June 10, 1952 R. B. BARNES 2,599,739

CATHODE-RAY TUBE

Filed April 12, 1950 2 SHEETS—SHEET 1

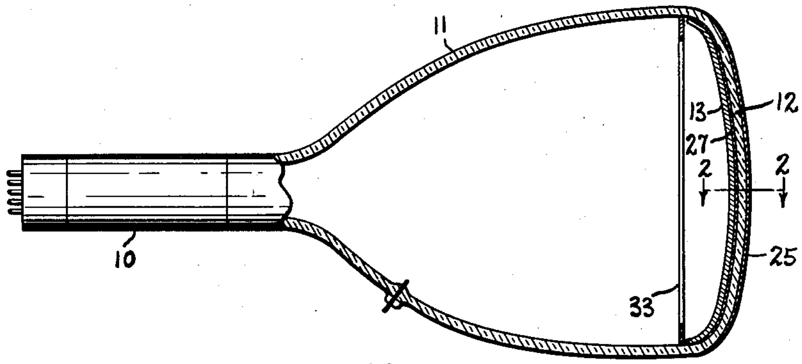

Fig. 1

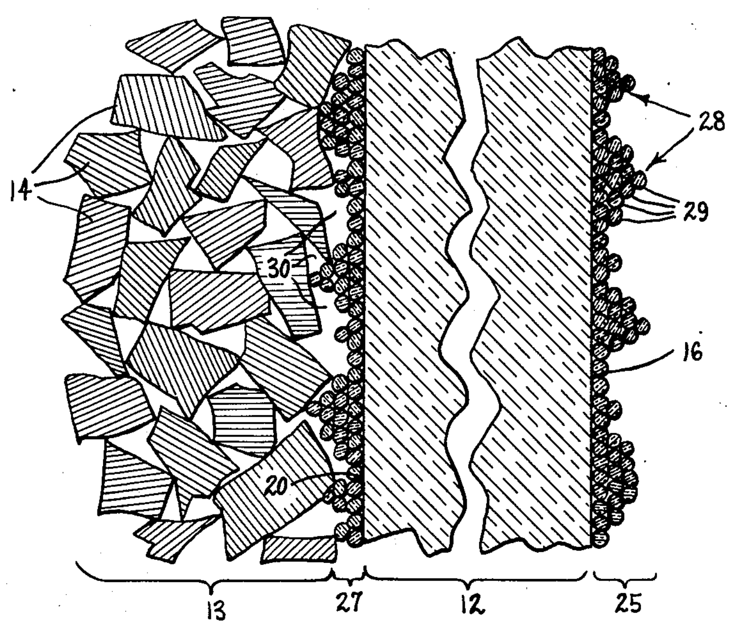

Fig. 2

INVENTOR
ROBERT BOWLING BARNES

BY Louis L. Gagnon
ATTORNEY

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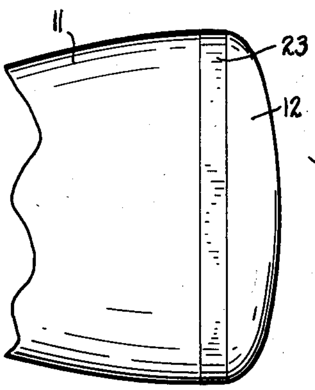

Fig. 3

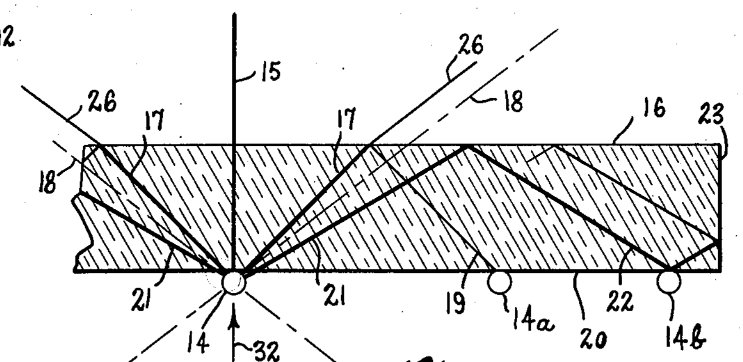

Fig. 4

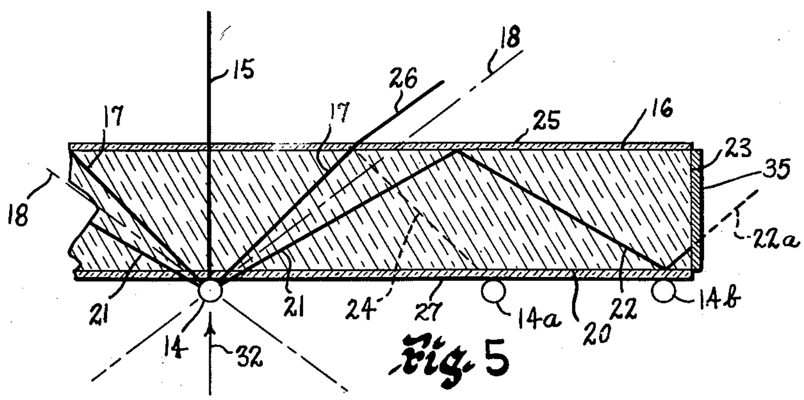

Fig. 5

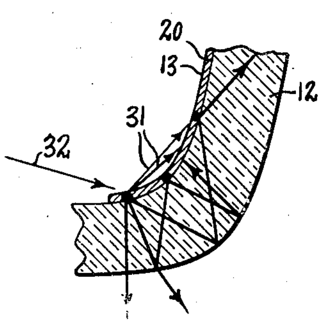

Fig. 6

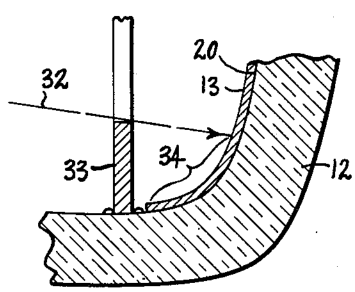

Fig. 7

INVENTOR
ROBERT BOWLING BARNES

BY Louis L. Lagnon
ATTORNEY

Patented June 10, 1952 2,599,739

UNITED STATES PATENT OFFICE

2,599,739

CATHODE-RAY TUBE

Robert Bowling Barnes, Stamford, Conn., assignor to American Optical Company, Southbridge, Mass., a voluntary association of Massachusetts

Application April 12, 1950, Serial No. 155,514

13 Claims. (Cl. 313—92)

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This invention relates to cathode ray tubes and has particular reference to novel means of improving the definition and contrast of images produced on the screens of such tubes.

In conventional types of cathode ray tubes such as used in television receiving apparatus or similar devices images are produced on a fluorescent screen when the particles forming said screen are bombarded by an electron beam and are caused to fluoresce in proportion to the intensity of the electrons of said beams. In such a device when a fluorescent particle has been made to fluoresce by the electrons, some of the light emitted from said particle is reflected back onto the screen from the surfaces of the tube face. This will cause illumination of other particles of the screen by the light so reflected and produce undesirable halations. Such halations tend to reduce contrast and definition of the image formed on the screen.

Therefore, it is a principal object of this invention to provide a cathode ray tube with means for reducing halation by eliminating to a substantial degree the amount of light reflected from the surfaces of the tube face onto the fluorescent screen.

Another object is to provide means for reducing halation in a cathode ray tube by providing the outer surface of the tube face with a reflection reduction coating for substantially decreasing the amount of light which may be reflected onto the fluorescent screen from said outer surface and to simultaneously reduce reflections from said surface caused by light rays from sources outside the tube.

Another object is to provide the inner surface of the tube face with a reflection reduction coating between the material of the tube face and the fluorescent screen, which coating, due to its natural characteristics, will considerably reduce the amount of reflected light reaching the fluorescent screen.

Another object is to provide a cathode ray tube with means on the periphery of the face portion thereof for preventing light rays striking said periphery from being reflected back toward the fluorescent screen, said means being in the form of a highly polished surface for permitting said light rays to escape, or a light absorbing coating on said periphery for absorbing the light rays.

Another object is to provide a cathode ray tube with means whereby fluorescent material on the tube face outside of the desired image area will be prevented from fluorescing and causing possible additional halation within the image area.

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Other objects and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a side elevational view partly in section of a cathode ray tube embodying the invention;

Fig. 2 is an enlarged fragmentary sectional view of a portion of the tube face taken on line 2—2 of Fig. 1;

Fig. 3 is a fragmentary side elevational view of the forward end portion of a cathode ray tube;

Fig. 4 is a diagrammatic illustration of light rays emitted by a fluorescent particle in accordance with conventional prior art devices of this nature;

Fig. 5 is a diagrammatic illustration of effect of the present invention upon the light rays emitted by a fluorescent particle;

Fig. 6 is a fragmentary sectional view of a conventional tube face adjacent the periphery thereof; and

Fig. 7 is a fragmentary sectional view similar to Fig. 6 illustrating a further feature of the invention.

Referring to the drawings wherein like characters of reference designate like parts throughout the several views, Fig. 1 illustrates a cathode ray tube embodying a neck portion 10, substantially conical sides 11, and a face portion 12 all of which may be formed integrally of a suitable glass. However, the sides 11 and neck 10 may be formed of metal and the face portion 12 alone formed of glass, if desired, whereupon the glass must be suitably sealed to the metal. The inner surface of the tube face portion 12 is provided with a fluorescent screen 13 composed of a myriad of contiguously related tiny particles which are adapted to fluoresce when bombarded by an electron stream and thereby produce an image which may be viewed by an observer through the face portion 12. Suitable means may be provided for projecting an electron stream upon the fluorescent screen 13 such as by providing an electron gun (not shown) within the neck portion 10.

When a fluorescent particle or spot on the fluorescent screen, designated by numeral 14 in Fig. 4, is caused to fluoresce, the light emitted thereby will pass into and through the glass of the face portion 12 substantially as illustrated diagrammatically in Fig. 4. Light rays 15 passing through the glass along paths normal to the surfaces of the glass will emerge from the outer surface 16 thereof with no deviations. However, light rays 17 directed through the glass at an angle less than the minimum angle of total reflection, called the critical angle and indicated diagrammatically by dot-dash line 18, will be partially reflected, as illustrated at 19 back through the glass toward the screen and will cause illumination of other particles 14a, as shown, which particles 14a also comprise part of the fluorescent screen and are in contact with the rear surface 20 of the tube face. Light rays 21 emanating from the fluorescent particle 14 and directed toward the outer surface 16 of the glass at an angle greater than the critical angle will be totally reflected by the outer surface 16 and will pass rearwardly through the glass as indicated by numeral 22 to the rear surface 20 where they will cause illumination of still other particles 14b of the fluorescent screen which are in optical contact with said glass. Such light rays which strike the front surface 16 of the glass at angles greater than the critical angle will be reflected back and forth from the respective front and rear surfaces 16 and 19 as well as the end walls 23 of the face portion 12 until they are dissipated.

The present invention, however, provides means whereby the light rays 17 striking the surface 16 at angles less than the critical angle will emerge from the surface 16, with only a negligible amount of light being reflected rearwardly from said surface 16, as indicated by numeral 24 in Fig. 5, which will greatly reduce the possible illumination of particles 14a. This means resides in the provision of a reflection reduction coating 25 on the outer surface 16 of the tube face portion 12, which coating may be of any suitable type which is adapted to reduce the amount of light reflected from the surface. Such a coating may be any one of the many well-known types such as is produced by evaporation of calcium or other fluorides on a glass surface, or formed by wetting the glass with silicic acid and treating with hydrochloric acid to precipitate the silicon dioxide, another type is made as a film of barium stearate which is produced by dipping the glass in water containing barium salts and having a layer of stearic acid on top; others are film of magnesium fluoride, calcium fluoride, sodium fluoride or sodium aluminum fluorides; still others are chemical decompositions of salts.

The preferred reflection reduction coating, however, is formed of a composition consisting of a colloidal suspension containing from about 0.1 to 6.0 per cent by weight of sub-microscopic, microgranular, discrete particles of solid anhydrous transparent material such as magnesium fluoride, lithium fluoride, strontium fluoride, calcium fluoride, barium fluoride or cryolite substantially uniformly dispersed in a volatile liquid inert to the particles, with the particles being approximately spherical in shape and less than 625 angstroms in diameter. A glass surface can be provided with the coating by applying to the surface a thin layer of the above composition and subjecting it to heat to evaporate the liquid and leave a dry coating of the particles on the surface, it being desirable to control the amount of the composition applied and the concentration of the particles in the suspension so as to produce a coating having a resultant thickness of approximately one quarter wave length of light.

The forming of such a coating on the glass surface will comprise sub-microscopic, discrete, micro-granular transparent solid particles which are deposited on the glass surface so as to form minute projecting irregularities on said surface, the concentration of the particles in the irregularities decreasing from the surface of the tube face outward, and the material of the particles being such that the effective index of refraction of the coatings varies from substantially unity at the layer-air interface to an index value which progressively increases as it approaches the material of the tube face portion 12 until it substantially approximates the index of refraction of the glass of the tube face portion. Such a coating will increase the transmission of light rays 26 from the surface 16 with a consequent decrease in the reflected light rays 24 (Fig. 5) as compared with the normal reflection 19 (Fig. 4). By comparing Figs. 4 and 5, it will be understood that by providing the surface 16 with the coating 25, a negligible amount of light will be reflected toward the fluorescent screen 13 from light rays striking the surface 16 at angles less than the critical angle. Consequently particles 14a will be only slightly if at all illuminated by such reflections.

In addition, it is pointed out here that the coating 25 will also prevent reflection into an observer's eyes of light rays striking the tube face portion from sources outside the tube. This feature is particularly desirable since it considerably improves the visibility of the image.

To further eliminate halations the inner surface 20 of the tube face portion 12 may be provided with a similar reflection reduction coating 27, the coating 27 being disposed between the surface 20 and the fluorescent screen 13.

Fig. 2 is a greatly enlarged fragmentary diagrammatical sectional view through a portion of the tube face 12 and diagrammatically shows the coatings 27 and 25 provided on the inner and outer surfaces 20 and 16 respectively. It will be noted that the coatings are disposed on the surfaces of the tube face as a plurality of minute irregularities 28 each of which is formed of a plurality of minute particles 29. The fluorescent screen 13 may be formed of any desired material capable of fluorescing when bombarded by electrons such as zinc silicate, zinc sulphide, beta zinc silicate, zinc beryllium silicate, zinc cadmium sulphide, zinc beryllium zirconium silicate, zinc borate, cadmium tungstate, and other known materials of mixtures thereof.

It will be noted that the particles 14 comprising the fluorescent screen are substantially larger than the particles 29 of the reflection reduction coatings, being from 1 to 6 microns in diameter if applied by spraying. However, still larger particles, from 10 to 30 microns in diameter, are usually deposited on the screen by dusting or settling through air. Thus, when a fluorescent coating 13 is applied over the inner reflection reduction coating 27, the particles 14 will, due to their large size, engage the irregularities 28 in such fashion that a plurality of vacant spaces 30 will be provided between the coating 27 and screen 13.

Upon again comparing Figs. 4 and 5, it will be seen that halation is reduced by applying the reflection reduction coating 27 to the inner surface 20 of the tube face portion 12 as described since the light rays 21 which strike the surface 16 at angles greater than the critical angle and are totally reflected back through the glass to the surface 20 thereof will be prevented by the reflection reduction coating 27 from directly striking and consequently illuminating particles 14b of the fluorescent screen. It will be understood that if the particles 14b are in direct engagement with the surface 20, as in the conventional cathode ray tube, they would be illuminated by the light rays 22, but by spacing the particles from the surface 20, the reflected light rays will be prevented from directly illuminating the particles. The inner reflection reduction coating 27 also greatly minimizes reflection back into the fluorescent material of light from the inner surface 20 of the glass 12.

Another cause of halation, particularly in the edge areas of the image, is shown in Fig. 6, wherein the fluorescent screen 13 is disposed directly upon the inner surface 20 of the tube face 12 by conventional methods which causes a supply of the fluorescent material 13 to be deposited on the inner surface of the side walls 11 of the tube adjacent their junction with the face portion 12. Thus, when fluorescent particles in this area are made to fluoresce when bombarded by an electron beam 32, light rays therefrom will pass in all directions and will, as indicated by lines 31, illuminate other portions of the fluorescent screen 13, subsequently causing a reduction in contrast discrimination in the image. To overcome this, several methods may be used. For example the fluorescent material in this marginal area may be removed or covered with a coating of material which would prevent the particles so covered from being effected by the electron beam, or means may be provided internally of the tube for limiting the image area by preventing the electron stream 32 from striking the fluorescent material in these areas. Therefore, means such as a ring-like member 33 may be inserted in the tube during the fabrication thereof with the size of the central opening of said member 33 being controlled so that the electron beam 32 will be prevented from striking the fluorescent screen 13 in the marginal areas thereof and thus will limit the size of the desired effective image area. Fig. 7 illustrates this feature and shows the electron beam 32 striking the fluorescent screen 13 at the margin of the desired image area, with the ring-like member 33 functioning as a baffle or stop for preventing the electron stream 32 from striking the fluorescent material in the marginal area 34 of the screen 13, and thus preventing undesirable halations from this source.

To reduce further the amount of undesirable light within the material of the tube face portion 12 which may be reflected upon the fluorescent screen 13 and cause undesirable halations, some of the light rays within the glass, particularly in the marginal areas of the face portion 12, can be made to emerge from the glass by providing the outer edge of the face portion 12 with a highly polished peripheral surface 23 (Fig. 3). This will permit without diffusion the escape of stray light rays which strike this surface at angles less than the critical angle as shown by dotted lines 22*a* in Fig. 5. It should be understood that this portion may be coated on either or both surfaces with reflection reduction coatings to reduce reflection below the critical angle.

If desired, the peripheral surface 23 may be coated with a light-absorbing material such as a suspension of graphite particles in oil or cement such as Canada balsam, or black lacquer, which coating should possess an index of refraction equal to or higher than the index of refraction of the tube face portion 12 for maximum efficiency.

Thus, light rays 22 (Fig. 5) striking the various surfaces at angles less than the critical angle may be either permitted to escape through the highly polished surface 23 as shown by dotted lines 22*a*, or may be absorbed by the absorbent coating 35.

From the foregoing, it will be seen that means and methods of a novel nature have been employed for accomplishing all of the objects and advantages of the invention.

While the novel features of the invention have been shown and described and are pointed out in the annexed claims, it will be understood that many changes may be made in the details shown and described without departing from the spirit of the invention. I, therefore, do not wish to be limited to the exact details shown and described as the preferred only are set forth by way of illustration.

I claim:

1. A cathode ray tube embodying a transparent face portion having a coating of transparent material on the rear surface thereof with a coating of fluorescent material on said transparent material having its effective portion confined to substantially the area desired of the resultant image and spaced from the inner surface of said transparent face portion by said transparent material, said face portion having a transparent light transmission increasing reflection reduction coating on the front surface thereof and having light controlling means surrounding the periphery thereof, said tube having means for producing a beam of electrons and for directing said electrons onto said fluorescent coating to produce a luminous spot thereon, said luminous spot having light rays emanating therefrom and striking the inner side of the front surface of said transparent face portion at angles less than and at angles greater than the critical angle, and said reflection reduction coating on the outer surface of the transparent face portion having an optical thickness and effective index of refraction such that it, while functioning to reduce reflection from light exteriorly of the tube, will simultaneously function to reduce the reflection of said rays within the critical angle by increasing the transmission of said light rays through said outer surface, and said coating of material between said fluorescent coating and the inner surface of the tube functioning to reduce the illumination of the fluorescent material by light rays at angles greater than the critical angle reflected from the inner side of the front surface of the face portion and said light rays at angles greater than the critical angle when at the periphery of the face portion being effectively obviated by said peripheral light controlling means.

2. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a reflection reduction coating disposed upon the outer surface of said transparent face portion for reducing reflection of light from sources outside the tube, said reflection reduction coating being formed of transparent material having an optical thickness and an effective index of refraction as to simultaneously increase transmission of light rays from said luminous spot by reducing reflections of said light rays emitted by said luminous spot and striking said outer sur-

face at angles less than the critical angle, a transparent coating on the inner surface of said transparent face portion for supporting said fluorescent screen in spaced relation with said transparent face portion and reducing reflections of light rays emitted by said luminous spot and striking said outer surface at angles greater than the critical angle, and means on the peripheral edge of said transparent face portion for reducing reflection of light rays emitted by said luminous spot and striking said peripheral edge.

3. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface composed of a plurality of contiguously related particles of fluorescent material, means for producing a beam of electrons and directing it upon said particles of the fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a reflection reduction coating disposed upon the outer surface of said transparent face portion for reducing reflection of light from sources outside the tube and for reducing reflections of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, a transparent coating on the inner surface of said transparent face portion for reducing reflection of light rays emitted by said luminous spot and striking said outer surface at angles greater than the critical angle, said transparent coating comprising a layer of sub-microscopic, discrete, micro-granular, transparent solid particles of a size considerably smaller than the fluorescent particles and forming minute irregularities on said inner surface which cause said particles of the fluorescent screen to be retained in spaced relation with said transparent face portion, and means on the peripheral edge of said transparent face portion for reducing reflection of light rays emitted by said luminous spot and striking said peripheral edge.

4. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a first light transmission increasing reflection reduction coating of transparent material disposed upon the outer surface of said transparent face portion for reducing reflection of light from sources outside the tube and for increasing transmission of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, said light transmission increasing reflection reduction coating comprising a thin layer of sub-microscopic, discrete, micro-granular, transparent solid particles forming minute irregularities on said outer surface, the concentration of the said particles in the irregularities decreasing from said outer surface outwardly and the material of said particles being such that the effective index of refraction of said coating varies from substantially unity at the layer-air interface to an index value which progressively increases in a direction inwardly of said coating and approaches the index of refraction of the material of said face portion, a second reflection reduction coating on the inner surface of said transparent face portion, said second reflection reduction coating being similar to said first reflection reduction coating with the irregularities thereof causing said fluorescent screen to be retained in spaced relation with said transparent face portion to reduce the illumination of the fluorescent screen by the light rays emitted by said luminous spot and reflected by said outer surface, and means on the peripheral edge of said transparent face portion for reducing reflections of light rays emitted by said luminous spot and striking said peripheral edge.

5. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, means for reducing undesirable illumination of said fluorescent screen comprising a reflection reduction coating disposed upon the outer surface of said transparent face portion for reducing reflection of light from sources outside the tube and for increasing transmission of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, a transparent coating on the inner surface of said transparent face portion for retaining said fluorescent screen in spaced relation with said transparent face portion and reducing the illumination of the fluorescent screen by light rays emitted by said luminous spot and reflected by said outer surface, and means for eliminating some of the light rays normally trapped within the material of said face portion to prevent reflection thereof onto said fluorescent screen comprising a highly polished outer surface formed on the peripheral edge of said face portion for permitting light rays striking said surface to emerge.

6. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, means for reducing undesirable illumination of said fluorescent screen comprising a transparent coating disposed upon the outer surface of said transparent face portion and having an optical thickness and an effective index of refraction such as to reduce reflection of light from sources outside the tube and increasing the transmission of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, a transparent coating on the inner surface of said transparent face portion for supporting said fluorescent screen in spaced relation with said transparent face portion and reducing the illumination of the fluorescent screen by light rays emitted by said luminous spot and reflected by said outer surface, and means for eliminating some of the light rays normally trapped within the material of said face portion to prevent reflection thereof onto said fluorescent screen comprising a coating of light absorbing material disposed on the peripheral

edge of said face portion for absorption of light rays striking said surface from within.

7. A cathode ray tube embodying a transparent face portion having a fluorescent screen disposed adjacent the inner side thereof, means for directing electrons upon said fluorescent screen for producing a luminous spot thereon and a transparent coating on the outer surface of said face portion which is formed of a material having an optical thickness and effective index of refraction such as to reduce reflections of light from sources outside the tube and to simultaneously increase transmission of light rays emitted by said luminous spot and striking the outer surface of said transparent face portion at angles less than the critical angle.

8. A cathode ray tube embodying a transparent face portion having a fluorescent screen disposed adjacent the inner side thereof, means for directing electrons upon said fluorescent screen for producing a luminous spot thereon, and a light transmission increasing reflection reduction coating on the outer surface of said face portion which has an optical thickness and effective index of refraction such as to reduce reflections of light from sources outside the tube and to simultaneously increase transmission of light rays emitted by said luminous spot and striking the outer surface of said transparent face portion at angles less than the critical angle, said light transmission increasing reflection reduction coating comprising a thin layer of sub-microscopic, discrete, micro-granular, transparent, solid particles forming minute irregularities on said outer surface, the concentration of the said particles in the irregularities decreasing from said outer surface outwardly and the material of said particles being such that the effective index of refraction of said coating varies from substantially unity at the layer-air interface to an index value which progressively increases in a direction inwardly of said coating and approaches the index of refraction of the material of said face portion.

9. In a cathode ray tube embodying a transparent face portion having a fluorescent screen disposed adjacent the inner side thereof and means for directing electrons upon said fluorescent screen for producing a luminous spot thereon, means for reducing halation produced by light rays emitted by said luminous spot and striking the outer surface of said transparent face portion at angles greater than the critical angle and which are reflected back upon said fluorescent screen comprising a transparent surface reflection reducing coating disposed on said inner surface of the transparent face portion between said inner surface and the fluorescent screen, said reflection reduction coating comprising a thin layer of sub-microscopic, discrete, micro-granular, transparent solid particles piled in the form of minute irregularities on said outer surface, the concentration of the said particles in the irregularities decreasing from said inner surface in a direction toward the fluorescent screen and the material of said particles being such that the effective index of refraction of said coating varies from substantially unity adjacent the fluorescent screen to an index value which progressively increases in a direction inwardly of said coating and approaches the index of refraction of the material of said face portion, the high points of said irregularities engaging said fluorescent screen and maintaining it in spaced relation with said inner surface to reduce illumination of the screen by said reflected light rays.

10. In a cathode ray tube embodying a transparent face portion having a fluorescent screen disposed adjacent the inner side thereof and means for directing electrons upon said fluorescent screen for producing a luminous spot thereon, said luminous spot having light rays emanating therefrom at angles both less than and greater than the critical angle, and means for eliminating the major portion of said light rays which are at angles greater than the critical angle comprising a highly polished surface on the peripheral edge of said transparent face portion for permitting said light rays striking said highly polished surface to pass therethrough.

11. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a reflection reduction coating disposed upon the outer surface of said transparent face portion, said coating being formed of a transparent medium having an effective optical thickness and index of refraction such as to reduce reflection of light from sources outside the tube and to reduce reflections of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle while simultaneously increasing the transmission of light rays from said luminous spot through said outer surface, and a transparent coating on the inner surface of said transparent face portion for maintaining said fluorescent screen in spaced relation with said transparent face portion for reducing the illumination of said fluorescent screen by reflections of light rays emitted by said luminous spot.

12. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface composed of contiguously related particles of fluorescent material, means for producing a beam of electrons and directing it upon said particles of the fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a reflection reduction coating of transparent material disposed upon the outer surface of said transparent face portion and having an effective optical thickness and index of refraction such as to reduce reflection of light from sources outside the tube and to increase transmission of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, and a transparent coating on the inner surface of said transparent face portion for reducing the illumination of said fluorescent screen by reflections of light rays emitted by said luminous spot, said transparent coating comprising a layer of sub-microscopic, discrete, micro-granular, transparent solid particles of a size substantially smaller than said fluorescent particles and forming minute irregularities on said inner surface which cause said fluorescent screen

to be retained in spaced relation with said transparent face portion.

13. A cathode ray tube embodying a transparent face portion having a fluorescent screen adjacent its inner surface, means for producing a beam of electrons and directing it upon said fluorescent screen to produce a luminous spot thereon, said luminous spot emitting light rays striking the surfaces of said transparent face portion at angles both less than and greater than the critical angle, and means for reducing undesirable illumination of said fluorescent screen comprising a first reflection reduction coating disposed upon the outer surface of said transparent face portion for reducing reflection of light from sources outside the tube and for reducing reflections of light rays emitted by said luminous spot and striking said outer surface at angles less than the critical angle, said reflection reduction coating comprising a thin layer of submicroscopic, discrete, micro-granular, transparent solid particles forming minute irregularities on said outer surface, the concentration of the said particles in the irregularities decreasing from said outer surface outwardly and the material of said particles being such that the effective index of refraction of said coating varies from substantially unity at the layer-air interface to an index value which progressively increases in a direction inwardly of said coating and approaches the index of refraction of the material of said face portion, and a second reflection reduction coating on the inner surface of said transparent face portion, said second reflection reduction coating being similar to said first reflection reduction coating with the irregularities thereof causing said fluorescent screen to be retained in spaced relation with said transparent face portion to reduce the illumination of said fluorescent screen by reflections of light rays emitted by said luminous spot.

ROBERT BOWLING BARNES.

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