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HIGH CONTRAST FLUORESCENT SCREEN HAVING SPACED PHOSPHOR LAYER AND METHOD OF MANUFACTURE

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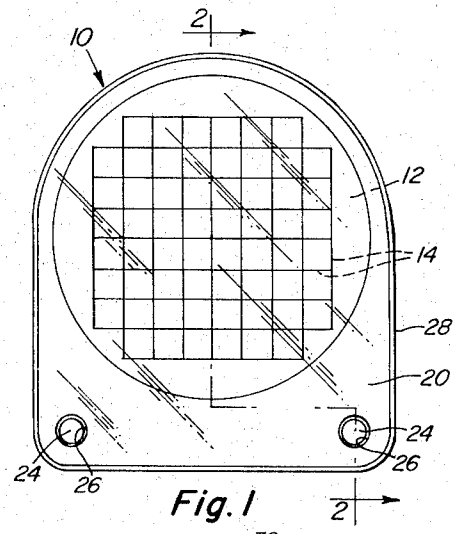


Fig. 1

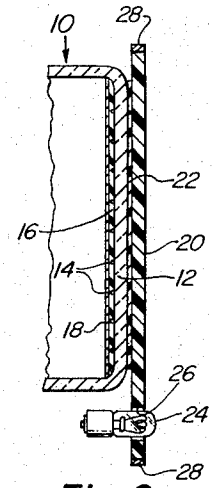


Fig. 2

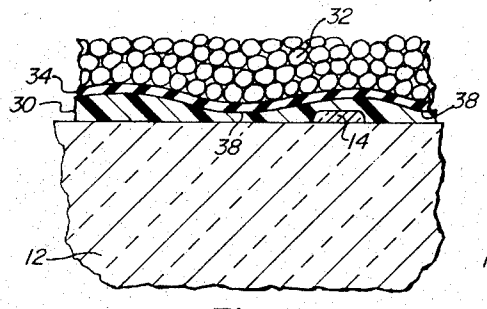


Fig. 3A

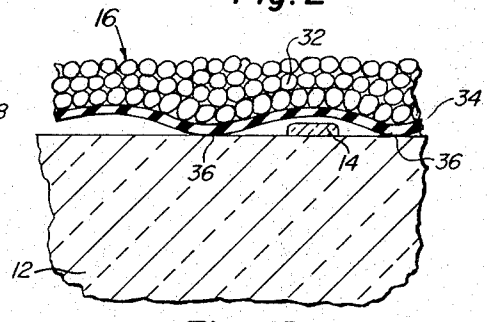


Fig. 3B

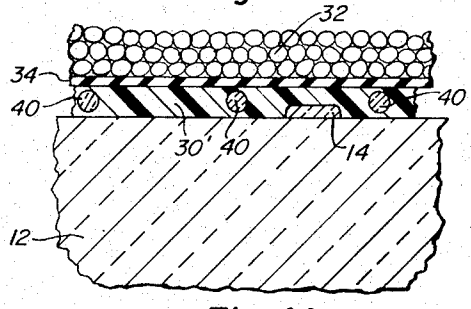


Fig. 4A

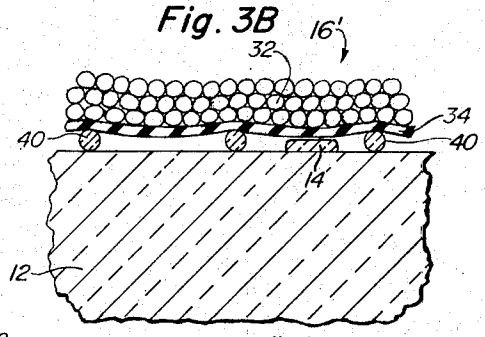


Fig. 4B

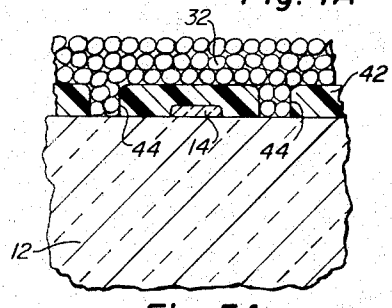


Fig. 5A

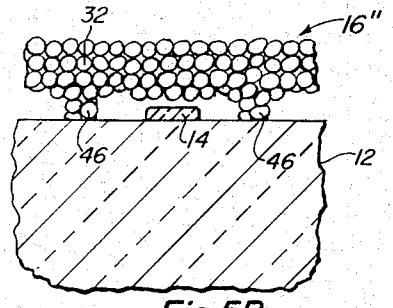


Fig. 5B

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HIGH CONTRAST FLUORESCENT SCREEN HAVING SPACED PHOSPHOR LAYER AND METHOD OF MANUFACTURE

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ABSTRACT OF THE DISCLOSURE

A fluorescent screen for a cathode ray tube is described, in which the phosphor layer is spaced out of contact with the glass face plate of such tube on which the phosphor layer is supported so that most of such phosphor layer is separated by open space from the face plate and an illuminated graticule scale provided on the inner surface of such face plate, in order to increase the contrast of the light images of electron beam traces produced on such screen and the graticule image.

The subject matter of the present invention relates generally to fluorescent screens, and in particular to a fluorescent screen for a cathode ray tube, such screen having a high contrast between the light image produced in the screen and its background. In addition, a cathode ray tube made in accordance with the present invention may be provided with an illuminated internal graticule scale, and the present fluorescent screen also enables a much higher contrast between the graticule image and the background of such fluorescent screen. Briefly, the fluorescent screen of the present invention provides this high contrast by supporting its phosphor layer only at widely separated points on the inner surface of the glass face plate of the cathode ray tube or other support member so that most of the phosphor layer is spaced out of contact with the face plate, and such phosphor layer is separated from the graticule scale and the face plate by open space.

The fluorescent screen of the present invention is especially useful in a cathode ray tube of the type employed in a cathode ray oscilloscope which has an illuminated internal graticule scale provided on the inner surface of its face plate. However, the present fluorescent screen may also be employed in X-ray fluoroscopy apparatus or in conventional television picture tubes, radar and sonar display tubes, and other cathode ray tubes not having such a graticule scale. A cathode ray tube employing a fluorescent screen in accordance with the present invention has several advantages over conventional tubes including the above-mentioned high image contrast and a high image brightness.

Conventional television tubes provide a greater image contrast by employing a gray colored glass in the face plate or implosion shield over such face plate to absorb room light reflected from the screen as background illumination and to attenuate halation light by a greater amount than image light. However this approach to increase contrast has the disadvantage that it also greatly decreases the brightness of the image emitted from such tube as seen by the observer even though it is not attenuated as much as reflected room light because the latter is transmitted through the filter twice. As a result such a gray glass filter cannot be employed with cathode ray tubes having illuminated internal graticules because it attenuates the graticule image to an unacceptably low level. However, with the fluorescent screen of the present invention the contrast between the light images of the illuminated graticule lines and of the signal waveforms

produced on the screen compared with screen background areas is greatly increased and the graticule image contrast is more than doubled, without decreasing the brightness of such images.

Previously television tubes have been made which employ a plurality of spherical glass beads in a continuous layer of beads between the fluorescent screen and the face plate of such tube, such beads acting as lenses to reduce the angle through which the light image is directed from the screen to the observer which allegedly increases the brightness of the light spots forming the image. However by employing a large number of closely packed spacer beads in contact with each other and covering the entire surface of the fluorescent screen, as shown in U.S. Patent 2,485,561 by G. Burroughs, issued October 25, 1949, much of the light emitted from such screen is absorbed within the spacer beads due to multiple reflections within such beads resulting in a reduction of total image brightness. Also a coating of black opaque paint is provided on the surface portions of the face plate between the glass spacer beads, which also increases the image contrast of the fluorescent screen but further decreases brightness. In addition, this fluorescent screen apparently has less image resolution than that of the present invention because the image is formed by widely spaced light spots transmitted through the spacer bead lens and separated by the black paint. Thus, the resulting fluorescent screen is very inefficient in that it has a very low brightness and is too expensive to be practical.

The fluorescent screen of the present invention overcomes the above disadvantages by employing a lacquer layer of plastic or other organic material between the phosphor layer and the face plate as a temporary spacer for such phosphor layer during the manufacture of such screen. After the application of the phosphor layer, the lacquer layer is removed by heating to cause the phosphor layer to be supported on the face plate only at widely separated points, while the remainder of such phosphor layer is spaced out of contact with such face plate so that most of the phosphor layer is separated by open space from the face plate and the graticule scale. This greatly reduces the amount of light directed into the phosphor layer through the face plate including halation light emitted from another spot on such phosphor layer and graticule light emitted from a source outside of the tube, and has the advantage of providing greater contrast without decreasing the brightness of the image transmitted through the face plate of the tube to the observer. Furthermore, a fluorescent screen made in accordance with the present invention is simpler and less expensive than those made by the above-mentioned prior methods.

It is therefore one object of the present invention to provide an improved fluorescent screen having a high contrast and brightness.

Another object of the present invention is to provide an improved cathode ray tube having a fluorescent screen which is spaced from the face plate of such tube to reduce its area of contact with such face plate and provide a screen of high contrast and brightness which is of simple and inexpensive structure.

A further object of the present invention is to provide an improved cathode ray tube having an illuminated internal graticule and a fluorescent screen which is attached to the face plate of such tube only at spaced points, while the remainder of such screen is separated by open space from such face plate and such graticule in order to provide a high contrast between the graticule image and the background of the fluorescent screen, as well as between the light images emitted by such screen and such background.

An additional object of the present invention is to provide an improved method of manufacture of a fluorescent

screen which is simple and inexpensive and results in a screen of high contrast and brightness.

Still another object of the present invention is to provide an improved method of manufacture of a fluorescent screen for a cathode ray tube in which an intermediate layer of organic material is provided temporarily between the phosphor layer and the face plate of such tube to space such phosphor layer from the face plate so that when the intermediate organic layer is removed most of the phosphor layer remains out of contact with the face plate to provide a fluorescent screen of greater image contrast.

Other objects and advantages of the present invention will be apparent from the following detailed description of certain preferred embodiments thereof and from the attached drawings of which:

FIG. 1 is a plan view of the face plate end of a cathode ray tube having an illuminated internal graticule and a fluorescent screen in accordance with the present invention;

FIG. 2 is a vertical section view taken along the line 2—2 of FIG. 1;

FIGS. 3A and 3B show different steps in one method of manufacture of one embodiment of the fluorescent screen of the present invention;

FIGS. 4A and 4B show another method of manufacture of a second embodiment of the fluorescent screen of the present invention; and

FIGS. 5A and 5B show steps of still another method of a third embodiment of the fluorescent screen of the present invention.

As shown in FIGS. 1 and 2, a cathode ray tube **10** in accordance with the present invention includes a light transparent glass face plate **12** forming a portion of the evacuated envelope of such tube with an internal graticule scale **14** formed on the inner surface of such face plate. A fluorescent screen **16** having a substantially flat outer rear surface, is provided on the inner surface of the face plate **12** over the graticule scale lines **14** in a manner hereafter described. In order to increase the brightness of the fluorescent screen a thin light-reflecting coating **18** of aluminum may be provided on the rear surface of the fluorescent screen nearest the electron gun (not shown) within the cathode ray tube.

The graticule scale **14** is formed by a plurality of intersecting horizontal and vertical lines which may be formed in many different ways, such as by scribing notches in the surface of the face plate, by chemically etching such lines, or by printing the lines of glass frit, titanium dioxide or other suitable material. One preferred method of forming the graticule lines is to provide a coating of photosensitive solution such as a mixture of polyvinyl alcohol, water, and dichromate activator, containing particles of titanium oxide or glass frit on the inner surface of the face plate and exposing such photosensitive material to the light image of a graticule scale. The unexposed polyvinyl alcohol is then washed away so that only the hardened graticule lines remain. Next the polyvinyl alcohol is removed from the graticule lines leaving only lines of titanium oxide or glass frit.

The internal graticule scale **14** on the inner surface of the face plate of the cathode ray tube is illuminated from a light source outside the cathode ray tube **10**. This illumination can be accomplished in a number of different ways by which the light is transmitted through the outer edge of the face plate **12**. However, this is somewhat difficult due to the rounded corner at the outer edge surrounding a conventional molded face plate. Another suitable technique is that shown in FIG. 2 to include an external light guide **20** in contact with the outer surface of the face plate. The light guide **20** may be in the form of a flat plate of glass or plastic having a similar index of refraction to that of the face plate **12**. This light guide may be attached to the outer surface of the face plate by any of the techniques described in my copending United States patent application Serial No. 320,874, now U.S. Patent 3,281,618 entitled "Graticule Lighting Structure," filed November 1, 1963. One suitable technique for eliminating the glass-to-air interface at the surface of the face plate to enable light to be transmitted into such face plate, is to provide an intermediate bonding layer **22** of epoxy resin plastic between such face plate and the light guide member **20** to attach such light guide to the face plate. Of course the bonding layer **22** must also have an index of refraction similar to that of the face plate and the light guide.

A pair of incandescent light bulbs **24** are positioned within two spaced apertures **26** provided through a portion of the light guide **20** extending laterally of the cathode ray tube to provide the light for illuminating the internal graticule scale **14**. The light emitted from light bulbs **24** is transmitted into the light guide **20** through the walls of the apertures **26** and is reflected within such light guide until it passes into the face plate through the bonding layer **22**. A portion of this light strikes the graticule lines **14** and is reflected back through the face plate **12**, the bonding layer **22** and the light guide **20** out of the cathode ray tube. A light-reflecting coating **28** of white enamel paint or aluminum may be provided on the outer edge of the light guide **20** to prevent light from passing out of such light guide through such outer edge, to increase the intensity of illumination of the graticule scale.

In previous cathode ray tubes employing illuminated internal graticules, the phosphor layer of the fluorescent screen is applied directly over and in contact with the glass face plate, so that a portion of the light transmitted from the external source into the face plate to illuminate such graticule lines, also illuminates the phosphor particles in contact with the face plate by transmission through the points of contact rather than being reflected from the inner surface of the face plate. As a result, the fluorescent screen is provided with a high background illumination which greatly decreases the contrast between the light image of the graticule scale and the fluorescent screen. In addition, even in cathode ray tubes not employing an internal graticule scale, the contrast between the light image emitted by the fluorescent screen when such screen is bombarded with electrons and the background areas of such screen is reduced by a portion of such light image being reflected back into the fluorescent screen to illuminate such background areas due to the fact that substantially the entire front surface of such screen is in contact with the face plate. As a result, conventional television receiver tubes have a halation lighting problem which considerably reduces the contrast of the fluorescent screens of such tube.

Both of the above-mentioned contrast problems are overcome by the fluorescent screen of the present invention as a result of supporting the phosphor layer of such screen only at widely spaced points on the face plate separated by distances much greater than the thickness of the phosphor layer, so that the majority of the front surface of such phosphor layer is not in contact with such face plate.

One embodiment of the fluorescent screen **16** of the present invention is made in accordance with a method of manufacture including the steps of FIGS. 3A and 3B. As shown in FIG. 3A, after the graticule scale **14** is formed on the inner surface of the face plate **12**, a temporary spacer layer **30** of organic lacquer, such as a plastic, is provided over the inner surface of the face plate and the graticule lines. For example, a lacquer solution of 100 grams of methyl methacrylate, 1090 milliliters of toluene solvent and 1040 milliliters of ethyl acetate is mixed and heated at a temperature of 40° centigrade for 20 minutes to dissolve the solids and then an additional 24 milliliters of methanol solvent is added to the solution and stirred for an additional 20 minutes. After filtering to remove any undissolved particles, the lacquer solution is poured into the glass envelope of the cathode ray tube

and caused to flow over the inner surface of the face plate and the walls of the envelope before the neck end of such envelope is moved to a downward position to allow the excess lacquer to drain away from the face plate by the force of gravity. Then the lacquer layer is dried by circulating warm air into the tube envelope. It should be noted that for a tube having a face plate of 5 inches in diameter approximately 35 milliliters of the lacquer solution is required to provide the spacer layer 30.

A phosphor layer 32 of phosphor particles and binder is provided over the spacer layer 30 of FIG. 3A in any suitable manner, such as by water settling phosphor particles in a suspension solution of potassium silicate and barium acetate provided within the tube envelope. After about 30 minutes of settling, the suspension solution is poured off, leaving the phosphor layer 32 coated over the spacer layer 30. This phosphor layer is dried by circulating warm air into the envelope. It has been found that when the above-described methyl methacrylate lacquer is employed for the spacer layer 30 that a thin intermediate layer 34 of buffer material, such as aluminum oxide, must be provided to enable the phosphor layer 32 to stick to the spacer layer, because the conventional "water glass" bonding agent, such as sodium silicate or potassium silicate, in such phosphor layer will not adhere to such lacquer. This intermediate layer of aluminum oxide is formed by vacuum evaporating a thin layer of aluminum approximately 20 to 50 angstroms thick onto the exposed surface of the spacer layer 30, and allowing such aluminum layer to quickly oxidize by exposure to air to form a thin porous layer of aluminum oxide.

As shown in FIG. 3B, the spacer layer 30 is removed to cause the phosphor layer 32 and intermediate buffer layer 34 to be drawn down into contact with the inner surface of the glass face plate 12 at spaced points 36 to provide the finished phosphor screen 16 which may subsequently be provided with the reflecting coating 18 of FIG. 2 if so desired. This removal of the spacer layer 30 can be accomplished by heating the coated structure of FIG. 3A at a temperature of 400° C. in air for about 15 minutes, which causes the lacquer of the spacer layer 30 to oxidize and evaporate through the porous intermediate layer 34 and the porous phosphor layer 32, leaving substantially no residue.

Alternatively, it is possible to remove the lacquer layer 30 of FIG. 3A by dissolving such layer with a chemical solvent solution of toluene and methanol similar to that described above with reference to forming the lacquer solution. After the lacquer of the spacer layer 30 is dissolved through the phosphor layer 32 and intermediate buffer layer 34 this solution is poured off, leaving some slight residue which can be reduced by repeating this solvent step. It should be noted that while an organic material is employed for the lacquer when the spacer layer 30 is removed by heating, an inorganic material such as one of the silicones can be employed for such lacquer when the spacer layer 30 is removed by dissolving with a chemical solvent.

The lacquer layer 30 of FIG. 3A is inherently formed with a plurality of random spaced thin portions 38 of less thickness than the remainder of the spacer layer, so that the overlying phosphor layer 32 is more closely spaced to the face plate 12 over these thin portions. As a result, when the spacer layer 30 is removed, the portions of the phosphor layer 32 which come into contact with the face plate at points 36 of FIG. 3B through the intermediate buffer layer when such intermediate layer is employed, correspond to those portions over the thin portions 38 of the spacer layer. As shown in FIG. 3B the distance between the contact points 36 is much greater than the thickness of the phosphor layer 32, so that the majority of the front surface of the phosphor layer 32 is spaced out of contact with the face plate and with the graticule lines 14 and is separated therefrom by open space. While the spacing between the contact points 36 is random, the average spacing is approximately 1 millimeter and the phosphor layer is about .05 to .20 millimeter thick.

Another embodiment of the fluorescent screen 16' is made by the method of manufacture of FIGS. 4A and 4B. The fluorescent screen 16' and method of FIGS. 4A and 4B are very similar to that of FIGS. 3A and 3B, so that the same reference numerals have been employed to indicate like components and only the differences between these two screens and their methods of manufacture will be described. Thus, as shown in FIG. 4A the spacer layer 30' includes a lacquer material similar to that employed in the spacer layer 30 of FIG. 3A except that a plurality of permanent spacer beads 40 are uniformly mixed throughout such spacer layer. While many different types of spacer beads can be employed, spherical beads provide the least area of contact with the face plate 12 and should have a diameter of about .05 millimeter or about ⅓ or ¼ the thickness of the phosphor layer 32. For example selected silica sand particles may be employed for spacer beads 40. The intermediate aluminum oxide layer 34 is applied over the spacer layer 30' in a similar manner to that of FIG. 3A, as is the phosphor layer 32.

As shown in FIG. 4B the lacquer in the spacer layer 30' is removed by heating or chemically dissolving in a similar manner to that of FIG. 3B, which, however, leaves the spacer beads 40 between the intermediate buffer layer 34 and the face plate 12. Thus the spacer beads 40 support the phosphor layer 32 only at spaced points on the inner surface of the face plate 12 to provide the completed fluorescent screen 16' of FIG. 4B. As a result, the area of contact between the phosphor layer 32 and the graticule lines 14 as well as between such phosphor layer and the face plate is materially reduced, thereby increasing the contrast of such fluorescent screen. The distance between the spacer beads 40 is random but has an average value of about 1 millimeter, which is much greater than the .05 to .20 millimeter thickness of the phosphor layer 32, or than the .05 millimeter spacing of such phosphor layer from the face plate.

It should be noted that unlike the spherical beads of U.S. Patent 2,485,561 referred to above, the spacer beads 40 in the embodiment of FIG. 4B of the present invention do not function as lenses but are merely to prevent contact between the phosphor layer and the face plate, so that such spacer beads may be made of a light opaque material. In fact, in some instances this is preferred because the spacer beads may produce tiny bright spots when they act as lenses. In addition, the phosphor layer 32 is of a more uniform thickness than that of the above-mentioned patent because of the use of the temporary lacquer spacer material between the beads, so that no light opaque coating need be employed on the surface of the face plate between such beads as is provided in such patent. Also the spacing between the phosphor layer 32 and the face plate 12 is on the order of two or three times the average wavelength of the visible light emitted by the phosphor layer, so that the spacer beads 40 do not provide a quarter wavelength coating to prevent light reflection at the interface of the phosphor layer and glass face plate in the manner of some previous tubes.

A third embodiment of the fluorescent screen 16'' is made in accordance with the method of FIGS. 5A and 5B. Also the embodiment of FIGS. 5A and 5B is similar to that of FIGS. 3A and 3B so that the same reference numerals have been employed to designate like components. The primary difference between the fluorescent screen 16 of FIG. 3B and the fluorescent screen 16'' of FIG. 5B is that the latter screen eliminates the intermediate buffer layer 34 of aluminum oxide. This is accomplished by providing a temporary spacer layer 42 of photosensitive material, such as a solution of 100 grams of polyvinyl alcohol, 1000 milliliters of water, 1 milliliter of isopropanol and 20 grams of ammonium dichromate activator, on the inner surface of the glass face plate 12 over the graticule lines 14. The photosensitive spacer

layer 42 is exposed to light through a film negative or other light mask to harden the spacer layer 42 in all areas except a plurality of spaced dots which may be circular or of any other desirable shape. Then the unexposed portions of the spacer layer beneath such spots are removed by washing with water. This results in a plurality of spaced apertures 44 being provided through the spacer layer 42, as shown in FIG. 5A. Next the phosphor layer 32 is water settled over the spacer layer 42 so that portions of the phosphor particles and binder in such phosphor layer fall into the apertures 44 to bind the phosphor layer directly to the face plate sufficiently so that the intermediate layer 34 of aluminum oxide is not required.

As shown in FIG. 5B, the temporary spacer layer 42 is removed by heating or chemical dissolving of the hardened photosensitive material. This leaves the phosphor layer 32 spaced from the face plate 12 except at small spaced contact points 46 corresponding to the apertures 44 in the spacer layer. Here again it should be noted that the contact points 46 are spaced from each other by a distance greater than the thickness of the phosphor layer 32 in a similar manner to the embodiment of FIG. 3B. However, the embodiment of FIG. 5B has the additional advantage that the size and spacing of the contact points 46 can be regulated by the dotted negative light image used to expose the photosensitive spacer layer 42. Thus, a regular pattern of contact points 46 may be provided to ensure that none of such contact points falls upon one of the graticule lines 14.

Another way of eliminating the intermediate buffer layer 34 of aluminum oxide of FIGS. 3A and 3B without employing the photographic technique of FIGS. 5A and 5B is to use a different type of carrier material in the phosphor layer 32 of FIGS. 3A and 3B to enable such phosphor layer to stick to the lacquer spacer layer 30. In this regard polyvinyl alcohol can be used as this carrier for the phosphor particles, since it will adhere to the lacquer spacer layer and is removed along with the lacquer during the heating step. However, it should be noted that in this embodiment of the invention, the polyvinyl alcohol is not employed as a photosensitive material, except perhaps to control the thickness of the phosphor layer by uniform exposure of the layer to light for a predetermined time.

In addition, other methods of manufacture of the fluorescent screen of the present invention may be employed, such as the decalcomania technique disclosed in copending U.S. patent application Serial No. 313,091 by H. J. Mepham, filed October 1, 1963. If such a decalcomania technique is employed in place of the conventional water settling method for applying the phosphor layer to the face plate, the decal would be provided with at least two layers, the first layer corresponding to the temporary spacer layer 30 of FIG. 3A and the second layer corresponding to the phosphor layer 32. The advantage of such a technique is that the decal may be cut to the exact size of the face plate and held in place temporarily by a pressure sensitive adhesive which is also employed as the binder of the phosphor layer and as the organic material in the lacquer spacer layer 30.

It will be obvious to those having ordinary skill in the art that many changes may be made in the details of the above described preferred embodiments of the present invention without departing from the spirit of the invention. Therefore the scope of the invention should only be determined by the following claims.

I claim:

1. A fluorescent screen comprising:
a light transparent support member;
a layer of phosphor material having a substantially flat outer surface; and
spacer means for supporting the phosphor layer on said support member only at spaced points separated by distances greater than the thickness of said layer, and for spacing the remainder of said phosphor layer out of contact with said support member to separate it from the support member by open space to provide greater contrast for light images emitted from said phosphor layer.

2. A fluorescent screen comprising:
a light transparent support member;
a graticule scale provided on said support member;
a layer of phosphor material provided on said support member over said graticule scale; and
means for supporting the phosphor layer on said support member only at spaced points separated by distances greater than the thickness of said layer, and for maintaining the remainder of said phosphor layer out of contact with said support member to separate it from the support member and the graticule scale by open space to provide greater contrast for light images emitted from said phosphor layer and for the light image of said graticule scale.

3. A fluorescent screen comprising:
a light transparent support plate;
a layer of phosphor material; and
means including a plurality of spacer beads positioned between the phosphor layer and said support plate, for supporting the phosphor layer on said support plate only at spaced points separated by distances greater than the thickness of said layer, and for maintaining the remainder of said phosphor layer out of contact with said support plate to separate it from the support plate by open space to provide greater contrast for light images emitted from said phosphor layer.

4. A fluorescent screen comprising:
a light transparent support plate of glass;
a graticule scale formed by lines of fused glass frit provided on one side of said support plate;
a layer of phosphor material provided on said one side of said support plate over said graticule scale; and
means including a plurality of substantially spherical spacer beads positioned between the phosphor layer and said support plate, for supporting the phosphor layer on said support plate only at spaced points separated by distances between said beads greater than the thickness of said layer, and for maintaining the remainder of said phosphor layer out of contact with said support plate to separate it from the support plate and the graticule scale by open space to provide greater contrast for light images emitted from said phosphor layer and for the light image of said graticule scale.

5. A cathode ray tube, comprising:
an envelope having a light transparent face plate portion;
a layer of phosphor material provided on the inner surface of said face plate and having a substantially flat outer surface, and
spacer means for supporting the phosphor layer on said face plate only at spaced points separated by distances greater than the thickness of said layer, and for spacing the remainder of said phosphor layer out of contact with said face plate to separate it from the face plate by open space to provide greater contrast for light images emitted from said phosphor layer.

6. A cathode ray tube, comprising:
an envelope having a light transparent face plate portion;
a graticule scale provided on the inner surface of said face plate so that said graticule scale is illuminated by light transmitted inside said face plate;
a layer of phosphor material provided on the inner surface of said face plate over said graticule scale; and
means for supporting the phosphor layer on said face plate only at spaced points separated by distances

greater than the thickness of said layer, and for maintaining the remainder of said phosphor layer out of contact with said face plate and said graticule scale to separate it from the face plate and graticule scale by open space to provide greater contrast for light images emitted from said phosphor layer and for the light image of said graticule scale.

7. A cathode ray tube, comprising:

an envelope having a light transparent face plate portion;

a graticule scale provided on the inner surface of said face plate;

means for illuminating said graticule scale by transmitting light into said face plate;

a layer of phosphor material provided on the inner surface of said face plate over said graticule scale; and

a plurality of spacer elements positioned between the phosphor layer and said face plate to reduce the area of contact between said phosphor layer and said face plate so that most of the phosphor layer is separated by open space from the face plate and the graticule scale, such spacer elements being spaced from each other by a greater distance than the thickness of said phosphor layer.

8. A cathode ray tube, comprising:

an envelope having a light transparent molded glass face plate portion;

a graticule scale provided on the inner surface of said face plate;

a light guide member of material having substantially the same index of refraction as said face plate fastened to the outer surface of said face plate;

at least one light bulb provided in a hole in such light guide member to illuminate said graticule scale through said light guide member and said face plate;

a layer of phosphor material provided on the inner surface of said face plate over said graticule scale; and

a plurality of substantially spherical spacer beads positioned between the phosphor layer and said face plate to reduce the area of contact between said phosphor layer and said face plate so that most of the phosphor layer is separated by open space from the face plate and the graticule scale, such spacer beads being spaced from each other by a greater distance than the thickness of said phosphor layer.

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