

Jan. 25, 1966

D. H. PRITCHARD

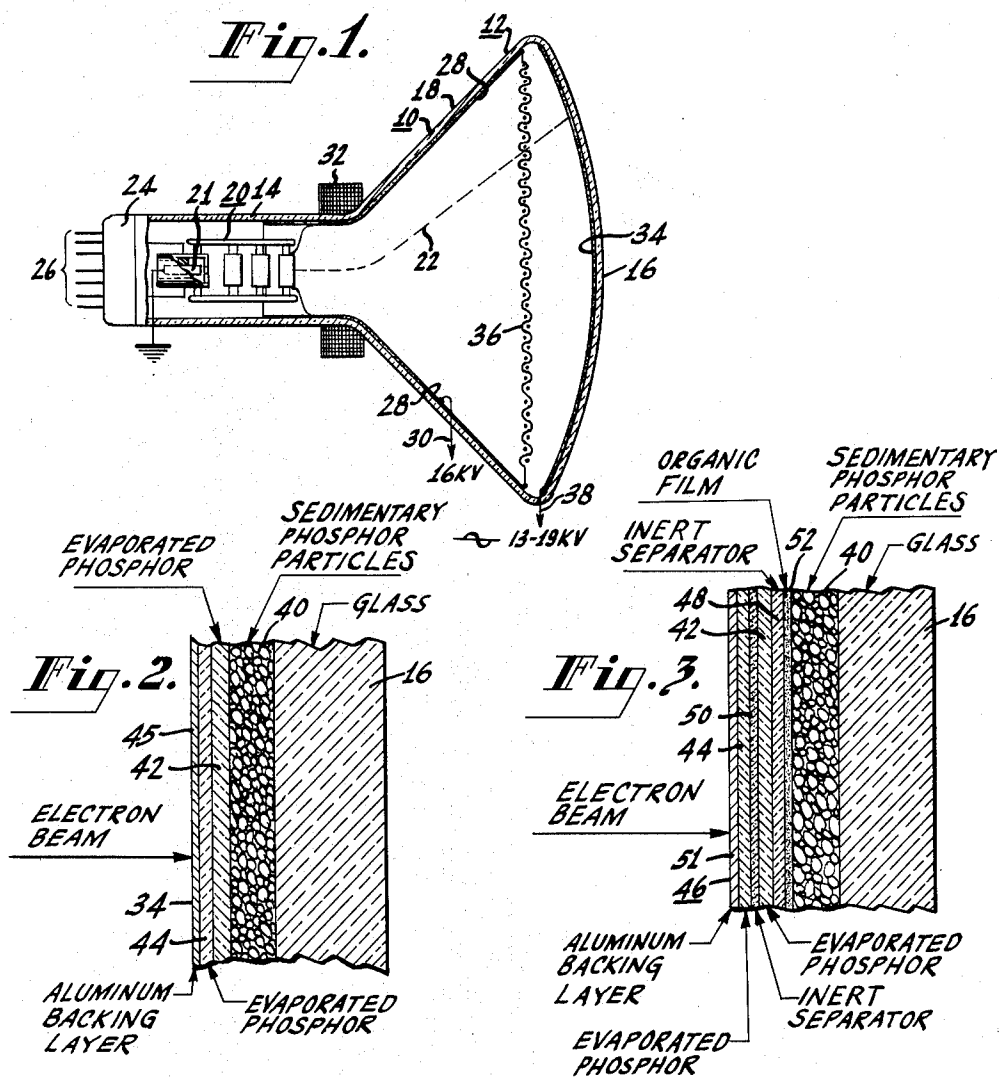
3,231,775

CASCADED PHOSPHOR LAYERS FOR COLOR DISPLAY INCLUDING

ONE OF DISCRETE COHERENT PARTICLES

Filed Dec. 27, 1961

2 Sheets-Sheet 1



INVENTOR.
DALTON H. PRITCHARD
BY
William A. Gale
ATTORNEY

Jan. 25, 1966

D. H. PRITCHARD

3,231,775

CASCADED PHOSPHOR LAYERS FOR COLOR DISPLAY INCLUDING

ONE OF DISCRETE COHERENT PARTICLES

2 Sheets-Sheet 2

Filed Dec. 27, 1961

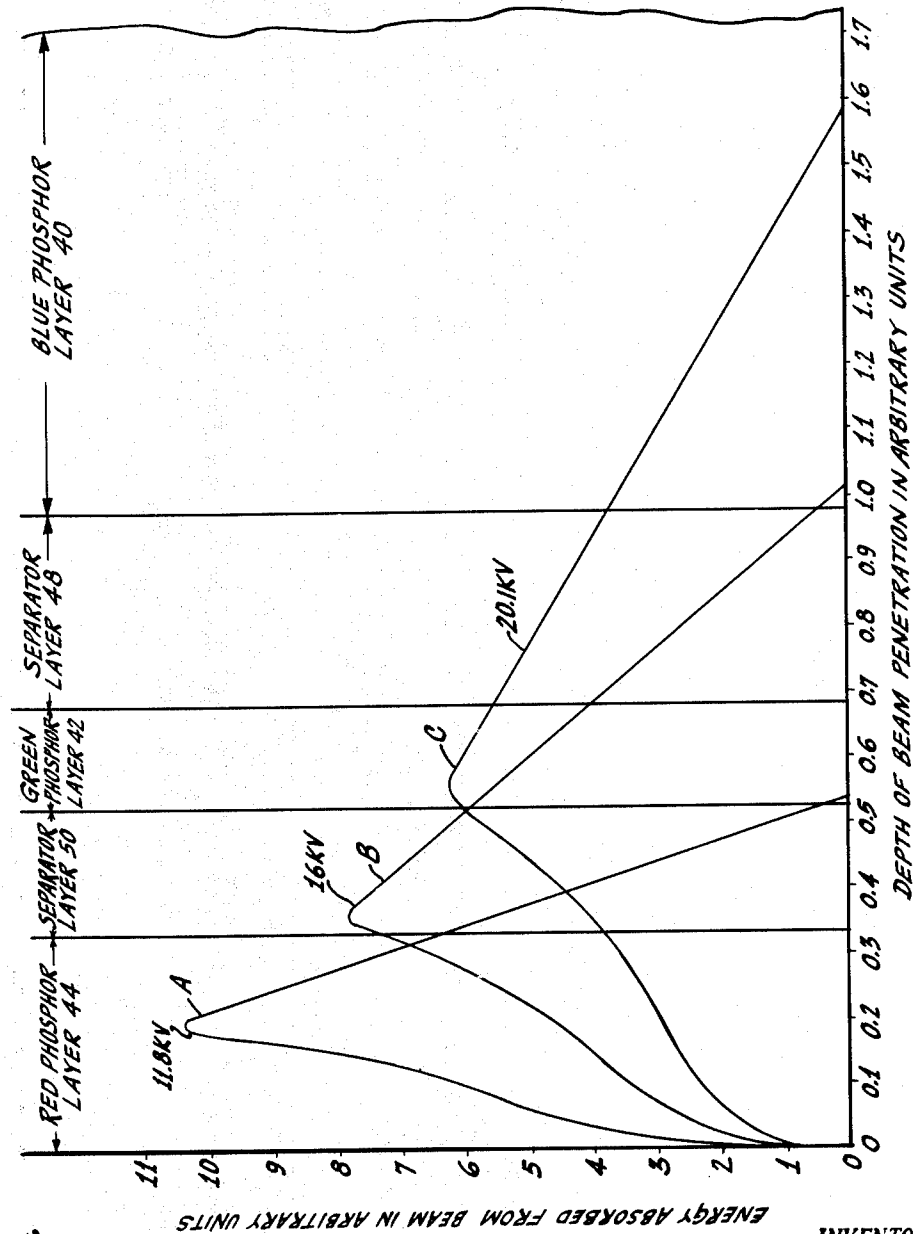


Fig. 4.

INVENTOR.

DALTON H. PRITCHARD

BY

William A. Zalesak
ATTORNEY

1

2

3,231,775

CASCADED PHOSPHOR LAYERS FOR COLOR DISPLAY INCLUDING ONE OF DISCRETE COHERENT PARTICLES

Dalton Harold Pritchard, Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Filed Dec. 27, 1961, Ser. No. 162,331

9 Claims. (Cl. 313—92)

This invention relates to cathode ray tubes capable of producing color images and particularly to luminescent screens which comprise superimposed layers of different color light emitting phosphors for use in such tubes.

In kinescopes having the type of luminescent screen described above, the color of light emitted at any given moment is a function of the velocity of the exciting electron beam. The greater the velocity of the beam, the further the beam will penetrate into the plural layer screen. The penetrating beam neither gives up its energy uniformly throughout the depth of the beam penetration, nor at one single point in the penetrated depth, for example, the deepest point of penetration. For any given depth of beam penetration, there is a point at some fraction of this depth at which maximum energy dissipation of the electrons occurs. A change of the beam velocity will shift the depth of this point of maximum energy dissipation and change the color of the light emitted from the screen. Accordingly, by properly varying the velocity of the electron beam and applying suitable video and chrominance signal information, a color image can be reproduced.

Screens of the above-described type have been made by superimposing layers of coarse, sedimentary-size phosphor particles. One advantage of such layers is that they inherently provide relatively high light output efficiency. Moreover, simplified screening methods and existing manufacturing facilities can be used. One example of such methods is the settling of sedimentary-size phosphor particles through a liquid cushion and onto a support surface. Although such coarse phosphor particles do result in high light output efficiency and make possible the use of desirable screening methods, they also result in rather thick and porous layers. Thick layers are undesirable because excessively high signal voltages are required to switch from one color emission to another, that is, from excitation of one phosphor layer to an adjacent layer. The use of high signal voltages in turn requires expensive circuitry. Porous, or nonhomogeneous, layers are undesirable since the beam may approach a layer at the position of a space between the coarse particles of a layer and then may pass through that layer and excite the next layer when, in fact, according to the color signal, the beam's energy should be primarily dissipated in the first layer.

Screens of the multiple-layer type have also been made by evaporating superimposed layers of different phosphors. An advantage of evaporated layers is that they can be made sufficiently thin to permit color switching with a relatively small voltage. However, known evaporated color phosphors exhibit relatively low light-output efficiencies. A low light-output efficiency is not only undesirable in itself, but also means that in order to obtain sufficient light therefrom, the layers must be made relatively thick so that the electrons can excite the phosphor throughout a greater depth of penetration. However, greater thickness and greater penetration again means that a greater voltage color switching signal is required.

In addition to the problems described above, the use of superimposed evaporated phosphors has other disadvantages. Known techniques of preparing suitable evap-

orated layers include a firing or bake step after deposition of the layer in order to recombine or activate the phosphor material. Different evaporated phosphors require different temperature baking. Thus, in the case of superimposed layers, the phosphor requiring the highest temperature bake must be deposited first so that its high temperature baking does not damage the other layers. The phosphor layers thus must be arranged from their support surface toward the electron gun in the order of descending bake temperatures. However, this order is not necessarily preferred or even acceptable from the standpoint of other factors such as their relative efficiencies and of the color gamut desired.

Another disadvantage of superimposed evaporated phosphor layers may occur when they are placed in intimate contact with each other. Some phosphors in evaporated form interact chemically with certain other evaporated phosphors when they are in contacting relationship. This possible interaction then places another restriction on the combining of evaporated layers and on the order of their superimposition.

Still another difficulty of superimposed evaporated layers arises when the layer deposited on a glass support surface, such as the faceplate of a tube, has a substantial degree of transparency. The first phosphor evaporated onto the glass substrate makes intimate contact with the glass surface. Since the indices of refraction of phosphors are generally higher than those of glass, the very high degree of optical contact results in trapping within the glass a large fraction of the light emitted by the phosphor. This fraction is conducted away laterally by the glass instead of reaching the viewer. A subsequently evaporated layer likewise lies in intimate optical contact with the preceding layer, so that a large fraction of its light output likewise fails to reach the viewer.

It is therefore an object of this invention to provide a new and improved luminescent screen of the superimposed layer variety which overcomes or mitigates the problems or disadvantages described above.

It is also an object of this invention to provide a new and improved luminescent screen of superimposed layers of different color, light-emitting phosphors which both possesses relatively high light output efficiency and requires relatively small voltage change for color switching.

Another object of this invention is to provide a new and improved color image, luminescent screen of superimposed phosphor layers which includes a high efficiency, coarse particle phosphor layer permitting the use of preferred screening techniques and which yet possesses relatively low voltage color switching characteristics.

It is another object of this invention to provide a luminescent color image reproducing screen of superimposed phosphor layers which both possesses desirably low color switching characteristics and exhibits relatively high forward light transmission into and through its transparent support to a viewer.

Another object of this invention is to provide a new and improved color image reproducing plural phosphor layer luminescent screen which reduces the limitation of color order of layers while retaining the color switching advantages of thin layer, evaporated screens.

Briefly, according to my invention a luminescent screen suitable for reproducing images in color includes superimposed phosphor layers of different physical textures, one comprising coarse, sedimentary-size particles of one color light emitting phosphor which may be relatively porous; and another layer adjacent thereto comprising a thin, relatively nonporous, for example, evaporated, layer of a different color light emitting phosphor. The inclusion of the coarse particle layer permits use of known screening methods, such as settling, and provides at least

one layer of the type exhibiting relatively high light output efficiency. The combining with this coarse particle layer of one or more evaporated layers still provides the advantage of low voltage color switching and lessens the severity of required order of layer superimposition. Moreover, the coarse particle layer is preferably deposited first, thus improving forward light transmission to the viewer and reducing the color switching voltage since the beam need not penetrate this coarse layer very deeply in order to provide adequate light output.

Luminescent screens according to this invention, such as those hereinafter detailed, also preferably incorporate teachings set forth in my copending application Serial No. 108,565, filed May 8, 1961 and entitled "Electrical Devices and Methods."

In the drawings:

FIG. 1 is a longitudinal section of a cathode ray tube incorporating a luminescent screen according to my invention;

FIGS. 2 and 3 are enlarged sections of modifications of a luminescent screen made according to my invention; and

FIG. 4 is a chart illustrating the nature of dissipation of energy from various velocity electron beams in excitation of the screen of FIG. 3.

In FIG. 1, a cathode ray tube 10 is shown which has an envelope 12, including a neck section 14, a faceplate 16, and an interconnecting funnel 18. An electron gun 20 including a cathode 21 in the neck 14 is adapted to project a beam 22 of electrons toward the faceplate 16. The neck 14 is closed at one end with a stem structure 24 through which a plurality of lead-in conductors 26 are sealed. These lead-ins are connected in the usual manner to the various electrodes within the tube envelope. Suitable potentials are supplied to the electron gun 20 through the lead-in conductors 26.

A conductive coating 28 is provided on the internal surface on the funnel 18 and serves as an accelerating electrode. A suitable potential is supplied to the coating electrode 28 by terminal means sealed through the funnel 18 and schematically represented by the arrow 30. A suitable magnetic deflection yoke 32 is disposed externally around the envelope 12 for deflecting the electron beam 22 to scan a raster over the faceplate 16.

A luminescent screen 34 according to my invention is provided on the internal surface of the faceplate 16 and comprises superimposed phosphor layers, one of which comprises coherent phosphor particles, preferably of sedimentary size, and one or more of which comprises relatively nonporous thin layers such as evaporated phosphor films. Each of the phosphor layers consists of a different kind of phosphor for producing different color light output.

As hereinbefore described, operation of a cathode ray tube such as the tube 10 involves modulation of the electron beam at different electron velocities to selectively excite the various phosphor layers.

Where operation of the tube involves a single beam of varying velocity, means may be provided according to known practices for preventing raster distortion as a function of the varying beam velocity. Such means may take the form of either a mesh 36 disposed transversely within the funnel 18 or other alternative suitable means known in the art. Where the mesh electrode 36 is used, it may be connected to the coating electrode 28, and, if desired, the tube 10 is operated according to well-known post deflection acceleration principles. A separate lead-in means, as indicated schematically by the arrow 38, is provided for supplying suitable electric signals between the cathode 21 and the plural layer screen 34 to change the velocity of the beam for effecting color selection.

FIG. 2 illustrates an enlarged section view of a portion of the luminescent screen 34 according to my invention. The screen 34 comprises a powder texture layer 40 of sedimentary-size phosphor particles deposited on the face-

plate 16 and two evaporated texture phosphor layers 42 and 44 superimposed on the powder layer 40. Each of the phosphor layers 40, 42, and 44 emit a different color of light, for example blue, green, and red, respectively, when excited by electrons. A metal backing layer 45, such as evaporated aluminum, is provided on the phosphor layer 44.

The powder layer 40 has a thickness of, for example, approximately from 1 to 10 microns and includes phosphor particles having a size of, for example, 1 to 10 microns. The powder layer 40 should have a diffuse light transparency of at least approximately 75 percent. Diffuse transparency is a measure of transparency to diffused light as opposed to parallel rays of light. The powder layer 40 may be deposited by one of the methods well known in the art, for example applying a slurry or by settling through a liquid cushion layer onto the faceplate.

The evaporated layers 42 and 44 comprise relatively thin, nonporous films as compared with the powder layer 40. The evaporated films 42 and 44 may, for example, preferably have thicknesses of about $\frac{1}{8}$ and $\frac{1}{2}$ micron, respectively.

The evaporated phosphor layers 42 and 44 are applied by well-known evaporation techniques. For example, the surface onto which the phosphor material is to be evaporated and a small cup containing the desired phosphor material are placed in a vacuum chamber; the cup is then electrically heated to vaporize the phosphor material and cause it to be deposited on the desired surface.

Insofar as the practice of this invention is concerned, the thickness of the evaporated layers 42 and 44 need not be within a range of submicron thicknesses. However, absolute and relative thicknesses of the layers may be somewhat critical because of certain tube operational characteristics which may be desired. For example, the thicknesses of the phosphor layers have a bearing on the color gamut produced, the color balance which will enable white light to be produced, and the circuit requirements for providing color switching.

On the other hand, the thickness of the powder layer 40 in the screen 34 is not as critical as the other layer. The powder layer 40 should be sufficiently thin to have an acceptable light transmissivity and sufficiently thick to be substantially impermeable so as to insure adequate and uniform light output.

FIG. 3 illustrates a preferred embodiment of the luminescent screen according to my invention suitable for incorporation in the tube of FIG. 1. In FIG. 3 corresponding numerals have been used to identify like parts of the screen 34 of FIG. 2. The screen 46 of FIG. 3 includes on the faceplate 16 a superimposed sedimentary-size particle powder layer 40 and evaporated layers 42 and 44 in the order named. In addition to these layers, suitable inert (nonluminescent) separator layers 48 and 50 are provided between adjacent phosphor layers. The separator layers may, for example, comprise evaporated calcium tungstate or evaporated aluminum, which is subsequently baked in an oxidizing atmosphere to convert it to aluminum oxide. However, other materials such as silica or silica compounds are suitable.

Methods of applying the separator layers other than by evaporation are known and may be used where the separator material chosen lends itself to such other method of application. The use of separator layers is well known in the art and generally provides the advantage of obtaining the best possible color gamut with a color switching signal of given magnitude. The desirability of both a large color gamut and low signal voltage color switching have been hereinbefore discussed and are well appreciated by those skilled in the art. The screen 46 also includes, according to well-known practices, a metal backing layer 51 which may be an evaporated layer of aluminum.

The luminescent screen 46 also illustrates an optional feature which can also be used with equal advantage in

the screen 34 of FIG. 2. According to the preferred practice of my invention, after the powder layer 40 is deposited on the faceplate 16 and before the first separator layer 48 (or in the case of the screen 34 before the first evaporated layer 42) is applied thereon, a smooth surface, decomposable film 52 is provided on the powder layer 40. The film 52 may, for example, comprise an organic lacquer such as nitrocellulose or methyl methacrylate, which can be removed by a heating and vaporizing thereof after all of the screen layers have been deposited. Where such an organic lacquer is used to provide the film 52, it may be applied by any one of the well-known techniques such as are used to apply similar lacquer films prior to aluminizing phosphor powder layers. For example, the film may be floated on a liquid which is subsequently decanted, thus allowing the film to contact the powder layer 40; alternatively, the lacquer may be sprayed upon the powder layer 40. A methyl methacrylate surface can be provided simply by covering the powder layer 40 with a liquid solution of such and then removing the excess of the methyl methacrylate and drying the film which is left on the phosphor layer. In all cases the decomposition temperature of the filming material should exceed the application temperatures of the subsequently applied screen layers so as not to prematurely decompose the film 52.

In all of the variations of the film 52, the purpose is to provide a smooth support surface for the subsequent evaporated phosphor layers. The desirability of including the smoothing film 52 depends upon the coarseness of the particles of the powder layer 40. The larger the particles of the powder layer 40, the more desirable the addition of the smoothing film 52 becomes. For example, if a $\frac{1}{2}$ micron thick evaporated phosphor layer 42 were to be applied directly on a powder layer 40 having 10 microns size particles, the evaporated layer would be extremely irregular in thickness and likely would contain discontinuities which would render it unacceptable.

In the chart of FIG. 4, the various phosphor and separator layers of the luminescent screen 46 of FIG. 3 are graphically represented together with the nature of energy dissipation of various velocity electron beams which are directed into the layers from left to right as viewed in the chart. The phosphor and separator layers are represented by the vertical columns in the chart as labeled, the relative widths of the columns representing the relative thicknesses of these layers. The complete thickness of the blue phosphor layer has not been illustrated; instead only a sufficient portion of that layer which exceeds the maximum beam penetration is shown.

Curves A, B, and C represent the "Energy Dissipation vs. Depth of Penetration" for representative electron beams of 11.8 kv., 16 kv., and 20.1 kv. as they penetrate the layers from left to right as viewed in FIG. 4. As is illustrated by these curves, the energy dissipated at any depth of penetration by an electron beam increases as the depth of penetration increases until a point of maximum energy dissipation is reached. For example, for the 11.8 kv. beam as illustrated by curve A, this maximum or peak energy dissipation point occurs at approximately 0.2 depth unit of penetration. At points beyond this peak point, the energy given up by the penetrating electrons gradually decreases until zero energy dissipation is reached at the maximum depth of penetration. In the case of the 11.8 kv. beam as illustrated by curve A, this maximum penetration point is approximately 0.55 unit.

The light output of any electron beam is a function of the product of the area under its respective curve and the luminescent efficiency of the material through which the beam penetrates. Thus, the area under a curve does not directly represent the amount of light out. In the case of the 11.8 kv. beam as illustrated by curve A, the light output would be essentially all red and would be a

function of the area under curve A within the red phosphor layer column times the luminescent efficiency of the particular red phosphor used. The area under the curve in the separator layer 50 column does not represent light output since the material of the separator layer is non-luminescent. It will be noted that the tail of curve A extends very slightly into the green phosphor layer area. Thus, a very slight amount of green light will be produced. However, the red light output will greatly predominate and thus produce an overall red output.

When it is desired to switch from red light out to green light out, the electron beam velocity is switched, for example, to 16 kv. The energy dissipation vs. depth of penetration of such a beam is illustrated by curve B. In the case of the 16 kv. beam as illustrated by curve B, the total light output will include a substantial portion of both red and green since major areas of the red and green phosphor columns are contained under this curve. Since only the tail of curve B extends into the blue phosphor layer area, only an insignificant amount of blue light will be produced. This blue light may thus be ignored. However, in order that the composite light produced by the 16 kv. beam be predominately green, the phosphors are so chosen that the green phosphor has a relatively much higher luminescent efficiency than the red phosphor. By this means the output of the 16 kv. beam will be such that the green will predominate over the red and thus give a resultant overall green light.

Curve C illustrates the energy dissipation vs. depth of penetration of a 20.1 kv. beam such as might be used for producing a blue light output. It will be noted that the blue phosphor layer is excited by a relatively small portion of the total energy of the 20.1 kv. beam. This is indicated by the fact that only the tail of curve C extends into the area of the blue phosphor layer 40. However, by virtue of this invention, whereby the blue phosphor layer comprises a very highly efficient powder layer 40 of sedimentary-size particles, the low energy excitation thereof produces a relatively intense blue light output. In fact, because of the relatively much higher efficiency of the blue phosphor layer 40 than that of the red and green phosphor layers 44 and 42, the light output, by virtue of a 20.1 kv. beam as represented by curve C, will be predominately blue. At the same time, by virtue of the fact that the red and green phosphor layers 44 and 42 according to this invention comprise relatively nonporous, thin layers, the color switching signal is relatively small.

From a comparison of curves A, B, and C superimposed on the phosphor layers represented in FIG. 4, it will be appreciated that switching from one color output to another does not necessitate the shifting of the respective peaks of the three curves from one phosphor layer to the other. This fact results from the advantage obtained by the practice of this invention wherein the third, or blue, phosphor layer, being a highly efficient coarse particle powder, need be excited with only relatively little electron energy as is represented by the tail of the "Energy Dissipation vs. Depth of Penetration" curve of the 20.1 kv. beam. This, of course, would not be possible if a low efficiency evaporated layer were provided as the layer adjacent the faceplate of the tube.

The porous nature of powder layers, such as the layer 40, which makes a screen of superimposed coarse powder layers undesirable, is not detrimental to the screens 34 or 46 when the powder layer comprises the layer directly in contact with the faceplate 16. Even if the electron beam penetrating into the powder layer 40 should occasionally enter an interstice of the layer and possibly pass completely therethrough and strike the faceplate 16, it would cause no substantial adverse effects. Moreover, when a powder layer, such as the layer 40, is in contact with the faceplate 16, that layer can be made sufficiently thick to substantially eliminate apertures completely therethrough. Also, with the powder layer 40 directly in contact with the faceplate 16, light loss such as is experi-

enced with intimate optically contacting evaporated layers is avoided.

The use of a powder layer in combination with evaporated layers superimposed thereon also lessens the restrictions on the color order of superimposition. Powder phosphors, regardless of composition and hence color output, are usually characterized by the ability to withstand extremely high temperatures, e.g., 1000° C. and over. In the manufacture of such phosphors, it is common to fire the powders at a temperature in this vicinity. This being the case, the powder phosphor, whatever it might be, is readily selected to have a higher processing temperature than has either of the two evaporated layers. For this reason, a powder layer 49 of the desired color phosphor can be applied to the faceplate 16 first and then any other desired color phosphor evaporated thereupon and baked at its required temperature without injuring the first-applied powder layer. In a two-color screen, wherein a single powder layer and a single evaporated layer are used, there would be absolutely no restriction as to the order of color superimposition because of processing temperature requirements. In the three-color screen 34 or 46, the possibilities of color order of layer superimposition are increased three-fold as compared to an all-evaporated screen. In a three-layer evaporated screen where the layers must be put down in order of descending processing temperatures, only one color order of superimposition is possible. In the screen 34 or 46 any one of the three color phosphors can be provided as the first layer on the faceplate 16 simply by making that phosphor in the form of a powder layer.

Even in an application where it is desired to provide the combination of a powder layer superimposed on a previously deposited evaporated layer, the advantage of one high efficiency layer and low color switching signal voltage would still be obtained. At the same time, no disadvantage would result insofar as restriction of color order of particular phosphors, since powder layers do not require a high temperature processing after they have been applied to their support surface.

I claim:

1. A luminescent screen comprising a plurality of superimposed layers of different color light emitting phosphors, one of said layers comprising discrete coherent particles and another of said layers comprising an evaporated film.

2. A luminescent screen according to claim 1 and wherein said one layer is disposed between a support surface and said another layer.

3. A luminescent screen comprising a plurality of superimposed phosphor layers of different physical texture and of different color light emitting phosphors, one layer consisting of coherent particles and being multiparticle in thickness, another layer being relatively nonporous compared to said one layer and having a thickness less than the largest particles of said one layer.

4. A luminescent screen according to claim 3 and wherein said another layer comprises an evaporated phosphor layer.

5. A luminescent screen according to claim 3 and wherein said one layer includes phosphor particles having a size greater than one micron.

6. A luminescent screen according to claim 3 and wherein said superimposed phosphor layers are supported on a support surface with said one layer adjacent thereto.

7. A luminescent screen comprising a support surface, a first phosphor layer on said support surface, said first phosphor layer comprising coherent sedimentary size phosphor particles, and second and third phosphor layers relatively thin and nonporous compared with said first phosphor layer superimposed on said first phosphor layer on the side thereof opposite said support surface, each of said phosphor layers being adapted to emit light of a different color when excited by electron bombardment.

8. A luminescent screen comprising in the order named: a substrate, a multiparticle thick first phosphor layer of coherent phosphor particles, a first inert separator layer, a second phosphor layer, said second phosphor layer being of a different physical texture from and relatively nonporous compared to said first phosphor layer and thinner than the largest particles of said first phosphor layer, a second inert separator layer, and a third phosphor layer, said third phosphor layer being of a different physical from, and relatively nonporous compared to, said first phosphor layer and thinner than the largest particles of said first phosphor layer, each of said phosphor layers emitting light of a different color upon electron excitation.

9. A luminescent screen according to claim 8 and wherein said second and third phosphor layers are evaporated layers.

References Cited by the Examiner

UNITED STATES PATENTS

2,590,018	3/1952	Koller et al.
2,958,002	10/1960	Cusano et al.

GEORGE N. WESTBY, *Primary Examiner*.