April 18, 1944. C. J. T. YOUNG 2,346,810

CATHODE RAY TUBE

Filed Nov. 13, 1941

FIG. 1

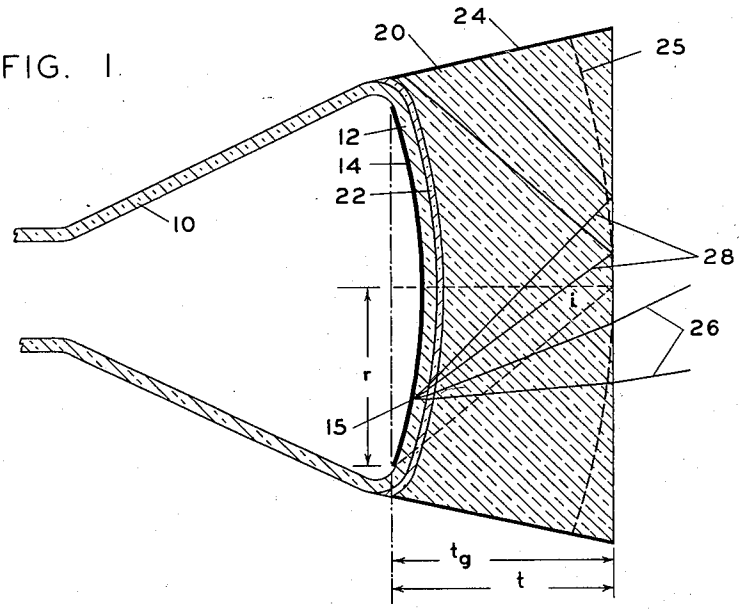


FIG. 2

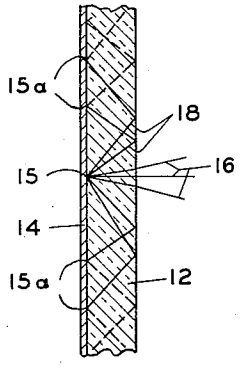


FIG. 3

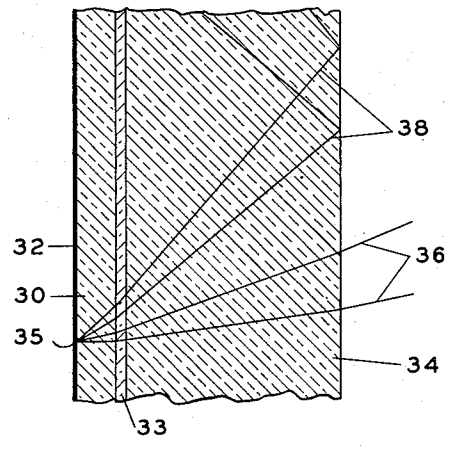
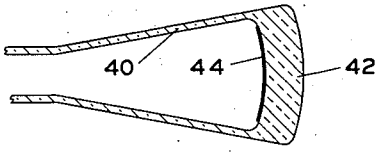


FIG. 4



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CATHODE RAY TUBE

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6 Claims. (Cl. 250—164)

This invention relates to cathode ray tubes, and more particularly to means for improving the definition of images produced on the screen of a cathode ray tube, as for example in a television receiver.

In one form of television receiving apparatus, a picture is reproduced by means of a cathode ray tube having a fluorescent screen formed on the inner surface of part thereof. In such an arrangement, some of the light emitted from the screen is reflected back again on to the screen from the outer surface of the wall of the tube, which results in substantially diminishing the definition of the desired image. It is a primary object of this invention to provide means for overcoming loss of definition caused in this manner.

Another object of the invention is to provide an improved cathode ray tube wherein light emitted from the screen and reflected within the wall of the tube is prevented from falling again upon the screen.

A further object is to provide simple means which may be combined with conventional cathode ray tubes and will result in preventing the above loss of definition in the image produced on the screen of said tubes.

Other objects and advantages will in part appear and in part be pointed out in the course of the following detailed description of one or more embodiments thereof, which are given as non-limiting examples, in connection with the accompanying drawing, in which:

Figure 1 is a partially diagrammatic view in section showing part of a cathode ray tube constructed in accordance with an embodiment of the invention;

Figure 2 is an enlarged, fragmentary view in section illustrating the operation of a conventional cathode ray tube;

Figure 3 is a view similar to Fig. 2 showing the operation of a modification of the embodiment of the invention shown in Fig. 1; and

Figure 4 is a view similar to Fig. 1 showing a further modification of the invention.

Referring to Fig. 1, element 10 represents a conventional glass cathode ray tube whose end wall 12 is provided on its inner face with a fluorescent screen 14. In operation, any conventional form of ray generating apparatus (not shown) directs rays against screen 14, and thereby produces the desired image thereon. For example, if a ray strikes screen 14 at point 15, said point is thereby caused to emit light in all directions and accordingly becomes a bright spot in the image being reproduced on screen 14.

Now referring to Fig. 2, it will be seen that in the conventional type of cathode ray tube, the courses of light rays emitted from point 15 vary depending upon their initial directions. Thus with rays such as rays 16, which are propagated in such directions that they are incident upon the outer surface of wall 12 at angles approaching the normal, only a small amount of light is reflected back to the screen. The rest continues in substantially the same directions, with the exception of such refraction as takes place as it passes from the glass into the air. Rays such as rays 18, on the other hand, which are propagated in such directions that they are incident upon the external surface of wall 12 at angles approaching or exceeding the critical angle, suffer considerable internal reflection and are directed back on to screen 14, as is indicated at points 15a. Furthermore, they will continue to be reflected further, as is indicated by the dotted lines leading from points 15a, until they are ultimately dissipated. The effect of this internal reflection in the present example is to produce a ring or series of rings of light around point 15. Since this effect is repeated for every other point on screen 14 from which light rays are emitted, it will be seen that the result is a substantial loss in definition and contrast in the image on said screen. The present invention is directed to means for preventing this undesirable effect.

In accordance with the present invention, it has been discovered that if the end wall of the cathode ray tube is sufficiently increased in thickness, the paths of the internally reflected light rays will be so lengthened that they can be caused to fall outside the range of the screen. This increase in thickness may be produced by initially forming a tube or envelope 40 with an extra thick end wall 42 as in the manner shown in Fig. 4. Alternatively, it may be produced as in the manner shown in Fig. 1, by securing an additional transparent layer or block 20 in optical contact with wall 12 of a conventional cathode ray tube 10, as by means of layer 22 of a suitable transparent adhesive. In either case, wall 42 or layer 20 is preferably provided on its sides with suitable light-absorbing means, such for example as black lacquer or other conventional means as is indicated at 24, and preferably of an index of refraction substantially matching that of said wall or layer.

Layer 20 in Fig. 1 may be formed of any desired transparent material such as glass or other trans-

parent plastic of sufficient hardness, such for example as methyl methacrylate. It may be formed of a material having the same index of refraction as the glass forming wall 12, as in the embodiment shown in Fig. 1, but in the preferred embodiment of the invention, as will be pointed out below, it will comprise material having a lower index refraction than the glass used in conventional cathode ray tubes. Moreover, as is indicated by the dotted lines 25 in Fig. 1, layer 20 may if desired be so formed as to function as a lens to magnify the image on screen 14 or as part of a projection system therefor.

The adhesive used in layer 22 should secure layer 20 in optical contact with wall 12. If the index of refraction of layer 20 matches that of wall 12, then the index of refraction of the adhesive in layer 22 should preferably match that of the other layers. If, on the other hand, the index of refraction of layer 20 does not match that of wall 12, then the index of refraction of the adhesive may match that of either wall or layer 20, and in any case it should not so differ from that of either of the other layers as to cause substantial reflection.

It is believed that the operation of the embodiment of the invention shown in Fig. 1 will be readily apparent from the ray diagrams therein. As in the case of the conventional cathode ray tube shown in Fig. 2, rays 26, emanating from point 15 and incident upon the boundaries of wall 12 and layer 20 at angles approaching the normal, are propagated without substantial reflection back towards the screen. Rays 28 correspond to rays 16 in Fig. 2, and represent the rays which in the conventional tube would suffer substantial internal reflection at the outer surface of wall 12. However, if the indices of refraction of wall 12 and layers 20 and 22 are substantially matching, said rays are propagated beyond wall 12 without suffering substantial internal reflection until they reach the outer surface of layer 20. At this point they will be internally reflected in the same manner as shown in Fig. 2, but owing to the fact that their paths have been lengthened by reason of their passage through layer 20, after reflection they will be directed on to the blackened sides of layer 20 and there absorbed without again striking screen 14.

The construction shown in Fig. 1 is in general quite satisfactory for tubes of relatively small size. Furthermore, as has been pointed out above, the same results may be obtained in the manner indicated in Fig. 4, by initially forming tube 40 with an extra thick end wall 42 on the inner side of which is fluorescent screen 44. It will be seen, however, that layer 20 will have to be increased in thickness if the size of the tube and screen is increased, in order to lengthen the paths of rays 28 sufficiently so that when they are internally reflected they will not again reach screen 14.

It should be understood that it is not essential to the operation of the invention that none of the reflected rays 28 reach the screen. If their paths are lengthened only to such an extent that when reflected they reach the screen again at points relatively far removed from that at which they originated, the result will still be a substantial improvement over the operation of the conventional device shown in Fig. 2, although for best results, the device of the invention should be so constructed that a minimum of reflected light again reaches the screen. It may be stated as a general rule, therefore, that the additional layer of material should be of such thickness and index of refraction that light emitted from the screen and incident on the outer surface of the thickened wall at angles approaching the critical angle will be reflected in a direction which will intersect the surface defined by the screen at a point relatively remote from its point of origin thereon.

This general rule may also be stated mathematically. Referring to Fig. 1, for optimum results the minimum thickness of a layer 20 uniformly composed of the same material of index of refraction n may be expressed as follows:

$$t>r \cot i$$
$$t>r \cot \sin^{-1}1/n$$
$$r<t \tan \sin^{-1}1/n$$

It will be noted that in Fig. 1 angle i is assumed to be the critical angle for the material of layer 20, and that t is measured along a normal from the plane of the periphery of screen 14 to the point of incidence on the outer surface of layer 20 of a ray originating at the periphery of the screen and incident on the outer surface of layer 20 at the critical angle. The distance r is similarly measured on the plane of the periphery of screen 14, but it will be understood that in the case of tubes having a flat end wall, the screen and the plane of its periphery will coincide.

As a specific example of the above rule, if it may be assumed that layer 20 is composed of material of index of refraction substantially equal to 1.4, then the critical angle will be of the order of 45°. Accordingly, t should be not less than r and will preferably be somewhat greater, owing to the fact that there is substantial internal reflection at angles approaching but less than the critical angle. Otherwise the purposes of the invention will be accomplished by changing the above inequalities to:

$$t=r \cot i=r \cot \sin^{-1}1/n$$
$$r=t \tan \sin^{-1}1/n$$

It will be seen further that if layer 20 be composed of material of still lower index of refraction, the required thickness thereof will be reduced.

In the case especially of tubes having screens of relatively large size, preferred results will be obtained by making the layer added to the tube of material of lower index of refraction than the material of the tube wall itself. An example of such construction is shown in Fig. 3, wherein element 30 represents the front wall of a conventional cathode ray tube provided with a screen 32 on its inner surface, and having secured to its outer surface as by means of a suitable layer of adhesive 33 an additional layer 34 corresponding to layer 20 in Fig. 1. Layer 34 is assumed to be of material of lower index of refraction than the glass in wall 30, and examples of suitable material for use therein include any of the relatively hard, transparent resins such as methyl methacrylate and similar materials. Adhesive layer 33 may have an index of refraction matching that of either wall 30 or layer 34, but preferably falling therebetween. It is, moreover, within the scope of the invention to make layer 34 of material which will adhere to wall 30 without additional adhesive, or to use a relatively thick layer of adhesive. It may also be desirable to use an outer protective layer of glass or similar hard material, which need not be in optical contact with the remainder of the device.

The advantage of the type of construction shown in Fig. 3 lies in the fact that because the critical angle of layer 34 is higher, rays incident upon the outer surface of layer 33 at angles approaching the critical angle traverse layer 34 more obliquely with respect to the optical axis of the system, and so for a given thickness of layer 34 are reflected back upon the screen at points farther removed from their point of origin than would be the case if the index of layer 34 were higher. This will be more readily apparent by reference to Fig. 3 wherein point 35 corresponds to point 15 in Figs. 1 and 2, and rays 36 and 38 correspond to rays 26 and 28 respectively in Fig. 1. The course of rays 36 will be seen to correspond substantially to that of rays 26 in Fig. 1, with the exception of some slight degree of refraction taking place as they pass from wall 30 and layer 33 into layer 34. Rays 38, on the other hand, are refracted to such an extent as they enter layer 34 that their lateral path within said layer is substantially lengthened, and thus when they are internally reflected at its exterior surface they are directed towards points farther removed from that at which they originated than would be the case if layer 34 were of higher index than wall 30.

It will be seen from the above that by making layer 34 of material of lower index of refraction than wall 30, it is possible to produce satisfactory results with a layer 34 of less thickness than would be necessary if it were material of as high index of refraction as wall 30. At the same time, it should be noted that the advantage of using a material of low index in layer 34 resides in the fact that said index is relatively low, and not in the difference between the indices of layer 34 and wall 30. In the operation of the device of the invention, it is preferred that the rays incident on the outermost surface of the tube at angles approaching the critical angle for said surface impinge thereon at points as far displaced laterally from their respective points of origin as possible. It is by using materials of low indices that such results are most easily obtainable. An additional advantage derived from using material of low index in layer 34 lies in the fact that rays incident on its outer surface at angles approaching the normal will be transmitted with a minimum of reflection. Substantially the same advantages may be obtained in a construction such as that shown in Fig. 4 by making the entire tube, or at least the front wall 42, of material of relatively low index.

It should be noted that in choosing material for use in layer 34 care should be taken to avoid using a material having an index of refraction so widely different from that of wall 30 as to cause internal reflection of rays 38 at the inner surface of layer 34. The same factor should be considered in choosing the proper adhesive for layer 33, and it will be seen that the most satisfactory results will be obtained by using an adhesive of an index of refraction somewhere between that of wall 30 and layer 34 in order to obtain progressive refraction of rays 38. It should also be pointed out that instead of making layer 33 or layer 34 of a single, uniform construction, either may advantageously comprise a plurality of layers of different materials, each of which preferably has a lower index of refraction than the layer adjacent thereto on the side nearer wall 30.

The general rule for constructions of this type is that for optimum results, the minimum thickness of each layer and of the entire structure can be determined by the inequality

$$r<t_1 \tan \sin^{-1} 1/n_1+t_2 \tan \sin^{-1} 1/n_2+t_3 \tan \sin^{-1} 1/n_3+ \ldots$$

wherein t_1, t_2 and t_3 are the thicknesses respectively of layers 30, 33 and 34, and n_1, n_2 and n_3 are the respective indices of refraction of said layers. This relation may be expressed more generally for the case of a structure of g layers as follows:

$$\sum_s t_s \tan \sin^{-1} 1/n_s > r$$

$$\sum_g \frac{t_g}{\sqrt{n_g^2-1}} > r$$

It should be noted that the various values for t in the above equations are measured along a normal drawn from the plane of the periphery of the screen to intersect at the outer surface of the tube wall with a ray originating at the periphery of the screen and incident on the outer surface of the outermost layer at the critical angle. It should also be noted that it is assumed for the purpose of the above relations that a tangent to the point where said normal intersects with the outer surface of the outermost layer will be parallel to the plane of the periphery of the screen.

It should be understood that the invention is not to be construed as limited to any particular shape or size for layers 20 and 34 in wall 42. As has already been pointed out, for example, it is within the scope of the invention to make said elements in the shape of a lens, as indicated at 25 in Fig. 1. Furthermore, by making layer 20 or 34 in the shape of a convex lens, satisfactory results may be obtained with less material than is required if the outer surface of said layer is to be flat. Preferably sides 24 of layer 20 should be tapered as shown, and the degree of taper is determined primarily by the width of the viewing aperture desired for screen 14. That is to say, if it is desired to provide for a wide viewing aperture for the image on screen 14, than the sides of layer 20 should be considerably tapered, and the greater the extent to which sides 24 approach parallelism, the narrower will be the angle through which the entire surface of screen 14 will be visible.

It should again be pointed out that the invention is in no way to be considered as limited to such embodiments thereof as prevent any light from being reflected back on to the screen whence it originates. In conventional cathode ray tubes it is to the light rays incident on the outer wall thereof at angles approaching the critical angle which are the chief cause of objectionable reflection. If by following the teachings of the invention the construction of the tube is so modified that said rays are reflected on to the screen at points relatively far removed from their source and from the points at which they would again reach the screen in a conventional tube, said modification is to be considered as falling within the scope of the invention, even though it may not be a preferred embodiment thereof. Many such modifications will doubtless be apparent to other skilled in the art, and are also to be considered as within the scope of the invention.

Since certain changes may be made in the above article and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter

contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent plastic material of an index of refraction less than that of the material of said wall, and a layer of adhesive bonding said plastic layer in optical contact with the outer surface of said wall, the index of refraction of said adhesive being less than that of the material of said wall and greater than that of said outer layer, the combined thickness of said wall and said layers being such that light emanating from a point on said screen and incident on the outer surface of said outer layer at angles approaching the critical angle thereof is reflected in directions which intercept the surface defined by said screen at points relatively remote from the point of origin thereon of said light.

2. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent solid material in optical contact with the outer surface of said wall, said layer comprising a plurality of layers of transparent material, adjacent elements in said plurality being in optical contact with each other, adjacent layers having indices of refraction sufficiently close to prevent substantial internal reflection at the interfaces therebetween, said layers having progressively lower indices of refraction than that of the material of said wall, the combined thickness of said wall and said plurality of layers being such that light emanating from a point on said screen and incident on the outer surface of said outer layer at angles approaching the critical angle thereof is reflected in directions which intercept the surface defined by said screen at points relatively remote from the point of origin thereon of said light.

3. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent plastic material of an index of refraction less than that of the material of said wall, and a layer of adhesive bonding said plastic layer in optical contact with the outer surface of said wall, the index of refraction of said adhesive being less than that of the material of said wall and greater than that of said outer layer, the combined thickness of said wall and said layers being such that light emanating from a point on said screen and incident on the outer surface of said outer layer at angles approaching the critical angle thereof is reflected against the sides of said layer.

4. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent solid material in optical contact with the outer surface of said wall, said layer comprising a plurality of layers of transparent material, adjacent elements in said plurality being in optical contact with each other, adjacent layers having indices of refraction sufficiently close to prevent substantial internal reflection at the interfaces therebetween, said layers having progressively lower indices of refraction than that of the material of said wall, the combined thickness of said wall and said plurality of layers being such that light emanating from a point on said screen and incident on the outer surface of said outer layer at angles approaching the critical angle thereof is reflected against the sides of said layer.

5. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent plastic material of an index of refraction less than that of the material of said wall, and a layer of adhesive bonding said plastic layer in optical contact with the outer surface of said wall, the index of refraction of said adhesive being less than that of the material of said wall and greater than that of said outer layer, the combined thickness of said wall and said layers being restricted by the relation

$$r<t_1 \tan \sin^{-1} 1/n_1+t_2 \tan \sin^{-1} 1/n_2+t_3 \tan \sin^{-1} 1/n_3+ \ldots$$

wherein r is the radius of the plane of the periphery of said screen, t_1 is the thickness of said tube wall, t_2 is the thickness of said adhesive layer, t_3 is the thickness of said plastic layer and n_1, n_2 and n_3 are the respective indices of refraction of said layers.

6. In a cathode ray tube having a wall thereof provided on its inner surface with a fluorescent screen, means for preventing undesirable light reflections, said means comprising a layer of transparent solid material in optical contact with the outer surface of said wall, said layer comprising a plurality of layers of transparent material, adjacent elements in said plurality being in optical contact with each other, adjacent layers having indices of refraction sufficiently close to prevent substantial internal reflection at the interfaces therebetween, said layers having progressively lower indices of refraction than that of the material of said wall, the combined thickness of said wall and said plurality of layers being restricted by the relation

$$\sum_g t_g \tan \sin^{-1} 1/n_g > r$$

$$\sum_g \frac{t_g}{\sqrt{n_g^2-1}} > r$$

wherein t_g is the thickness of the g'th layer, n_g is its index of refraction, and r is the radius of the plane of the periphery of said screen.

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