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3,089,052

CATHODE RAY TUBE FACEPLATE CONSTRUCTION

Filed March 10, 1960

3 Sheets-Sheet 1

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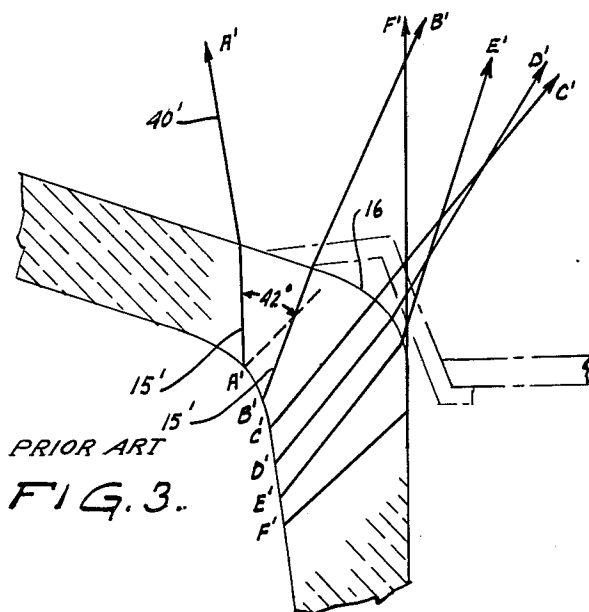


FIG. 1.

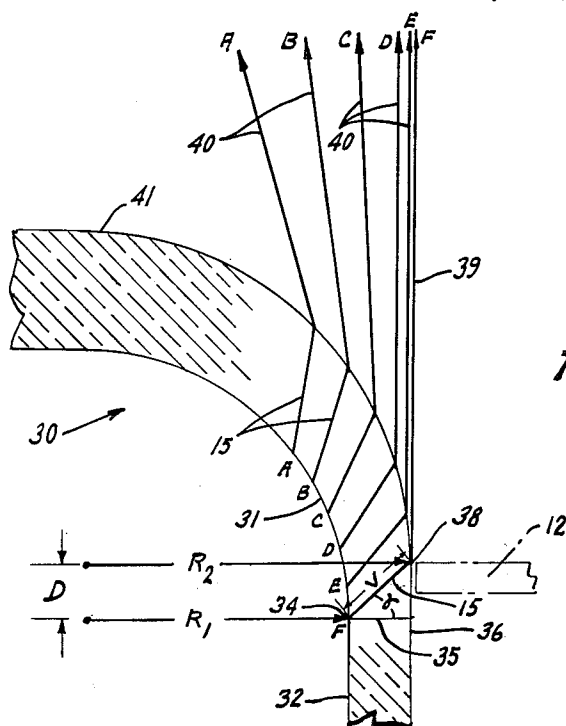


FIG. 2.

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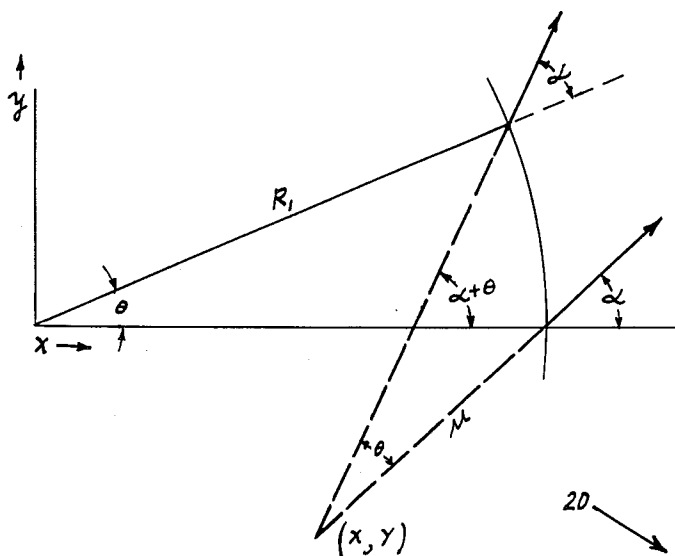


FIG. 5.

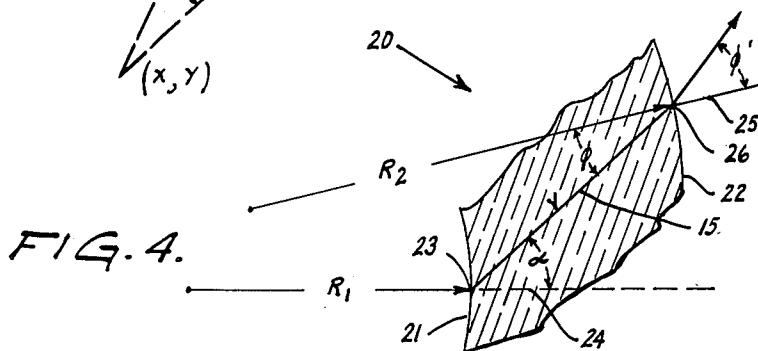


FIG. 4.

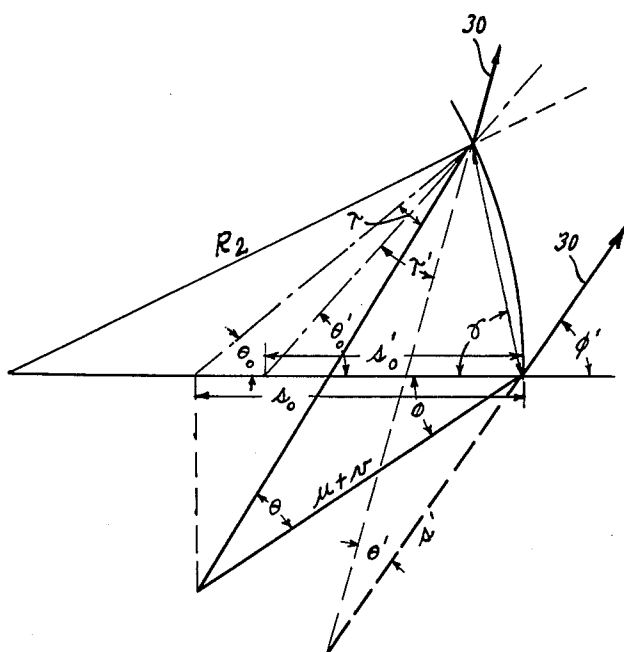


FIG. 6.

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CATHODE RAY TUBE FACEPLATE CONSTRUCTION

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FIG. 7.

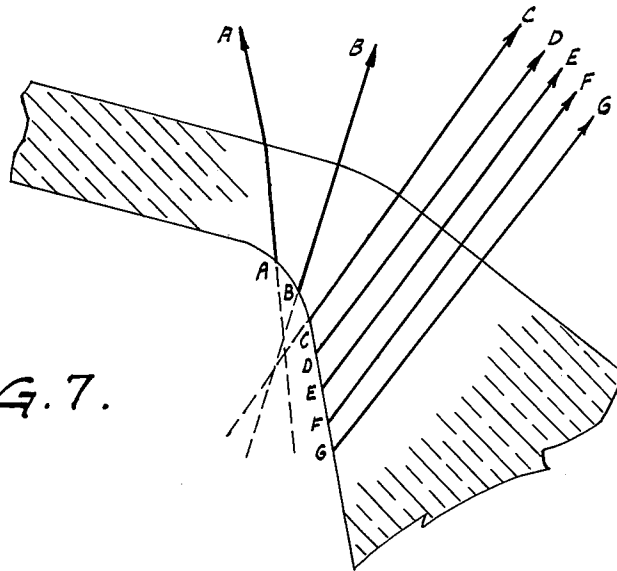
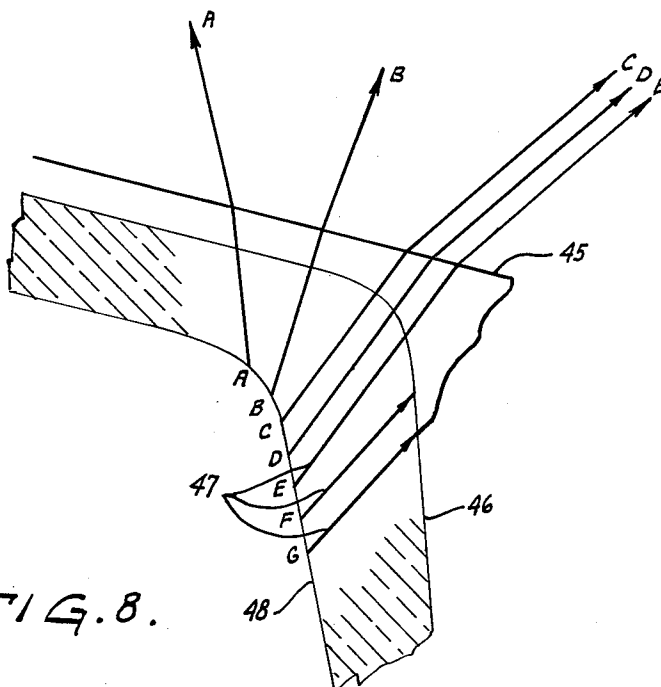


FIG. 8.



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CATHODE RAY TUBE FACEPLATE
CONSTRUCTION

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Filed Mar. 10, 1960, Ser. No. 17,724

10 Claims. (Cl. 313-110)

This invention relates generally to cathode ray tubes and more particularly to improvements in the construction of such tubes, the present application being a continuation-in-part of my copending application bearing Serial No. 9,622 filed February 18, 1960, now abandoned.

It has been an objective in the television art, from the standpoint of utility as well as aesthetics, to construct a cathode ray tube whose frontal edge portions may be exposed for television viewing without the necessity of masking off substantially peripheral areas of the tube. By projecting the tube beyond the confines of the receiver cabinet, a considerable reduction in the depth dimension of the cabinet may be achieved which both enhances the receiver's appearance and permits a reduction in constructional costs. This aim, however, has been frustrated in part by the objectionable appearance in the tube's frontal area, due in part to striation of light passing through edge portions of the tube face plate.

This problem is particularly severe in cathode ray tubes having a substantially flat face plate in which the radius of curvature of the face is considerably greater than the radius of deflection of the electron beam. The sharp edge radii of curvature necessitated by the abrupt transition from the relatively thick face plate to the thinner walled, bell portion of the tube produces an objectionable lens effect resulting in fractionation of the emitted light. When the tube protrudes from the front of the cabinet in such manner as to expose the edge of such a tube to the viewer through wide viewing angles, this lens effect produces alternate bands or striae of light and dark which appear or recede according to the position of the viewer.

Prior art solutions to this problem have been to rim the face plate with band of opaque material or to use a bezel to mask off those portions of the tube having an objectionable appearance. This solution however involves additional expense and does not allow full use of the tube's frontal area.

Simply stated, striation results from the inability of the viewer to receive emission from points on the inner surface of the tube face plate in conformity with their actual spatial orientation. This produces emission gaps and the phenomenon herein termed edge striation.

Accordingly a principal object of the present invention is to eliminate the striation of phosphorescent emission produced by passage of light through frontal edge portions of a cathode ray tube.

Another object of the invention is to provide a simplified method and means for extending the useful viewing area of a cathode ray tube and to improve tube performance.

A still further and more particularized object of this invention is to provide means for improving the viewing appearance of an unmasked cathode ray tube which projects beyond the confines of its associated television cabinetry.

Another and subordinate object of the invention is to provide a solution to the problem of cathode ray tube edge emission which is simple, inexpensive and adaptable to present tube configurations.

These and other objects within contemplation will be apparent from a consideration of the following description and accompanying drawings, in which:

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FIGURE 1 is a perspective showing of a television receiver incorporating a cathode ray tube embodying the present invention;

FIGURE 2 is a partial, sectional view taken along the cutting plane 2—2 shown in FIGURE 1, showing an edge portion of the cathode ray tube face plate;

FIGURE 3 is a view analogous to FIGURE 2, showing a cathode ray tube face plate edge construction characteristic of the prior art;

FIGURES 4 through 6 are diagrams used in the derivation of the constructional formulae employed in the practice of the invention;

FIGURE 7 depicts a variant form of tube construction for overcoming edge striation; and

FIGURE 8 shows a tube overlay for eliminating striation in tubes of conventional construction.

In accomplishment of the foregoing general objectives I have found that striation and distortion of the transmitted intelligence through frontal edge portions of the tube may be eliminated or substantially reduced by proper contouring of the external surface of the transitional section connecting the tube front and sides, this portion of the tube hereinafter being referred to as the tube face plate. If this connecting section is modified in accordance with my invention the useful viewing area of the screen may be extended to the full width of the cathode ray tube face plate. This eliminates the need for masking, and permits optimum utilization of the tube's frontal surfaces with attendant economic and aesthetic advantages.

Referring to FIGURE 1 there is shown a television receiver 10 comprising a cathode ray tube 11 embodying features of the present invention, the tube projecting a considerable distance beyond the front surface 12 of the receiver cabinet 13. When the entire tube face is thus exposed, it has been the practice in the prior art as mentioned above to mask off a substantial width of the tube's edge. By means of the present invention full use of the tube face is now realized.

To facilitate explanation of the optical phenomenon giving rise to the light striation produced by the tube edge, reference is made to FIGURES 2 and 3 in which there is shown a series of discrete light emitting points A through F arrayed on the inner surface of the face plate edge. These points are in actuality phosphor particles undergoing irradiation by an electron beam. It is assumed that these particles are not in optical contact with the tube's inner-surface and accordingly the light radiated from them through the tube edge is confined within a cone of half angle

$$\sin^{-1} \frac{1}{n}$$

For glass having an index of refraction for example of 1.5 this angle would be about 42°. Only the upper limit ray of the pencil of rays emanating from each point source is shown since it is this way with which we are concerned. Light coming from a point on this inner surface is observable by the viewer only when he is positioned to the right (in the plane of the paper) of the limit ray emanating from that point. As will be observed the prior art tube construction shown in FIGURE 3 results in the light coming from points A' through F' being scrambled by the tube's edge curvature 16. The inversion of the actual geometric pattern of these points produces edge striation.

Tubes constructed in accordance with the teachings of this invention, as for example that shown in FIGURE 2, eliminate this problem. In FIGURE 2 as the viewer walks in front of the screen in a clockwise direction from left to right he observes points A, B, C, etc., in their normal viewing sequence, there being no discontinuities in the viewing spectrum and hence no striation.

I have found that by proper design of the exterior edge curvature of the tube face, given a particular inside surface configuration whether it be convex or concave, that the problem of light striation may be totally obviated, providing certain boundary conditions are met.

There are, however, only a limited range of solutions for any given situation, which solutions can best be understood by describing the general procedure to be followed in the point by point construction of an exterior surface contour which eliminates edge striation for any given internal surface configuration.

To facilitate explanation, reference is made to FIGURES 4, 5 and 6. FIGURE 4 shows a fragment 20 of an edge portion of a cathode ray tube face plate in which R_1 is the inside radius of curvature of the tube's internal surface 21 at the area under construction and R_2 is the outside radius of curvature at the point where the exterior surface 22 is intercepted by a light ray 15 emanating from a phosphorescent point 23 contiguous with the inside surface 21. This ray makes a critical angle

$$\alpha = \sin^{-1} \frac{1}{n}$$

with the normal 24 to the inner surface at point 23. The angle ϕ is the angle which the incident ray 15 makes with the normal 25 drawn to the external surface 22 at the ray's point of interception 26 with that surface, v the length of the ray between points 23 and 26, and n the index of refraction of the material out of which the face plate is made.

The sign convention to be followed in the derivation of the constructional formulae is that concave radii are negative and convex radii positive as viewed from outside the tube, hence the surfaces traced by R_1 and R_2 are positive as illustrated in FIGURES 4 through 6 and v is positive as shown.

For any given tube construction two of the three quantities R_1 , R_2 and ϕ may be assigned and the third derived to satisfy the condition necessary for non-striation which conditions are hereinafter set out in detail.

Referring to FIGURE 5 it can be shown that:

$$u = \frac{R_1}{n} \sqrt{n^2 - 1} \quad (1)$$

as θ approaches zero as a limit.

Similarly the distance s' as seen in FIGURE 6 may be expressed in terms of $(u+v)$, R_2 and ϕ , as θ approaches 0 as a limit. The relationship is given by the following equation:

$$\frac{s'}{u+v} = \frac{1 - n^2 \sin^2 \phi}{n \cos^2 \phi - \left(\frac{n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}}{R_2} \right) (u+v)} \quad (2)$$

Hence, it follows from (1) and (2) that

$$\frac{s'}{u+v} = \frac{1 - n^2 \sin^2 \phi}{n \cos^2 \phi - \left(\frac{n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}}{R_2} \right) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)} \quad (3)$$

In applying the general Formula 3 to a specific tube configuration certain limiting conditions must be observed.

In the case where R_1 is positive and the angle ϕ less than the critical angle of incidence the condition for non-convergence of rays refracted at the outer surface boundary is that the object and image be on the same side of the refracting surface. This condition is met when

$$\frac{s'}{u+v} > 0$$

Since the numerator on the right hand side of Equation 3

is never negative its denominator must be equal to or greater than zero, namely positive, to fulfill the above condition. This condition is expressed mathematically below:

$$n \cos^2 \phi - \left(\frac{n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}}{R_2} \right) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right) \geq 0 \quad (4)$$

With this formula, given the radius of curvature R_1 of various points on a convex surface, the curvature of the outer surface necessary to prevent striation may be easily constructed.

To illustrate the application of this formula to a specific case, reference is made to FIGURE 2. The first step, given an internal surface 30 comprised of a convex curved portion 31, here chosen for purposes of illustration as having a fixed radius R_1 and a tangential straight portion 32, is to construct a ray 15 at the point of tangency 34 of the straight portion 32 with the curved surface 31 making an angle

$$\alpha = \sin^{-1} \frac{1}{n}$$

with the normal 35 drawn to the point of tangency 34. Next select a desired glass thickness v measured along the ray 15. At the end 38 of this ray determined by the selected thickness construct surface 36 parallel to surface 32 making the angle ϕ at this initial point 38 on the outer surface equal to the critical angle of incidence with the result that the first ray 39 will be tangentially refracted as shown. This point can conveniently be used as a terminal point for the exposed curve, the cabinet face 12 being shown in phantom as one possible complementary cabinet construction. Once, the condition of tangential refraction is met, the curve below the point 38 may either be convex or straight since all rays below that point will necessarily be non-intersecting. By setting Formula 4 equal to zero the smallest radius permissible under the assumed conditions may be readily computed. By using a selected thickness v of .625 inch, $n=1.5$ and $R_1=2.0$ inches the minimal dimension that R_2 can assume, and still meet the required conditions, is 2.84 inches. By constructing such a radius it is obvious that this will necessitate a number of additional constructions. By choosing a radius greater than 2.84 such as a radius R_2 of 3.0 inches it can readily be shown that each point on the surface of the curve generated by R_2 fulfills the conditions imposed by Formula 4. By constructing a fan of limit rays 15 emanating from the inner surface 31 it can be shown that the emerging limit rays 40 are refracted so as to maintain their normal orientation thereby insuring striation free viewing.

The tube edge configurations shown in FIGURE 7, and similarly the composite construction shown in FIGURE 8, conform to Formula 4, each of these curves lying within the family of curves derived by application of Formula 4.

In the construction shown in FIGURE 8 the overlay 45 must be closely adherent to the outer surface 46 of the face plate edge to insure against an interfacial air space which would act as a converging lens. With this qualification in mind the surface 45 may be constructed in the same general manner discussed above by constructing a fan of limit rays 47 emanating from points A through G on the tube's inner surface 48. By proceeding to assign values of v and ϕ and knowing R_1 at each of these points the value of R_2 required to prevent striation can be readily computed. When a sufficient number of these curves have been plotted, the number depending on the accuracy ultimately desired, a smooth curve connecting these surfaces can be drawn producing a non-striating outer surface. By using an overlay of this type, the invention can be easily applied to tubes of conventional design. One desirable approach would be to use the overlay both as a protective shield and as a means for preventing edge striation.

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While it is thought that the most practical embodiments from a standpoint of contemporary molding technology and general ease of fabrication are those having an inner surface of convex curvature, the invention is equally applicable to tubes having an inner surface of concave curvature.

When considering this invention from the standpoint of its application to negative internal radii of curvature, R_1 must have a radius longer than $nv/\sqrt{n^2-1}$ to prevent ray crossover. In terms of physical parameters the object and image must be on opposite sides of the refracting surface, hence the ratio $s'/u+v$ is negative. This condition insures the non-intersection of emerging light rays. Again looking at Formula 3 it is seen that this condition is met when

$$n \cos \phi - \left(\frac{n \cos \phi - \sqrt{1-n^2 \sin^2 \phi}}{R_2} \right) \left(\frac{R_1}{n} \sqrt{n^2-1} + v \right) \leq 0 \quad (5)$$

Accordingly a point by point construction of the outer surface curvature may be made in the manner previously described for any given internal negative radius of curvature providing the inner radii at any given point is longer than $nv/\sqrt{n^2-1}$.

From the foregoing it will be apparent that the curvature of the outside surface, whether the inside surface is convex or concave, providing that if the surface is concave that R_1 be longer than $nv/\sqrt{n^2-1}$ is given by the expression

$$\frac{1}{R_2} \leq \frac{n \cos \phi}{(n \cos \phi - \sqrt{1-n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2-1} + v \right)} \quad (6)$$

and further that R_2 is independent of R_1 when

$$\phi \leq \sin^{-1} \frac{1}{n}$$

This latter condition was made use of in the construction of FIGURE 2 described previously, the curve below point 38 in FIGURE 2 being subject to a wide latitude of choice.

A further advantage to be gained from this invention is the elimination of halation caused by the internal reflection of light from tube edge surfaces. This advantage may be achieved by simply imposing the additional requirement, when applying Formula 6 to the construction of a particular tube edge, that

$$\phi \leq \sin^{-1} \frac{1}{n}$$

This insures the escape of all light rays passing through tube edge portions and prevents the spreading of light, materially improving overall picture contrast.

In sum, I have discovered a novel geometrical requirement for cathode ray tubes which both eliminates edge striation and improves tube performance. Moreover, I have found that all tube edge curvatures fulfilling the conditions necessary to prevent light striation fall into a unique envelope of curves the curvature of which is defined by Formula 6 set out above.

Although the invention has been described with reference to specific practice and embodiments, it will be understood by those skilled in the art that the invention will cover numerous other embodiments without departing from the essential scope of the invention, as defined in the appended claims.

I claim:

1. A cathode ray tube envelope having a frontal curved edge portion whose inside radius of curvature R_1 , at any given point, has a value outside the range of from zero

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to $-nv/\sqrt{n^2-1}$ and whose outer surface has a curvature at any given point defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos \phi}{(n \cos \phi - \sqrt{1-n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2-1} + v \right)}$$

where the elements of said formulae have the following meaning

ϕ = the angle subtended by a ray traversing a tube edge portion and the normal to the outer surface of said edge portion at the point of said ray's impingement with said surface and in which said ray forms a critical angle

$$\alpha = \sin^{-1} \frac{1}{n}$$

with the normal drawn to the inner surface of said edge portion at the point of said ray's impingement with that surface

n = refractive index of the cathode ray tube material
 v = length of said traversing ray included between the inner and outer surfaces of the tube edge portion under consideration

R_1 = inside radius of curvature of said tube edge portion

R_2 = outside radius of curvature of said tube edge portion.

2. A cathode ray tube face plate having a sharply curved edge portion every increment of whose outer surface has a curvature defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos \phi}{(n \cos \phi - \sqrt{1-n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2-1} + v \right)}$$

with the qualification that if R_1 is negative then the expression only applies where R_1 is less than

$$\frac{-nv}{\sqrt{n^2-1}}$$

where n is the index of refraction of the face plate material, v the edge thickness measured along a ray drawn to any surface point and making an angle

$$\alpha = \sin^{-1} \frac{1}{n}$$

with the normal drawn to the inner surface at the point of said ray's intersection with said inner surface, R_1 and R_2 the radii respectively of the inside and outside surfaces at their point of intersection with said ray, and ϕ the angle subtended by said ray and the normal drawn to the point where said ray intersects the outer surface.

3. A cathode ray tube face plate having a transitional section connecting front and edge portions of said face plate in which the angle ϕ measured at any location in said transitional section is defined by the expression

$$\phi = \sin^{-1} \frac{1}{n}$$

where ϕ and n have the meaning as set forth in claim 1.

4. A cathode ray tube face plate having a transitional section connecting front and side portions of said face plate in which the curvature of the outer surface of said section at points lying on rays making an angle

$$\phi < \sin^{-1} \frac{1}{n}$$

is defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos \phi}{(n \cos \phi - \sqrt{1-n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2-1} + v \right)}$$

where the elements of said formulae have the meaning as set forth in claim 1.

5. A cathode ray tube face plate having a frontal viewing area of larger radius of curvature and edge portions

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of lesser radii of curvature in which at least one of said edge portions has an internal surface of convex curvature and an external surface every increment of whose surface has a curvature defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos^2 \phi}{(n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)}$$

where the elements of said formula have the meaning as set forth in claim 1.

6. A cathode ray tube face plate having a frontal viewing area of large radius of curvature and edge portions of reduced radii curvature in which at least one of said edge portions has an internal surface of concave curvature every increment of which has a radius of curvature R_1 less than $-nv/\sqrt{n^2 - 1}$ and an external surface every increment of which has a curvature defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos^2 \phi}{(n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)}$$

where the elements of said formulae have the meaning as set forth in claim 1.

7. A cathode ray tube face plate cover adapted for placement over frontal edge portions of a cathode ray tube, and so constructed that when placed in optical contact with such edge portions it provides an external tube-edge curvature defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos^2 \phi}{(n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)}$$

where the elements of said formula have the meaning as set forth in claim 1.

8. A cathode ray tube face plate having face and side portions connected by an arcuate section having a fixed inside and outside radius of curvature R_1 and R_2 respectively, the inner surface of said arcuate section being tangent to an inner surface of said side portion and the center of said outside radius of curvature being displaced from the center of said inside radius of curvature by a distance

$$\frac{v}{n}$$

where n is the index of refraction of the tube material and v the distance between said point of tangency and the outside surface of said section measured along a ray originating at said point of tangency and making an angle

$$\alpha = \sin^{-1} \frac{1}{n}$$

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with the normal drawn to said point of tangency, and said radii being related by the formula

$$R_1 - R_2 = \frac{v}{\cos \left(\sin^{-1} \frac{1}{n} \right)}$$

9. A cathode ray tube envelope having a front edge portion whose inside radius of curvature R_1 , at any given point, has a value outside the range of from 0 to

$$\frac{-nv}{\sqrt{n^2 - 1}}$$

and whose outer surface has a curvature at any given point defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos^2 \phi}{(n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)}$$

and in which said latter expression the angle

$$\phi \leq \sin^{-1} \frac{1}{n}$$

and where the elements of said formulae have the meaning as set forth in claim 1.

10. A cathode ray tube envelope having a frontal curved edge portion whose inside radius of curvature R_1 , at any given point, has a value outside the range of from zero to $-nv/\sqrt{n^2 - 1}$ and whose outer surface has a curvature at any given point defined by the expression

$$\frac{1}{R_2} \leq \frac{n \cos^2 \phi}{(n \cos \phi - \sqrt{1 - n^2 \sin^2 \phi}) \left(\frac{R_1}{n} \sqrt{n^2 - 1} + v \right)}$$

when

$$\phi \leq \sin^{-1} \frac{1}{n}$$

and

$$\frac{1}{R_2}$$

is unrestricted when

$$\phi \leq \sin^{-1} \frac{1}{n}$$

where the elements of said formulae have the meaning ascribed to them in claim 1.

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