

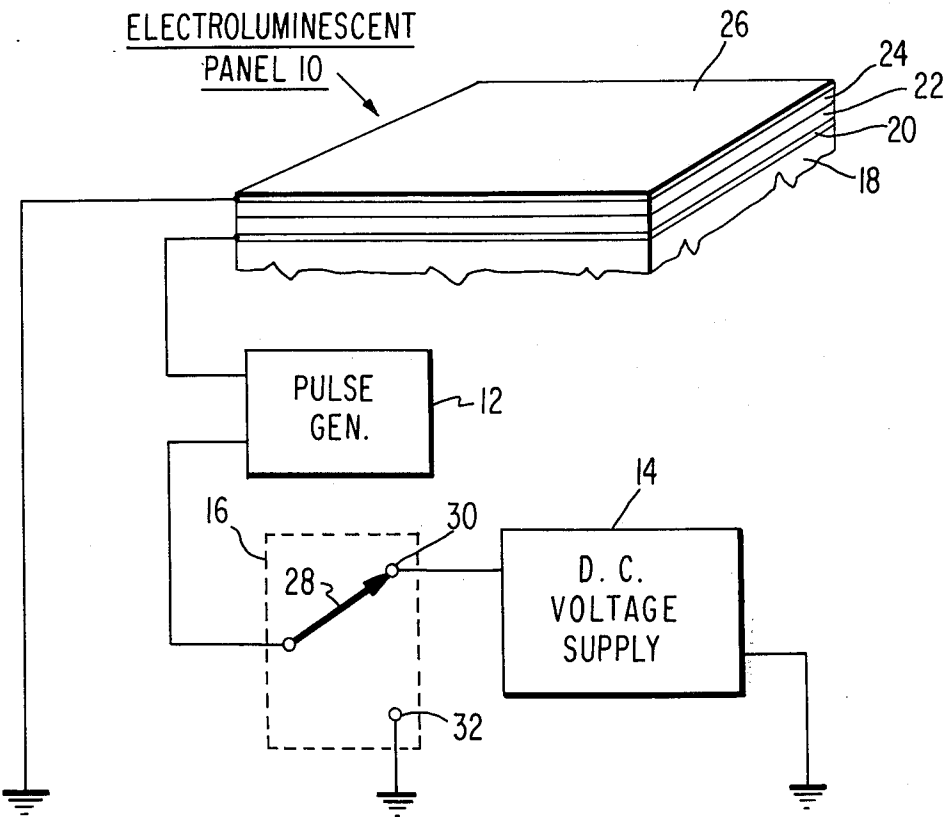
[54] **ENERGIZING TECHNIQUE FOR ELECTROLUMINESCENT DEVICES**
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[51] Int. Cl. **H05b 37/00**
[58] Field of Search **250/213 R; 313/494; 315/169 TV, 169 R, 170, 175, 176**

[56] **References Cited**
UNITED STATES PATENTS
2,972,692 2/1961 Thornton 315/176 X

3,710,181 1/1973 Tanaka et al. 315/175
Primary Examiner—R. V. Rolinec
Assistant Examiner—Lawrence J. Dahl
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[57] **ABSTRACT**
An energizing voltage provided by a DC voltage source in series with a pulse generator provides unexpectedly high brightness of light emitted from an electroluminescent device. The DC voltage in itself has a magnitude which results in insignificantly small current through and light emission by the electroluminescent device, which may have a non-linear current-voltage characteristic.

12 Claims, 3 Drawing Figures



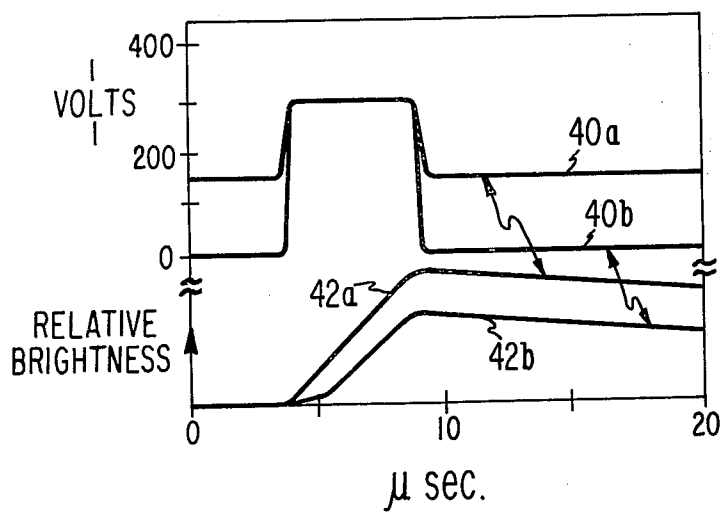
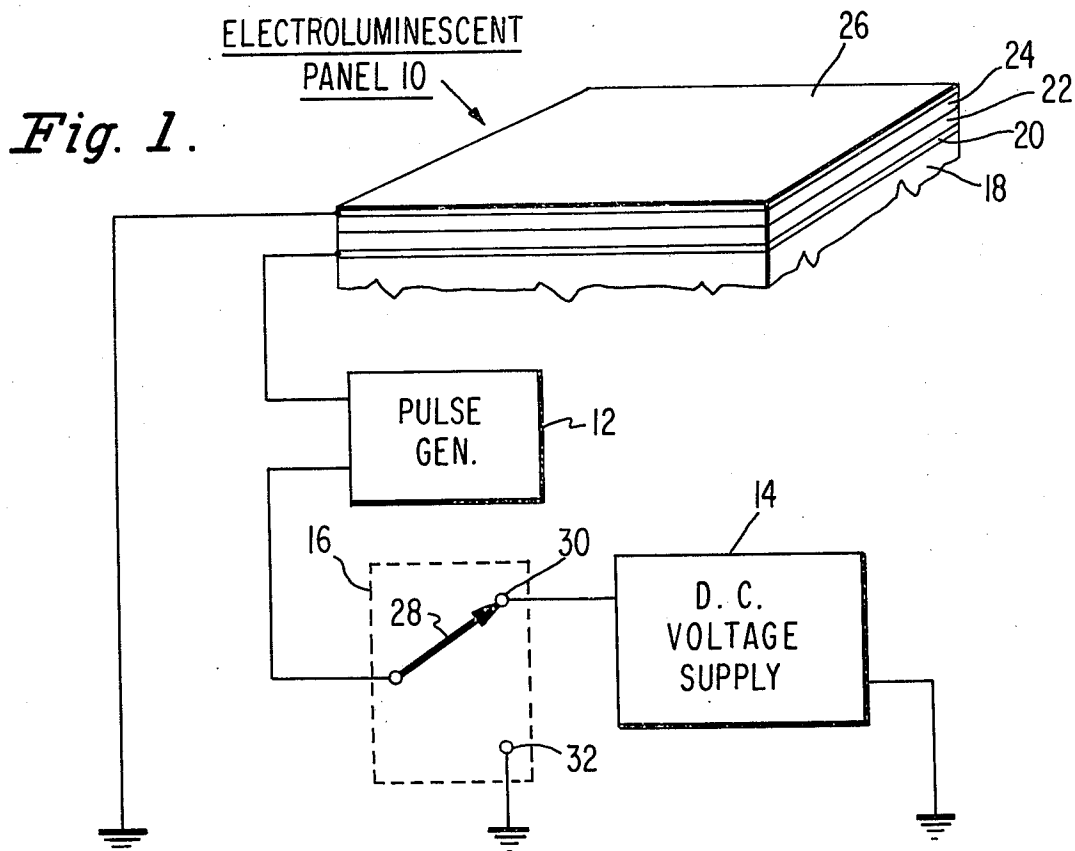
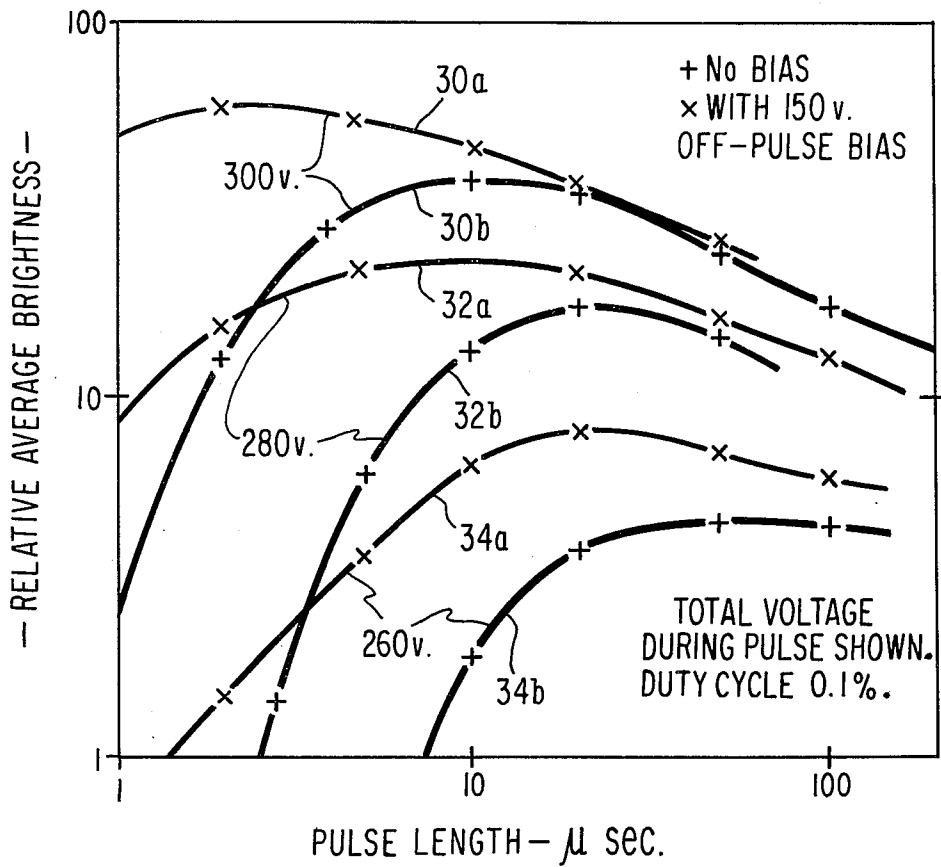


Fig. 3.

*Fig. 2.*

ENERGIZING TECHNIQUE FOR ELECTROLUMINESCENT DEVICES

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of the Army.

This invention relates to electroluminescent devices and, more particularly, to an improved method and means for operating such electroluminescent devices.

As is known, selected light emitting materials, such as phosphors, when placed within the influence of an electric field, are energized by the field to emit light. Electroluminescent phosphors will display the phenomenon of electroluminescence under either AC or DC potential excitation. However, the process may be a relatively inefficient one from the point of view of the brightness of the light produced. In order to improve this efficiency, and obtain greater brightness, certain types of special waveform energizing voltages have been suggested by the prior art.

More specifically, U.S. Pat. No. 2,972,692, which issued February 21, 1961 to Thornton, suggests the use of superimposed continuous AC and DC voltages of appropriate values to provide the required energizing electric field. On the other hand, U.S. Pat. No. 3,165,667, issued Jan. 12, 1965 to C. H. Haake, suggests the use of a superimposed continuous-wave high-frequency AC voltage and pulses from a pulse generator to provide the required energizing electric field for the electroluminescent device.

In accordance with the present invention, it has been discovered that an energizing voltage for a non-linear current-voltage characteristic electroluminescent device provided by a low-level DC voltage, which in itself results in an insignificantly small current through the device and an insignificant brightness of light emitted thereby, and a series of pulses of appropriate values from a suitable pulse generator connected in series with the DC voltage source to obtain a significantly large current through the device, provides an unexpected increase in the brightness of the light emitted from the electroluminescent device.

This and other features and advantages of the present invention will become more apparent from the following detailed description taken together with the accompanying drawing, in which:

FIG. 1 illustrates an experimental embodiment of the present invention which demonstrates the benefits thereof, and

FIGS. 2 and 3 are graphs which illustrate the operating results of the experimental embodiment shown in FIG. 1.

Referring to FIG. 1, there is shown electroluminescent panel 10, pulse generator 12, DC voltage supply 14 and switch 16. Electroluminescent panel 10 is composed of a glass substrate 18, which may have a surface area of about 3 millimeter square. On this surface area is disposed lower electrode 20. The active element 22 of electroluminescent panel 10 may consist of a layer, about 2 micrometers thick, of sputtered zinc sulfide, forming a hast, doped with an activator element, forming a suitable light emitting center, such as manganese. In the present example, the zinc sulfide hast was doped with 0.7 mole percent manganese and 0.3 mole percent copper. Cermet 24, also about 2 micrometers thick, which acts as a current-limiting resistor, is disposed, as shown, in series with active element 22 and upper electrode 26. The cermet contained

about ten volume percent nickel and the remainder SiO_2 .

In the switch position shown, with wiper 28 of switch 16 connected to upper pole 30 thereof, the respective outputs from pulse generator 12 and DC voltage supply 14 are connected in series between lower electrode 20 and upper electrode 26 of electroluminescent panel 10. In the other position of switch 16, with wiper 28 of switch 16 connected to its lower pole 32, the output of pulse generator 12 alone is connected between electrodes 20 and 26 of electroluminescent panel 10.

For experimental purposes, the magnitude of the DC voltage supply 14 was set at a fixed value of 150 volts, which in itself provides a negligible current through panel 10. However, both the amplitude and duration of pulses generated by pulse generator 12 were capable of being independently varied. In particular, pulse generator 12 was capable of generating a series of pulses, each of which had a duration which could be varied from a value extending from 1 microsecond to more than 100 microseconds, and each of which had an amplitude which could be varied from a value extending below 110 volts to a value of at least 300 volts. In all cases, pulse generator 12 is operated at a duty cycle of one-tenth of one percent.

Graph 30a of FIG. 2 is a plot of the relative average brightness of electroluminescent panel 10 as a function of the pulse duration or length in microseconds for the case where wiper 28 of switch 16 is connected to upper pole 30 thereof and the total voltage between electrodes 20 and 26 is 300 volts (the sum of a 150 volt DC pedestal bias voltage from DC voltage supply 14 and a 150 volt amplitude pulse from pulse generator 12). Since the active element 22 has a thickness of about 2 micrometers and is the main resistive element, the total electric field is about 150 volts per micrometer, with the output from DC voltage supply 14 supplying a 75 volt per micrometer portion of this total.

Graph 30b is a plot obtained when the total voltage between electrodes 20 and 26 remains at 300 volts, but wiper 28 of switch 16 is switched to lower pole 32 thereof (so that DC voltage supply 14 is disconnected) and pulse generator 12 is adjusted to provide a pulse amplitude equal to the entire total voltage of 300 volts.

Graphs 32a and 34a correspond with graph 30a in all respects except that the total voltage between electrodes 20 and 26 in the case of graph 32a is 280 volts and the total voltage between electrodes 20 and 26 in the case of graph 34a is 260 volts. Thus, in the case of graph 32a, the pulse amplitude from pulse generator 12 is 130 volts and in the case of graph 34a the pulse amplitude from pulse generator 12 is 110 volts, since the magnitude of the output from DC voltage supply 14 remains at 150 volts. In a similar manner, graphs 32b and 34b correspond with graph 30b. Specifically, the amplitude of each pulse from pulse generator 12 in the case of graphs 32b is 280 volts, the total voltage applied across electrodes 20 and 26, and in the case of graph 34b, the amplitude of each pulse is 260 volts, the total voltage applied across electrodes 20 and 26.

It will be noted from FIG. 2 that in all cases as the pulse length or duration increases from a minimum, the brightness rises to a maximum; after which, as the pulse length is further increased, the brightness falls off. However, from the point of view of the present invention, what is most noteworthy is the fact that the maximum brightness of each of graphs 30a, 32a and 34a, re-

spectively, is significantly higher than the maximum of corresponding graphs 30b, 32b, and 34b, respectively. Thus, an energizing voltage composed of a pulse riding on a DC pedestal to provide a given total energizing voltage results in a significantly higher brightness of emitted light being achieved than in the case when this total given energizing voltage is applied solely in pulses. Furthermore, the use of the pedestal makes it possible to employ pulses of lower voltage amplitudes.

It can be further noted from FIG. 2 that the duration of the pulse length which results in maximum brightness for each of graphs 30a, 32a and 34a, respectively, is shorter than the corresponding pulse length which results in maximum brightness for each of corresponding graphs 30b, 32b and 34b, respectively. In fact, the brightness achieved in graphs 30a exceeds that obtainable from graph 30b over a pulse length range extending from a minimum of one microsecond to a maximum of about twenty microseconds. Similarly, the brightness achieved with graph 32a exceeds that obtainable with graph 32b over the entire pulse length range extending from a minimum of one microsecond to more than 100 microseconds. In the case of graphs 34a and 34b, the brightness of graph 34a exceeds that of graph 34b over the entire range of 34a extending from a minimum value of less than 3 microseconds to a maximum value of more than 100 microseconds.

Graph 40a of FIG. 3 illustrates a typical waveform of a voltage pulse of given duration riding on a DC pedestal. In particular, the DC pedestal has a magnitude of 150 volts and the pulse has an amplitude of 150 volts, to provide a total voltage during the presence of the pulse of 300 volts. Graph 40b is identical to 40a in all respects except that there is no pedestal and the amplitude of the pulse is 300 volts. Graph 42a shows the waveform of the relative brightness of the light being emitted from electroluminescent panel 10 when energized by waveform 40a, while graph 42b shows the waveform of this relative brightness when electroluminescent panel 10 is energized by voltage waveform 40b. It can be seen that the rise time of graph 42a is significantly faster, as well as higher, than graph 42b. Thus, equal or even greater brightness can be achieved with the pedestal employing pulses of shorter duration. As is known, the use of pulses of shorter duration can extend the lifetime of electroluminescent devices.

In the actual practice of the present invention, switch 16 is not required, because the use of the DC voltage pedestal would be employed at all times. Since this is true, the amplitude of the pulse from pulse generator required to achieve any given total energizing voltage is equal to only the difference between this given total energizing voltage and the magnitude of the DC pedestal voltage. Thus, pulses of lower amplitude may be employed. This permits the use of a smaller, less costly pulse generator than otherwise would be required.

What is claimed is:

1. The combination comprising:

- a. a given electroluminescent device having a non-linear current-voltage characteristic that a first voltage there across having a first level of a given polarity results in an insignificantly small current therethrough and an insignificant brightness of light emitted thereby and a second voltage there-

across having a second level of said given polarity which is higher than said first level results in a significantly large current therethrough and a significant brightness of light emitted thereby, and

- b. power supply means coupled across said device, including a DC voltage supply and a pulse generator connected in series with each other, said DC voltage supply supplying a continuous DC voltage magnitude of said first level and given polarity, and said pulse generator generating a series of intermittent DC pulses at a given duty cycle which is not in excess of one percent, with each pulse having said given polarity and an amplitude equal to the difference between said second level and said first level.
2. The combination defined in claim 1, wherein said first level DC voltage has a magnitude sufficient by itself to provide an electric field across said device in the order of seventy-five volts per micrometer.

3. The combination defined in claim 2, wherein said electroluminescent device comprises a film about two micrometers thick and said first level DC voltage is substantially one-hundred fifty volts.

4. The combination defined in claim 3, wherein said film is a zinc sulfide host doped with an activator element forming a suitable light emitting center.

5. The combination defined in claim 3, wherein said second level voltage is between two-hundred sixty volts and three-hundred volts.

6. The combination defined in claim 3, wherein said second level voltage is substantially three-hundred volts and each pulse has a duration in the range of one to twenty microseconds.

7. The combination defined in claim 3, wherein said second level voltage is substantially two-hundred eighty volts and each pulse has a duration in the range of one to one-hundred microseconds.

8. The combination defined in claim 3, wherein said second level voltage is substantially two-hundred sixty volts and each pulse has a duration in the range of three to one-hundred microseconds.

9. The combination defined in claim 1, wherein said brightness is at a maximum when said pulses each have a duration equal to a given value at said given duty cycle, and wherein each of the pulses generated by said pulse generator has a duration substantially equal to said given value.

10. The combination defined in claim 1, wherein said given duty cycle is in the order of one-tenth of one percent.

11. A method for energizing an electroluminescent device comprising the step of:

applying an energizing voltage across said device composed of a series of DC pulses of given amplitude and given polarity occurring at a given duty cycle which is not in excess of one percent, said series of pulses riding on a continuous DC pedestal of a given magnitude and said given polarity.

12. The method defined in claim 11, wherein the brightness of light emitted from said device is a maximum when the duration of each said pulses has a given value, and wherein said duration has substantially said given value.

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