April 26, 1949. H. W. LEVERENZ 2,468,452

CATHODE-RAY INDICATOR SYSTEM

Filed March 29, 1946 2 Sheets-Sheet 1

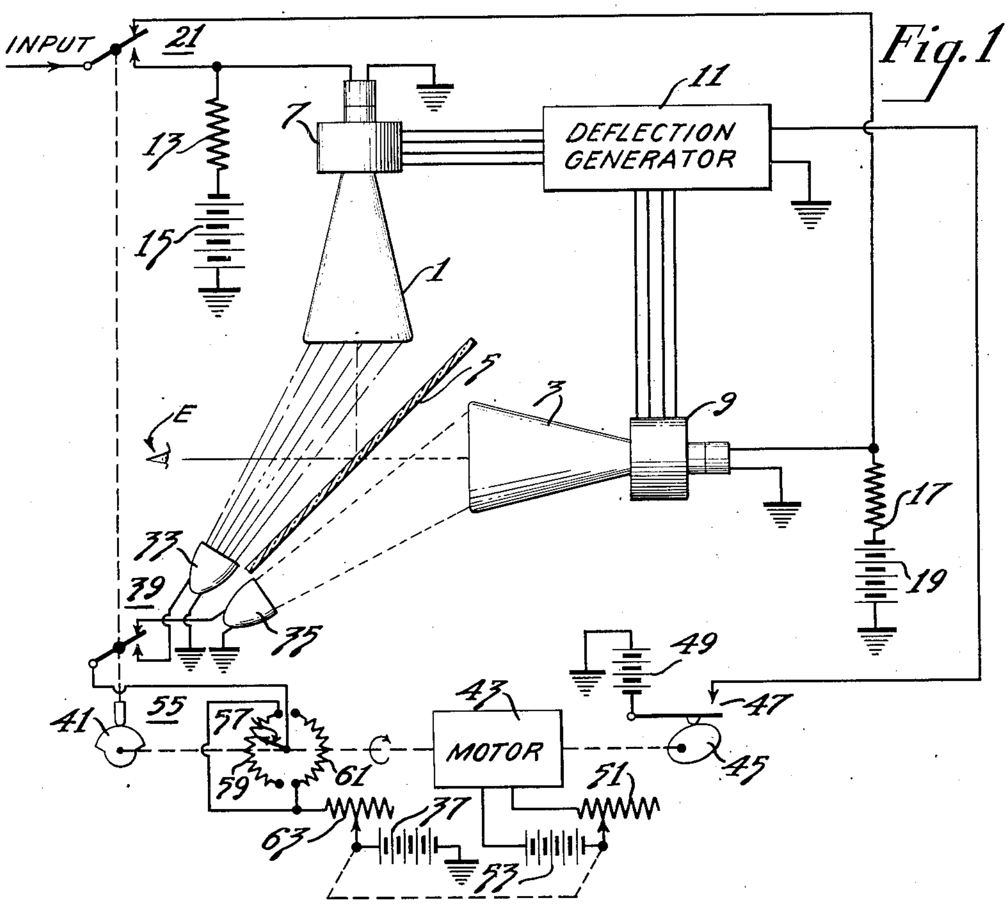


Fig. 1

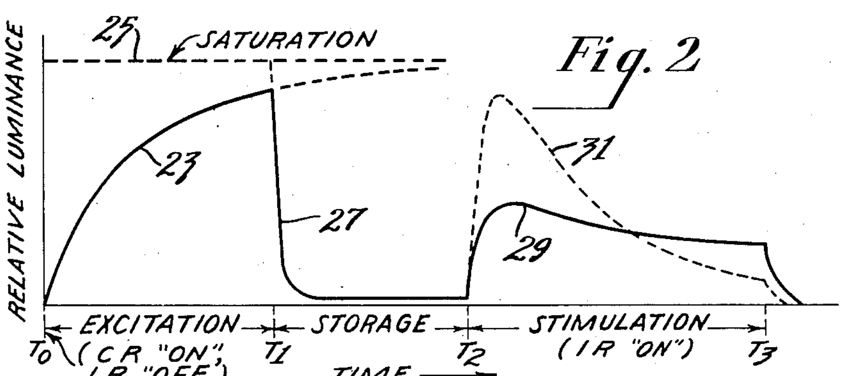


Fig. 2

INVENTOR.
Humboldt W. Leverenz
BY
C. D. Tuska
ATTORNEY

April 26, 1949. H. W. LEVERENZ 2,468,452

CATHODE-RAY INDICATOR SYSTEM

Filed March 29, 1946 2 Sheets-Sheet 2

Fig. 3

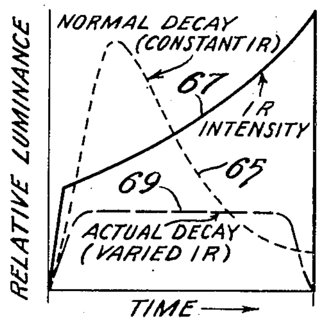


Fig. 4

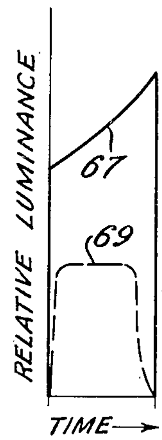


Fig. 5

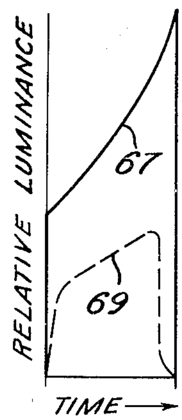
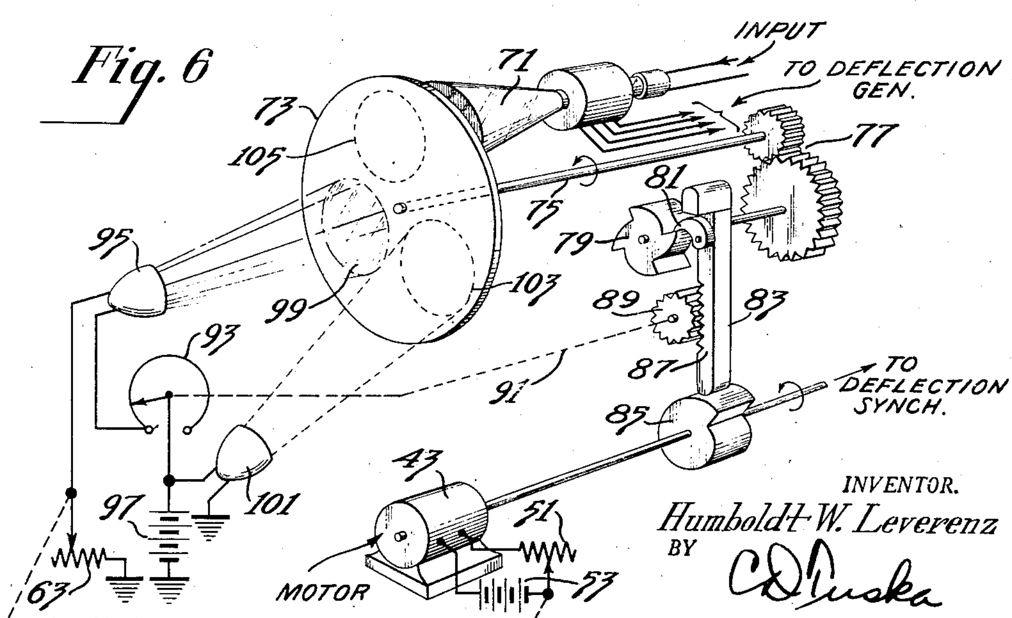


Fig. 6



INVENTOR.
Humboldt W. Leverenz
BY
C D Tuska
ATTORNEY.

Patented Apr. 26, 1949

2,468,452

UNITED STATES PATENT OFFICE

2,468,452

CATHODE-RAY INDICATOR SYSTEM

Humboldt W. Leverenz, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application March 29, 1946, Serial No. 657,972

12 Claims. (Cl. 250—164)

1

This invention relates to cathode ray indicator systems, and more particularly to improvements in systems of the type in which the image to be exhibited is traced out during an extended scanning period. When the scanning period is of the order of one-tenth second or less, all parts of the image appear visible simultaneously owing to persistence of vision. With longer scanning periods, special long-persistence screens are employed.

The materials used in the screen, and their proportions, are selected to provide as nearly as possible the best compromise between maximum luminescence of the image during the scanning period and minimum carry-over of an image into the following scanning period. Principally as a result of the remarkable tolerence of the human eye to variations in brightness, such compromises can be effected with reasonable success. However, a different screen material, or phosphor, is required for optimum results with each different length of scanning period. In many applications of cathode ray tubes, such as oscillography and radar indication, it is desirable to use scanning periods of variable or different lengths.

The principal object of the present invention is to provide improved methods of and means for cathode ray indication which afford images of substantially constant luminance.

Another object of the present invention is to provide improved methods of and means for cathode ray indication which afford images whose luminance and persistence can be varied at will.

Another object of this invention is to provide improved methods of and means for cathode ray indication which exhibit negligible carry-over of an image from one scanning period to the next.

A further object is to provide, in systems of the described type, methods of and means for achieving the foregoing objects substantially independently of the scanning period durations, and of the normal concave-upward phosphorescence of luminescent materials.

Another object is to provide methods of and means for efficient utilization of substantially all of the available excitation energy in a luminescent indicator system.

The invention will be described with reference to the accompanying drawing, wherein:

Figure 1 is a schematic diagram of a cathode ray indicator system embodying the present invention,

Figure 2 is a graph showing the characteristics of an infrared sensitive phosphor used in the system of Figure 1,

2

Figures 3, 4 and 5 are graphs illustrating variations of the stimulation of a phosphor, as practiced in accordance with the present invention, and the response of said phosphor thereto, and

Figure 6 is a modified cathode ray indicator system according to the invention.

Referring to Figure 1, two substantially identical cathode ray tubes 1 and 3 are disposed at right angles to each other, with a sheet 5 of plate glass or similar material between them at 45 degrees. The tubes 1 and 3 are provided with deflecting yokes 7 and 9 respectively, connected to a deflection generator 11.

The beam intensity control electrode of the tube 1 is connected through a high resistance 13 to a bias source 15. The intensity control electrode of the tube 3 is similarly connected through a resistor 17 to a bias source 19. A double throw switch 21 connects either the intensity control electrode of the tube 1 or that of the tube 3 to a source, not shown, of signals corresponding to the images to be displayed. The input signals may be variably timed pulses, such as are obtained in the operation of certain known radio locator or "radar" systems, or a variable voltage, corresponding at each instant to the intensity of a respective element of the image.

The screens of the tubes 1 and 3 are coated with a stimulable phosphor, which has the ability to store energy supplied to it directly or indirectly by the cathode ray beam, and release energy in the form of visible light when stimulated. One example of such a phosphor is strontium sulphide containing small amounts of samarium and cerium. This material will absorb and store cathode ray energy, and give up a portion of the stored energy as visible light when irradiated by infrared.

Another type of stimulable phosphor is described in copending U. S. Patent Application Serial No. 595,146, filed May 22, 1945 by H. W. Leverenz, and entitled Phosphor material. This phosphor has the characteristic of being excited or sensitized by blue, green, or ultraviolet light, and stimulated by infrared or heat.

Figure 2 shows the light output as a function of time, in a typical cycle of excitation, stimulation, and quenching. During the period T_0 to T_1, the phosphor is being excited by blue or ultraviolet light of constant intensity. Some of the energy of the exciting light is converted immediately to visible light of longer wavelength, by fluorescence. This effect builds up at a decreasing rate as shown by the portion 23 of the graph. If excitation were continued indefinitely, the fluorescence would finally reach a constant value corresponding to the dash line 25 marked "Saturation."

The area above the curve, bounded by the lines 23, 25, T_0 and T_1, represents energy stored in the phosphor, while the area under the curve 23 represents energy released immediately as light. When the exciting energy is cut off at T_1, the fluorescence subsides quickly as shown by the line 27. The stored energy remains in the phosphor, and if not liberated by stimulation or quenching, will remain to a substantial extent for a period of days.

During the period T_2 to T_3, the phosphor is being stimulated by irradiation with infrared of constant intensity. The solid line 29 shows the light output with one intensity of infrared, while the dash line curve 31 shows the light output which would result with a higher intensity of infrared. The color of the light emitted under stimulation is generally the same as that produced by fluorescence in the excitation period T_0—T_1.

When stimulation is stopped at the time T_3, the phosphor stops emitting light. Unless substantially all of the stored energy has been used, subsequent irradiation with inflared will produce further emission of light. This may be prevented by "quenching" or erasing, by exposing the phosphor to intense orange light, which dissipates the remainder of the stored energy. The cycle of excitation, stimulation and quenching can then be repeated. The above mentioned strontium sulphide phosphor responds to stimulation and quenching substantially like that described with reference to Figure 2, but is excited directly by corpuscular radiations, such as cathode rays or ionic rays, instead of by blue or ultraviolet light.

Either a directly or an indirectly excited phosphor may be used in the practice of the present invention. If the latter is employed, the screens of the tubes 1 and 3 are provided with two layers: an inner layer, made of any of the known phosphors, which provide blue, green, or ultraviolet light in response to cathode rays, and an outer layer of stimulable material, which may be either inside or outside the glass envelope of the cathode ray tube, and is excitable by emission from the inner layer.

Resuming the description of Figure 1, a pair of infra-red lamps 33 and 35 are positioned to flood the screens of the tubes 1 and 3 respectively. The lamps 33 and 35 are connected to their power source 37 through a resistor network described hereinafter, and a double throw switch 39. The switch 39 is mechanically coupled to the switch 21 so that when the input signal is applied to one cathode ray tube, inflared light is applied to the other.

The switches 21 and 39 are operated cyclically from one position to the other by a cam 41, driven by a motor 43. The motor 43 also drives a cam 45, operating a switch 47 to periodically connect a D.-C. source 49 to the deflection generator 11. This provides a synchronizing signal to cause the deflection generator to initiate a scanning pattern on the cathode ray tubes 1 and 3 with each operation of the switches 21 and 39. A rheostat 51 is connected between the motor 43 and its power supply 53 for adjustment of the motor speed and hence the scanning repetition frequency.

A variable resistor device 55 is provided in the supply circuit to the inflared lamps 33 and 35. The device 55 includes a rotatable contact 57, coupled to the motor 43 and connected to the switch 39. Two arcuate resistor elements 59 and 61 are provided, with the upper end of one and the lower end of the other connected together and to the power supply. As the contact 57 is rotated clockwise by the motor 43, the resistance introduced by the device 55 is relatively high at each instant the switch 39 operates, and decreases until the switch 39 operates again. A rheostat 63, like the rheostat 51, is connected between the device 55 and the source 37. The rheostats 51 and 63 may be mechanically ganged for common operation.

In the operation of the system of Figure 1, the rheostat 51 is adjusted to make the motor 43 run at a speed corresponding to one-half the desired image repetition rate. Thus, if a complete image is scanned every ten seconds, the motor runs at three revolutions per minute. Suppose the switches 21 and 39 are initially in their upper positions. The input signal is then applied to the tube 3, and the image is traced out by the cathode ray on the screen of that tube, storing an identical image in the infrared sensitive phosphor. The cathode ray beam of the tube 1 is meanwhile cut off by the bias supplied by the source 15.

During the next scanning period, the switches 21 and 39 are in their lower positions. The input is applied to the tube 1 and the current image is stored in its screen. While this is taking place, the screen of the tube 3 is flooded with infrared from the lamp 35. The stored image is luminous in response to the infrared excitation, and may be viewed through the transparent plate 5 from the point E. During the viewing period, which is preferably (though not necessarily) of the same length as the scanning period, the energy stored in the screen of the tube 3 is being released as light.

If the infrared excitation were maintained constant, the luminance of the image would decay in a manner like that indicated by the line 29 or the line 31 in Figure 2. However, the variable resistance device 55 operates as described above to decrease the resistance and thus increase the current to the infrared lamp. The device 55 is designed so that the increase in excitation compensates the decrease in remaining available stored energy, so that each element of the image being displayed has a substantially constant luminance during the viewing period.

Referring to Figure 3, the dotted curve 65 shows the luminance as a function of time which would appear with constant infrared excitation. The solid line 67 indicates the intensity of infrared as it is varied by the device 55. The dash line curve shows the resulting stimulated luminance. The resistor 63 is adjusted so that the total infrared energy applied to the screen of the cathode ray tube during the viewing period is just sufficient to substantially exhaust the energy stored therein during the previous scanning cycle. Thus, at the end of the viewing period, the image decays rapidly and completely, leaving the screen prepared for storing another image. Moreover, substantially all of the available excitation energy is utilized to provide luminescence during the viewing period, instead of carrying over into the subsequent scan as in prior art systems. Figure 4 shows the conditions with a viewing period shorter than that of Figure 1. The rheostat 63 is adjusted to provide a higher intensity of infrared, so that the total energy integrated throughout the viewing period is again substantially enough to exhaust the stored energy. As before, the intensity increases during the period to maintain a substantially constant rate of light output.

The above described cycle is repeated with each scanning cycle, first in one and then in the other of the tubes 1 and 3. The images on the tube 1 are reflected by the plate 5 and viewed from the same position E as those on the tube 3.

It will be apparent that the stimulation may be varied to provide substantially any desired variation in luminance of the stimulated image. For example, if the infrared intensity is increased at a rate greater than that corresponding to the rate of decay of the stored energy, as shown by the line 67 in Figure 5, the stimulated luminance will actually increase, as shown by the dash line curve 69 in Figure 5.

Owing to fluorescence during the excitation periods, the image being stored will be visible at the point where the cathode ray beam strikes the screen. Although this may be prevented from reaching the observer by means of a shutter which is closed while the screen is scanned, it may be advantageous in affording direct visual comparison between successive images, as described in copending U. S. patent application Serial No. 657,971 filed on March 29, 1946, by H. W. Leverenz, and entitled Radar system.

It will be apparent to those skilled in the art that numerous modifications of the system of Figure 1 may be made without departing from the spirit of the present invention. One example is illustrated in Figure 6, wherein a single cathode ray tube 71 is required. The tube 71 is provided with a deflection yoke connected to a source of deflection current like the generator 11 (not shown in Figure 6). The input is applied directly to the intensity control electrode, so that each successive image is traced on the screen of the tube 71. The screen in this case is coated with a blue, green, or ultraviolet phosphor and need not include any stimulable material.

A transparent disc 73, coated with stimulable phosphor, is supported off-center in front of the screen of the tube 71, on a shaft 75. The shaft 75 is coupled through gears 77 to a ratchet wheel 79, engaged by a pawl 81 on a reciprocable rod 83. The lower end of the rod 83 engages a spiral cam 85, driven by the motor 43. The rod 83 is provided with rack teeth 87 engaged by a pinion 89 on a shaft 91. A rheostat 93 is coupled to the shaft 91.

An infrared lamp 95 is connected to a power source 97 through the rheostat 93, and is directed to irradiate an area 99 on the disc 73. An orange-emitting lamp 101 is connected to the source 97, and is directed to illuminate an area 103 on the disc 73.

The adjustment and operation of the system of Figure 6 is as follows:

The motor 43 runs at a speed (set by the rheostat 51) of one revolution per scanning cycle. The cam 85 is set so that the rod 83 is at its lowest position at the beginning of each scanning cycle. The image traced on the screen of the cathode ray tube 71 is stored, as it appears, on the area 105 on the disc 73. Meanwhile the cam 85 lifts the rod 83, which reaches its uppermost position substantially at the end of the scanning cycle. At this time, the rod 83 moves quickly to its lower position. The pawl 81 rotates the ratchet wheel 79 through a fraction of a turn. The gears 77 are proportioned so that the fractional turn of the wheel 79 rotates the disc 73 through 120 degrees, in the present example.

At any given time, the image stored during the last previous scanning cycle is at the position 99. At the beginning of the viewing period, the rod 83 is in its lowermost position and the pinion 89 is at its extreme clockwise position, so that the rheostat 93 is set to provide its maximum resistance. As the viewing period progresses, the rod 83 and its rack 87 are raised by the cam 85, rotating the shaft 91 counter-clockwise to reduce the resistance of the rheostat 93. This increases the intensity of the infrared light from the source 95, producing substantially constant luminance of the image stimulated thereby in the area 99 of the disc 73.

Although the rheostat 63 may be adjusted as in the system of Figure 1, to provide substantial exhaustion of the stored image during the viewing period, there may be a certain amount of residual stored energy under some conditions of operation. After each viewing period, the last viewed area of the disc 73 is flooded, at the position 103, with orange light. This quenches or dissipates any vestiges of the stored image in preparation for the next exposure to the cathode ray tube 71.

Summarizing briefly, the present invention provides controllable luminance of a cathode ray image during a viewing period whose length is not restricted to a definite period, as in prior art practice, by the characteristics of the particular phosphor used. The cathode ray image is stored as it is traced out, in a screen of stimulable phosphor, and subsequently rendered visible as a whole by stimulating the phosphor. To maintain constant luminance during the viewing period, the intensity of stimulation is increased as the available stored energy decreases. To provide a maximum luminous efficiency, the average level of stimulation may be set to provide substantial exhaustion of the stored energy during the viewing period.

I claim as my invention:

1. A visual display system of the type in which an image is built up by successive presentation of its elements during a scanning period, including a screen coated with an infrared stimulable phosphor, means for applying said image elements to said phosphor as presented to store therein a latent image, a source of infrared energy, means for irradiating said phosphor with a predetermined quantity of infrared energy from said source to render said latent image visible during a viewing period subsequent to said scanning period, said quantity being substantially that required to exhaust said latent image, and means for increasing the intensity of said infrared irradiation during said viewing period.

2. A visual display system of the type in which an image is built up by successive presentation of its elements during a scanning period, including a screen coated with an infrared stimulable phosphor, means for applying said image elements to said phosphor as presented to store therein a latent image, a source of infrared energy, means for irradiating said phosphor with a predetermined quantity of infrared energy from said source to render said latent image visible during a viewing period subsequent to said scanning period, said quantity being substantially that required to exhaust said latent image, and means for increasing the intensity of said infrared irradiation during said viewing period, at a rate corresponding to the rate of decay of said stored image.

3. A visual display system of the type in which an image is built up by successive presentation of its elements during a scanning period, including a screen coated with an infrared stimulable

phosphor, means for applying said image elements to said phosphor as presented to store therein a latent image, a source of infrared energy, means for irradiating said phosphor with infrared energy from said source to render said latent image visible during a viewing period subsequent to said scanning period, and means for increasing the intensity of said infrared irradiation during said viewing period.

4. A cathode ray indicator system of the type in which an image is traced out during an extended scanning period, including a screen coated with a stimulable phosphor, means for tracing said image with exciting energy on said screen during said scanning period to store said image in latent form in said phosphor, a source of stimulating energy, means for applying said stimulating energy to said phosphor during a viewing period subsequent to said scanning period to render said latent image visible, and means for increasing the intensity of said stimulating energy during said viewing period to maintain substantially constant luminance of said visible image.

5. A cathode ray indicator system of the type in which an image is traced out during an extended scanning period, including a screen coated with a stimulable phosphor, means for tracing said image with exciting energy on said screen during said scanning period to store said image in latent form in said phosphor, a source of stimulating energy, means for applying a predetermined quantity of said stimulating energy to said phosphor during a viewing period subsequent to said scanning period to render said latent image visible, said quantity being substantially that required to exhaust said latent image within said viewing period, and means for increasing the intensity of said stimulating energy during said viewing period to maintain substantially constant luminance of said visible image.

6. In a visual display system wherein an image is built up during an extended scanning period by sequential presentation of its elements, the method of exhibiting said image as a whole during an extended viewing period, comprising the steps of storing said image as presented in a body of stimulable phosphor, applying stimulating energy to said body to render said image visible during said viewing period, and increasing the intensity of said stimulating energy during said viewing period.

7. In a visual display system wherein an image is built up during an extended scanning period by sequential presentation of its elements, the method of exhibiting said image as a whole and with substantially constant luminance during an extended viewing period, comprising the steps of storing said image as presented in a body of stimulable phosphor, applying a predetermined quantity of stimulating energy to said body to render said image visible during said viewing period, said quantity being substantially that required to exhaust said stored image, and increasing the intensity of said stimulating energy during said

viewing period at a rate corresponding to the rate of decay of said stored image.

8. In a cathode ray indicator system of the type in which an image is traced out during an extended scanning period, the method of exhibiting said image with substantially constant luminance during an extended viewing period, comprising the steps of storing said image in a stimulable phosphor during said scanning period, applying stimulating energy to said phosphor during said viewing period, and increasing the intensity of said stimulating energy during said viewing period at a rate corresponding to the rate of decay of said stored image.

9. In a cathode ray indicator system of the type in which an image is traced out during an extended scanning period, the method of exhibiting said image with substantially constant luminance during an extended viewing period, comprising the steps of storing said image in a stimulable phosphor during said scanning period, applying stimulating energy to said phosphor during said viewing period, and increasing the intensity of said stimulating energy during said viewing period at a rate corresponding to the rate of decay of said stored image, the average value of said intensity being such that said stored image is substantially exhausted at the end of said viewing period.

10. The method of exhibiting a luminous image with substantially constant luminance during a viewing period of predetermined length, comprising the steps of storing the image to be exhibited in a body of infrared stimulable phosphor, applying infrared energy to said phosphor to render said stored image visible during said viewing period, and increasing the intensity of said infrared energy during said period to compensate the decrease in available energy of said stored image.

11. The method of exhibiting a luminous image with controllable luminance during a viewing period of predetermined length, comprising the steps of storing the image to be exhibited in a body of stimulable phosphor, stimulating said phosphor to render said stored image visible during said viewing period, and increasing the intensity of stimulation during said period.

12. The invention set forth in claim 11, wherein the average intensity of said stimulation is such as to substantially exhaust the energy of said stored image at the end of said viewing period.

HUMBOLDT W. LEVERENZ.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,996,492	Schroter	Apr. 2, 1935
2,074,226	Kunz et al.	Mar. 16, 1937
2,156,392	Iams	May 2, 1939
2,239,887	Ferrant	Apr. 29, 1941
2,240,844	Goggin et al.	May 6, 1941
2,351,889	Strubig	June 20, 1944