Nov. 21, 1961 A. BRAMLEY ET AL 3,010,025

TRIGGERING ELECTROLUMINESCENT PANELS

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Fig. 1.

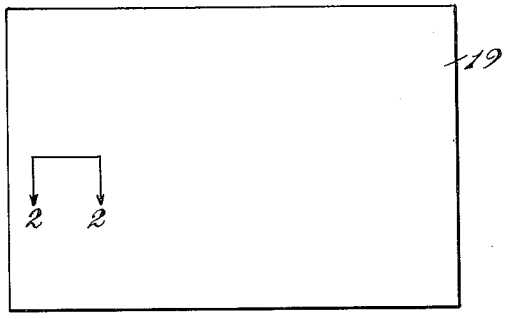


Fig. 2.

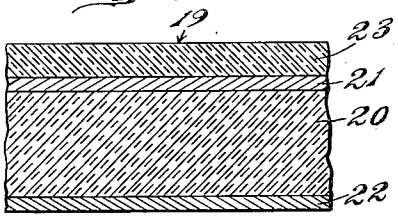


Fig. 3.

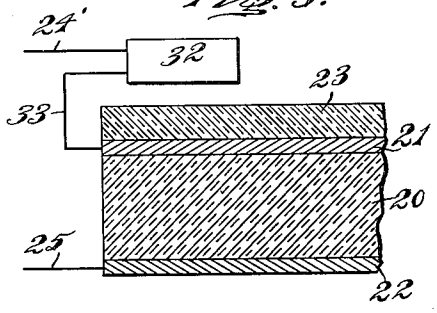


Fig. 4.

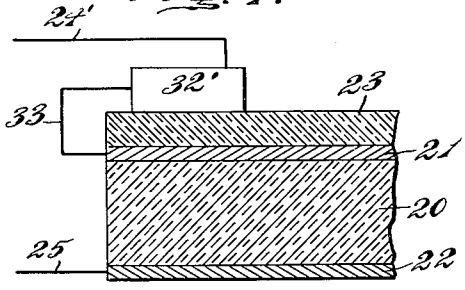


Fig. 5.

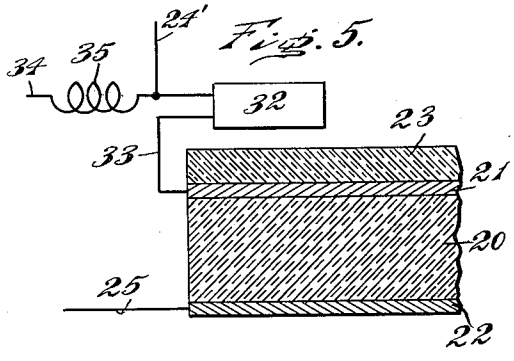
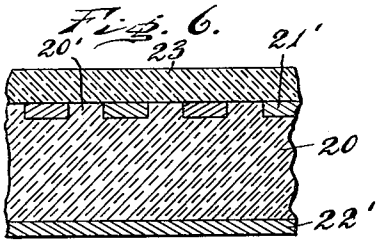


Fig. 6.



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TRIGGERING ELECTROLUMINESCENT PANELS

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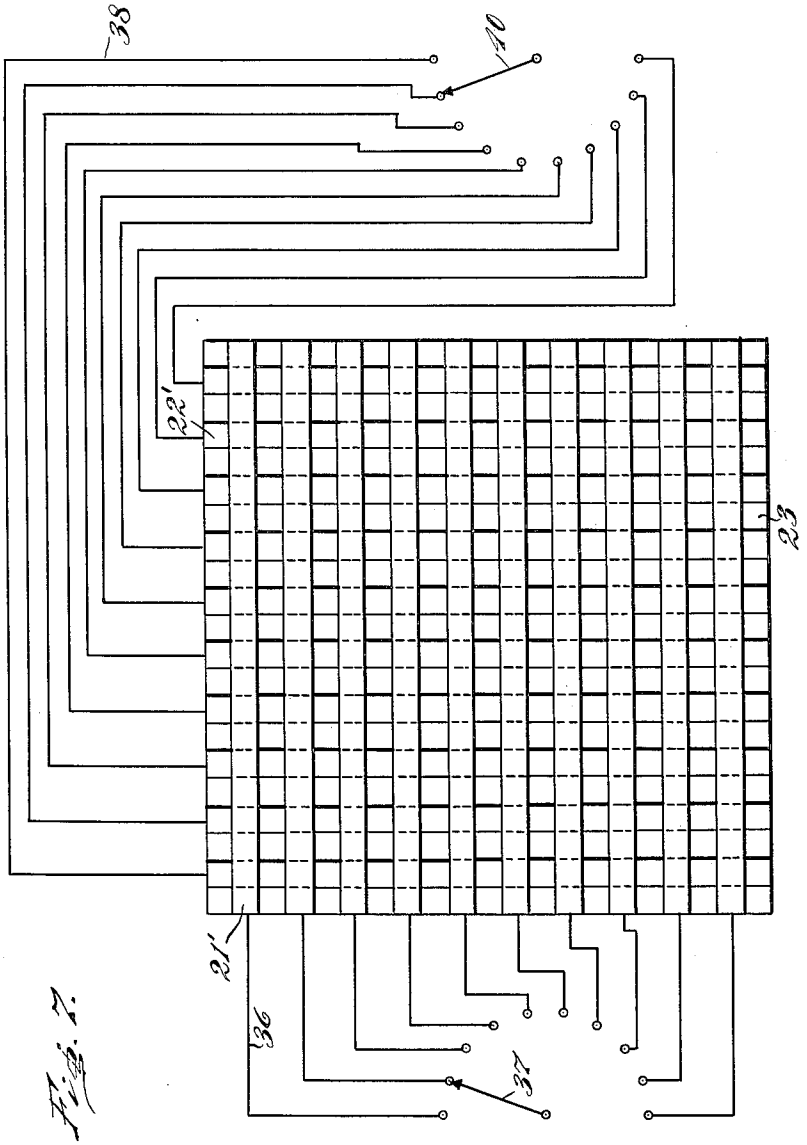


Fig. 2.

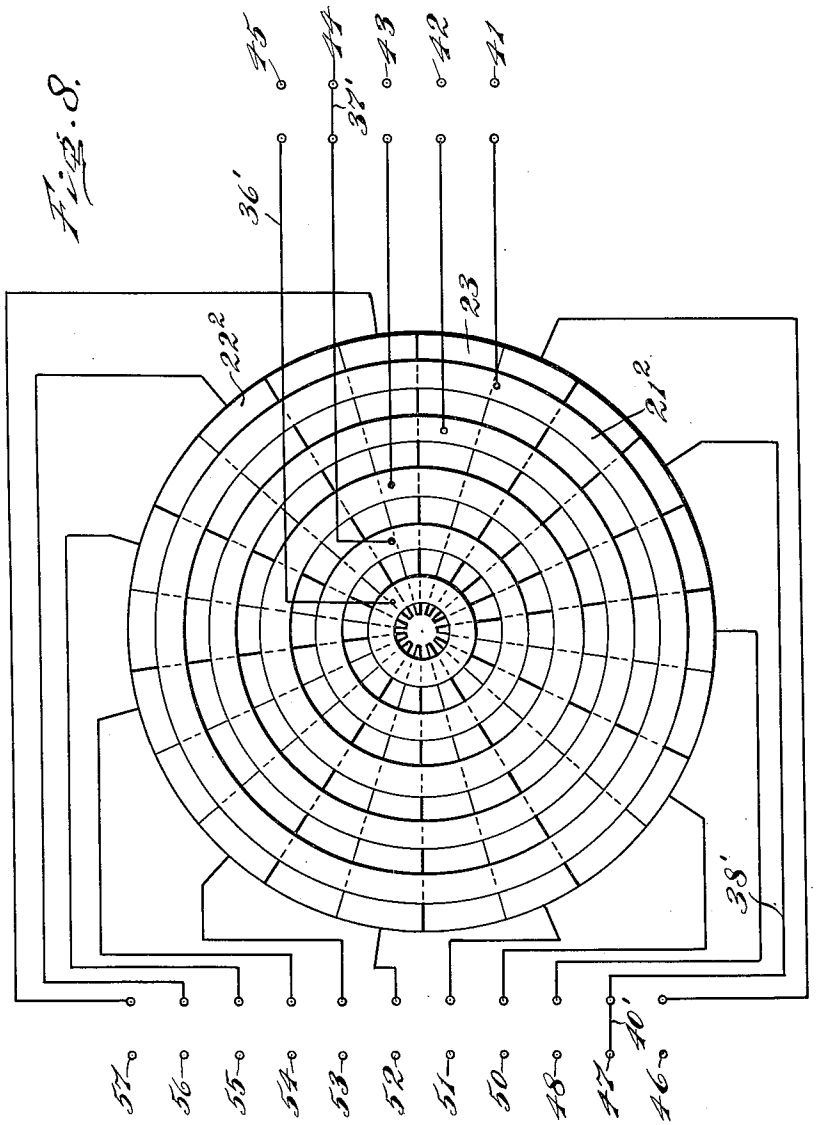
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TRIGGERING ELECTROLUMINESCENT PANELS

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Fig. 8.



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TRIGGERING ELECTROLUMINESCENT PANELS

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Fig. 9.

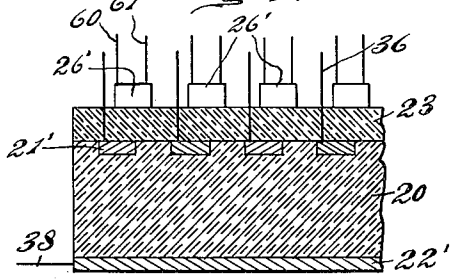


Fig. 10.

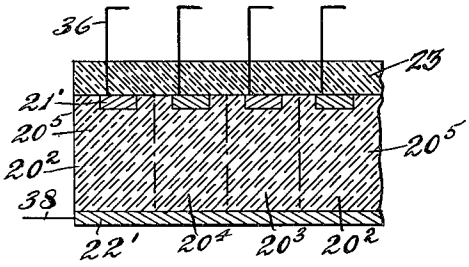


Fig. 9a.

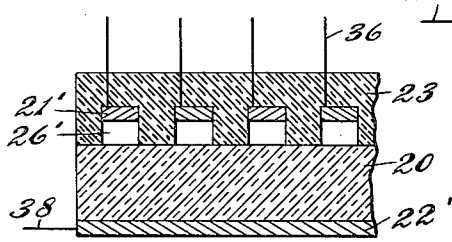


Fig. 12.

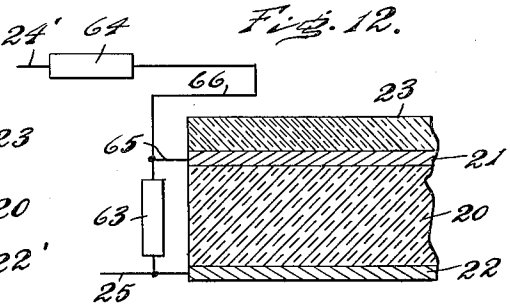


Fig. 11.

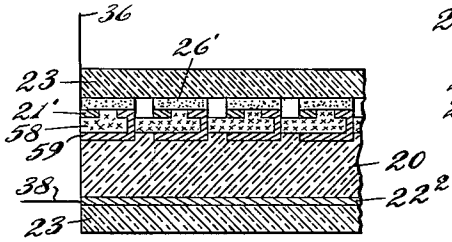


Fig. 13.

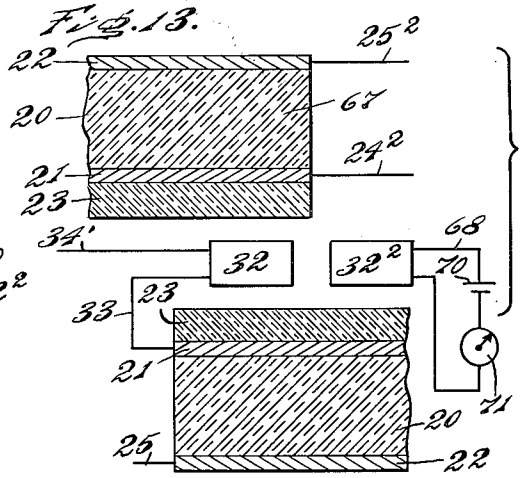
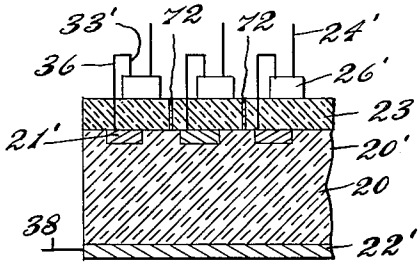


Fig. 14.



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TRIGGERING ELECTROLUMINESCENT PANELS

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Fig. 15.

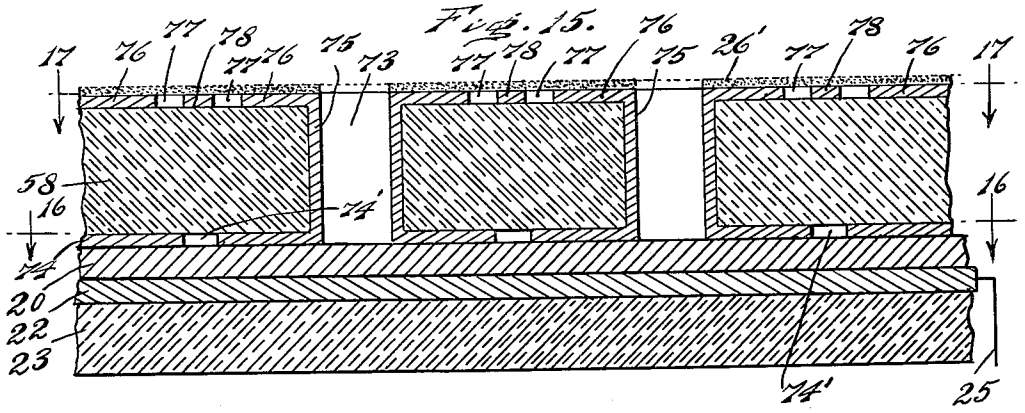
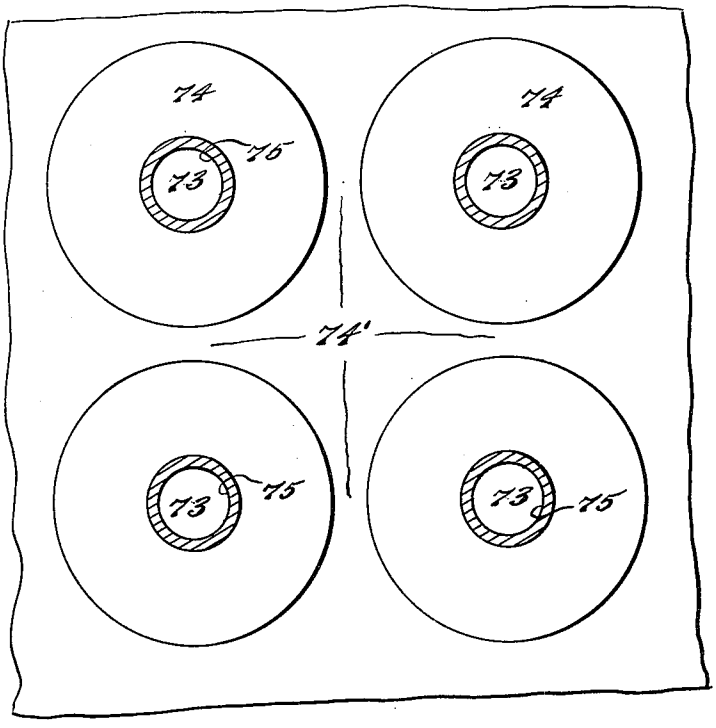


Fig. 16.



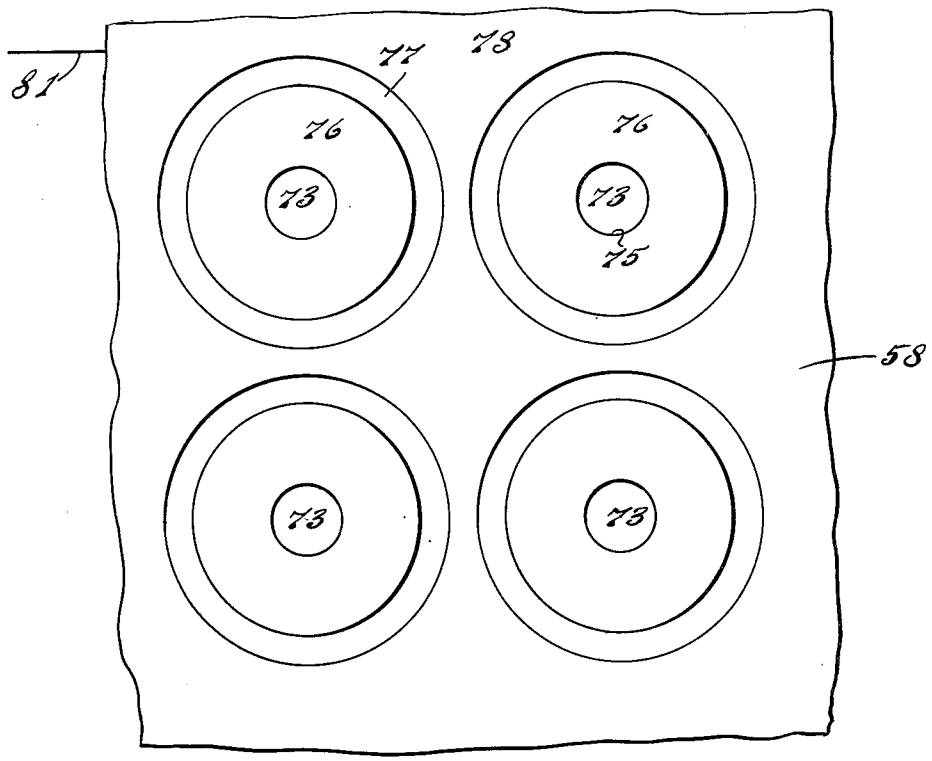
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TRIGGERING ELECTROLUMINESCENT PANELS

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Fig. 17.



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United States Patent Office 3,010,025 Patented Nov. 21, 1961

3,010,025

TRIGGERING ELECTROLUMINESCENT PANELS

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Filed Apr. 20, 1956, Ser. No. 579,571
2 Claims. (Cl. 250—213)

The present invention relates to devices responsive to voltage, which may be employed either as voltmeters, voltage or transient indicators, viewers or screens.

The present invention is a continuation-in-part of our U.S. patent application for Electroluminescent Voltage Device, Serial No. 328,757, filed December 30, 1952.

A purpose of the invention is to render electroluminescent phosphor dispersed in a semitransparent dielectric layer luminous by applying a voltage across conducting layers on opposite sides of the dielectric layer, one of the conducting layers preferably being semitransparent.

A further purpose is to apply a mirror on the conducting layer opposite to the semitransparent conducting layer to direct most of the light through the semitransparent conducting layer.

A further purpose is to render an electroluminescent, semitransparent dielectric layer with impurity centers dispersed therein luminous by applying a voltage across conducting layers on opposite sides of the dielectric layer, one of the conducting layers preferably being semitransparent.

A further purpose is to employ a dielectric having an electroluminescent phosphor content of between 1 and 50 percent on the weight of the mixture and preferably about 30 percent.

A further purpose is to use an electroluminescent dielectric, with impurity centers dispersed therein, having a breakdown voltage greater than 30,000 volts per centimeter.

A further purpose is to employ the dielectric in a thickness between 0.01 millimeter and 0.2 millimeter.

A further purpose is to use a semitransparent conductor layer on the side on which the light is to be observed.

A further purpose is to provide a protecting dielectric layer over the semitransparent conducting layer.

A further purpose is to measure the light, given off by the electroluminescent phosphor, by a photometer.

A further purpose is to interpose a series impedance between the multilayer element of the invention and the source of voltage.

A further purpose is to connect the voltage being indicated to the multilayer element through a photosensitive element receiving light from the multilayer element.

A further purpose is to provide a maintaining voltage across the multilayer element and the photoconductive element to maintain luminescence once it is initiated.

A further purpose is to apply a first set of conducting strips desirably of semitransparent character on one side of an electroluminescent semitransparent dielectric layer having impurity centers dispersed therein and a second set of conducting strips on the other side of the dielectric layer and running at an angle to the strips of the first set, and to cause luminescence at a coincidence point by applying a voltage across one of the strips of one set and one of the strips of the other set.

A further purpose is to apply a multiple set of conducting strips, desirably of semitransparent character or permissibly of metallic wire conductors, on one side of the electroluminescent semitransparent dielectric layer having impurity centers dispersed therein, and a continuous conducting sheet on the other side of said dielectric layer, desirably semitransparent, and to cause luminescence by applying a voltage between certain of the multiple set of conductors and the continuous conducting sheet.

A further purpose is to apply a continuous strip, desirably of semitransparent character or a wire conductor, on one side of or within an electroluminescent semitransparent dielectric layer having impurity centers dispersed therein, and a continuous conducting sheet on the other side of the dielectric layer, desirably semitransparent, and to cause electroluminescence along the continuous strip or wire conductor by propagating an electric pulse along such strip or wire conductor, at the same time keeping the continuous conducting sheet on the other side of the dielectric layer at a potential which is selected according to the decrease of luminescence desired in the dielectric layer.

A further purpose is to apply a first set of conducting strips desirably of semitransparent character on one side of the dielectric layer having the dispersed phosphor and a second set of conducting strips on the other side of the dielectric layer and running at an angle to the strips of the first set, and to cause luminescence at a coincidence point by applying a voltage between one of the strips of one set and one of the strips of the other set.

A further purpose is to modulate the voltage applied to different strips of the respective sets.

A further purpose is to modulate the frequency of alternating current applied across the different strips of the different sets.

A further purpose is to avoid danger of distortion or wandering spot positions and to avoid difficulty with abnormally large spots on the information viewing screen.

A further purpose is to obtain longer life of an information viewing screen.

A further purpose is to secure greater resistance of an information viewing screen to shock and vibration.

A further purpose is to energize an information viewing screen at a voltage less than one thousand volts.

A further purpose is to avoid the flicker present in viewing screens such as the oscilloscope.

A further purpose is to obtain a screen which will not require appreciable depth so that it can be employed as a thin panel or picture.

A further purpose is to energize selectively electroluminescent phosphor radiating a particular color by providing strips of dielectric side by side having electroluminescent phosphor radiating different colors dispersed therein, suitably arranged in sets, such as red, blue and green, and to energize a particular color at a particular location by choice of the conducting strips on the two sides of the dielectric which are energized, a particular conducting strip being individual to a particular color at a particular coincidence point.

Further purposes appear in the specification and in the claims.

In the drawings we have chosen to illustrate a few only of the numerous embodiments in which our invention may appear, selecting the forms shown from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

FIGURE 1 is a front elevation of the basic element of the invention, suitably employed as a voltage indicator, transient indicator, information viewing screen, radar screen, or the like.

FIGURE 2 is a fragmentary enlarged section of FIGURE 1 on the line 2—2.

FIGURES 3 to 6 are views corresponding to FIGURE 2, illustrating variations.

FIGURE 7 is a front elevation of the screen of FIGURE 6.

FIGURE 8 is a front elevation of a variant form of screen according to the invention.

FIGURES 9, 9*a*, 10, 11, 12, 13 and 14 are views corresponding to FIGURE 2, showing further variations.

FIGURE 15 is an enlarged fragmentary section of FIGURE 2, showing a modified embodiment of the invention especially suitable for a storage light amplifier.

FIGURE 16 is a fragmentary section on the line 16—16 of FIGURE 17.

FIGURE 17 is a fragmentary section on the line 17—17 of FIGURE 15.

The invention has many advantages over the cathode ray tube, and over existing voltmeters of the standard moving coil type. It is extremely rugged, and not sensitive to vibration or shock. It has a high impedance, making it valuable for many applications where a high impedance device is desired. The space requirement is not large and particularly the depth requirement is small, thus making it possible to reduce greatly the depth at present required by the oscilloscope.

Furthermore the device of the invention is capable of construction in large sizes, making viewing screens possible which are as large as pictures or as large as motion picture screens.

In all of the forms of the invention, the fundamental characteristics present in the device of FIGURES 1 and 2 are employed. A dielectric layer **20** extends suitably over the whole area of the screen, panel or viewer **19** and has a thickness which is preferably in the range between 0.01 millimeter and 0.2 millimeter. The dielectric is very desirably of a character which has a high breakdown voltage, that is higher than 30,000 volts per centimeter. The device operates at a voltage below the breakdown voltage, and, if the structural requirements permit, the thickness may be even less than 0.01 millimeter with corresponding reduction in voltage, or it may be greater than 0.2 millimeter with corresponding increase in voltage.

The dielectric **20** must, of course, be provided with impurity centers, which contribute to the activation of the dielectric so that the material can become electroluminescent. The impurity centers may also function to induce a state of semiconductivity in the dielectric either per se or as a result of strong electric fields or of radiation.

An electroluminescent material is defined as a material capable of emitting radiation under the action of a strong electric field below its breakdown potential.

The dielectric is semitransparent, and by that it is meant that it is at least semitransparent, since it may of course be fully transparent.

Various materials for the dielectric may be used, depending on the particular requirements. Glass is suitable, permissibly glass having a low melting point. Sheets of semitransparent crystalline salts may also be used, of which zinc sulphide is a suitable example. Transparent plastic or resin dielectrics may be employed, of which vinyl resin and shellac are examples respectively.

Dispersed throughout the dielectric **20** may be an electroluminescent phosphor, which may in the most general form be any phosphor which is energized by subjecting it to the electric field here used. Obviously a wide variety of phosphors are available, and any suitable material can be employed, the examples given merely being suggestive. Where the dielectric is a vitreous material such as glass, zinc silicate, or zinc beryllium silicate, magnesium activated, are desirable phosphors. If a crystalline salt dielectric, such as zinc sulphide or zinc sulphoselenide is used, the dielectric impregnated with copper or manganese activator to act as impurity centers will suitably be its own phosphor. For dispersion in a plastic, such as vinyl resin or a resin such as shellac, the phosphor will suitably be zinc sulphide, lead and copper activated.

The concentration of phosphor dispersed in the dielectric will vary with the particular service requirements but in general should be between 1 and 50 percent of the weight of the mixture of dielectric and phosphor. The lower concentrations of dielectric are usually less desirable because the light intensities are lower, although they are suitable for indicating purposes where the presence of light alone is sufficient. The higher concentrations of phosphor are less desirable because they tend to lower the dielectric properties and interfere somewhat with the transparency. For most purposes it is best to use a concentration of phosphor of about 30 percent by weight.

The character of phosphor will depend also on the time of the repeat cycle. If the device is simply an indicator it may be desirable to use persistent phosphor, but in application having short shift-over time as in television and radar, phosphors of short duration will be preferable. Phosphors of various durations as well known in the art are applicable in the present invention.

On one side of the dielectric layer **20** containing the dispersed phosphor is placed a conducting layer **21**. Where the luminescence is to be viewed from the edge of the dielectric it may be permissible to employ an opaque conducting layer **21**, but in most cases the light from the phosphor should pass through the conducting layer **21**, and the conducting layer **21** should be semitransparent. By this it is meant that it should be at least semitransparent, although it may permissibly be transparent.

The manner of applying the conducting layer **21** to the dielectric will depend upon the character of the dielectric, and the character of the conducting layer. Evaporated metallic layers such as aluminum, silver and gold are suitable for application to any of the dielectrics, the order of thickness being 10^{-5} centimeters so that the metallic layers are semitransparent. In the case of coatings on glass, semitransparent conducting layers are made as described in Leverenz, Luminescence of Solids (1950) 471; Pittsburgh Plate Glass Company Technical Glass Bulletin No. 15 on "Nesa Coated Glass"; Corning Glass Works Bulletin on "E. H. Coated Glass" and T. W. Littleton U.S. Patent 2,118,795, granted May 24, 1938. In one procedure, tin chloride is used to deposit tin oxide. Any other suitable character of conducting layer **21** may be used.

On the opposite side of the dielectric layer **20** from the conducting layer **21**, a conducting layer **22** is placed, which may suitably be of the same character as the conducting layer **21**, except that, since it does not ordinarily need to be semitransparent, it may be thicker, there being no exact limit on thickness. For example, it could be as thick as ⅛ inch, in which case it would provide a structural support for the device. In this case, of course, the conducting layer **22** would be a metallic sheet or plate, such as copper, stainless steel, aluminum, or other suitable electrically conducting structural metal or alloy.

It is preferred to provide a mirror surface on the face of the conducting layer **22** which is directed toward the dielectric layer **20** so that substantially all light will be reflected out through the conducting layer **21**. For this purpose it is preferable to use an evaporated layer of aluminum or silver or a highly polished surface on a sheet of stainless steel, silver or gold, or a chemically deposited silver mirror surface.

As a protection against damage to the conducting layer **21** which is exposed toward the observer, and also to protect the observer against electric shock, a semitransparent dielectric layer **23** is applied on the side of the conducting layer **21** remote from the dielectric layer **20**. The dielectric layer **23** will preferably be thin so as not to cut off much light, and will desirably be a glass sheet or a plastic layer of transparent dielectric such as polystyrene, methylmethacrylate, ureaformaldehyde or polyvinylchloride.

The element, as shown in FIGURES 1 and 2, which is employed with some modifications in the other forms, is for the sake of convenience referred to elsewhere herein as a multilayer element, and consists of the electroluminescent dielectric layer **20** will impurity centers dis-

persed therein, and the conducting layers 21 and 22 on the opposed sides thereof.

It will be evident that the device of FIGURES 1 and 2 can extend over considerable areas, the only limitations being increase in capacity and increase in leakage current, and can be mounted substantially flat against or adjoining walls, without requiring the depth away from the observer which is necessary in an oscilloscope.

The invention is applicable as shown in FIGURES 3 and 4 to a specialized type of voltmeter known as a transient indicator. A lead 24' from one side of the voltage being measured is connected to one terminal of photocell 32, the other terminal of the photocell being connected by lead 33 to conducting layer 21. Instead of the photocell 32, a photoconductive element 32' may be employed, as shown in FIGURE 4. In either of the forms of FIGURES 3 and 4, the light produced in the electroluminescent dielectric with impurity centers dispersed therein passes through the conducting layer 21 and reduces the impedance of the photoresponsive element 32 or 32'. If all applied voltage ceases, the light will be extinguished except for the afterglow, but if some applied voltage remains, even though it is not at the peak, the voltage applied across the multilayer element is a larger proportion of the total voltage because the photoresponsive element reduces its impedance when it is lighted. Therefore if the remaining voltage applied across the multilayer element is greater than the cut-off voltage, the luminescence will remain for an additional period of time.

In the form of FIGURE 5, the transient indicator will trigger and remain luminous. In this form, in addition to the lead 24' applied to the input side of the photocell 32, a lead 34 from a suitable source through impedance 35 is applied to the input side of the photocell to introduce a maintaining voltage across to the lead 25. In view of the high impedance of the photocell 32 when the electroluminescent dielectric with impurity centers dispersed therein is not luminous, the maintaining voltage between the leads 34 and 25 is insufficient to permit the multilayer element to be luminous, but when the transient voltage across between leads 24' and 25 renders the dielectric luminous, the light received in photocell 32 reduces its impedance to such an extent that a higher fraction of the maintaining voltage is applied across the multilayer element, and this being above the cut-off voltage, maintains the multilayer element luminous indefinitely.

The impedance 35 prevents the transient from being dissipated in the maintaining circuit.

In many cases it is necessary to record not a single voltage transient but a multiplicity of them. In these cases it is convenient to set up, instead of an array of single transient voltage indicators as shown in FIGURE 5, a panel embodying several indicators like FIGURE 5 in a single unit.

Various embodiments are possible for the generalization of the multilayer shown in FIGURE 2, which multilayer is limited to the impression of a single voltage at any given time. Two simple devices of this character are shown in FIGURES 6 and 10 referred to below.

In the embodiment of the voltage indicator shown in FIGURE 12, the multilayer element is used in parallel with a variable impedance 63 whose impedance falls as the voltage across it increases. Such impedances are described in the literature in 13 Oscillographer 15 (No. 3, July-August 1952) and are sold under trade names such as Thyrite and Varister. In this device the voltage indicated is impressed across an impedance 64, suitably a resistor, in series with a multilayer element which is in parallel with the impedance 63. The multilayer element has a terminal 65 connected to the conductor 21 and a terminal 25 connected to the conductor 22. A suitable lead 24' from one side of the source of voltage being indicated is connected to one terminal of the impedance 64, the other terminal of which is connected through the lead 66 to the terminal 65. The terminals of the variable impedance 63 are connected to the terminals 65 and 25 respectively of the multilayer element. This circuit device reduces the possibility of the voltage across the multilayer element exceeding the breakdown voltage because at high voltages the impedance of the variable impedance 63 falls. Therefore the voltage across the multilayer element does not increase as rapidly as it would if the variable impedance 63 in the parallel path were not present. The same function may be achieved by using for the variable impedance 63 a photoresponsive device, which is positioned to receive a fraction of the radiation from the multilayer element comprising 23, 21, 20 and 22. By choosing a photoresponsive device with suitable impedance ratio to that of the multilayer element, the impedance of the photoconductor 63 can be made to fall below that of the multilayer element as the voltage across the multilayer element becomes excessive. As a consequence the radiation emitted cannot become higher than that for safe operation of the multilayer element.

However, the assembly is still liable to damage from very rapid transients. To prevent this possibility, the photo-responsive device 32, from which one lead 33 is connected to the conductor 21 of the associated multilayer element, is energized by radiation from a separate multilayer element 67, to which a transient is applied through leads 24^2 and 25^2 as shown in FIGURE 13. This form is really a variation of FIGURE 3.

Once the transient has caused the multilayer element 67 to give off radiation and this radiation has triggered the photoresponsive device 32, and the multilayer element at the bottom of FIGURE 13, consisting of the dielectric layer 20 and the conducting layers 21 and 22, has become luminous, the maintaining voltage applied to the terminals 34' and 25 is of such a level as to maintain the multilayer element in continuous radiation. However, the maintaining voltage is sufficiently low so that the multilayer element at the bottom of FIGURE 13 remains dark until the photoresponsive device 32 is triggered by radiation from the multilayer element 67. This radiation from the multilayer element 67 is a consequence of a transient voltage pulse being impressed on the multilayer element 67.

In certain circumstances the passage of the transient voltage pulse may be extended not by observing the radiation from the multilayer element at the bottom of FIGURE 13, but by ascertaining electrically the impedance of another photoresponsive device 32^2, whose impedance is influenced only by the multilayer element at the bottom of FIGURE 13. The impedance of the photoresponsive device 32^2 is conveniently measured in a circuit 68 having a source of alternating or direct current 70 and a suitably sensitive meter 71 in series with the photoresponsive device. A photoresponsive device, as the term is used herein, refers to a device whose impedance at a definite A.C. voltage and frequency, or in certain circumstances at a definite D.C. voltage, is a function of the radiation incident on it. Such devices include photocells, phototransistors and photoconductors.

In the form of FIGURES 6 and 7, the conducting layer on one side of the dielectric is not continuous, but consists of a series of separate strips 21' side by side and desirably parallel. They are insulated from one another by the intervening portions 20' of the dielectric layer 20. The strips 21' will very desirably be semi-transparent although since light can pass through the spaces between the strips it will be evident that light is visible at the front even though the strips 21' are opaque.

Any suitable way of applying the strips can be employed, one method being to evaporate a suitable metal such as aluminum, gold or silver on the dielectric through a mask consisting of separated ribs which prevent the evaporated metal from coating the areas between the strips.

On the opposite side of the dielectric layer 20 con-

taining the dispersed phosphor is placed a series of conducting strips 22' which are side by side in spaced relation and preferably parallel but which desirably are transverse to or at least at a substantial angle to the strips 21'. Thus there is for each strip 21' a point of coincidence with each strip 22' and if one strip 21' and one strip 22' only are energized at a particular instant, the phosphor is luminous at that point of coincidence only. It is therefore merely necessary to carry out individual leads 36 from the individual strips 21' to a selector switch 37 and to carry out individual leads 38 from each of the strips 22' to a selector switch 40, in order to be able to energize any chosen coincidence point having desired X and Y coordinates. Thus a raster or picture can be formed on the screen by successively energizing different coincidence points at short time intervals within the persistance of vision period, similar to the raster produced by the oscilloscope. This can be combined with the usual scanning technique to produce a large number of energized coincidence points in a short time interval. Thus the screen is applicable for animated electric signs, animated pictures, motion pictures, radar viewing screens, television screens and the like.

Of course the switches 37 and 40 are merely diagrammatic, and will take any desired form. In the case of electric signs they may be sign flashers, such as rotary commutator switches and they may be switching tubes such as the well known 12-position Phillips switching tube, or they may be step selector switches of the type commonly employed in telephone exchanges.

Instead of dividing the conducting layers 21 and 22 into strips on rectilinear coordinates, they may be divided according to any other system, for example employing annular strips 21^2 of progressively larger diameter for one conducting set of strips arranged side by side and radial segmental strips 22^2 of general wedge shape for the other conducting strips. This latter type of subdivision as shown in FIGURE 8 connects by leads 36' to a selector switch 37' and by leads 38' to a selector switch 40', the selector switches here being shown as step by step switches.

The device may be used as an adjunct to an oscilloscope instead of to replace the oscilloscope, for example by placing the screen of the invention in parallel with the oscilloscope and using it as an enlarger or image amplifier.

It is desirable in some cases to apply different voltages between different conducting strips 21' and 22' or 21^2 and 22^2, and this can readily be done with the step by step switching, the applied voltage for example on terminals 41 to 45 and 46 to 57 being progressively different, either to allow for differences in leakage currents, or to obtain different colors of phosphor radiation, or different intensities of phosphor radiation. In some instances a change in intensity or a change in hue is preferably introduced by difference in frequency. In this case the frequencies applied to the terminals 41 to 45 and 46 to 57 may vary to create different intensities or different color effects in different areas, the differences in intensities and color effects being obtained either from the same phosphor or preferably from a mixture of phosphors.

The invention has a great advantage over the oscilloscope when used in the forms of FIGURES 6 and 7 and FIGURE 8, because there is no danger that distortion or other conditions will cause the spot to wander or will create a spot of abnormally large size. Furthermore the structure is of longer life than the oscilloscope, will operate at potentials below a thousand volts, and in some cases well below such potentials, while the oscilloscope ordinarily will not, and is much more sturdy and resistant to vibration and shock. The device of the invention also eliminates flicker which is objectionable, particularly for television, and is capable of being employed in large relatively thin structures such as signs. For the purpose of erasing it is merely necessary to reduce the voltage to zero for a few microseconds in the case of a nonpersistent phosphor as in the retracing time of a television scanner. On the other hand, a display can be frozen by maintaining the same sequence of energizing and omitting the erasure.

The invention is applicable also inside the cathode ray tube, as well as for use independently.

The structure as shown, for example, in FIGURES 6 and 7 can be employed with photometers 26' placed at various coincidence points of the conducting strips 21' and 22', in order to indicate luminescence at particular areas, as for example in radar applications. The individual photometers 26' may record or may trigger alarms or signals as desired. The arrangement with the photometers 26' is shown diagrammatically in FIGURE 9.

The elements at 26', instead of being photocells, can simply be blocks of photoconductive material provided with suitable leads 60 and 61 to the indicating circuits and responding to change in impedance when light is present.

The invention is applicable for presentation of color by a screen, as already explained, through modulation of voltage or frequency. Color presentation is also accomplished, as shown in FIGURE 10, by dividing the dielectric layer 20^2 into a series of strips 20^3, 20^4 and 20^5, arranged side by side, but including only dispersed phosphor radiating different colors in the different strips. Thus strips 20^3 may have phosphor fluorescing red, strips 20^4 fluorescing blue, and strips 20^5 fluorescing green, and these strips recure in repeated cycles over the entire screen. Each conducting strip 21' extends along one of the dielectric strips 20^3, 20^4, or 20^5 having the particular color of phosphor. Thus the selector switches 37 and 40 determine not only the location of luminescence, but each of the strips 21' which will cause luminescence of a particular color to be energized in coincidence with the proper one of the strips 22' which determines the location. Any suitable definite pattern of color strips may be employed, but in each case preferably only phosphor fluorescing in one color adjoins a particular conducting strip 21'.

It will thus be evident that the invention makes it possible for the designer to create screens of a wide variety of sizes and contours adapted to many uses in signal communication and amusement devices.

Although the embodiment shown in FIGURE 10 has been discussed with the dielectric 20 in the form of strips 20^3, 20^4, and 20^5, having phosphors radiating different colors dispersed in them, the same embodiment is applicable to the case where the strips 20^3, 20^4 and 20^5, which luminesce in different colors, are composed of electroluminescent semitransparent dielectrics with impurity centers, the dielectrics and impurity centers in the different strips being selected so that the strips luminesce in the desired colors.

It is obvious that in the embodiments shown in FIGURES 6, 7, 8 and 10 the electroluminescent dielectric with impurity centers dispersed therein at the point of intersection of the selected conducting strips X' and Y' of the sets 21' and 22' will radiate as long as the large potential difference is applied between them. However, by applying the storage effect discussed above in reference to FIGURES 3 and 4 this restriction can be relaxed. In this way any particular point of intersection can be made to radiate by applying a high voltage pulse between the two conducting strips X' and Y' intersecting at this point. The same point will continue to radiate after the voltage pulse has passed if a moderate potential difference is applied between the same two strips X' and Y'. If such a moderate potential is applied before a high voltage pulse, it will produce only weak, if any, radiation. On the other hand, if it is applied during and after the high voltage pulse has passed, it will cause the radiation to continue with at least moderate intensity as long as this moderate potential is maintained.

When the panel is used as an enlarger or image amplifier, the photocell **32** or the photoconductor **32'** of FIGURES 3 and 4 will still be placed above the conductive coating **21** but with the photosensitive surface facing away from the layer **21**. The voltage applied across the photosensitive surface and the multilayer element between the terminals **24'** and **25** must be fixed so that the voltage is just below the value at which the multilayer element becomes luminous. Then when light shines on the photosensitive surface, the panel will become luminous as viewed from the opposite side through the transparent layer **22**. This will be the case even though the panel was dark but the impedance of the photosensitive element **32** or **32'** was lowered by the incident radiation.

In FIGURE 9*a* the coincidence points of the conducting strips **21'** and **22'** have variable impedances, suitably photoconductors, **26'** positioned between the conducting strips **21'** and the electroluminescent semitransparent dielectric **20**. The variable impedances **26'** can be simply blocks of photoconductive material making electrical contact to the strips **21'** at the area of coincidence. These photoconducting blocks **26'** are also positioned so that part of the electrical potential difference between any two conducting strips X' and Y' is applied across the block **26'** lying at the point of coincidence and part through the electroluminescent semitransparent dielectric **20**.

In this structure the peak potential difference applied between X' and Y' reduces the impedance of the corresponding element **26'** so that a greater fraction of the potential difference applied between X' and Y' is applied across the electroluminescent dielectric **20**. This peak potential must be sufficiently high so that the electroluminescent dielectric **20** is made to radiate. For certain applications the element **26'** may be an impedance whose value is determined by the potential applied across it. An example of it is a variable condenser whose capacity increases with the potential applied across it. When the element **26'** is a photoconductor, the moderate value to which the peak potential falls can be selected so that the electroluminescent dielectric **20** continues to radiate as long as that moderate potential is applied. The moderate value for the voltage may be so low that no radiation would be produced if it were applied without the previous action of a high voltage pulse.

The structure of FIGURE 9*a* will where desired be operated as an image amplifier. For this application, external radiation is made to shine on the structure through the transparent layer **23**. Since the strips **21'** are at least semitransparent, the external light or radiation will lower the impedance of the photoconductors **26'**. If the external radiation has sufficient intensity, then the voltage difference applied across the electroluminescent dielectric **20** will become sufficient to make it luminous provided the aforesaid moderate potential difference is applied between the strips **21'** and **22'**. In this embodiment, the conducting strip **22'** must of course be at least semitransparent since the luminescence of the panel is viewed from that side.

The structure of FIGURE 9*a* can be modified still further as shown in FIGURE 11 to make it easier to fabricate. In this embodiment the semitransparent conducting strips **21'** are no longer insulated electrically from each other but form part of a pattern of conducting films connected to one side of the individual photoconducting elements **26'**, the films **21'** being all at the same potential. The conducting strips **22'** are replaced by a continuous semitransparent conducting layer or film 22^2 at the other potential. The moderate potential difference which supplies the energy to the system is applied between the conducting elements **21'** and 22^2 through leads **36** and **38** respectively. The light which activates the device shines through the glass or other transparent insulating cover **23** on the individual photoconducting element **26'**. As already explained in connection with FIGURE 9*a*, if the moderate potential difference has a suitable value, the electroluminescent phosphor in layer **20** will glow in those regions which are in 1-to-1 correspondence with the regions where the photoconducting elements are located which have their impedance lowered by the activating light. This radiation is viewed through the semitransparent conducting layer 22^2 and through the bottom transparent cover **23**.

There is an additional structural element introduced in FIGURE 11. It has an insulating sheet **58** suitably of glass on which the photoconductors are positioned or mounted. The sheet **58** will suitably be semitransparent where desired. One voltage terminal for the photoconducting elements is applied on this insulating sheet. This voltage terminal will suitably be in the form of the semitransparent conducting films **21'**. If the insulating sheet **58** is glass, the semitransparent films **21'** may be a suitable NESA pattern on the glass. As is shown in FIGURE 11, the photoconducting blocks or layers are not positioned directly between the semitransparent conductors **21'** and the electroluminescent dielectric **20** as is the case in the embodiment shown in FIGURE 9*a*. In FIGURE 9*a* the voltage between **21'** and **22'** is applied directly across the photoconductor **26'**. Similarly in FIGURE 11 if the potential between the conductors **21'** and 22^2 is to be divided between the photoconductor **26'** and the electroluminescent layer **20**, then the electrode other than **21'** on the photoconducting blocks or layers must direct contact with the electroluminescent layer **20**. To make effective contact to the electroluminescent layer **20**, the insulator **58** is slotted with channels, one for each photo-responsive element **26'**, in the simplest arrangement. Through these channels an electrical contact **59** is made between one end of the photoconducting elements **26'** remote from the contact **21'**, and to one side of the electroluminescent layer **20** removed from the other semitransparent conductor 22^2.

It may occur that the amount of light feedback from a radiating region of the electroluminescent layer **20** into the photoconductor **26'** is sufficient to reduce the impedance of that photoconductor **26'** which is directly over the radiating region and whose impedance controls the brightness of the region. As a result, the radiating region which fed light back to the photoconductor **26'** will remain luminous even after the activating radiation shining on that particular photoconductor **26'** through the upper cover **23** has been cut off. The amount of radiation feedback will depend on the transparency of the insulating layer **58** and of the electrical contact **59**.

In case the electroluminescent dielectric with impurity centers **20** is a variable semiconductor, the function of the variable impedance **26'** can be assumed by the electroluminescent dielectric **20** itself. In this class of electroluminescent dielectric with impurity centers, the radiation is emitted at the conductor-dielectric interface, i.e., at the interface between **21'** and **22'** respectively and **20**, as shown in FIGURE 6. Thus any reduction in the volume impedance of the electroluminescent dielectric **20** will allow a greater fraction of the potential difference between X' and Y' to be applied at the interface with a corresponding increase in light output.

The photoresponsive device, which can be a photocell, a photoconductive element or a photometer, is suitably applied locally as shown in FIGURE 14 to receive radiation only from a definite region of the multilayer element excited by voltage impressed between a definite pair of conductive strips on opposite sides of the dielectric or a conductive strip on one side and a common conductor on the other side. Thus the voltage applied can be separately determined and separately evaluated.

A multiple unit having the triggering action in accordance with this conception appears in FIGURE 14. In this case a lead **33'** from one side of each photoresponsive device **26'** is connected to a lead **36** from the adjacent conductive strip **21'**. To reduce the influence of the radiation of one strip other than the one with which the photo[illegible]ve device is associated [illegible]

parent sheet **23** is desirably provided with opaque areas **72** extending longitudinally in the zones between strips **21'**. Glass plates of this character are on the market, produced by Corning Glass Works, known as Foto Form B. Any other suitable means may be used to protect one photoresponsive device from radiation from adjoining areas.

In this discussion, variable semiconductor means a semiconductor whose impedance can be reduced either by the direct action of an intense electric field or by the action of radiation.

The form of FIGURES 15 to 17 inclusive illustrates a detailed structural analysis of a specific type of storage light amplifier based on the design shown in FIGURE 11.

For more detail on this device see article by Jenny Bramley (under her professional name) 43 Proceedings of IRE (December 1955), 1882, "Theory and Experiments of a Basic Element of a Storage Light Amplifier." The device stores and radiates a pattern impressed upon it as long as electrical power is supplied. The intensity of the re-emitted pattern may be greater than, equal to or less than that of the original pattern. The sustaining intensity of the device is obtained by feedback.

In the device shown in FIGURES 15, 16 and 17 the glass plate **23**, the semitransparent conducting layer **22** and the dielectric layer **20**, having electroluminescent phosphor dispersed therein, may suitably be as shown in the other forms. The rest of the structure is modified to include a glass plate **58** having holes **73** formed therein transverse to the front of the storage amplifier and extending over the storage amplifier as a pattern best seen in FIGURES 16 and 17. Surrounding each hole on the side of the glass plate **58** toward the dielectric layer **20** there is a conducting area in the form of layer **74** (desirably circular) on the glass surface. Separating each conducting area **74** from the next is an insulating area **74'** on the glass surface. Connected with each area conducting layer **74** is a conducting layer **75** on the inside of each hole **73**, and an outwardly extending suitably circular area conducting layer **76** on the outer face of the glass plate **58** which is connected with the conducting layer **75**.

The area conducting layers **76** are suitably circular and terminate in insulating gaps **77** and radially outside the gaps between the conducting layers **76** over other areas of the glass plate on the surface remote from the dielectric layer **20**, there is a continuous conducting layer **78**.

Over the conducting layers **76** and **78** and across the insulating gaps **77** extends a photoresponsive layer **26'**.

At the edge an electrical connection **81** is made to the layer **78**, and an electrical connection **25** is made to the conducting layer **22** and a maintaining voltage suitably of alternating current is applied between electrical connection **81** and electrical connection **25**.

In the specific example, the conducting layers were NESA layers. The electroluminescent layer **20** was about 0.0025 inch thick consisting of a resin impregnated with green phosphor powder, as later explained. The glass plate **58** was about 0.015 inch thick and the diameters of the holes **73** were about 0.017 inch measured at the center of the glass. The NESA layer **74** makes intimate contact with the top surface of the electroluminescent layer **20**. The diameters of the conducting areas **74** were about 0.20 inch and the width of the minimum separations of the conducting areas **74** across the insulating areas **74'** was about 0.010 inch. The photoresponsive layer **26'** was cadmium sulphide evaporated onto the top of the NESA layers **76** and **78** suitably according to the technique of A. Bramley, 98 Physical Review 246 (April 1, 1955).

When the cadmium sulphide photoresponsive layer is exposed to different light levels its resistance across gap **77** in the NESA coatings changes.

The conducting rings **76** are about 0.010 inch in diameter and the insulating gaps **77** are about 0.012 inch wide.

It will be evident that the basic design of the display area can be repeated in any appropriate pattern over the screen.

The various conducting areas **74** should be separated by a minimum width of the insulating areas **74'** which is suitably greater than the thickness of the electroluminescent layer **20** (which is desirably 0.0025 inch) in view of the fact that there are several different areas **74**. This minimizes the possibility of arcing across the gap.

A suitable center-to-center distance of the holes is 0.080 inch. For the equivalent resolution of a 525 line raster, this requires over-all dimensions of 42 inches, slightly larger than the usual television raster.

It is evident that the photoconductor area at the gap of slot **77** is only a small fraction of the total area of the device illuminated by the incident light. This causes no difficulty.

The brightness levels of the incident light energizing the unit need not be in excess of 1 foot-lambert, while the lowest brightness level should be greater than 0.2 foot-lambert for reliable response. The triggering light flux should be incident on the photoconductor for a few milliseconds, which is sufficiently greater than the minimum responsive time of the photoconductor. It will be evident, of course, that by lenses or other optical means, the light can be concentrated on the areas over the slots **77**.

It will be evident that provided the photoconductor is selected so that its impedance is lowered by electron bombardment, the device can be the target of a cathode-ray tube. Ultraviolet rays or X-ray radiation can also be used to energize the photoconductor.

In the preferred embodiment the dielectric used was polyvinylchloride resin. The electroluminescent phosphor-resin matrix consisted of approximately 22.5 percent by weight of phosphor powder, 15 percent by weight of VYNS resin and the remainder isobutyl ketone solvent with a small amount of plasticizer DOPE (Americian Cyanamid Co.).

This mixture was ballmilled for 48 hours and then applied to the NESA layer **22** on the gas plate **23** by a draw plate. Finally the phosphor resin matrix was heated to about 110 to 200° C. with the top plate in position and was subjected at this temperature for a few minutes to a pressure of a few p.s.i. On cooling the panel was firmly bound.

For best results the impedance of the photoconductor in the dark should be matched against that of the electroluminescent element. In the particular example the impedance of the multilayer element at 200 cycles per second was 32 megohms, this is the order of magnitude required of the dark resistance of the photoconductor across the gap **77**.

The following procedures may be used to form the photoconducting layer: evaporation, or flow coating finely divided crystalline photoconducting particles in a plastic matrix over the glass surface with the conducting areas **76** and **78**.

For the last method, the particles therein should be less than 0.001 inch, that is, less than the thickness of the electroluminescent layer. However, it has been found that layers of very fine cadmium sulphide particles have a low sensitivity. This may be due to failure to obtain particles of uniformly high sensitivity.

Evaporation is the most suitable method of deposition. Combined with suitable processing, it gives a cadmium sulphide layer with good photoconducting properties, which is sensitive not only to visible radiation in the green and blue but also extremely sensitive to ultraviolet radiation and to X-ray. Thus various wave radiations can be utilized.

Since both electrodes are NESA coated, the element obviously shows no photovoltaic effect. The breakdown voltage of the cadmium sulphide film for a 0.012 inch gap is well over 300 volts D.C.

Another advantage of these evaporated cadmium sulphide films is that they have high dark resistance.

The voltage maintained is preferably 250 to 500 volts at audio frequency such as 20 to 2000 cycles per second.

In operation, it will be evident that when the photoconductor is dark, at the particular location or spot on the glass, the resistance of the photoconductor across the gap 77 is very high and therefore the energy drop between the conducting film 74 and the conducting film 22 is so low that the multilayer element does not luminesce. On the other hand, when the particular area or spot on the glass is subjected to illumination or other radiation, the impedance of the photoconductor across the gap 77 drops markedly, and therefore the voltage drop impressed at that point between conducting layer 74 and conducting layer 22 increases, and luminescence is caused in the multilayer element at that localized area or spot. This luminescence remains as long as the maintaining voltage is applied and as long as the photoconductor receives radiation to lower its impedance.

It will be evident, of course, that the light can be seen either through the bottom glass 23, if the conducting layer 22 is translucent, or possibly through the glass 58 and the translucent conducting and photoconducting layers.

In view of our invention and disclosure, variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of our invention without copying the structure and method shown, and we, therefore, claim all such insofar as they fall within the reasonable spirit and scope of our claims.

Having thus described our invention what we claim as new and desire to secure by Letters Patent is:

1. In a light storage device, an electroluminescent semitransparent dielectric layer having impurity centers dispersed therein, making the dielectric an impurity semiconduction, a plurality of separate area first conducting layers on one side of the dielectric layer, a second conducting layer on the other side of the dielectric layer, at least one of the first and second conducting layers being semitransparent, a semitransparent dielectric sheet on the side of the first conducting layers remote from the semitransparent dielectric layer, the dielectric sheet having a hole extending therethrough in each area, a plurality of separate third conducting layers on the side of the dielectric sheet remote from the first conducting layers, an electrical conductor connecting the first and third conducting layers through the hole in each area, a fourth conducting layer positioned on the side of the dielectric sheet remote from the first conducting layer and spaced from the third conducting layers by gaps, a photoresponsive layer extending over the third and fourth conducting layers and across the gaps, the photoresponsive layer being adapted to vary its impedance across the gap depending upon the presence or absence of radiation, and electrical connections to supply maintaining voltage to the fourth conducting layer and to the second conducting layer.

2. In a light storage device, a semitransparent electroluminescent layer comprising a dielectric and electroluminescent phosphor dispersed in the dielectric, a first conducting layer on one side of the dielectric layer and in contact therewith in a localized area, there being electrically separate first conducting areas in different localized areas, a second conducting layer on the other side of the dielectric layer and in contact therewith, at least one of the first and second conducting layers being semitransparent, a photoconductor at each area connected to the first conducting layer in that area on the side of the first conducting layer remote from the dielectric layer and adapted to change its impedance in accordance with radiation received by the photoconductor in the localized area, a third conducting layer on the same side of the dielectric layer as the first conducting layer and separated from the first conducting layer in each localized area by a gap, the gap being bridged by the photoconductor, a dielectric sheet on the side of the first conducting layer remote from the dielectric layer, there being a hole through the dielectric sheet in each localized area, the first conducting layer extending through the holes and over the dielectric sheet in a localized area on the side remote from the dielectric layer and forming one side of the gap with the third conducting layer on such remote side, the photoconductor being distributed over the outside of the dielectric sheet remote from the dielectric layer, and means for impressing and maintaining a source of A.C. voltage across between the third conducting layer and the second conducting layer.

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