations in which it is desired to form the different sets of screen elements. The details of this process are fully described in the copending U. S. patent application of Paul D. Payne, Jr., Serial No. 376,345, filed August 25, 1953 and assigned to the assignee of the present invention. Consequently they need not be recapitulated here.

It is apparent that this basic photodeposition technique can be practiced by exposing the successively deposited layers of photosensitive material to illumination either from the interior side of the face plate or from its exterior side. Since the screen structure is formed by the superposition of successive layers of material on the interior surface of the plate, exposure from the exterior side of this face plate has the basic disadvantage that the light used for any given exposure must traverse all previously deposited layers of material. Particularly is this so with respect to the formation of the indexing elements since they are customarily separated from the phosphor elements by the aforementioned aluminum film. To form them by exposure from the exterior side of the face plate requires that the light traverse the aluminum film, which is relatively opaque, as well as the phosphor elements. This necessitates the use of a more intense source of illumination and exposure for a much longer time. Furthermore, if the thickness of the aluminum film varies appreciably from one region of the screen to another, then non-uniform exposure of the superposed photosensitive material and consequent uneven deposition of the indexing elements will occur. This, in turn, complicates the deposition of the aluminum film itself, for its dimensions must be more carefully controlled than would otherwise be necessary.

Finally, when it is attempted to expose the various layers of photosensitive material from the exterior side of the face plate, the light must traverse the face plate itself before reaching the photosensitive material, so that the optical properties of the face plate also become important and must be controlled to a degree which makes its manufacture unnecessarily costly.

It has been recognized that the foregoing difficulties would be eliminated if it were feasible to carry out at least certain ones, and preferably all, of the various screen forming exposures from the interior side of the face plate, for, in that event, the light used for any given exposure would not have to traverse previously formed layers of the screen structure. However, in the manufacture of such screen structures there must be considered one additional factor which has not yet been dis-

cussed and which has made impractical, heretofore, the use of processes involving exposure from the interior side of the face plate. The difficulty stems from the fact that the complete cathode ray tube under consideration uses not a single electron beam, as do conventional black-and-white cathode ray tubes, but rather two separate electron beams, the intensity of one beam being modulated in accordance with picture intelligence while the intensity of the other is independent of picture intelligence. The use of such a separate beam, whose intensity is independent of picture intelligence, has the important advantage that loss of indexing indications, which occurs with a single beam tube when the beam is cut off by the picture signal, can be avoided. While, for the purpose of obtaining accurate indications of impingement of the picture intelligence modulated beam upon the screen structure, it would be preferable to impinge both beams upon exactly the same portion of the screen structure, undesirable interaction would occur between the beams under these circumstances. Accordingly it is necessary to displace appreciably the regions of impingement of the two beams. It has been found that the advantages of exactly coincident beams are most closely approximated by mutually displaced beams if the displacement is in a direction parallel to the long dimensions of the strip-like screen elements since this causes the two beams, at any given time, to impinge on the same phosphor and/or on the same indexing strip. If the two electron beams under consideration maintained the same relative positions, e. g. one directly above the other, during all parts of their respective scanning deflections across the screen structure, then the desired objective, namely impingement on the same screen element, could be achieved by the use of a uniform array of parallel, vertical strips of phosphor and indexing materials. In practice, however, it is found that the peculiarities of electron beam deflection systems are such that the relative positions of impingement of the two beams remain the same only over certain comparatively small portions of the scanned area. In particular, two beams, which are vertically displaced when they are initially projected toward the screen, impinge on regions which are also displaced exactly vertically only in two relatively small regions of the screen structure. These two regions of undistorted impingement are two narrow belts or zones which extend respectively horizontally and vertically across the screen structure and which intersect at the center of deflection. Whenever the beams impinge on regions of the screen structure outside these two narrow zones, the beams tend to assume a relative displacement which has an appreciable component in a direction radially outward from the center of deflection. Furthermore, this radial component of mutual displacement increases with increasing radial displacement from the center of deflection. This form of distortion of the relative beam positions is called pin-cushion distortion. Under these circumstances, both beams will impinge on a single strip-like element of the screen structure at the extreme corners of the raster, as well as within the aforementioned zones of undistorted impingement, only if these strip-like elements themselves are formed with corresponding pin-cushion distortion.

When the usual kind of face plate is used, namely one which is convex toward the exterior of the tube, then even the simplest kind of mask, namely a plane mask having substantially parallel opaque and translucent portions, when used for exposure from this exterior side, is inherently capable of producing strips with the desired distortion. This is because the convex side of the interior surface of the face plate then confronts the source of illumination and the mask, and a pattern of plane, parallel strips, when projected on such a convex surface, is inherently reproduced thereon with pin-cushion distortion. If, on the other hand, a similar mask, having substantially parallel opaque and translucent portions, is used to expose the strips of photosensitive material from

the interior of the face plate, then the concave side of the same interior surface confronts the source of illumination and the mask, and the opposite form of distortion, namely barrel distortion of the exposed strips, results.

A way of overcoming this difficult immediately suggests itself: this is to predistort the shape of the opaque and translucent portions of a mask which is to be used for exposure from the interior side so that the desired exposure pattern will be produced on the face plate in spite of the fact that its concave side now confronts the mask and the light source. However, the design and production of such a predistorted mask by conventional techniques, involving the mathematical computation of the required predistortion and the use of ruling machines capable of providing arbitrarily distorted patterns, is extremely complicated and costly. Furthermore, since a new predistorted mask with different parameters would have to be designed and produced each time the face plate curvature and/or the desired exposure patterns are modified, this cost would be multiplied. For this reason, exposure from the exterior (convex) side of the face plate has been used up to the present time in spite of its numerous inherent disadvantages compared with exposure from the interior (concave) side.

Accordingly, it is an object of the invention to provide a method of producing a mask having a first pattern of portions of substantially different light transmissivities of such configuration that the same light pattern is projected therethrough onto a surface of a predetermined curvature as would be projected onto a surface of opposite curvature through a mask having a second and substantially different pattern of portions of different light transmissivities.

It is also an object of the invention to provide a method of producing a mask having a first pattern of opaque and translucent portions of such configuration that the same pattern is projected therethrough onto a surface of predetermined curvature as would be projected onto a surface of opposite curvature through a mask having a second and different pattern of opaque and translucent portions.

It is another object of the invention to provide an improved method of producing a plane mask having a pattern of opaque and translucent portions of such configuration that the same pattern is projected therethrough onto a surface of predetermined curvature as would be projected onto a surface of opposite curvature through a plane mask having a pattern of elongated, parallel portions, alternate ones of which are opaque and translucent.

It is a further object of the invention to provide an improved method of producing a plane mask having a pattern of opaque and translucent portions of such configuration that the same pattern is projected therethrough onto a concave surface as is projected onto a convex surface through a mask having a pattern of elongated, parallel portions, alternate ones of which are opaque and translucent.

It is yet another object of the invention to provide an improved method of making a mask having a pattern of elongated opaque and translucent portions occurring in alternate sequence, said portions having such configurations that a pattern of alternate bright and dark lines with pin-cushion distortion will be projected on a concave surface when the mask is interposed between a source of illumination and such a surface.

It is still another object of the invention to provide a simplified method of producing a plane mask having opaque and translucent portions, side-by-side, in such relative configurations that, when the mask is interposed between a source of illumination and a concave surface, a pattern of generally parallel bright lines having pin-cushion distortion will be projected on the concave surface.

Still another object of the invention is the formation of a multi-layer screen structure for cathode ray tubes by

an improved method which involves the exposure of selected portions of the concave interior surface of a cathode ray tube face plate through a mask which has been produced by a simple and yet accurate process.

Still a further object of the invention is the provision of an improved method of forming, on a concave surface, a cathode ray tube screen structure having adjacent strip-like portions which are responsive to electron beam impingement to produce different indications thereof, the said strip-like portions being generally parallel but having appreciable pin-cushion distortion, and the method involving the illumination of a tube face plate in patterns corresponding to said strip-like portions through the translucent portions of a plane mask.

In order to achieve the foregoing objects, as well as others which will appear, one begins by making an auxiliary mask of the kind which would normally be used for formation of a screen structure by exposure of the cathode ray tube face plate from its exterior, convex side. This auxiliary mask is preferably of the kind which is simplest to manufacture, namely plane and with parallel opaque and translucent portions.

One further provides an auxiliary translucent plate which has opposite concave and convex sides with substantially the same degree of curvature as the cathode ray tube face plate on which it is eventually desired to form a screen structure. The aforementioned auxiliary mask is then interposed between a source of illumination and the convex side of the auxiliary translucent plate, as a result of which there is formed, on the auxiliary translucent plate, a pattern of spaced illuminated strips which are generally parallel but which exhibit pin-cushion distortion. By appropriate relative placement of the source of illumination, of the auxiliary mask and of the auxiliary translucent plate, these illuminated strips may be caused to occupy the same relative positions on the auxiliary plate as actual screen elements of one particular kind are to occupy on a tube face plate.

Next there are formed on the auxiliary plate strips of opaque material in positions corresponding to those of the aforementioned illuminated strips. This may be accomplished in any conventional manner, as by depositing a suitable unexposed photosensitive material on the auxiliary plate where it is subjected to illumination and consequently exposed in the aforementioned pattern of strips, and by subsequently removing those portions of this material which have remained unexposed. The residual strips of opaque material will then likewise occupy the same relative positions on the auxiliary plate as are to be occupied by one kind of actual screen elements on a face plate.

Once the pattern of opaque strips on the auxiliary translucent plate has been photographed, this pattern may be removed from the plate and the aforementioned auxiliary mask may be used, in an appropriately relocated position, to produce on the auxiliary plate a second pattern of opaque strips in the positions in which it is desired to form, on an actual face plate, screen elements of a second particular kind. This second opaque line pattern is then imaged on a second plane-surfaced photographic plate confronting the concave side of the auxiliary plate and this plate is subsequently developed to produce a second mask. The same process is repeated for each group of phosphor strips of a distinctive color and, unless the indexing strips correspond exactly in location to one of the groups of phosphor strips, again for the indexing strips.

Thus there are formed a minimum of three, and generally four, separate masks, each having a pattern of translucent portions which is an image of a pattern of opaque strips simulating the desired arrangement, including pin-cushion distortion, of actual screen elements of a particular kind. It is believed to be apparent that, when a tube face plate is illuminated from its concave, interior side through the translucent portions of any one

of these predistorted masks, there will be produced on the face plate a pattern of alternate illuminated and unilluminated strips having the same pin-cushion distortion as if the projection had been made from the exterior side through a mask having an undistorted (i. e. parallel strip) pattern. Accordingly the several predistorted masks are used successively to expose, from the concave interior side of the face plate, photosensitive materials bearing the appropriate different phosphors and/or indexing material. It is also believed to be evident that the new screen forming process hereinbefore outlined possesses the aforescribed advantages associated with exposure from the interior side of the face plate, and yet produces the type of distortion which is characteristic of exposure from the exterior side.

A particular manner in which the formation of predistorted masks may be carried out in accordance with our invention, and in which such masks may be used to form certain elements of a cathode ray tube screen structure, is described in detail in the following discussion which is to be considered in conjunction with the accompanying drawings, wherein:

Figures 1 and 2 show apparatus which is suitable for the performance of the two principal steps which are involved in the formation of a predistorted mask in accordance with our invention;

Figure 3 shows apparatus which includes the predistorted mask formed by the apparatus of Figures 1 and 2 and which is useful in the formation of certain elements of a cathode ray tube screen structure; and

Figure 4 shows the structural details of a device which is suitable for mounting several predistorted masks, each formed in accordance with our invention, for the practice of the method illustrated in Figure 3.

As has been indicated, the initial step in producing a predistorted mask suitable for use in the subsequent formation of a screen structure in accordance with our invention, is to deposit a pattern of opaque lines on a curved surface. In particular, this surface should have substantially the same curvature as the interior surface of the face plate on which the actual screen structure will eventually be formed. The basic components of apparatus which is needed to practice this step are illustrated in Figure 1 of the drawings, to which reference may now be had. This apparatus comprises a curved plate 10, formed of a material which may be transparent but which is at least translucent. Glass is suitable for this application. This plate may, of course, be formed specially for the present purpose with a concave surface having substantially the same curvature as the interior surface of the face plate on which the screen structure is to be formed. However a more convenient way of obtaining this plate 10 is to sever, from all other portions of the tube envelope, the face plate of an actual cathode ray tube, taken from the same production lot as the tube or tubes in which the actual screen structure is to be formed. This severed face plate then constitutes the auxiliary translucent plate 10. Present day methods of producing cathode ray tubes are sufficiently accurate so that different tubes from the same production lot have interior curvatures which are sufficiently similar for our purposes.

Confronting the convex side of this translucent plate 10 there is placed a source of illumination 11, which is preferably as nearly a point source of light as possible. For example, this source may be a mercury vapor lamp sold commercially by the General Electric Company under the type designation BH6. Interposed between the plate 10 and the light source 11 is a mask 12 which has alternate translucent and opaque portions, respectively designated by reference numerals 13 and 14. The different degrees of light transmissivity of these different portions have been indicated diagrammatically in Figure 1 by selective darkening of the opaque portions. It will be noted that this mask 12 has plane surfaces, and that the portions of different light transmissivities are

in the form of elongated, parallel strips. No unusual problems are encountered in the formation of mask 12. In fact, this mask may be manufactured by an entirely conventional technique which involves the ruling of parallel grooves in a flat metal plate by means of a conventional ruling machine. To these grooves there is applied a material adapted to give them light reflective properties which distinguish them from ungrooved portions of the plate. This structure is then photographed to obtain a transparency of suitable size having the desired alternate strips of different light transmissivities. When the light source 11 is disposed along the axis of symmetry of auxiliary plate 10, and when the mask 12 is interposed between this light source and the face plate, there is projected, onto the plate 10, a pattern of light which also has the form of elongated strips whose long dimensions are generally parallel. However, as has been previously pointed out, the illuminated strips which are thus formed on the curved surface of plate 10 are no longer exactly parallel, as were the translucent portions of mask 12. Instead they exhibit curvature whose degree increases with distance from the aforementioned axis of symmetry of the plate. The reason for the occurrence of this distortion will be readily understood when one considers the light which passes through any one translucent strip of the mask 12 other than that which is located in the plane of the aforementioned axis of symmetry. This light impinges on the translucent plate 10 in a narrow region extending generally vertically across the plate. Since this plate is convex toward the mask, the central portion of the illuminated region will be closer to the mask, and also to the source of illumination, than either the upper or the lower extremes of this illuminated region. Consequently, light traveling to the extreme portions of the illuminated regions under consideration will have to traverse a longer path prior to impingement. Since the velocity of this light is fixed, and since any given ray thereof continuously diverges from the axis of symmetry of the apparatus (owing to the point source character of the source of illumination), light which reaches the extreme portions will have been in transit disproportionately longer and will have diverged disproportionately farther from the axis of symmetry than light which reaches the central portion of the illuminated region. Consequently each illuminated strip, other than that which lies in the plane of the axis of symmetry (where there is no divergence in a direction transverse to the long dimension of the strips), will be curved so that its ends point away from the axis of symmetry. It is also clear that this effect will become increasingly pronounced as the distance between this axis and the strip under consideration increases. This accounts for the pin-cushion distortion of the illuminated strip pattern. In Figure 1 the pattern of illuminated strips with pin-cushion distortion, which results from illumination of the tube face through the translucent portions of mask 12, has been schematically represented by broken line 15. It will be understood that, in practice, the number of illuminated strips which are formed in this manner may be much greater than illustrated, and also that the relative dimensions of the strips, the spacing between them, and the overall size of the transparent plate may be entirely unlike those which have been shown in Figure 1 for purely illustrative purposes.

Before the projection of an illuminated strip pattern on the translucent plate 10 is actually carried out, the concave side of this plate is coated with a photosensitive material. In this photosensitive material there will then be produced a pattern of exposed portions having the same configuration as the pattern of illuminated portions of the plate 10, and consisting of a plurality of generally vertical lines with pin-cushion distortion of the form which has been noted. After this exposure of the photosensitive material through the mask 12 has been carried out, an opaque material is applied to the surfaces

of both the exposed and the unexposed portions of the photosensitive material. This opaque material may be one of the phosphor materials used in the formation of an actual screen structure. However, better results are often obtained if a suitable opaque dye is applied to this photosensitive material. A suitable dye for this purpose is that sold commercially as "Congo red." The structure formed in the foregoing manner is then washed with a material which is a solvent for unexposed photosensitive material but which is not a solvent for the same material after exposure. Consequently, only the exposed portions of the photosensitive material, which have the aforescribed configuration of strips with pin-cushion distortion, will remain unaffected by this washing action and will remain fixed in place together with the opaque material which has been applied to these exposed portions.

The photographic aspects of the method of forming these strips of opaque material are conventional and need therefore not be described in detail. However, for a full description of this photographic deposition technique reference may be had to the aforementioned compending application of Paul D. Payne, Jr.

It will be apparent that the exact location of the pattern of opaque strips which is thus formed depends upon several parameters. In particular it is affected by the widths and mutual spacings of the translucent portions of mask 12 and also by the alignment and spacing of this mask relative to translucent plate 10 and to light source 11. However, the auxiliary plate is similar in shape and size to an actual face plate. Furthermore it is only required that the opaque strips occupy the same positions on the auxiliary plate as screen elements made of one particular material are to occupy on an actual face plate. With this in mind, it is a simple matter, involving only the application of elementary principles of geometry, to determine the proper values of the aforementioned parameters in any particular case.

It will also be apparent that some auxiliary equipment may be required to produce and maintain during exposure the desired mechanical alignment between the components of Figure 1. However it is well within the skill of a worker in the art to devise a variety of forms of such auxiliary equipment. In view of this, and to avoid obscuring the relations between the essential components illustrated, this auxiliary alignment equipment has been omitted from Figure 1. For a complete disclosure of one form which this auxiliary equipment may take, reference may also be had to the aforementioned compending application of Paul D. Payne, Jr.

The same translucent plate 10 which has been illustrated in Figure 1 is reproduced in Figure 2, to which more particular reference may now be had, but in the latter figure it is shown with the opaque strips formed by the apparatus of Figure 1. These opaque strips are represented schematically by solid lines 15a which occupy the same positions on the plate 10 as the broken lines 15 of Figure 1. In Figure 2 there are also illustrated the structural essentials of apparatus which can be used in cooperation with the translucent plate 10 for performing the second important step of our invention, namely the actual production of a predistorted mask. This additional apparatus consists of a source of illumination 17 which is effective to project diffused light upon the convex side of the translucent plate 10. Except where this light is intercepted by opaque strips 15a it is freely transmitted through the plate 10 and emerges from its concave side. The pattern of light and dark areas which is thus formed on the concave side of plate 10 is imaged by means of focusing lens 18 upon a plane photographic plate 19. Upon this plate it produces a pattern of exposed and unexposed portions which correspond respectively to the light and dark areas on the auxiliary plate 10. In Figure 2 the portions of this photographic plate which remain unexposed in this process are sche-

matically represented by broken lines 20 and are seen to exhibit pin-cushion distortion corresponding in form to the pin-cushion distortion of the opaque strips 15a on translucent plate 10.

As in Figure 1, auxiliary apparatus which maintains the components of the system of Figure 2 in their proper relative alignment has been omitted from the illustration to avoid obscuring the essential structural components. This alignment apparatus may take any one of numerous conventional forms which a person skilled in the art will have no difficulty in devising.

The source 17 of diffuse illumination which is required for the operation of this system may also take any conventional form. However, apparatus which has been found particularly suitable for this purpose comprises a group of photoflood lamps 21, each equipped with a reflector and oriented so as to illuminate a large plate 22 of translucent, light diffusing material, such as for example cryolite glass, which is disposed intermediate the photoflood lamps and the plate 10. It is to be noted that the photographic reproduction of the opaque strip pattern is preferably made considerably smaller than this strip pattern itself. This enhances the economy of the process because a smaller photographic plate can be used and also because subsequent operations involved in the production of an actual screen structure, in which this photographic reproduction is used, can be performed more conveniently.

It will be noted that the formation of a predistorted mask by means of the apparatus of Figures 1 and 2 involves the preliminary formation of opaque strips 15 on an auxiliary plate 10. If desired, however, the formation of these opaque strips may be dispensed with. To this end that side of the auxiliary plate 10 which fronts away from the source of illumination 11 is provided with a light diffusing finish. This plate is then illuminated through the undistorted mask 12, whereby there is formed, on the light diffusing surface of the plate, an image of the light pattern projected by mask 12 and having the desired pin-cushion distortion. Instead of forming opaque strips from this light pattern in the manner of Figure 1, the image of this pattern may now be further projected upon a photosensitive plate positioned with respect to plate 10 in the same manner as the photosensitive plate 19 of Figure 2. As a result, an exposure pattern corresponding to the light image which exists on the diffusing surface will be produced in this photosensitive plate. This exposure pattern may then be utilized, in conventional manner, to form a predistorted mask suitable for utilization in the apparatus of Figure 3.

This alternative procedure is particularly advantageous where only small quantities of any particular form of predistorted mask are to be made so that it is not worthwhile to make a permanent record of the light pattern on the auxiliary plate 10. It is also advantageous where the shape of this auxiliary plate is such as to make it difficult to give it the optical characteristics which it should have for the formation thereon of an opaque strip pattern.

So far there has been described the basic process of manufacturing a predistorted mask which is suitable for the photodeposition, by exposure from the concave side, of one of the several different materials which constitute the screen structure of a color cathode ray tube. It does not appear feasible to deposit the other screen constituent materials on this face plate merely by locating the same predistorted mask in other positions relative to the face plate. Consequently it becomes necessary to produce a different predistorted mask for each pattern of different material.

To this end the pattern of opaque strips is removed from the auxiliary translucent plate 10 of Figures 1 and 2, once it has served its purpose in the formation of one of the predistorted masks, and a different pattern

of opaque strips is deposited on this same plate. More particularly these new opaque strips are formed on the auxiliary plate in positions which correspond to those in which it is desired to deposit strips of a second screen material on an actual face plate. This newly formed pattern of opaque strips can then be projected on a second plane photographic plate (in the manner of Figure 2) to yield a second predistorted mask, suitable for the subsequent deposition of a second screen constituent material.

The foregoing process is repeated as often as is necessary to produce a separate predistorted mask for the deposition of each pattern of screen constituent material. In general this will require the production of four separate masks, three for the different phosphor materials and one for the indexing material.

The manner in which any one of these predistorted masks is utilized in the formation of an actual cathode ray tube screen structure will be described with particular reference to Figure 3 of the drawings. The face plate 23 of the cathode ray tube upon which this screen structure is to be formed is preferably similar in dimensions to the translucent plate 10 which was used previously in the formation of the predistorted mask. While some structural differences between the face plate 23 and the plate 10 are, of course, permissible, at least the curvatures of their concave surfaces should be substantially identical. At this stage in the manufacture of the final cathode ray tube, the face plate 23 is not attached to other components of the envelope, such as its neck and the flared portion which connects the neck to the face plate. Before carrying out the present operation its interior surface is coated with photosensitive material in the manner hereinbefore referred to. Confronting the concave interior surface of this face plate 23 there is placed a source of illumination 24 which may be substantially identical to the source of illumination 11 used in the arrangement of Figure 1. Between this source of illumination and the face plate there is interposed the distorted mask 19 which has previously been manufactured by the process described with reference to Figures 1 and 2. Preferably this mask 19 is placed in the same spatial relationship to the face plate 23 as existed between the photographic plate 19 (from which this mask was manufactured) and the auxiliary translucent plate 10 in the apparatus of Figure 2. A condensing lens 25 is interposed between the source of illumination 24 and the distorted mask 19. This lens, which may be constructed in accordance with conventional optical technique, serves to change the diverging light originating from point source 24 into converging light and to direct this converging light through the translucent portions of mask 19. The condensing power of lens 25 is made such that the light passing through the translucent portions of mask 19 substantially retraces, in the opposite direction, the paths which light followed from the translucent plate 10 to the photographic plate 19 in the arrangement of Figure 2. Consequently there will be produced on the face plate 23 a pattern of illuminated strips in substantially the same relative positions as were occupied by the opaque lines on the concave surface of translucent plate 10, and portions of the coating of the photosensitive coating on the interior surface of face plate 23 will be exposed in accordance with this pattern. Phosphor material of the particular kind which it is desired to form into strips on these portions of the face plate is then applied to both exposed and unexposed portions of the photosensitive material, and finally the unexposed portions of photosensitive material, and also the phosphor material deposited thereon, are washed off, leaving in place only the exposed portions of photosensitive material and the phosphor material deposited thereon.

It will now be noted that the condensing lens 25 should be at least as large as the mask through which it causes

light to converge. Since the cost of such a lens increases rapidly with size it is desirable to use the smallest possible lens. The achievement of this objective will be promoted if the predistorted mask is made as small as possible. Typically a mask five by seven inches in size may be used to project the desired strip-like pattern on a rectangular face plate which is fifteen by twenty inches in size. With a mask of such reduced size the required converging lens is not prohibitively expensive and yet the problems of undistorted magnification during projection remain manageable.

As has been pointed out, the relative positions of the elements of the apparatus illustrated in Figure 3 should be such that the light passing through mask 19 substantially retraces the paths which light followed to the photographic plate in the arrangement of Figure 2. If the locations of these elements are further chosen in such a manner that the light rays travelling toward the face plate 23 intersect at a point which occupies substantially the same position relative to the face plate as the center of beam deflection in the finished cathode ray tube, then the shape of the interior surface of the face plate becomes immaterial and need no longer be the same as the shape of the auxiliary plate 10 which is used in the fabrication of the distorted mask 19. This is because the scanning electron beams of the finished tube will then intercept the screen formed on the face plate at the same points as the light projected on the face plate during screen formation, irrespective of the actual shape of this face plate.

The foregoing steps of depositing the photosensitive material, exposing it to illumination through an appropriate mask, coating it with phosphor material and washing it to remove the unexposed portions are now repeated successively for each of the different phosphor materials. Of course, care must be taken each time to place the appropriate predistorted mask before the source of illumination so that there will be produced three different patterns of exposed portion, respectively occupying the positions intended for the three different phosphor materials.

An aluminum film is next deposited on the portions of the screen structure thus formed. This may be done by any one of a variety of known techniques. For example, a film of organic material of comparatively high plasticity may be spread over the previously formed phosphor strips, and also over the spaces between phosphor strips. Such a film tends to bridge irregularities in these phosphor strips and forms a smooth protective surface upon which the aluminum film may be formed by spraying, evaporation, or otherwise without causing damage to the aluminum film. It is to be noted that the thickness of this aluminum film is no longer a matter of great concern, because no exposure of photosensitive materials through this aluminum film need be attempted in the course of screen structure formation. Of course, the film should be thin enough to permit passage of an intelligence-modulated electron beam.

Finally the indexing elements are formed on the interior surface of this aluminum film in a manner similar to that in which the several sets of phosphor strips are made. In particular, another layer of photosensitive material is deposited on the aforementioned aluminum film and exposed from the interior side through a mask which has been produced with the requisite distortion by means of the process described with reference to Figures 1 and 2. As has been pointed out, unless the positions of the indexing elements happen to correspond exactly with the positions of at least one set of phosphor strips a separate predistorted mask is also required for the formation of the indexing elements. Indexing material, e. g. magnesium oxide, is then applied to the entire surface of the photosensitive material and unexposed portions thereof are selectively removed, as was done in the formation of phosphor strips.

While the predistorted masks manufactured by the process described in connection with Figures 1 and 2 are capable of producing screen structures whose elements have dimensions which are sufficiently accurately controlled for most applications, there exists a further refinement which may be incorporated in the process and which yields structures of even greater dimensional precision. Referring again to Figure 1, it will be noted that the light which is projected through auxiliary mask 12 on a central region of plate 10 (where the latter is closest to light source 11) is more intense than that which is projected on a peripheral region of the same plate. Furthermore, it has been found that the regions in the photosensitive material on plate 10, which are thus exposed, increase in width with increasing intensity of illumination. As a result, the exposed strips of photosensitive material are wider near the center of the plate than near its periphery and a corresponding variation occurs in the widths of the opaque strips which are formed in coincidence with these exposed strips.

When this pattern of opaque strips is then reproduced in the predistorted mask the same width variation will be introduced into the translucent portions of the latter and will finally reappear in the actual screen elements formed by exposure through this predistorted mask.

This difficulty can be avoided by the following procedure. A surface is provided which has substantially the same curvature and which occupies substantially the same position as auxiliary plate 10 in Figure 1. This surface is coated with unexposed photosensitive material and is subjected to illumination by source 11, without any intervening mask. By this illumination the photosensitive material will be exposed at different portions of the coated surface to different extents according to the variations in intensity of the illumination due to variations in the distance from the light source to different portions of the surface. The exposed material is then developed to yield a negative transparency whose opacity exhibits corresponding variations, being greatest in the regions where the photosensitive material was subjected to the most intense illumination. This negative transparency is interposed between the light source 11 and the auxiliary plate 10, during exposure of the latter through mask 12 whereby light falling on the portions of plate 10 which are closest to the light source is attenuated more than light falling on the portions of plate 10 which are farthest from the light source. Consequently, more nearly uniform illumination of the plate 10 is produced and the opaque strips formed thereon are caused to be more nearly uniform in width.

In practice it may be convenient to form the corrective transparency under discussion directly on that surface of auxiliary plate 10 which confronts the light source 11. This may be accomplished by coating this surface with a suitable photosensitive material, exposing the same to illumination by source 11 without any intervening mask and developing the exposed material into the desired transparency of varying opacity.

A device which is particularly suitable for the accurate placement of the four predistorted masks which are required in the course of formation of the different type of screen elements is illustrated in Figure 4 of the drawings to which more particular reference may now be had. This device consists of a circular disk 27 provided with four accurately located apertures, spaced at substantially equal intervals around the circumference of the disk and adapted to receive and to hold firmly mounted therein the four masks in question. The entire disk is rotatably mounted within a rigid frame 28 and has four radial protrusions which are also spaced equally about the circumference of the disk. To frame 28, there is attached a clamping member 29 which may be a U-shaped piece of metal whose arms are spaced just widely enough apart to permit them to engage one of the radial protrusions on disk 27. This clamp 29 is supported

with the frame 28 so as to slidable toward and away from the rim of disk 27. Any one of the four apertures in this disk, together with the mask positioned therein, may then be brought into a given position merely by rotating this disk until the appropriate radial protrusion is in alignment with the clamping member 29 and by sliding this clamping member into engagement with the protrusion to hold the disk in place. It will be understood that the arrangement of Figure 4 is merely illustrative of one particular form which the registering device for the several different masks may take. A number of other forms of such arrangements will readily occur to those skilled in the art.

As a matter of fact, it will be seen from the foregoing discussion that considerable latitude is available to the practitioner of our method in the choice of the specific auxiliary alignment apparatus which is to be used at each stage of the process, without however departing from the basic concept of the invention. Also it will be apparent that the method hereinbefore described is broadly applicable to any situation in which it is desired to form a mask adapted to project a certain pattern on a surface of one predetermined curvature, but in which it is, for any one of a variety of practical reasons, very much simpler to manufacture initially a mask adapted to project the same pattern on a surface of the opposite curvature. Accordingly we desire our inventive concept to be limited only by the appended claims.

We claim:

1. The method of forming an optical mask for use in producing a screen structure on the concave interior surface of a curved cathode ray tube faceplate, said method comprising the steps of: subjecting a substantial replica of said faceplate provided with a light diffusing surface on its concave side to illumination by light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting plane-surfaced mask having alternate translucent and opaque portions, thereby to form on said diffusing surface an illumination pattern corresponding to said translucent portions of said preexisting mask; forming a real, focused image of said pattern on a plane surface disposed on the concave side of said replica and spaced therefrom; and forming on said plane surface a record of said image which constitutes an optical mask whose opacity varies in accordance with the variations in brightness of said image.

2. The method of forming an optical mask for use in producing a screen structure on the concave interior surface of a curved cathode ray tube faceplate, said method comprising the steps of: subjecting a substantial replica of said faceplate provided with a light diffusing surface on its concave side to illumination by light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting plane-surfaced mask having alternate translucent and opaque portions, thereby to form on said diffusing surface an illumination pattern corresponding to said translucent portions of said preexisting mask; photographing said illumination pattern from said concave side of said replica; and developing the resultant photograph into a photographic transparency constituting an optical mask whose opacity varies in accordance with the variations in exposure of said photograph.

3. The method of forming a cathode ray tube screen structure on the concave, interior side of a curved cathode ray tube faceplate, said method comprising the steps of: illuminating a substantial replica of said faceplate having a light diffusing surface on its concave side with light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting mask having translucent and opaque portions in alternate, substantially parallel strips, thereby to form on said diffusing surface an illumination pattern corresponding to said translucent portions of said pre-

existing mask; forming a real, focused image of said illumination pattern on a second surface disposed on said concave side of said replica and spaced therefrom; forming on said second surface a record of said image which constitutes a second optical mask whose opacity varies in accordance with the variations in brightness of said image; and subjecting to exposure through said second optical mask from the interior side of said faceplate a layer of unexposed photo-sensitive material coating said concave interior side.

4. In the method of claim 3, the further steps of coating said layer of photosensitive material with a screen constituent material after exposure through said second mask, and selectively removing unexposed portions of said photosensitive layer and screen constituent material supported by said unexposed portions, while leaving in place exposed portions of said photosensitive material and screen constituent material supported by said exposed portions.

5. The method of forming an optical mask for use in producing a screen structure on the concave interior side of a curved cathode ray tube faceplate, said method comprising the steps of: exposing portions of a layer of unexposed photosensitive material coated on the concave side of a replica of said faceplate with light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting plane-surfaced mask having alternate translucent and opaque portions, thereby to form in said layer an exposure pattern corresponding to said translucent portions of said preexisting mask; developing an image of said pattern produced in said layer; forming a real, focused image of said developed image on a plane surface disposed on the concave side of said replica and spaced therefrom; and forming on said plane surface a record of said real, focused image which constitutes an optical mask whose opacity varies in accordance with the variations in brightness of said last-named image.

6. The method of forming an optical mask for use in producing a screen structure on the concave interior side of the curved cathode ray tube faceplate, said method comprising the steps of: exposing portions of a layer of unexposed photosensitive material coated on the concave side of a replica of said faceplate with light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting plane-surfaced mask having alternate translucent and opaque portions; coating said layer of photosensitive material with substantially opaque material; selectively removing unexposed portions of said photosensitive layer and opaque material supported by said unexposed portions, while leaving in place exposed portions of said photosensitive material and opaque material supported by said exposed portions; photographing the resultant pattern of opaque material left in place on said replica from said concave side of said replica; and developing the resultant photograph into a photographic transparency constituting an optical mask whose opacity varies in accordance with the variations in exposure of said photograph.

7. The method of forming a cathode ray tube screen structure on the concave, interior side of a curved cathode ray tube faceplate, said method comprising the steps of: exposing portions of a layer of unexposed photosensitive material coated on the concave side of a replica of said faceplate with light transmitted to said replica from its convex side along diverging paths through the translucent portions of a preexisting plane-surfaced mask having translucent and opaque portions in alternate substantially parallel strips, thereby to form in said layer an exposure pattern corresponding to said translucent portions of said preexisting mask; developing an image of said pattern produced in said layer; forming a real, focused image of said developed image on a plane surface disposed on said concave side of said replica and spaced

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therefrom; forming on said plane surface a record of said image which constitutes a second optical mask whose opacity varies in accordance with the variations in brightness of said image; and subjecting to exposure through said second optical mask from the interior side of said faceplate a layer of unexposed photo-sensitive material coating said concave interior side.

8. In the method of claim 7, the further steps of coating said layer of photosensitive material with a screen constituent material after exposure through said second mask, and selectively removing unexposed portions of said photosensitive layer and screen constituent mate-

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rials supported by said unexposed portions, while leaving in place exposed portions of said photosensitive material and screen constituent material supported by said exposed portions.

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