Feb. 16, 1960 D. W. DAVIS 2,925,525

IMAGE REPRODUCING DEVICE

Filed April 26, 1954 2 Sheets-Sheet 1

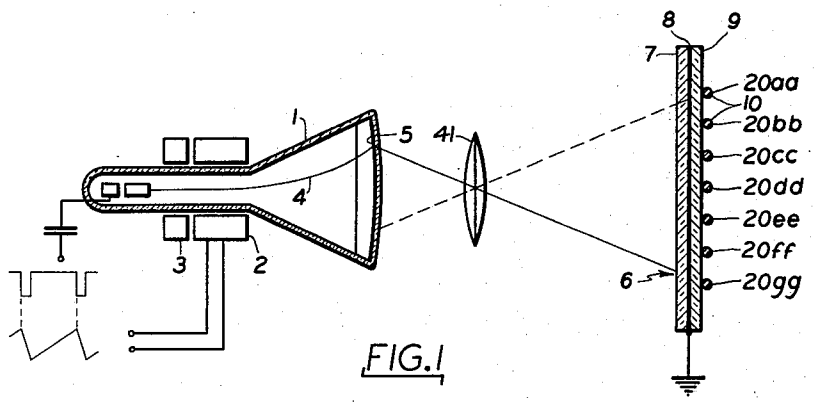


FIG. 1

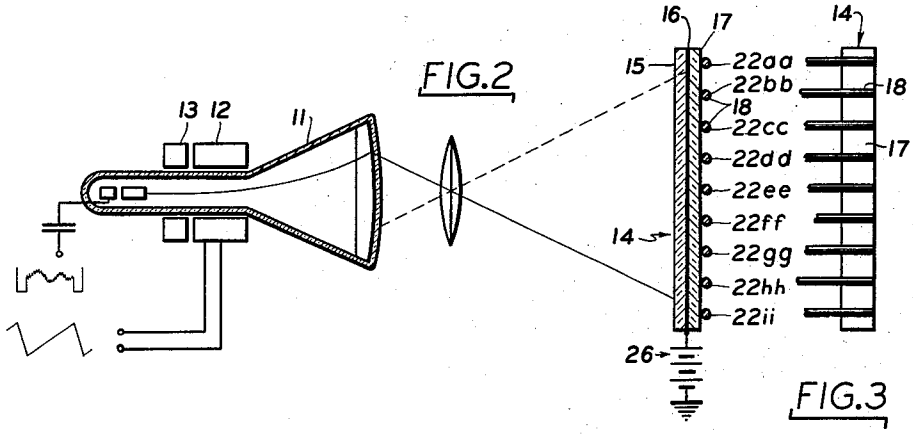


FIG. 2

FIG. 3

FIG. 4

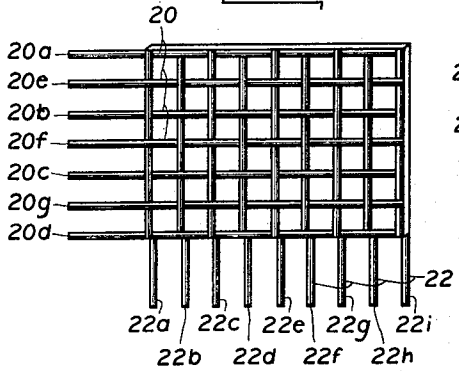
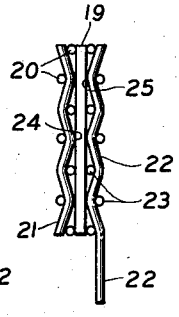


FIG. 5



INVENTOR.
DEAN W. DAVIS

BY

George A. Gust
ATTORNEY

Feb. 16, 1960 D. W. DAVIS 2,925,525

IMAGE REPRODUCING DEVICE

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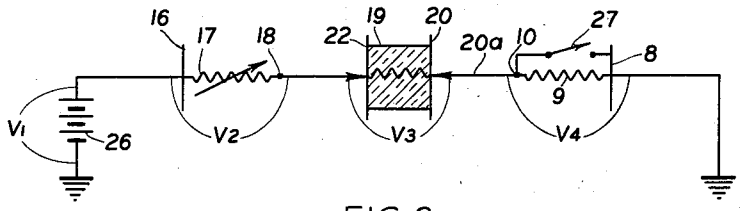


FIG.6

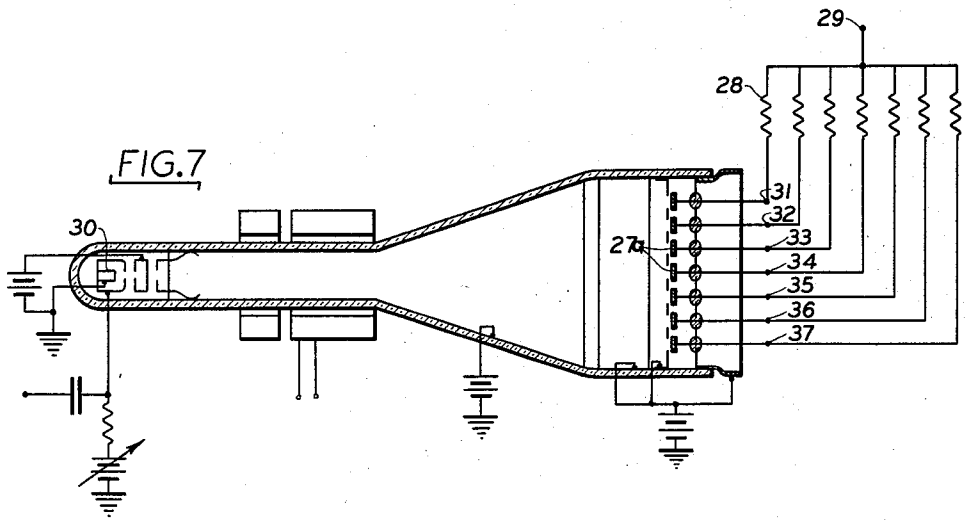


FIG.7

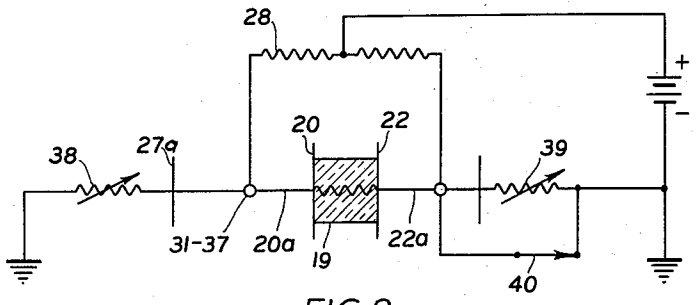


FIG.8

INVENTOR.
DEAN W. DAVIS

BY

George R. Gust

ATTORNEY

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2,925,525

IMAGE REPRODUCING DEVICE

Dean W. Davis, Fort Wayne, Ind., assignor to International Telephone and Telegraph Corporation

Application April 26, 1954, Serial No. 425,559

6 Claims. (Cl. 315—10)

The present invention relates to an image-producing device and more particularly to an apparatus for reproducing radiation images on a viewing screen.

This invention contemplates the utilization of a dielectric material or phosphor which is excitable to luminescence by the application of a variable electric field thereto. A typical suitable material known in the art to which this invention appertains is a copper activated zinc oxide and zinc sulphide mixture as explained by Destriau in the 1937 edition, volume 38, of Philosophical Magazine on pages 700–739, 774–793 and 800–887, and has been characterized as "electroluminescent." One method of exciting this material is to apply a variable A.C. voltage to two opposite electrode plates having the electroluminescent material therebetween, the resulting structure resembling that of a simple parallel plate condenser.

Several applications have been submitted to the art as being practical, which include, among others, use in illuminating lamps and in radiation amplifiers such as that disclosed in Orthuber et al. application Serial No. 385,802, filed October 13, 1953, now Patent No. 2,837,660.

An object of this present invention is to provide a display device for producing radiation images.

It is another object of this invention to provide a radiation display device composed of an electroluminescent phosphor viewing screen and an image signal control device electrically coupled to but physically separated from said screen, the control device serving to apply image information to the screen for display reproduction by the latter.

It is still another object of this invention to provide an image screen using an electroluminescent phosphor panel which converts voltage differences into light output, such voltage differences being applied to said panel in spaced discrete elemental areas corresponding to elements of an image to be reproduced.

In accordance with the principles of this invention, an image reproducing device is provided which includes an electroluminescent phosphor panel contained between electrode members which apply control voltages to elemental areas of the panel in accordance with an image which is to be reproduced. The control voltages are supplied to the electrode members by means of a voltage-varying apparatus controlled to produce different voltages which correspond to elemental areas of an image. This voltage-varying apparatus may take different forms, two of which are disclosed and described in detail hereinafter. Generally, one device utilizes a photoconductive material for varying the voltages applied to the electroluminescent panel, and the other device utilizes an electron beam for accomplishing the same end.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawings, the scope of the invention being defined by the appended drawings.

In the drawings:

Fig. 1 is a diagrammatic sectional illustration of one voltage-varying apparatus which may be used in controlling the reproduction of an image by an electroluminescent phosphor screen;

Fig. 2 is a sectional illustration of a similar voltage-varying apparatus used in conjunction with the device of Fig. 1 for reproducing the aforementioned image;

Fig. 3 is an elevational view of the devices of Figs. 1 and 2;

Fig. 4 is a perspective illustration of an electroluminescent phosphor screen in diagram form;

Fig. 5 is a partial sectional view of Fig. 4;

Fig. 6 is a circuit diagram used in explaining the operation of this invention;

Fig. 7 is a diagrammatic illustration of another type of voltage-varying apparatus for controlling potentials applied to the screen of Figs. 4 and 5; and

Fig. 8 is a circuit diagram used in explaining the operation of the device of Fig. 7.

With reference to the drawings, and more particularly to Fig. 1, a conventional cathode ray tube **1**, commonly characterized as a "flying spot" tube, is coupled into a conventional television display circuit which includes the usual deflection coil **2** and focusing coil **3**. A suitable saw-tooth voltage wave occurring at the rate of, for example, 60 cycles per second, is applied to the coil **2** for deflecting the cathode ray beam **4** in a straight line path over the usual phosphor screen **5**. As the beam **4** strikes the screen **5**, it produces a spot of light. As the beam is scanned over the screen, this spot moves correspondingly; hence, the tube is commonly characterized as producing a "flying spot" of light.

Impedance-changing means which is sensitive to the spot of light is generally indicated by the reference numeral **6** and is comprised of a transparent glass reinforcing plate **7**, a transparent conductive coating or electrode **8**, a layer of photoconductive material **9**, and a plurality of spaced electrode elements or members **10**. The photoconductive layer **9** is laid in contact with the electrode film **8** and may comprise the usual crystalline cadmium sulphide material which changes in resistance or impedance in accordance with variations in light energy impressed thereon. The electrode elements **10** may consist of ordinary lengths of wire laid in contact with the layer **9** and spaced apart in parallel relation substantially as shown. The particular spacing between these elements **10** and the character of the elements themselves will become apparent from the following description. The elements obviously may take different forms than that illustrated.

The light spot produced by the tube **1** is focused by means of a simple lens **41** through the glass plate **7** and film electrode **8** onto the photoconductive layer **9** in such a manner that the photoconductive material is scanned on the side opposite the electrode elements **10**.

The control device **6** is generally in strip-like form and in front elevation appears as illustrated in Fig. 3. As will now be apparent, the spot of light produced by the tube **1** is scanned from end to end of the strip.

With reference to Fig. 2, it will be noted that a system is provided which appears in diagram form to be substantially identical to that illustrated in Fig. 1. In the reproduction of a television image by means of the conventional scanning techniques, the arrangement of Fig. 1 is the vertical or low frequency scanning system whereas that of Fig. 2 is the horizontal or high frequency system. The exact details of construction will be further explained in the following.

The "flying spot" tube **11** as well as the associated deflecting and scanning coils **12** and **13** are substantially

the same as the tube **1** and its associated coils. The principal difference between the two tubes and the associated coils is that the tube **1** is operated at the usual vertical scanning rate of 60 cycles per second, whereas the tube **11** is operated at the usual horizontal scanning rate of 15,750 cycles per second. It will be apparent that these scanning rates are conventional in the television art.

A strip-like voltage-controlling device **14** which may be substantially identical to the device **6** of Fig. 1 is composed of a glass plate **15**, a transparent electrode film **16** and a layer of photoconductive material **17**. The electrode elements **18** mounted on the photoconductive layer **17** correspond to the elements **10** of Fig. 1. Fig. 3 is a front elevation of the voltage-controlling device **14** and shows the conductive electrodes **18** mounted thereon in spaced parallel relation. The left-hand ends of these elements **18** are, in the illustrated embodiment, mere wire extensions of the elements **18** which are coupled to an electroluminescent phosphor panel as will be explained in more detail in the following.

As explained earlier, the voltage-controlling device **6** of Fig. 1 in front elevation looks substantially the same as that illustrated in Fig. 3. For all practical purposes the two devices **6** and **14** may be identical in construction. The film electrode **8** of the device **6** is grounded as illustrated and the electrode **16** of device **14** is connected to a suitable source of positive voltage as illustrated.

Referring now to Figs. 4 and 5, the electroluminescent phosphor panel is illustrated as being composed of a thin layer **19** of phosphor material which is substantially flat and of such width and length as would be desired in a television viewing screen. Electrode means are applied to opposite sides of the panel **19** for applying controlling voltages thereto to cause the latter to luminesce in a predetermined manner. This electrode means is composed of a reticulate screen or the like having bare wire conductors extending in one direction and insulated strands of the same wire or a plastic material extending transversely thereto. This screen is illustrated as being substantially similar to ordinary fine mesh screen which is conventionally used in the art. As will be observed more clearly in Fig. 5, the screen applied to the left-hand face of the panel **19** is composed of wires **20** and insulated strands **21**, and the screen applied to the right-hand face is composed of similar wires **22** and insulated strands **23**. The wires **20** and **22** preferably extend in directions at right angles to each other as is illustrated in the perspective view of Fig. 4.

As will be seen in Fig. 5, the individual wires **20** and **22** pass alternately over and under the respective insulated strands **21** and **23** such that the wires have spaced point contacts with the respective panel faces, for example, as at **24** on the left-hand face and **25** on the right-hand face.

In a practical embodiment of this invention, there are preferably 500 such wires **20** and **22** suitably spaced apart in parallel relation on the respective faces of the panel **19** in order to provide an arrangement which will produce a number of picture elements corresponding to the operative capabilities of present television display devices. For example, it is estimated that present day television tubes will provide images composed of approximately 250,000 elemental image areas, and from the foregoing it will be apparent that by the use of 500 conductive wires on opposite sides of the phosphor panel **19**, this same number of image areas may be obtained. Of course, it is obvious that as the screen is enlarged, the number of wires **20** and **22** which may be used may be substantially increased per unit area of the screen such that more elemental image areas may be obtained than is considered practically feasible today.

All of the wires **20** are provided with connecting leads **20***a* through **20***g* as illustrated, and similarly the wires **22** are provided with connecting leads **22***a* through **22***i*. These respective connecting leads extend over to the voltage-controlling devices of Figs. 1 and 2 in a suitable manner such as, for example, the leads **20***a* through **20***g* being connected to the electrode elements **10** in the order indicated by the reference symbols **20***aa* through **20***gg*. The connecting leads **22***a* through **22***i* are in turn connected to the electrode elements **18** of Fig. 2 in the order indicated by the reference symbols **22***aa* through **22***ii*. Thus it is seen that the voltage-controlling apparatus of Fig. 1 is electrically coupled to the left-hand face of the phosphor panel **19** whereas the system of Fig. 2 is coupled to the right-hand face of the panel.

In explaining the operation of this invention in reproducing an image by the use of the usual television reproducing standards and techniques, reference is made to Fig. 6 which shows an equivalent circuit diagram of the construction just described. Like numerals will indicate like parts. The battery **26** of Fig. 2 is indicated as providing a voltage "V1" which is connected in series with all of the photoconductive and phosphor assemblies **6**, **14** and **19**. Under "no-light" conditions (i.e., the photoconductive assemblies **6** and **14** of Figs. 1 and 2 are contained inside a completely darkened enclosure) the voltage V1 of battery **26** will be distributed over the impedance elements **17**, **19** and **9** of Fig. 6 in the manner illustrated, the voltage "V2" appearing across the photoconductive elements **17**, the voltage "V3" appearing over the corresponding elemental area of the phosphor panel **19** and the voltage "V4" appearing over the photoconductive element **9**. Stated in other words, the sum of the voltages V2, V3 and V4 will equal the battery **26** voltage V1.

If it were possible to completely short out the photoconductive element or impedance **9** (Fig. 6) by means of a switch **27**, the full voltage of the battery **26** would be impressed over the two impedance elements **17** and **19**. This would produce a redistribution of voltages across the respective impedance elements **17** and **19**. This redistribution would occur, obviously, immediately upon closure of the switch **27** such that a voltage change or variation would occur between the two conductors **20** and **22**, for example, which embrace the phosphor impedance **19**. This phosphor having the characteristic, as explained earlier, that it luminesces upon being excited by a variable potential, it is seen that that portion of the phosphor material **19** between the two conductors **20** and **22** will produce light provided that impedance **17** is small compared to impedance **19** such that voltage V3 exceeds the threshold voltage required to produce luminescence. By alternately opening and closing the switch **27**, the elemental area of the phosphor panel **19** shown in Fig. 6 may be caused to luminesce.

The shorting effected by the switch **27** is actually produced by the spot of light produced by the tube of Fig. 1. By directing this spot of light onto the photoconductive layer **9** at a point just opposite the topmost electrode element **10** specifically indicated by the reference symbol **20***aa*, the resistance of the photoconductive material between the electrode **8** and the element **10** will immediately lower. This resistance is negligibly small with intense light, thus resembling a short circuit. Switching the spot of light on and off thus resembles opening and closing the switch **27** of Fig. 6. By scanning an intense spot of light from one end of the photoconductive assembly **6** to the other, the spot will alternately register in succession with the respective electrode elements **10** in the sequence **20***aa*, **20***bb*, etc., through **20***gg*. Since these elements **10** are connected to the parallel wires **20** on the phosphor panel **19**, it is seen that these wires **20** are sequentially grounded as the spot of light in tube **1** (Fig. 1) registers with the respective electrode element **10**.

Assuming that the spot of light produced by tube **1**

is stationary on the layer **9** in registry with the electrode element **20***aa*, variation in the intensity of the spot from tube **11** (Fig. 2) trained on the photoconductive layer **17** just opposite the electrode element **22***aa* will serve to produce a variation in the resistance between the electrode film **16** and this element **22***aa*. Hence, the equivalent resistor **17** of Fig. 6 is indicated as being variable. By varying this resistance **17** (Fig. 6) the voltage applied to the phosphor element **19** correspondingly changes, causing the latter to luminesce in corresponding changing brightness. By modulating the beam of light produced by the tube **11** of Fig. 2 with video information, the corresponding elemental area of the phosphor panel **19** is caused to luminesce according to such information.

Having now explained how controlled voltages are applied to opposite sides of the phosphor panel **19**, it will be apparent that by scanning the spot of light of Fig. 1 at the usual 60 cycle vertical scanning rate and the spot of light of Fig. 2 at line scanning frequency or 15,750 cycles per second, the result will be an application of exciting voltages to elemental areas of the phosphor panel **19** in a manner which corresponds almost exactly to that of the scanning action of a cathode ray beam in a conventional picture tube. Essentially, the spot of light from tube **1** excites wire **20***a* while the spot from tube **11** scans over all of the wires **22***a* through **22***i*. Where the respective wires **20***a* and **22***a* cross on opposite sides of the phosphor panel **19**, an exciting voltage will be applied to the latter to produce corresponding point luminescence. By analogy, connecting a voltage to one wire **20** and one wire **22**, only the point or elemental area in the phosphor panel **19** where these wires cross will luminesce. Thus it is seen that scanning the wires **20***a* through **20***g* at a vertical scanning rate and the wires **22***a* through **22***i* at a horizontal scanning rate serves to produce the usual television scanning field or frame.

By alternating the connections between the wire elements **20** as shown in Fig. 4, it is possible to obtain interlaced scansion.

From the foregoing, it will appear obvious that other expedients are available for applying the necessary control voltages to the opposite sides of the phosphor panel **19**. An example of such an alternative arrangement is shown in Figs. 7 and 8 wherein a cathode ray tube is provided with a plurality of tiny electrode targets indicated by the reference numeral **27***a*. Two such cathode ray tubes are used, one tube being connected to the horizontal extending wires **20** and the other tube being connected to the vertical wires **22**. Each target electrode **27***a* is connected through a suitable fixed resistor **28** to a source of B supply voltage at the terminal **29**, there being one target **27***a* for each wire **20**, **22**. Thus, with an electron beam issuing from the cathode **30** which is grounded, a current is produced through the impinged target and the respective resistor **28**. This current in turn produces a voltage drop over the respective resistor **28** which may be applied to the various wires **20** and **22** from suitable terminals indicated by the reference numerals **31**, **32**, **33**, **34**, **35**, **36** and **37**. Connecting all these terminal points **31–37** to the leads **20***a*–**20***g* will serve to provide a control voltage for the horizontally extending wires **20** and connecting a similar set of wires from another cathode ray tube to the other set of wires **22** will serve to apply the necessary control voltages to the other side of the phosphor panel. The beam issuing from the cathode **30** may be modulated in the conventional manner and scanned in a rectilinear path over the electrodes **27***a*, a variation in intensity of this beam serving to produce different voltages at the terminals **31–37**.

While a phosphor panel **19** has been disclosed as a specific working embodiment of this invention, it will readily occur that other light-transmitting or light-producing means may be substituted therefor and be controlled by the crossed electrode wires **20** and **22**. For example, incandescent material or fluorescent gas may be used as the light-producing medium. Further, the voltage difference between two wires may control the position of tiny elemental shutters which control transmission or reflection of light.

In explaining the operation of this alternative embodiment, reference is made to Fig. 8 wherein the equivalent circuit diagram shows the electron beam as corresponding to the variable resistor **38**. The electron beam of the other cathode ray tube is indicated by the variable resistor **39**. Other parts of the diagram bear reference numerals which correspond to corresponding parts of the physical construction.

By switching the resistor **39** alternately into and out of the circuit by means of the electrode switch **40**, it is seen that the voltage between the two elemental electrodes **20** and **22** of the phosphor panel **19** can be correspondingly changes to cause the latter to luminesce. With the switch **40** closed as illustrated, the resistor **38** (electron beam) when modulated will serve to vary the potential at terminals **31–37** to produce corresponding voltage variations between the two panel electrodes **20** and **22**.

By scanning the beam **38** over all the target electrodes **27***a* at one scanning rate and modulating this beam with video information, and scanning the beam **39** (Fig. 8) over its electrodes at the other scanning rate, it will be seen that voltages may be applied to the elements of the panel **19** in the same manner as explained in connection with the preceding embodiment.

Having explained two different modes of applying picture control voltages to the phosphor panel **19**, alternative apparatus will be apparent to a person skilled in the art, which will not depart from the scope of this invention. Such an alternative apparatus serves to modulate both tubes **1** and **11**, and both beams **38** and **39** with video information in opposite respective phase thereby doubling the potential differences between the crossed phosphor electrodes **20** and **22**. This serves to increase picture brightness. Practical design desiderata will determine which alternative arrangement is preferred.

What is claimed is:

1. An image-reproducing device comprising phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, electrodes contacting opposite sides of said phosphor sheet, said electrodes comprising a plurality of wire-like elements, the electrode elements on each respective side being spaced apart and extending in essentially the same direction, the electrode elements on opposite sides of said sheet extending in directions transverse to each other, and voltage control means operatively coupled to all of said electrode elements such that only one element on each sheet side will have voltage applied thereto simultaneously, said voltage control means comprising two radiation-sensitive devices, each device comprising a member composed of photoconductive material which varies in impedance in accordance with varying radiation impressed thereon, a plurality of spaced electrode members mounted on each photoconductive member, the number of electrode members on each photoconductive member corresponding to the number of electrode elements on a particular one of said phosphor sheet sides, the electrode members of each photoconductive member being electrically coupled to respective ones of said electrode elements on opposite sides of said phosphor sheet, and means for applying voltage to both photoconductive members in such a manner that the photoconductive material, the electrode elements, the electrode members and said phosphor sheet are connected in series.

2. An image-reproducing device comprising phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, electrodes contacting opposite sides of said phosphor sheet, said electrodes comprising a plurality of

wire-like elements, the electrode elements on each respective side being spaced apart and extending in essentially the same direction, the electrode elements on opposite sides of said sheet extending in directions transverse to each other, voltage control means operatively coupled to all of said electrode elements such that only one element on each sheet side will have voltage applied thereto simultaneously, said voltage control means comprising two radiation-sensitive devices, each device comprising a member composed of photoconductive material which varies in impedance in accordance with varying radiation impressed thereon, a plurality of spaced electrode members mounted on each photoconductive member, the number of electrode members on each photoconductive member corresponding to the number of electrode elements on a particular one of said phosphor sheet sides, the electrode members of each photoconductive member being electrically coupled to respective ones of said electrode elements on opposite sides of said phosphor sheet, means for applying voltage to both photoconductive members in such a manner that the photoconductive material, the electrode elements, the electrode members and said phosphor sheet are connected in series, and means for scanning each photoconductive member with radiation modulated in accordance with an image to be reproduced, said scanning serving to alter the impedance of the respective photoconductive members according to the scanning movement of said modulated radiation.

3. An image-reproducing device comprising phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, electrodes contacting opposite sides of said phosphor sheet, said electrodes comprising a plurality of wire-like elements, the electrode elements on each respective side being spaced apart and extending in essentially the same direction, the electrode elements on opposite sides of said sheet extending in directions transverse to each other, voltage control means operatively coupled to all of said electrode elements on one side of said sheet and sequential switching means coupled to all of said electrode elements on the other side of said sheet such that only one element on each sheet side will have voltage applied thereto simultaneously, said voltage control means comprising a cathode ray scanning device having a plurality of anode electrode members, each of said electrode members being connected to a source of anode potential by a resistor and being connected to a corresponding one of said electrode elements on said one side of said sheet, said scanning device thereby serving to apply voltages of controllable amplitude to said electrode elements.

4. An image-reproducing device comprising phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, electrodes contacting opposite sides of said phosphor sheet, said electrodes comprising a plurality of wire-like elements, the electrode elements on each respective side being spaced apart and extending in essentially the same direction, the electrode elements on opposite sides of said sheet extending in directions transverse to each other, voltage control means respectively operatively coupled to all of said electrode elements on each side of said sheet such that only one element on each sheet side will have voltage applied thereto simultaneously, each of said voltage control means comprising a cathode ray scanning device having a plurality of anode electrode members with each of said electrode members being connected to a source of anode potential by a resistor and being connected to corresponding one of said electrode elements on a respective side of said sheet, said scanning devices thereby serving to apply voltages of controllable amplitude to said electrode elements.

5. An image reproducing device comprising: phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, a first woven mesh contacting one side of said phosphor sheet and having parallel strands extending in one direction formed of conductive material and parallel strands formed as insulators and extending at right angles to said conductive strands, said parallel conductive strands of said first woven mesh contacting said phosphor sheet at spaced intervals forming first electrodes, a second woven mesh contacting the other side of said phosphor sheet and having parallel strands extending in one direction formed of conductive material and parallel strands formed as insulators and extending at right angles to its parallel conductive strands, said parallel conductive strands of said second woven mesh extending transversely of said parallel conductive strands of said first woven mesh and contacting said phosphor sheet at spaced intervals forming second electrodes, the respective points of contact of said electrodes with said phosphor sheet on opposite sides thereof being in transverse alignment, voltage control means operatively coupled to all of said electrode elements such that only one element on each side of said sheet will have voltage applied thereto simultaneously, and switching means cooperatively associated with said voltage control means for applying a voltage to said elements in a predetermined sequence.

6. In an image reproducing device: phosphor material supported in sheet-like form, said material luminescing upon the application of a varying electrical field thereto, a first woven mesh contacting one side of said phosphor sheet and having parallel strands extending in one direction formed of conductive material and parallel strands formed as insulators and extending at right angles to said conductive strands, said parallel conductive strands of said first woven mesh contacting said phosphor sheet and spaced at intervals along their length forming first electrodes, a second woven mesh contacting the other side of said phosphor sheet having parallel strands extending in one direction formed of conductive material and parallel strands formed as insulators extending at right angles to its parallel conductive strands, said parallel conductive strands of said second woven mesh extending transversely of said parallel conductive strands of said first woven mesh and contacting said phosphor sheet at spaced intervals along their length forming second electrodes, the respective points of contact of said electrodes with said phosphor sheet on opposite sides thereof being in transverse alignment.

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